COURSE PREVIEW

CHOOSE FROM 72 COURSES AND WORKSHOPS

2–7 February 2019
The Moscone Center
San Francisco, CA, USA
Efficient Training from Leading Experts

Courses and workshops at Photonics West include relevant and current practices in optomechanical design, AR/VR, laser safety, basic optics for non-technical staff, autonomous vehicles, project management, and more. Stay informed on the latest trends and build on your expertise.

Featured Courses at Photonics West 2019

SC504  Introduction to CCD and CMOS Imaging Sensors and Applications
SC1247 Polarized Light and Optical Design
SC1253  How to Develop Profitable Technology Products
SC1254  Fourier Optics
SC1255  Solid-State Laser Design for Environmental Stability
SC1256  Basic Laser Safety
SC1257  Laser Lab Design, Do's and Don'ts
SC1258  Quantum Cryptography
SC1259  Introduction to Vertical-Cavity Surface-Emitting Lasers (VCSELs) and Applications
SC1260  Optical Super Resolution and Extended Depth of Focus

Register Early

Courses and workshops have limited seating and can sell out prior to the conference. To get the training you need, early registration is recommended. There will not be a wait list for sold out courses. Registering for a course or workshop gains you FREE admission to the exhibition. For the most up-to-date information on courses and workshops including pricing and scheduling, please refer to our website: www.spie.org/pwcourses
**Advanced Quantum and Optoelectronic Applications**

SC1191 Sun **Quantum Sensors** (Lanzagorta, Venegas-Andraca) 8:30 am to 12:30 pm, $330 / $390 ............ 27

SC1258 Sun **Quantum Cryptography** (Venegas-Andraca, Lanzagorta) 1:30 pm to 5:30 pm, $330 / $390 ... 28

**Biomedical Spectroscopy, Microscopy, and Imaging**

SCI072 Sat **Statistics for Imaging and Sensor Data** (Bajorski) 8:30 am to 5:30 pm, $650 / $765 ............ 15

SCI260 Tue **Optical Super Resolution and Extended Depth of Focus** (Zalevsky) 1:30 pm to 5:30 pm, $330 / $390 ... 15

**Clinical Technologies and Systems**

SC312 Sun **Principles and Applications of Optical Coherence Tomography** (Fujimoto) 1:30 pm to 5:30 pm, $330 / $390 ............ 13

SC981 Mon **Biomedical Applications of Specialty Optical Fibers and Fiber Sensors** (Mendez, Arkwright) 1:30 pm to 5:30 pm, $400 / $460 ............ 28

SCI228 Tue **Diffuse Optics in Biology and Medicine: Noninvasive Probes of Tissue Health** (Busch) 1:30 pm to 5:30 pm, $330 / $390 ............ 31

**Displays and Holography**

SCI1234 Sun **Introduction to VR, AR, MR and Smart Eyewear: Market Expectations, Hardware Requirements and Investment Patterns** (Kress) 8:30 am to 10:30 am, $185 / $210 ... 17

SCI1096 Tue **Head-Mounted Display Requirements and Designs for Augmented Reality Applications** (Browne, Melzer) 8:30 am to 5:30 pm, $625 / $740 ... 8

SCI1218 Wed **Optical Technologies and Architectures for Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) Head-Mounted Displays (HMDs)** (Kress) 8:30 am to 5:30 pm, $580 / $695 ............ 31

**Imaging**

SCI1222 Sun **Deep Learning and Its Applications in Image Processing** (Nasrabadi) 8:30 am to 5:30 pm, $580 / $695 ... 33

SCI504 Tue **Introduction to CCD and CMOS Imaging Sensors and Applications** (Crisp) 1:30 pm to 5:30 pm, $470 / $530 ............ 28

SCI1231 Wed **Designing and Specifying Digital Cameras** (Baldwin) 8:30 am to 12:30 pm, $330 / $390 ............ 43

**Laser Safety**

SCI1256 Mon **Basic Laser Safety** (Barat) 10:30 am to 12:30 pm, $225 / $250 ............ 44

SCI1257 Mon **Laser Lab Design, Do’s and Don’ts** (Barat) 1:30 pm to 3:30 pm, $210 / $235 ............ 45

**Laser Sources**

SCI748 Sun **High-Power Fiber Sources** (Nilsson) 8:30 am to 5:30 pm, $580 / $695 ... 19

SCI752 Sun **Solid State Laser Technology** (Hodgson) 8:30 am to 5:30 pm, $580 / $695 ............ 20

SCI1255 Sun **Solid-State Laser Design for Environmental Stability** (Lee) 8:30 am to 5:30 pm, $580 / $695 ... 19

SCI1020 Sun **Splicing of Specialty Fibers and Glass Processing of Fused Components for Fiber Laser and Medical Probe Applications** (Wang) 8:30 am to 12:30 pm, $330 / $390 ............ 17

SCI1174 Mon **Improving Laser Reliability: an Introduction** (Grossman, Asbury) 8:30 am to 5:30 pm, $580 / $695 ... 24

SCI972 Tue **Basic Laser Technology: Fundamentals and Performance Specifications** (Sukuta) 8:30 am to 12:30 pm, $330 / $390 ............ 20

SCI1181 Tue **Ultrafast Lasers and Amplifiers** (Paschotta) 8:30 am to 5:30 pm, $580 / $695 ............ 15

SCI1207 Thu **High-Power Laser Technologies** (Paschotta) 8:30 am to 12:30 pm, $330 / $390 ............ 18

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**MONEY-BACK GUARANTEE**

We are confident that once you experience an SPIE course for yourself you will look to us for your future education needs. However, if for any reason you are dissatisfied, we will gladly refund your money. We just ask that you tell us what you did not like; suggestions for improvement are always welcome.

SPIE reserves the right to cancel a course due to insufficient advance registration.

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**CONTINUING EDUCATION UNITS**

SPIE is accredited by the International Association for Continuing Education and Training (IACET) and is authorized to issue the IACET CEU.

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**THIS PDF PROGRAM IS CURRENT AS OF 1 OCTOBER 2018**

Find complete, up-to-date information and create your personalized schedule at spie.org/pwcourses
## COURSE INDEX

### Macro Applications

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<tr>
<td>SC1144</td>
<td>Tue</td>
<td>Laser Systems Engineering</td>
<td>Kasunic</td>
<td>8:30 am to 5:30 pm</td>
<td>$650 / $765</td>
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### Metrology & Standards

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<tr>
<td>SC212</td>
<td>Mon</td>
<td>Modern Optical Testing</td>
<td>Wyant</td>
<td>8:30 am to 12:30 pm</td>
<td>$365 / $425</td>
</tr>
<tr>
<td>SC700</td>
<td>Tue</td>
<td>Understanding Scratch and Dig Specifications</td>
<td>Aikens</td>
<td>8:30 am to 5:30 pm</td>
<td>$430 / $490</td>
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<tr>
<td>SC1017</td>
<td>Tue</td>
<td>Optics Surface Inspection Workshop</td>
<td>Aikens</td>
<td>1:30 pm to 5:30 pm</td>
<td>$430 / $490</td>
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### Micro/Nano Applications

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<tr>
<td>SC743</td>
<td>Tue</td>
<td>Micromachining with Femtosecond Lasers</td>
<td>Nolte</td>
<td>8:30 am to 12:30 pm</td>
<td>$330 / $390</td>
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### MOEMS-MEMS in Photonics

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<tr>
<td>SC454</td>
<td>Tue</td>
<td>Fabrication Technologies for Micro- and Nano-Optics</td>
<td>Suleski</td>
<td>8:30 am to 12:30 pm</td>
<td>$330 / $390</td>
</tr>
<tr>
<td>SC1125</td>
<td>Thu</td>
<td>Design Techniques and Applications Fields for Digital Micro-optics</td>
<td>Kress</td>
<td>8:30 am to 5:30 pm</td>
<td>$580 / $695</td>
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### Nano/Biophotonics

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<tbody>
<tr>
<td>SC1186</td>
<td>Tue</td>
<td>Fluorescence Sensing and Imaging: Towards Portable Healthcare</td>
<td>Levi</td>
<td>1:30 pm to 5:30 pm</td>
<td>$330 / $390</td>
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### Neurophotonics, Neurosurgery, and Optogenetics

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<tbody>
<tr>
<td>SC1126</td>
<td>Mon</td>
<td>Neurophotonics</td>
<td>Levi, Dufour</td>
<td>1:30 pm to 5:30 pm</td>
<td>$330 / $390</td>
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### Nonlinear Optics and Beam Guiding

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</thead>
<tbody>
<tr>
<td>SC047</td>
<td>Mon</td>
<td>Introduction to Nonlinear Optics</td>
<td>Fisher</td>
<td>8:30 am to 12:30 pm</td>
<td>$330 / $390</td>
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### Optical Systems & Lens Design

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<tr>
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<tbody>
<tr>
<td>SC156</td>
<td>Sun</td>
<td>Basic Optics for Engineers</td>
<td>Poutous</td>
<td>8:30 am to 5:30 pm</td>
<td>$625 / $740</td>
</tr>
<tr>
<td>SC690</td>
<td>Sun</td>
<td>Optical System Design: Layout Principles and Practice</td>
<td>Greivenkamp</td>
<td>8:30 am to 5:30 pm</td>
<td>$615 / $730</td>
</tr>
<tr>
<td>SC011</td>
<td>Mon</td>
<td>Design of Efficient Illumination Systems</td>
<td>Cassarly</td>
<td>1:30 pm to 5:30 pm</td>
<td>$330 / $390</td>
</tr>
<tr>
<td>SC003</td>
<td>Mon</td>
<td>Practical Optical System Design</td>
<td>Youngworth, Olson</td>
<td>8:30 am to 5:30 pm</td>
<td>$685 / $800</td>
</tr>
<tr>
<td>SC1177</td>
<td>Mon</td>
<td>Practical Guide to Spectral Measurements</td>
<td>Kaltenbacher</td>
<td>8:30am to 12:30 pm</td>
<td>$330 / $390</td>
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<tr>
<td>SC720</td>
<td>Tue</td>
<td>Cost-Conscious Tolerancing of Optical Systems</td>
<td>Youngworth</td>
<td>8:30 am to 12:30 pm</td>
<td>$330 / $390</td>
</tr>
<tr>
<td>SC935</td>
<td>Tue</td>
<td>Introduction to Lens Design</td>
<td>Bentley</td>
<td>8:30 am to 5:30 pm</td>
<td>$675 / $790</td>
</tr>
<tr>
<td>SC1199</td>
<td>Tue</td>
<td>Stray Light Analysis and Control</td>
<td>Fest</td>
<td>8:30 am to 5:30 pm</td>
<td>$625 / $740</td>
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### Optoelectronic Materials and Devices

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<tr>
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<tr>
<td>SC1091</td>
<td>Sun</td>
<td>Fundamentals of Reliability Engineering for Optoelectronic Devices</td>
<td>Leisher</td>
<td>8:30 am to 12:30 pm</td>
<td>$330 / $390</td>
</tr>
<tr>
<td>SC747</td>
<td>Sun</td>
<td>Semiconductor Photonic Device Fundamentals</td>
<td>Linden</td>
<td>5:30 pm to 5:30 pm</td>
<td>$580 / $695</td>
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### Optomechanics

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<tr>
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<tr>
<td>SC014</td>
<td>Mon</td>
<td>Introduction to Optomechanical Design</td>
<td>Vukobratovich</td>
<td>8:30 am to 5:30 pm</td>
<td>$1,150 / $1,370</td>
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<tr>
<td>SC015</td>
<td>Mon</td>
<td>Fastening Optical Elements with Adhesives</td>
<td>Daly</td>
<td>8:30 am to 12:30 pm</td>
<td>$330 / $390</td>
</tr>
<tr>
<td>SC010</td>
<td>Tue</td>
<td>Introduction to Optical Alignment Techniques</td>
<td>Castle</td>
<td>8:30 am to 5:30 pm</td>
<td>$580 / $695</td>
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<tr>
<td>SC1085</td>
<td>Thu</td>
<td>Optomechanical Systems Engineering</td>
<td>Kasunic</td>
<td>8:30 am to 5:30 pm</td>
<td>$580 / $695</td>
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### Photonic Integration

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<tr>
<td>SC1071</td>
<td>Sat</td>
<td>Understanding Diffraetive Optical Components Using Unique Means</td>
<td>Gobov</td>
<td>1:30 pm to 5:30 pm</td>
<td>$330 / $390</td>
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<tr>
<td>SC1204</td>
<td>Sun</td>
<td>Volume Bragg Gratings—Optical Components Providing Unique Means</td>
<td>Gobov</td>
<td>1:30 pm to 5:30 pm</td>
<td>$330 / $390</td>
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<tr>
<td>SC817</td>
<td>Wed</td>
<td>Silicon Photonics</td>
<td>Michel, Saini</td>
<td>1:30 pm to 5:30 pm</td>
<td>$330 / $390</td>
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### Photonic Therapeutics and Diagnostics

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<tr>
<td>SC1221</td>
<td>Mon</td>
<td>Physiological Optics of the Eye for Engineers</td>
<td>Lakshminarayan</td>
<td>8:30 am to 5:30 pm</td>
<td>$615 / $730</td>
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<tr>
<td>SC702</td>
<td>Tue</td>
<td>Optics and Optical Quality of the Human Eye</td>
<td>Roorda</td>
<td>8:30 am to 5:30 pm</td>
<td>$330 / $390</td>
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<tr>
<td>SC1175</td>
<td>Wed</td>
<td>Optics in the Hospital—Endoscope Specification and Design</td>
<td>Leiner</td>
<td>8:30 am to 12:30 pm</td>
<td>$355 / $415</td>
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COURSE INDEX

Semiconductor Lasers, LEDs, and Applications

SC1146 Mon Laser Diode Beam Basics, Characteristics and Manipulation (Sun) 1:30 pm to 5:30 pm, $330 / $390 .......... 29

SC1259 Wed Introduction to Vertical-Cavity Surface-Emitting Lasers (VCSELs) and Applications (Choquette) 8:30 am to 12:30 pm, $330 / $390 .. 29

SC386 Thu Advanced Thermal Management Materials for Optoelectronic, Microelectronic and MEMS Packaging (Zweben) 8:30 am to 5:30 pm, $580 / $695 ................. 30

Snapshot Courses: Basic 2-Hour Courses for Sales, Marketing, and Industry

SC1234 Sun Introduction to VR, AR, MR and Smart Eyewear: Market Expectations, Hardware Requirements and Investment Patterns (Kress) 8:30 am to 10:30 am, $185 / $210 .. 46

SC1224 Mon Fundamentals of Optical Engineering (Vogt) 10:30 am to 12:30 pm, $185 / $210 .................. 45

SC609 Mon Basic Optics for Non-Optics Personnel (Harding) 1:30 pm to 3:30 pm, $185 / $210 ................. 47

SC1170 Mon The Very Least You Need To Know About Optics (Diehl) 3:30 pm to 5:30 pm, $185 / $210 ............. 45

Tissue Optics, Laser-Tissue Interaction, and Tissue Engineering

SC029 Sun Tissue Optics (Jacques) 1:30 pm to 5:30 pm, $330 / $390 .......... 15

Professional Development Workshops

SC1253 Mon How to Develop Profitable Technology Products (Giltnner) 8:30 am to 12:30 pm, $200 / $225 .. 47

SC1208 Mon The Seven Habits of Highly Effective Project Managers (Warner) 1:30 pm to 5:30 pm, $200 / $225 .. 48

WS1250 Sun Think like an Entrepreneur (Samadan) 10:30 am to 5:00 pm, $65 / $75 ................. 48

Industry Workshops

WS9006 Wed Photodetectors, Raman Spectroscopy, and SiPMs versus PMTs: One-day Workshop (Piatek) 8:30 am to 5:00 pm ............... 49

WS9010 Wed How to Reduce Errors Found Downstream of the Optical Design with Zemax Virtual Prototyping (Pickering, Pegoero) 1:30 pm to 5:30 pm ......................... 59

WS9012 Wed High-power Laser Optics, Distance Measurement in LiDAR, and Infrared Detectors (Herott, Voke, Zhu, Carey) 9:00 am to 4:30 pm ............... 50

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<td><strong>Advanced Quantum and Optoelectronic Applications</strong></td>
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<td>SC1191 Quantum Sensors (Lanzagorta, Venegas-Andraca) 8:30 am to 12:30 pm, p.27</td>
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<tr>
<td>SC1258 Quantum Cryptography (Venegas-Andraca, Lanzagorta) 1:30 pm to 5:30 pm, p.28</td>
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<td><strong>Biomedical Spectroscopy, Microscopy, and Imaging</strong></td>
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<td>SC1072 Statistics for Imaging and Sensor Data (Bajorski) 8:30 am to 5:30 pm, p.15</td>
<td>SC1260 Optical Super Resolution and Extended Depth of Focus (Zalevsky) 1:30 pm to 5:30 pm, p.15</td>
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<td>SC981 Biomedical Applications of Specialty Optical Fibers and Fiber Sensors (Mendez, Arkwright) 1:30 pm to 5:30 pm, p.14</td>
<td>SC1228 Diffuse Optics in Biology and Medicine: Noninvasive Probes of Tissue Health (Busch) 1:30 pm to 5:30 pm, p.13</td>
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<td>SC1234 Introduction to VR, AR, MR and Smart Eyewear: Market Expectations, Hardware Requirements and Investment Patterns (Kress) 8:30 am to 10:30 am, p.32</td>
<td>SC1096 Head-Mounted Display Requirements and Designs for Augmented Reality Applications (Browne, Melzer) 8:30 am to 5:30 pm, p.30</td>
<td>SC1218 Optical Technologies and Architectures for Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) Head-Mounted Displays (HMDs) (Kress) 8:30 am to 5:30 pm, p.31</td>
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### DAILY COURSE SCHEDULE BY TRACK

#### SATURDAY | SUNDAY | MONDAY | TUESDAY | WEDNESDAY | THURSDAY
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**Imaging**

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<td>Deep Learning and Its Applications in Image Processing (Nasrabadi)</td>
<td>8:30 am to 5:30 pm</td>
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<tr>
<td>SC504</td>
<td>Introduction to CCD and CMOS Imaging Sensors and Applications (Crisp)</td>
<td>1:30 pm to 5:30 pm</td>
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<tr>
<td>SC1231</td>
<td>Designing and Specifying Digital Cameras (Baldwin)</td>
<td>8:30 am to 12:30 pm</td>
<td>p.43</td>
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**Laser Safety**

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<tbody>
<tr>
<td>SC1256</td>
<td>Basic Laser Safety (Barat)</td>
<td>10:30 am to 12:30 pm</td>
<td>$225 / $250, p.44</td>
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<tr>
<td>SC1257</td>
<td>Laser Lab Design, Do's and Don'ts (Barat)</td>
<td>1:30 pm to 3:30 pm</td>
<td>$210 / $235, p.45</td>
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**Laser Sources**

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<td>Improving Laser Reliability: an Introduction (Grossman, Asbury)</td>
<td>8:30 am to 5:30 pm</td>
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<tr>
<td>SC972</td>
<td>Basic Laser Technology: Fundamentals and Performance Specifications (Sukuta)</td>
<td>8:30 am to 12:30 pm</td>
<td>p.20</td>
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<tr>
<td>SC1207</td>
<td>High-Power Laser Technologies (Paschotta)</td>
<td>8:30 am to 12:30 pm</td>
<td>p.18</td>
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<tr>
<td>SC1225</td>
<td>Solid-State Laser Design for Environmental Stability (Lee)</td>
<td>8:30 am to 5:30 pm</td>
<td>p.19</td>
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<tr>
<td>SC1181</td>
<td>Ultrafast Lasers and Amplifiers (Paschotta)</td>
<td>8:30 am to 5:30 pm</td>
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<tr>
<td>SC752</td>
<td>Solid State Laser Technology (Hodgson)</td>
<td>8:30 am to 5:30 pm</td>
<td>p.20</td>
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<td>SC1020</td>
<td>Splicing of Specialty Fibers and Glass Processing of Fused Components for Fiber Laser and Medical Probe Applications (Wang)</td>
<td>8:30 am to 12:30 pm</td>
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# DAILY COURSE SCHEDULE BY TRACK

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<td><strong>Macro Applications</strong></td>
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<td></td>
<td>SC1144 Laser Systems Engineering (Kasunic) 8:30 am to 5:30 pm, p.22</td>
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<td><strong>Metrology &amp; Standards</strong></td>
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<tr>
<td>SC212 Modern Optical Testing (Wyant) 8:30 am to 12:30 pm, p.42</td>
<td>SC700 Understanding Scratch and Dig Specifications (Aikens) 8:30 am to 12:30 pm, p.42</td>
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<td></td>
<td>SC1017 Optics Surface Inspection Workshop (Aikens) 1:30 pm to 5:30 pm, p.41</td>
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<td><strong>Micro/Nano Applications</strong></td>
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<td>SC743 Micro-machining with Femtosecond Lasers (Nolte) 8:30 am to 12:30 pm, p.22</td>
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<td><strong>MOEMS-MEMS in Photonics</strong></td>
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<td>SC454 Fabrication Technologies for Micro- and Nano-Optics (Suleski) 8:30 am to 12:30 pm, p.27</td>
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<td>SC1125 Design Techniques and Applications Fields for Digital Micro-optics (Kress) 8:30 am to 5:30 pm, p.26</td>
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<td><strong>Nano/Biophotonics</strong></td>
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<td>SC1186 Fluorescence Sensing and Imaging: Towards Portable Healthcare (Levi) 1:30 pm to 5:30 pm, p.16</td>
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<td><strong>Neurophotonics, Neurosurgery, and Optogenetics</strong></td>
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<td>SC1126 Neurophotonics (Levi, Dufour) 1:30 pm to 5:30 pm, p.12</td>
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## DAILY COURSE SCHEDULE BY TRACK

### Nonlinear Optics and Beam Guiding

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<tr>
<td>SC047</td>
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<tr>
<td><strong>Introduction to Nonlinear Optics (Fisher)</strong></td>
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<td><strong>Cost-Conscious Tolerancing of Optical Systems (Youngworth)</strong></td>
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<td><strong>Fourier Optics (Popescu)</strong></td>
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<td>8:30 am to 12:30 pm, p.21</td>
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<td>8:30 am to 12:30 pm, p.38</td>
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<td>8:30 am to 5:30 pm, p.36</td>
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### Optical Systems & Lens Design

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<tr>
<td>SC156</td>
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<tr>
<td><strong>Basic Optics for Engineers</strong> (Poutous) 8:30 am to 5:30 pm, p.37</td>
<td></td>
<td><strong>Optical System Design: Layout Principles and Practice</strong> (Greivenkamp) 8:30 am to 5:30 pm, p.33</td>
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<td><strong>Fourier Optics</strong> (Popescu) 8:30 am to 5:30 pm, p.36</td>
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<td>SC003</td>
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<td>SC1177</td>
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<tr>
<td><strong>Practical Optical System Design</strong> (Youngworth, Olson) 8:30 am to 5:30 pm, p.33</td>
<td></td>
<td><strong>Practical Guide to Spectral Measurements</strong> (Kaltenbacher) 8:30 am to 12:30 pm, p.34</td>
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<td><strong>Polarized Light and Optical Design</strong> (Chipman, Young) 8:30 am to 5:30 pm, p.36</td>
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<td>SC690</td>
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<td>SC935</td>
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<td><strong>Optical System Design: Layout Principles and Practice</strong> (Greivenkamp) 8:30 am to 5:30 pm, p.33</td>
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<td><strong>Introduction to Lens Design</strong> (Bentley) 8:30 am to 5:30 pm, p.38</td>
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<td><strong>Introduction to LIDAR for Autonomous Vehicles</strong> (Shaw) 1:30 pm to 5:30 pm, p.35</td>
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<td>SC111</td>
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<td><strong>Design of Efficient Illumination Systems</strong> (Cassarly) 1:30 pm to 5:30 pm, p.33</td>
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<td><strong>Stray Light Analysis and Control</strong> (Fest) 8:30 am to 5:30 pm, p.34</td>
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<td>SC1091</td>
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<td>SC1197</td>
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<td><strong>Fundamentals of Reliability Engineering for Optoelectronic Devices</strong> (Leisher) 8:30 am to 12:30 pm, p.23</td>
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<td><strong>Fundamentals of Spectral Sensing</strong> (Linden) 8:30 am to 5:30 pm, p.23</td>
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<td>SC747</td>
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<td><strong>Semiconductor Photonic Device Fundamentals</strong> (Linden) 8:30 am to 5:30 pm, p.23</td>
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### Optoelectronic Materials and Devices

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<td><strong>Fundamentals of Reliability Engineering for Optoelectronic Devices</strong> (Leisher) 8:30 am to 12:30 pm, p.23</td>
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<td><strong>Optomechanics</strong></td>
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<td>SC014</td>
<td>Introduction to Optomechanical Design (Vukobratovich)</td>
<td>8:30 am to 5:30 pm, p.40</td>
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<td>SC010</td>
<td>Introduction to Optical Alignment Techniques (Castle)</td>
<td>8:30 am to 5:30 pm, p.39</td>
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<td>SC015</td>
<td>Fastening Optical Elements with Adhesives (Daly)</td>
<td>8:30 am to 12:30 pm, p.40</td>
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<td><strong>Photonic Integration</strong></td>
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<td>SC1071</td>
<td>Understanding Diffractive Optics (Soskind)</td>
<td>8:30 am to 5:30 pm, p.24</td>
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<td>SC1020</td>
<td>Volume Bragg Gratings—Optical Components Providing Unique Means (Glebov)</td>
<td>1:30 pm to 5:30 pm, p.25</td>
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<td>SC1178</td>
<td>Silicon Photonics (Michel, Saini)</td>
<td>1:30 pm to 5:30 pm, p.25</td>
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<tr>
<td>SC015</td>
<td>Silicon Photonics (Michel, Saini)</td>
<td>8:30 am to 5:30 pm, p.25</td>
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<td><strong>Photonic Therapeutics and Diagnostics</strong></td>
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<td>SC1221</td>
<td>Physiological Optics of the Eye for Engineers (Lakshminarayanan)</td>
<td>8:30 am to 5:30 pm, p.11</td>
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<td>SC0702</td>
<td>Optics and Optical Quality of the Human Eye (Roorda)</td>
<td>1:30 pm to 5:30 pm, p.12</td>
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<tr>
<td>SC1175</td>
<td>Optics in the Hospital-Endoscope Specification and Design (Leiner)</td>
<td>8:30 am to 12:30 pm, p.11</td>
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<td><strong>Semiconductor Lasers, LEDs, and Applications</strong></td>
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<tr>
<td>SC1146</td>
<td>Laser Diode Beam Basics, Characteristics and Manipulation (Sun)</td>
<td>1:30 pm to 5:30 pm, p.29</td>
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<td>SC1259</td>
<td>Introduction to Vertical-Cavity Surface-Emitting Lasers (VCSELs) and Applications (Choquette)</td>
<td>8:30 am to 12:30 pm, p.29</td>
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<td>SC386</td>
<td>Advanced Thermal Management Materials for Optoelectronic, Microelectronic and MEMS Packaging (Zweben)</td>
<td>8:30 am to 5:30 pm, p.30</td>
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## DAILY COURSE SCHEDULE BY TRACK

### Tissue Optics, Laser-Tissue Interaction, and Tissue Engineering

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<tr>
<td><strong>SC029 Tissue Optics</strong>&lt;br&gt;(Jacques) 1:30 pm to 5:30 pm, p.15</td>
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### Snapshot Courses: Basic 2-Hour Courses for Sales, Marketing, and Industry

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<tr>
<td><strong>SC1234 Introduction to VR, AR, MR and Smart Eyewear: Market Expectations, Hardware Requirements and Investment Patterns</strong>&lt;br&gt;(Kress) 8:30 am to 10:30 am, p.46</td>
<td><strong>SC1224 Fundamentals of Optical Engineering</strong>&lt;br&gt;(Vogt) 10:30 am to 12:30 pm, p.45</td>
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<tr>
<td><strong>SC609 Basic Optics for Non-Optics Personnel</strong>&lt;br&gt;(Harding) 1:30 pm to 3:30 pm, p.397</td>
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<tr>
<td><strong>SC1170 The Very Least You Need To Know About Optics</strong>&lt;br&gt;(Diehl) 3:30 pm to 5:30 pm, p.396</td>
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### Professional Development Workshops

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<tr>
<td><strong>WS1250 Think like an Entrepreneur</strong>&lt;br&gt;(Samadani) 10:30 am to 5:00 pm, p.398</td>
<td><strong>SC1253 How to Develop Profitable Technology Products</strong>&lt;br&gt;(Giltner) 8:30 am to 12:30 pm, p.397</td>
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<td><strong>SC1208 The Seven Habits of Highly Effective Project Managers</strong>&lt;br&gt;(Warner) 1:30 pm to 5:30 pm, p.397</td>
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## Industry Workshops

—Intended for students and early career professionals.

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<tr>
<td><strong>WS9006 Photodetectors, Raman Spectroscopy, and SiPMs versus PMTs: One-day Workshop</strong> (Piatek) 8:30 am to 5:00 pm, p.398</td>
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<td><strong>WS9010 How to Reduce Errors Found Downstream of the Optical Design with Zemax Virtual Prototyping</strong> (Pickering, Peguero) 1:30 pm to 5:30 pm, p.399</td>
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<td><strong>WS9012 High-power Laser Optics, Distance Measurement in LiDAR, and Infrared Detectors</strong> (Herdt, Voke, Zhu, Carey) 9:00 am to 4:30 pm, p.399</td>
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**Optics in the Hospital—Endoscope Specification and Design**

**SC1175 • Course Level: Intermediate • CEU: 0.4**

$355 Members • $196 Student Members • $415 Non-Members USD

Wednesday 8:30 am to 12:30 pm

Minimally invasive and robotic surgery rely on endoscopes to provide the “eyes” of the surgeon. Endoscopes are perhaps the most complex of commercial optical systems and may contain 30 or more optical components. The design of these medical devices must be robust enough to withstand the rigors of thousands of cycles of pressurized steam sterilization, yet address the requirements needed for incredibly delicate clinical procedures.

This course teaches how to approach the use of miniature optics in your medical device design. We examine the optics from the physicians' perspective; e.g., how the endoscope optics for abdominal surgery are different than those for knee surgery. Optical specifications are covered in detail, including ISO testing requirements and FDA requirements. The course finishes with the critical area of design for manufacturing.

**LEARNING OUTCOMES**

This course will enable you to:

- identify the types of medical procedures for which endoscopes can be deployed.
- classify the types of endoscope optics that are used in the body.
- explain the key specifications that define an endoscope design.
- describe the ISO specifications and FDA regulations pertinent to each endoscope design.
- identify at least three types of rigid endoscopes and two types of flexible endoscopes.
- identify elements of a substandard endoscope design and explain what needs to be improved.
- engineer the optics of a simple endoscope given the required clinical parameters.

**INTENDED AUDIENCE**

The course is intended for optical engineers and engineering managers who are beginning or continuing work with medical endoscopes or industrial borescopes. Familiarity with geometrical optics, and a minimum of a BS in Optics or equivalent work experience is assumed.

**INSTRUCTOR**

Dennis Leiner is the president of Leiner Optics, an engineering company that assists startups and Fortune 500 companies who are incorporating visualization into their medical devices. Dr. Leiner received his B.S. and M.S. degrees in Optics from the University of Rochester and his Ph.D. from the University of Connecticut. He taught optics at the University of Massachusetts in Lowell until 1985 when he started Lighthouse Imaging Corporation, a leader in endoscope optics design and manufacture. He holds multiple patents in endoscope design using gradient-index optics, infrared optics, fiberoptics, and injection-molded optics. He is a Chairperson Elect of the Optics and Electro Optics Standards Council (OEOSC) and is Group Leader for Existing Endoscope Standards at ANSI.


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**Physiological Optics of the Eye for Engineers**

**SC1221 • Course Level: Introductory • CEU: 0.7**

$615 Members • $322 Student Members • $730 Non-Members USD

Monday 8:30 am to 5:30 pm

Given the prevalence and potential impact of visual displays, head mounted, virtual reality and assisted reality devices, it is important for the optical engineer working in these areas to know about how the human eye works and how auxiliary devices can be interfaced to the eye. Devices vary by their relationship to the user’s eyes. Various visual factors, both perceptual and optical, will have to be taken into account. These factors include accommodation, aging, color, contrast, eye relief distance, field of view, flicker, glare, resolution, stereopsis, motion and aberrations of the eye. Design of such optical systems requires knowledge of the metrics of visual performance in spatial, temporal and color domains. These factors are important when selecting head-mounted displays for specific applications. These optical and human factors performance metrics constrain the design and use of such devices. I will describe and discuss these various factors.

**LEARNING OUTCOMES**

This course will enable you to:

- explain the visual system and identify various factors that influence vision
- describe the dioptrics of the eye and schematic eye models
- list various parameters of the visual system of interest to the optician
- describe various metrics such as contrast sensitivity function, flicker sensitivity function, the V-Lambda curve and spectral sensitivity, color vision, accommodation, etc.
- explain the human factors involved in the design and use of these technologies
- explain various aspects of visual performance and combine these various performance metrics to formulate a global model of vision
- compare various displays, HMD, VR and AR devices in terms of their capability for working with the human visual system

**INTENDED AUDIENCE**

Optical engineers, designers, managers, graduate students, and people interested in the visual system in general. Some knowledge of geometric optics is required. However, no knowledge of anatomy or physiology is necessary. The necessary biological aspects will be included in the course.
Neurophotonics, Neurosurgery, and Optogenetics

Neurophotonics
SC1126 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Monday 1:30 pm to 5:30 pm

The brain is the most widely studied body organ, and yet our understanding of its operation in normal and diseased conditions is limited. Modern imaging tools, including optical imaging techniques and optical fiber probing/sensing, have enabled the study of many neural diseases. They are critical in evaluating the effect of drugs in pre-clinical animal studies and in medical diagnosis.

As optics play a central role in neuroscience activities, this course will review the principles and the major optical techniques used for optical brain imaging as well as the technical challenges and solutions applied to translate them into medical applications. This class will (1) offer a quick introduction to neuroscience, (2) compare the major optical techniques and contrast mechanisms (such as scattering, absorption, light coherence, fluorescence) used in brain imaging, (3) give an overview of optogenetic techniques and (4) discuss the engineering challenges we face in developing reliable tools for clinical use, and the approaches to overcome them.

LEARNING OUTCOMES

This course will enable you to:
• review the major cellular components and functional areas of the brain
• explain the different optical contrast mechanisms used for brain functional or morphological imaging
• discuss the common optical imaging techniques used in neuroscience (in vitro) and brain (in vivo) imaging applications
• describe the use of these optical imaging techniques in evaluating functional brain information including blood flow, oxygen consumption, and neural activity
• review the basics of the optogenetics techniques using light to selectively control and probe brain activity
• discuss the major challenges in developing optical imaging tools for clinical applications in the brain, and progress towards system commercialization.

INTENDED AUDIENCE

Engineers, scientists, technicians, or managers who wish to learn more about optical imaging techniques and how to apply them to image biological cells and tissues in the brain. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Ofer Levi is a Professor of Electrical Engineering and Biomedical Engineering at the University of Toronto. He also holds a Visiting Professor position at Stanford University, CA. He has spent over two decades in academia and industry, designing and commercialization.

Optics and Optical Quality of the Human Eye

SC702 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Tuesday 1:30 pm to 5:30 pm

The eye has a complex and exquisitely designed optical system yet, when compared with modern optical systems, its image quality is surprisingly poor. This course will discuss the optical properties of the different components of the eye from the cornea to the retina, and how they impact visual quality. We will evaluate benefits and limitations of various techniques, such as adaptive optics and laser refractive surgery, which have been developed to overcome the eye’s optical limitations. Aberration limits will be presented so that designers of optical systems, where the eye often plays an intrinsic role, can estimate the degree of correction required for their products to produce high quality perceived imagery.

LEARNING OUTCOMES

This course will enable you to:
• name and describe the major optical components of the eye and how they work together to form an image on the retina
• identify the limitations of the optical system of the eye and how they impact perceived image quality
• compare and contrast the optical system of the eye with other man-made optical instruments
• design an optical system that appreciates and considers the intrinsic role of the eye in that system as an optical component

INTENDED AUDIENCE

This course is intended to impart practical knowledge to optical design engineers or clinicians (ophthalmologists, refractive surgeons, optometrists), but it will also be of general interest to anyone who is interested in learning about the unique optical system of the eye.

INSTRUCTOR

Austin Roorda has a PhD in Vision Science and Physics and is a Professor of Vision Science and Optometry at the University of California, Berkeley. His research areas include adaptive optics, high resolution ophthalmoscopy, and optics of the human eye.
developing optical imaging systems, laser sources, and optical sensors. He specializes in design and optimization of optical bio-sensors, Bio-MEMS, and optical imaging systems for biomedical applications, including in cancer and brain imaging. Dr. Levi is a member of OSA, IEEE-P, and SPIE.

Suzie Dufour is a biophotonics researcher at the National Optics Institute (INO) in Quebec, Canada. She received her BSc degree in physics from Laval University in 2004 and her PhD in neurobiology in 2012. Her PhD involved the design and fabrication of micro-optrodes for in vivo studies. She completed her postdoctoral research on in vivo brain imaging at University of Toronto and the Toronto Western Research Institute. Her past and current research interests include biophotonics, optical in vivo brain imaging, optogenetics, hyperspectral imaging, visible and IR imaging and ophthalmology applications. Dr. Dufour is a member of OSA and SPIE.

**Clinical Technologies and Systems**

**Diffuse Optics in Biology and Medicine: Noninvasive Probes of Tissue Health**

**SC1228 • Course Level: Introductory • CEU: 0.4**
$330 Members • $186 Student Members • $390 Non-Members USD
Tuesday 1:30 pm to 5:30 pm

This course explains principles and applications of diffuse optics in biology and medicine. Diffuse optical tools have a large and rapidly expanding set of pre-clinical and clinical applications. We will focus on measurements of ‘thick’ tissues (<1cm) with diffuse optical spectroscopy, diffuse correlation spectroscopy, diffuse optical tomography, and diffuse fluorescence. The primary goal of this course is to provide attendees with sufficient knowledge to grasp the underlying concepts, strengths, and weaknesses of the technologies involved. Examples will be taken from pre-clinical and clinical applications, especially critical care, including planning, conduction, and data analysis. Researchers considering use of diffuse optical tools, clinicians in search of technologies to address pressing monitoring needs, and translational researchers interested in applying diffuse optics will benefit from the course.

**LEARNING OUTCOMES**

This course will enable you to:
- describe the principle of diffuse correlation spectroscopy
- summarize the current range of preclinical and clinical diffuse optical applications
- determine the appropriate diffuse optical instrument for a particular application
- discriminate between studies undertaken with various diffuse optical data types
- access key resources for diffuse optical information

**Principles and Applications of Optical Coherence Tomography**

**SC312 • Course Level: Advanced • CEU: 0.4**
$330 Members • $186 Student Members • $390 Non-Members USD
Sunday 1:30 pm to 5:30 pm

Optical coherence tomography (OCT) is a new imaging modality, which is the optical analog of ultrasound. OCT can perform high resolution cross sectional imaging of the internal structure of biological tissues and materials. OCT is promising for biomedical imaging because it functions as a type of optical biopsy, enabling tissue pathology to be imaged in situ and in real time. This technology also has numerous applications in other fields ranging from nondestructive evaluation of materials to optical data storage. This course describes OCT and the integrated disciplines including fiber optics, interferometry, high-speed optical detection, biomedical imaging, in vitro and in vivo studies, and clinical medicine.

**LEARNING OUTCOMES**

This course will enable you to:
- explain a systems viewpoint of OCT technology
- describe OCT detection approaches and factors governing performance
- describe ultrafast laser technology and other low coherence light sources
- provide an overview of clinical imaging including clinical ophthalmology, surgical guidance, and detection of neoplasia and guiding biopsy
- describe OCT imaging devices such as microscopes, hand held probes and catheters
- describe functional imaging such as Doppler and spectroscopic OCT
- gain an overview of clinical imaging including clinical ophthalmology, surgical guidance, and detection of neoplasia and guiding biopsy
- provide an overview of clinical imaging including clinical ophthalmology, surgical guidance, and detection of neoplasia and guiding biopsy
- gain an overview of clinical imaging including clinical ophthalmology, surgical guidance, and detection of neoplasia and guiding biopsy
- discuss transitioning technology from the laboratory to the clinic

**INTENDED AUDIENCE**

This material is appropriate for scientists, engineers, and clinicians who are performing research in medical imaging.
This course provides a broad overview of optical fiber sensing principles and techniques for biological and medical applications, as well as on the generic uses of specialty optical fibers for biomedical devices and medical instruments. Healthcare industry trends, its sensing needs and the benefits brought on by fiber optics are also reviewed.

The course is divided into three sections. Section I provides an introduction to the ongoing status and trends in the healthcare industry and the medical needs that demand the use of optical fibers and fiber-based sensors. In Section II, a review of fiber optic sensor (FOS) technology is made, describing its operating principles, associated components (such as light sources, detectors, couplers, polarizers, etc.), and the specialty fiber types required for biomedical sensing system integration. A review of the non-sensing applications of fibers for illumination, imaging and laser delivery is also made. Finally, in Section III, a review of the major classes of biomedical fiber sensors and sensing techniques is made based on fiber Bragg gratings (FBG), Fabry-Perot cavities, interferometers and others, for single-point and distributed in-vivo sensing. A brief overview will also be given on fiber-optic endoscopic, intra-vascular and needle type probes for Optical Coherence Tomography (OCT).

LEARNING OUTCOMES
This course will enable you to:
- describe the operating principles, features and advantages of fiber optic sensors
- review a wide range of sensor types for physiological, bio-chemical and imaging applications
- learn how specialty optical fibers are used in diverse biomedical devices and sensors
- know some of the special biomedical considerations such as materials biocompatibility and related industry standards
- illustrate specific sensing solutions and their clinical impact through case-study analysis
- obtain an overall view of the healthcare and biomedical fiber sensing industries and their trends

INTENDED AUDIENCE
Technical managers, scientists, engineers, technicians and research students who wish to learn about biomedical sensors and fiber sensing technology and review their implementation and applications. The course is also suitable to gain an overview of the field and to learn about the state-of-the-art of fiber optic-based biomedical and life sciences applications and devices.

INSTRUCTOR
Alexis Mendez is President of MCH Engineering LLC, a consulting firm specializing in optical fiber sensing technology, and has over 25 years of experience in optical fiber technology, sensors and instrumentation. He was the former Group Leader of the Fiber Optic Sensors Lab within ABB Corporate Research (USA), working on the development of new fiber optic sensing systems for electric utility and oil & gas applications. He has written over 65 technical publications, holds 4 US patents and is recipient of an R&D 100 award. He is an SPIE Fellow, editor of the [i]Specialty Optical Fibers Handbook[/i] and co-author of the textbook [i]Fiber Optic Sensors: Fundamentals and Applications[/i]. Dr. Mendez was also past chair of the International Optical Fiber Sensors Conference (OFS-18). Dr. Mendez holds a PhD. degree in Electrical Engineering from Brown University.

John Arkwright is the South Australian Premier’s Professorial Research Fellow in biomedical engineering at Flinders University in Adelaide, Australia. Prof. Arkwright has an extensive background in optical fiber technology and devices, initially for the telecommunications industry and, more recently, for biomedical sensing. He has worked in both industrial R&D and academic roles always with an emphasis on developing and commercializing new technologies. At Flinders University, is conducting research on the design, fabrication, and commercialization of fiber optic catheters for in-vivo diagnostics. John is also Managing Director of Arkwright Technologies Pty Ltd.


ATTENDEE TESTIMONIAL:
Great course from the inventor! What more can you ask for.
Tissue Optics, Laser-Tissue Interaction, and Tissue Engineering

Tissue Optics

SC029 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Sunday 1:30 pm to 5:30 pm

This course outlines the principles of light transport in tissues that underlie design of optical measurement devices and laser dosimetry for medicine. Topics include radiative transport in turbid tissues, the optical properties of tissues, modeling techniques for light transport simulation in tissues, analysis of reflectance and fluorescence spectra measured in turbid tissues by topical and imbedded optical fiber devices, video techniques, and criteria involved in establishing laser dosimetry protocols. Lessons are illustrated using case studies of optical fiber devices, video imaging techniques, and design of therapeutic laser protocols.

LEARNING OUTCOMES

This course will enable you to:

• conduct optical measurements of tissue optical properties
• calculate light distributions in tissues
• design an optical measurement of tissue using optical fibers or video
• justify the dosimetry of therapeutic laser protocols

INTENDED AUDIENCE

This material is intended for biomedical engineers and medical physicists interested in medical applications of ultraviolet, visible, and near infrared wavelengths from both conventional and laser light sources.

INSTRUCTOR

Steven Jacques is Professor in Biomedical Engineering, Tufts University.

Biomedical Spectroscopy, Microscopy, and Imaging

Statistics for Imaging and Sensor Data

SC1072 • Course Level: Introductory • CEU: 0.7
$650 Members • $336 Student Members • $765 Non-Members USD
Saturday 8:30 am to 5:30 pm

The purpose of this course is to survey fundamental statistical methods in the context of imaging and sensing applications. You will learn the tools and how to apply them correctly in a given context. The instructor will clarify many misconceptions associated with using statistical methods. The course is full of practical and useful examples of analyses of imaging data. Intuitive and geometric understanding of the introduced concepts will be emphasized. The topics covered include hypothesis testing, confidence intervals, regression methods, and statistical signal processing (and its relationship to linear models). We will also discuss outlier detection, the method of Monte Carlo simulations, and bootstrap.

LEARNING OUTCOMES

• apply the statistical methods suitable for a given context
• demonstrate the statistical significance of your results based on hypothesis testing
• construct confidence intervals for a variety of imaging applications
• fit predictive equations to your imaging data
• construct confidence and prediction intervals for a response variable as a function of predictors
• explain the basics of statistical signal processing and its relationship to linear regression models
• perform correct analysis of outliers in data
• implement the methodology of Monte Carlo simulations

INTENDED AUDIENCE

This course is intended for participants who need to incorporate fundamental statistical methods in their work with imaging data. Participants are expected to have some experience with analyzing data.

INSTRUCTOR

Peter Bajorski is Professor of Statistics at the Rochester Institute of Technology. He teaches graduate courses in statistics including a course on Multivariate Statistics for Imaging Science. He also designs and teaches short courses in industry, with longer-term follow-up and consulting. He performs research in statistics and in hyperspectral imaging. Dr. Bajorski wrote a book on Statistics for Imaging, Optics, and Photonics published in the prestigious Wiley Series in Probability and Statistics. He is a senior member of SPIE and IEEE.

COURSE PRICE INCLUDES the text Statistics for Imaging, Optics, and Photonics (SPIE/Wiley, 2011) by Peter Bajorski.

Optical Super Resolution and Extended Depth of Focus New

SC1260 • Course Level: Intermediate • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Tuesday 1:30 pm to 5:30 pm

Digital imaging systems and human vision systems have limited capability for separating spatial features, thereby limiting imaging resolution. Reasons for this limitation are related to the effects of diffraction, i.e. the finite dimensions of the imaging optics, the geometry of the sensing array and its sensitivity, and the axial position of the object which may be out of focus. In this course, we will examine novel photonic approaches to imaging beyond the diffraction limit with an emphasis on practical methods to overcome these limitations.

We will use the eye to model optical extended depth of focus concepts based on the “interference” effect. Implementation on conventional refractive devices such as spectacles, contact lenses and intraocular lenses will help demonstrate practical considerations for development.
Extended depth of focus technology is capable of simultaneously correcting various refractive errors such as myopia, hyperopia, presbyopia, regular/irregular astigmatism, as well as their combinations.

**LEARNING OUTCOMES**
This course will enable you to:
- analyze and characterize the resolution limitations of imaging systems
- design a super resolution approach that is best matched to its imaging configuration
- simulate and experimentally investigate different super resolving approaches
- understand and design an extended depth of focus imaging system
- simulate and experimentally investigate depth of focus aspects of imaging systems

**INTENDED AUDIENCE**
Engineers, scientists, research students, and R&D managers in the industry who wish to learn more about the fundamentals of imaging systems and the ways to exceed resolution limitations and extend the depth of focus. Some prior knowledge in optical imaging is recommended.

**INSTRUCTOR**
Zeev Zalevsky received his B.Sc. and direct Ph.D. degrees in electrical engineering from Tel-Aviv University in 1993 and 1996 respectively. Zeev is currently a full Professor in the faculty of engineering in Bar-Ilan University, Israel. His major fields of research are optical super resolution, biomedical optics, nano-photonics and electro-optical devices, RF photonics and beam shaping. Zeev has published more than 460 refereed journal papers many of which are on the topic of optical super resolution.

**Nano/Biophotonics**

**Fluorescence Sensing and Imaging: Towards Portable Healthcare**

**SC1186 • Course Level: Intermediate • CEU: 0.4**

- $330 Members • $186 Student Members • $390 Non-Members USD

**Tuesday 1:30 pm to 5:30 pm**

Advances in medicine and technology are opening a new era of portable healthcare. Together with health apps, wearable/portable health monitoring systems are targeting medical diagnosis or health and wellness. The development of Wearable Health Monitoring Systems (WHMS) has been motivated mainly by increasing healthcare costs and by an aging world population. Fluorescent dyes are frequently used to mark biological samples, and track tissues, cells and individual molecules. In the lab, fluorescence is used to understand physiology and develop new cures to common diseases. In the clinic, fluorescence is used to diagnose health conditions and to evaluate treatments. Translating fluorescence imaging to portable healthcare systems will help us take better care of ourselves.

This course will review fundamental properties of fluorescent dyes, tissue absorption and scattering and show how these can be used to track vital signs and provide wellness indicators during a physical activity. Focusing on fluorescence imaging and sensing as a major technique for biomedical and healthcare applications, we will describe the design and optimization of an optical imaging system to specific dye spectra, and tailoring the optical system modules for specific applications such as bench-top microscopes, portable healthcare imaging, and in vivo fluorescence imaging in pre-clinical and clinical studies. We will review examples of portable fluorescence imaging systems in rapid disease diagnosis, and in health monitoring.

**LEARNING OUTCOMES**
This course will enable you to:
- describe dye properties such as excitation and emission spectra, quantum efficiency, and the schematic of a fluorescence process
- summarize the different main classes of fluorescent markers including small molecule dyes, nano-crystal quantum dots, and fluorescent proteins and their attributes
- explain the principles of fluorescence microscopy and the main modules (lenses, filters, sensors, light sources) involved in fluorescence imaging systems
- describe the design of miniature mobile fluorescence imaging systems and their unique challenges
- summarize common applications of fluorescence imaging in portable health monitoring systems
- explain some portable commercial fluorescence imaging solutions

**INTENDED AUDIENCE**
Engineers, scientists, students and managers who wish to learn more about fluorescent markers, tissue properties, design of fluorescence imaging systems, and their application in biomedical lab systems and in portable imaging. Some prior knowledge in microscopy and imaging is desirable.

**INSTRUCTOR**
Ofer Levi is a Professor of Electrical Engineering and Biomedical Engineering at the University of Toronto. He is serving as an Associate Editor of Biomedical Optics Express journal and currently hold a Visiting Professor position at Stanford University, CA. He has spent over 25 years in academia and industry, designing and developing optical imaging systems, laser sources, and optical sensors. He specializes in design and optimization of optical bio-sensors, Bio-MEMS, and optical imaging systems for biomedical applications, including in cancer and brain imaging. Dr. Levi is a member of OSA, IEEE-Photonics, and SPIE.
Laser Sources

Splicing of Specialty Fibers and Glass Processing of Fused Components for Fiber Laser and Medical Probe Applications

SCI020 • Course Level: Intermediate • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Sunday 8:30 am to 12:30 pm

This course provides attendees with the fundamentals of specialty fiber fusion splicing and fiber glass processing technologies with a focus on high power fiber laser and medical fiber probe applications. It provides an introduction on specialty fibers, reviews the fiber processing approach, and compares different techniques, especially on different fiber fusion processes along with different fusion hardware. It describes fiber waveguide and coupling optics associated with these processes and discusses practical fusion splicing methods for specialty fibers in order to achieve optimal optical coupling between dissimilar fibers. In addition, it illustrates fiber glass processing and fabrication techniques for producing fused fiber components, such as adiabatic taper, mode-field adaptor (MFA), fiber combiners and couplers, and other related fused fiber devices. The course also describes several practical application examples on fiber lasers and monolithic fiber-based probes for OCT imaging.

LEARNING OUTCOMES
This course will enable you to:
- become familiar with fiber processing fundamentals and state-of-the-art fiber splicing and fusion processing tools and hardware
- learn specialty fiber basics and waveguide coupling optics between dissimilar fibers
- gain in-depth knowledge of the fiber fusion splicing process and fiber glass processing techniques
- learn practical fiber fusion and glass processing methods for the splicing of various specialty fibers (including LMA fibers, PCF fibers, and soft-glass fibers), and fabrication of adiabatic taper, MFA, combiner, and other fiber coupling devices
- apply these fiber fusion and glass processing technologies to fiber laser and fiber based medical probe applications

INTENDED AUDIENCE
This material is intended for anyone who needs to handle and splice specialty fibers and wants to learn advanced fiber fusion splicing, tapering, and glassing processing technologies for fabricating high performance fiber-based devices. This course is valuable for those who want to develop or fabricate fiber-based devices or further improve their fiber system performance.

INSTRUCTOR
Baishi Wang is currently with Vytran Division of Thorlabs in Morganville, New Jersey. He received his Ph.D from SUNY at Stony Brook. His technical focus is on specialty fibers and fused fiber component, fiber lasers and amplifiers, fiber fusion process technologies and their applications to fiber lasers and fiber probes. Prior to joining Vytran in 2006, he was a technical staff member in Specialty Fiber Division at Lucent Technologies and OFS in Somerset, New Jersey. He has published numerous papers in referred conferences and journals, provided invited talks regularly, served as a conference committee member, and been awarded several patents. He is a reviewer for leading photonics and fiber optics journals. He is a senior member of SPIE and member of OSA.

Improving Laser Reliability: an Introduction

SCI1174 • Course Level: Introductory • CEU: 0.7
$580 Members • $308 Student Members • $695 Non-Members USD
Monday 8:30 am to 5:30 pm

From science to so-called secret sauces, we will share some of the tricks, techniques, and good practices that go into designing and manufacturing reliable lasers and systems. Lasers are often expensive. Eliminating laser failures, even one laser failure, is a big win. This course examines both optical and non-optical issues that affect reliability. We will emphasize solid-state lasers, frequency-converted lasers, aspects of fiber lasers, and systems that use lasers. We will cover semiconductor lasers, mainly from the perspective of using them as components. Our goal is to help you make more reliable lasers and more reliable laser systems. Together, we will discuss many examples illustrating key failure modes and how to avoid failures. This course has new examples and information for 2018.

LEARNING OUTCOMES
This course will enable you to:
- identify and mitigate risks to reliability for each phase of the laser product life cycle
- utilize best-practices in your design and manufacturing to increase laser reliability
- design tests for qualification and screening of lasers
- estimate laser lifetime
- troubleshoot problems for each phase of the laser product life cycle

INTENDED AUDIENCE
Includes designers and builders of lasers or of systems that use lasers. We welcome laser engineers, laser scientists, managing engineers, reliability engineers, quality engineers, optical engineers, laser technicians, optical technicians, project leaders, program leaders, and managers. A general understanding of lasers and optics is a prerequisite for this class, but you need not be an expert.

INSTRUCTOR
William Grossman pioneered making reliable diode-pumped solid-state infrared and ultraviolet lasers. Will and his team designed and refined the Q-series line of ultraviolet lasers, made by Lightwave Electronics Corporation and then by JDS Uniphase (now Lumentum LLC). These have
been among the best selling diode-pumped lasers ever built. Will has authored a broad range of publications and patents on lasers including work on: solid-state laser design, laser reliability, fiber lasers, laser applications, laser materials, nonlinear optics, and free-electron lasers. Will was Vice President of Engineering at Lightwave, Director of Lasers at JDSU, and Director of Lasers and Optics at Electro Scientific Industries. Currently Will is an independent consultant, and is hands-on active in experimental laser work. Will earned a Ph.D. in Applied Physics from Caltech.

Cheryl Asbury has over 20 years of experience developing laser systems for space applications that require high optical power output and high reliability over mission lifetimes of 10+ years. She currently serves as the Photonics Specialist in the Component Engineering and Assurance Office at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, CA. Cheryl came to JPL after 5 years at Lightwave Electronics Corporation, where she managed the development and delivery of 6 space-qualified diode-pumped solid-state lasers to the Tropospheric Emission Spectrometer (TES) Instrument on NASA's Aura spacecraft, which collected data on the Earth's atmosphere for 14 years from its launch in 2004 to instrument decommissioning in January 2018. Cheryl earned a BS in Applied and Engineering Physics from Cornell University and an MS in Applied Physics from the University of Michigan.

ATTENDEE TESTIMONIAL:
Excellent - I'm glad I invested the time to take this course. The real-world-examples were extremely instructive and valuable.

Ultrafast Lasers and Amplifiers
SC1811 • Course Level: Advanced • CEU: 0.7
$580 Members • $308 Student Members • $695 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course gives detailed insight into the operation principles and essential limitations of lasers and amplifiers for ultrashort pulse generation. Mode-locked lasers of different kinds, including both bulk lasers and fiber lasers, and the different mode-locking mechanisms used in those are discussed in detail and often demonstrated with numerical simulations. Also, principles and limitations of pulse amplification in bulk and fiber devices are treated.

LEARNING OUTCOMES
This course will enable you to:
• describe the principle of pulse generation with mode locking
• name several factors which can cause instabilities in mode-locked lasers
• describe the essential differences between bulk laser and fiber laser technology
• identify various limiting effects for the performance of ultrafast lasers and amplifiers
• know essential methods required for the efficient development of ultrashort pulse sources

INTENDED AUDIENCE
This course is intended for laser engineers and researchers being interested in the development of ultrafast lasers and amplifiers based on different technologies. They should already have some knowledge of optics and lasers.

INSTRUCTOR
Rüdiger Paschotta is an expert in laser physics, nonlinear optics and fiber technology, who previously was a researcher and is now working in his company RP Photonics Consulting GmbH, providing technical consultancy primarily for companies building or using lasers and related devices. Details are available on the web page https://www.rp-photonics.com/paschotta.html.

High-Power Laser Technologies
SC1207 • Course Level: Intermediate • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Thursday 8:30 am to 12:30 pm

This course starts with an overview on competing technologies for high-power solid-state laser sources, including bulk lasers, amplified and fiber-based sources. The primary topic is the analysis of performance potentials of different technologies in situations with different boundary conditions, such as continuous-wave operation with no restrictions or with high beam quality and/or a limited emission bandwidth, and the generation of intense laser pulses with nanosecond, picosecond or femtosecond durations. In this context, the concept of power scaling is given a meaningful basis, and scaling considerations are demonstrated in example cases.

LEARNING OUTCOMES
This course will enable you to:
• name different laser technologies for the generation of high optical powers or pulse energies
• identify the basic physical performance limitations for different laser types
• describe a methodology for comparing performance potentials
• explain the principle of power scaling, and apply scaling considerations to concrete cases

INTENDED AUDIENCE
Scientists, engineers, technicians, or R&D managers who wish to learn more about high-power laser technologies and how to compare them. A basic familiarity with the technical foundations of laser technology is assumed.

INSTRUCTOR
Rüdiger Paschotta is an expert in laser physics, nonlinear optics and fiber technology. He started a career as a researcher and later on founded his company RP Photonics Consulting GmbH, providing technical consultancy and software primarily for companies building or using lasers and related devices. Details are available on the web page https://www.rp-photonics.com/paschotta.html.
Solid-State Laser Design for Environmental Stability  New

SC1255 • Course Level: Intermediate • CEU: 0.7
$580 Members • $308 Student Members • $695 Non-Members USD
Sunday 8:30 am to 5:30 pm

Laser misalignment is a familiar phenomenon. Anyone who has endeavoured to build a laser resonator soon discovers the alignment precision required and that there can be a need for regular realignment to combat degrading performance. Lasers are sensitive to their environment through thermal, mechanical and atmospheric interactions and it is these interactions that cause laser performance to degrade if they are not given due consideration. This becomes ever more important as laser system sizes are reduced and they are taken from the laboratory and out into the field. This course will describe the mechanisms by which temperature, vibration, shock, humidity, contamination and vacuum interact with a solid-state laser and will present design approaches that mitigate these effects. If your laser is to be incorporated into a portable device, attached to a moving vehicle, used in defense applications, sent into space, or if your laser must survive being shipped to a customer and work reliably once it arrives, then you will benefit from this course.

LEARNING OUTCOMES
This course will enable you to:
• predict the misalignment sensitivity of a laser resonator and explain design strategies for minimizing that sensitivity, such as prism resonators and nonplanar ring resonators
• describe the influence of environmental temperature on resonator misalignment and the resulting considerations for engineering materials
• calculate the effects of thermal pump-diode tuning on laser output and determine the effectiveness of athermal pumping schemes
• list the effects of temperature on laser gain media and the consequences for laser performance
• identify strategies for minimizing sensitivity to vibration and shock.
• summarize the pros and cons of active interventions, such as cooling and automated alignment control, as opposed to passive approaches
• explain the pitfalls of sealing the laser in a box, with reference to the effects of mechanical stresses, choice of gas fill and desiccation strategy.

INTENDED AUDIENCE
Scientists and engineers involved in the development of reliable laser systems, particularly where the laser will be used outside of a laboratory environment. Undergraduate training in physics is assumed.

INSTRUCTOR
Stephen Lee earned his PhD in experimental laser physics at the University of Strathclyde in 2000 and since then has worked in laser product development. During his 6 years at Coherent he focused on lasers for bioscience and medical applications. He followed this with 10 years at Thales where he acted as Design Authority for the defense lasers product line, ensuring that laser systems operated in extreme environmental conditions with high reliability. He is now director of his own laser consultancy, Caledonian Photonics. Dr. Lee is a Fellow of the Institute of Physics and has acted as an organizing committee member and session chair at the SPIE Security & Defence conference.

High-Power Fiber Sources

SC748 • Course Level: Advanced • CEU: 0.7
$580 Members • $308 Student Members • $695 Non-Members USD
Sunday 8:30 am to 5:30 pm

This course describes the current state of the art, research directions, and principles of high-power fiber lasers and amplifiers. Recent advances have permitted output powers of these devices to reach well over a kilowatt, and underpinning fiber technology, pump lasers and pump coupling will be addressed. Rare-earth-doped fiber devices including those based on Yb-doped fibers at 1.0 - 1.1 μm and the more complicated Er-Yb codoped fibers at 1.5 - 1.6 μm and Tm-doped fibers at 2 μm will be described in detail. Operating regimes extend from continuous-wave single-frequency to short pulses. Key equations will be introduced to establish limits and identify critical parameters. For example, high pump brightness is critical for some devices but not others. Methods to mitigate limitations in different operating regimes will be discussed. A large core is a critical fiber design feature of high-power fiber lasers, and the potential and limits of this approach will be covered, e.g., as it comes to beam quality. Advanced options such as beam combining and electronic control for enhanced performance will be considered, as well, together with other topics of particular interest to attendees (insofar as time allows).

LEARNING OUTCOMES
This course will enable you to:
• describe the state of the art of high-power fiber lasers and amplifiers
• assess performance limitations and their underlytg physical reasons in different operating regimes
• design fiber devices to mitigate detrimental effects and reach required specifications
• describe possibilities, limitations, and implications of current technology regarding core size and rare earth concentration of doped fibers
• get a sense of areas in need of further research

INTENDED AUDIENCE
This course is intended for scientists and engineers involved in the research and development of commercial and military high power fiber systems.

INSTRUCTOR
Johan Nilsson leads the high-power fiber laser group at the Optoelectronics Research Centre (ORC), University of Southampton, England. He received a doctorate in Engineering Science from the Royal Institute of Technology, Stockholm, Sweden, for research on optical amplification, and
has worked on optical amplifiers and amplification in lightwave systems, optical communications, and guided-wave lasers, for both Samsung and the ORC. His research has covered system, fabrication, and materials aspects of guided-wave lasers and amplifiers, in particular device aspects of high power fiber lasers and erbium-doped fiber amplifiers. He has published approximately 400 scientific articles and served on several program committees. He was the chair of the 2006 Fiber Laser Technology & Applications conference at Photonics West and is the program chair for EuroPhoton 2018. In 2009, he guest edited two issues on high power fiber lasers and applications in IEEE J. Sel. Top. Quantum Electron. In 2016 he was a GIAN lecturer at IIT Madras. He is a senior member of SPIE and a fellow of the OSA.

Solid State Laser Technology
SC752 • Course Level: Intermediate • CEU: 0.7
$580 Members • $308 Student Members • $695 Non-Members USD
Sunday 8:30 am to 5:30 pm

This course provides an overview of the design, performance characteristics and the current state of the art of solid state lasers and devices. The course reviews the laser-relevant properties of key solid state materials, and discusses the design principles for flashlamp pumped and diode-pumped solid state lasers in cw, pulsed, Q-switched and modelocked operation. Solid state design emphasis include Nd and Yb-doped crystals but mid-IR materials such as Tm, Ho and Er-doped fluorides and oxides will be addressed as well. The course will cover the fundamental scaling laws for power, energy and beam quality for various geometries of the gain medium (rod, slab, disk, waveguide) and pumping arrangements (side and end-pumped) and provides an overview of the state-of-the-art of the art of solid state lasers. This includes a review of the design and performance of fiber lasers/amplifiers and their comparison to bulk solid state lasers. An overview of the state-of-the art of optically pumped semiconductor lasers (OPSL) will also be given. Important technical advances (such as diode pump developments) that allowed the technology to mature into diverse industrial and biomedical OEM devices as well as high power and scientific applications will be highlighted along with some remaining design and performance challenges. Topics also include nonlinear frequency conversion techniques, such as harmonic generation, Raman scattering and parametric processes, commonly used in solid state lasers to extend operation to alternative spectral regimes. The course includes an overview of currently available solid state laser products and their industrial and scientific applications.

LEARNING OUTCOMES

This course will enable you to:

- describe the significant laser-relevant properties of solid state laser materials
- acquire an up-to-date overview of solid state laser materials, components, resonators and applications
- assess how thermal properties limit power scaling and beam quality in practical laser systems
- acquire the design criteria for solid state lasers in cw and pulsed operation
- learn about the design methodology of Q-switched and modelocked lasers
- compare the properties, advantages and limitations of different high power solid state laser configurations including fiber lasers/amplifiers
- become familiar with design principles for solid state lasers with second and third harmonic generation
- develop an appreciation of the scope, depth and pace of technical progress of the state-of-the art of solid state lasers in the UV, visible, IR and mid-IR wavelengths range

INTENDED AUDIENCE

This course is intended for graduate students, engineers, scientists, technicians and managers working in solid state laser research or product development.

INSTRUCTOR

Norman Hodgson is Vice President for Technology and Advanced R&D at Coherent, Inc.. He has more than 30 years experience in solid state laser design, optimization and product development. Previously held positions include Vice President of Engineering at Coherent (2003-2009), Director of Engineering at Spectra-Physics (1998-2003), Inc., Senior Laser Engineer and Program Manager at Carl Zeiss, Inc. (1992-1996) and various university positions. He received his PhD in Physics from Technical University Berlin in 1990. He is co-author of the book “Optical Resonators” (Springer-Verlag 1996) which went into a second edition as “Laser Resonators and Beam Propagation” (Springer-Verlag 2005). Dr. Hodgson has authored over 90 publications and conference presentations and is co-inventor on more than 25 issued and pending patents.

Basic Laser Technology: Fundamentals and Performance Specifications
SC972 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Tuesday 8:30 am to 12:30 pm

If you are uncomfortable working with lasers as “black boxes” and would like to have a basic understanding of their inner workings, this introductory course will be of benefit to you. The workshop will cover the basic principles common to the operation of any laser/laser system. Next, we will discuss laser components and their functionality. Components covered will include laser pumps/energy sources, mirrors, active media, nonlinear crystals, and Q-switches. The properties of laser beams will be described in terms of some of their common performance specifications such as longitudinal modes and monochromaticity, transverse electromagnetic (TEM) modes and focusability, continuous wave (CW) power, peak power and power stability. Laser slope and wall-plug efficiencies will also be discussed.
LEARNING OUTCOMES
This course will enable you to:
• describe the overall inner workings of any laser
• describe the functionality of the key laser components
• know the difference between how acousto- and electro-optic Q-switches work
• explain how each key component in a laser may contribute to laser performance
• intelligently engage your clients or customers using proper laser terminology
• build stronger relationships with clients and customers by demonstrating product knowledge
• obtain the technical knowledge and confidence to enhance your job performance
• intelligently engage your clients or customers using proper laser terminology
• obtain the technical knowledge and confidence to enhance your job performance and rise above the competition, inside and outside your company

INTENDED AUDIENCE
Managers, engineers, technicians, assemblers, sales/marketing, customer service, and other support staff. This short course will help cultivate a common/standardized understanding of lasers across the company.

INSTRUCTOR
Sydney Sukuta is currently a Laser Technology professor at San Jose City College. He also has industry experience working for some of the world’s leading laser manufacturers in Silicon Valley where he saw first-hand the issues they encounter on a daily basis. In response, Dr. Sukuta developed prescriptive short courses to help absolve most of these issues.

Nonlinear Optics and Beam Guiding

Introduction to Nonlinear Optics
SC047 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Monday 8:30 am to 12:30 pm

This introductory-level course provides the basic concepts of bulk media nonlinear optics. Although some mathematical formulae are provided, the emphasis is on simple explanations. It is recognized that the beginning practitioner in nonlinear optics is overwhelmed by a constellation of complicated nonlinear optical effects, including second-harmonic generation, optical Kerr effect, self-focusing, self-phase modulation, self-steepening, fiber-optic solitons, chirping, stimulated Raman and Brillouin scattering, and photorefractive phenomena. It is our job in this course to demystify this daunting collection of seemingly unrelated effects by developing simple and clear explanations for how each works, and learning how each effect can be used for the modification, manipulation, or conversion of light pulses. Where possible, examples will address the nonlinear optical effects that occur inside optical fibers. Also covered are examples in liquids, bulk solids, and gases.

COURSES

LEARNING OUTCOMES
This course will enable you to:
• be able to explain to another person the origins and concepts behind the Slowly-Varying Envelope Approximation (SVEA)
• recognize what nonlinear events come into play in different effects
• appreciate the intimate relationship between nonlinear events which at first appear quite different
• appreciate how a variety of different nonlinear events arise, and how they affect the propagation of light
• comprehend how wavematching, phase-matching, and index matching are related
• be able, without using equations, to explain to others how self-phase modulation impresses “chirping” on pulses
• describe basic two-beam interactions in photorefractive materials
• develop an appreciation for the extremely broad variety of ways in which materials exhibit nonlinear behavior

INTENDED AUDIENCE
The material presented will be useful to engineers, scientists, students and managers who need a fundamental understanding of nonlinear optics.

INSTRUCTOR
Robert Fisher is the owner of RA Fisher Associates, LLC, his firm providing technical training in lasers, nonlinear optics, and in optics, provides private consulting, and provides expert witness legal services. He has been active in laser physics and in nonlinear optics for the last 40 years. He has taught graduate courses at the Univ. of California, Davis, and worked at both Lawrence Livermore National Lab. and Los Alamos National Lab. He is an SPIE Fellow and an OSA Fellow, and was a 3-year member of SPIE’s Board of Directors. He has served on the CLEO Conference Nonlinear Optics Subcommittee for 5 years, with two of those years as its chair. He has chaired numerous SPIE conferences. He was the Program Chair of the CLEO 2010 Conference and was General Chair of the CLEO 2012 Conference (now renamed CLEO: Science and Innovations). He is currently Chair of the CLEO Course Committee. In 2017 he was nominated for and has become one of the five top finalists for the International Bluegrass Association’s award “Mentor of the Year.”

ATTENDEE TESTIMONIAL:
I got a lot more inspiration than I expected and for this I am grateful.
Micromachining with Femtosecond Lasers

SC743 • Course Level: Intermediate • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Tuesday 8:30 am to 12:30 pm

This course provides attendees with the knowl-
edge necessary to understand and apply femto-
second laser pulses for micromachining tasks in a
variety of materials. Emphasis will be placed on
developing a fundamental understanding of how
femtosecond pulses interact with the sample. From
this knowledge, the advantages and limitations of
femtosecond lasers for various micromachining
tasks can be readily understood. Examples will be
given in the micromachining of the surface of met-
als, semiconductors, and transparent materials, as
well as the formation of photonic and microfluidic
devices in the bulk of transparent materials.

LEARNING OUTCOMES

This course will enable you to:
• summarize the linear and non-linear
  interaction mechanisms of femtosecond laser
  pulses with metals, semiconductors, and
  transparent materials
• explain mechanisms for material removal
  and modification, as well as factors affecting
  precision and degree of collateral damage
• describe unique capabilities afforded by
  femtosecond pulses for micromachining bulk
  transparent materials
• determine appropriate femtosecond laser
  parameters for a micromachining task
• compare various micromachining methods
  and evaluate the most appropriate for a given
  job

INTENDED AUDIENCE

This course is aimed at people already doing or
interested in starting research on short-pulse laser
micromachining, as well as at people who have
specific micromachining problems and wish to
evaluate the potential of femtosecond lasers for
accomplishing their task. Those who do not have
a background in some of the unique properties
of femtosecond laser pulses would benefit from
attending SC541, “An Introduction to Femtosecond
Laser Techniques,” by Eric Mazur and/or SC746
“Introduction to Ultrafast Technology” by Rick
Trebin before attending this course.

INSTRUCTOR

Stefan Nolte is a Professor at the Friedrich Schil-
er University and at the Fraunhofer IOF in Jena,
Germany. His research topics include ultrashort
pulses micromachining for industrial and medical
applications. He has been actively engaged in
research on femtosecond laser micromachining
since the field’s inception in the mid-1990s.

COURSE PRICE INCLUDES a detailed reading list
of key papers.

Laser Systems Engineering

SC1144 • Course Level: Introductory • CEU: 0.7
$650 Members • $336 Student Members •
$765 Non-Members USD
Tuesday 8:30 am to 5:30 pm

While there are a number of courses on laser
design, this course emphasizes a systems-level
overview of the design and engineering of systems
which incorporate lasers. Starting with a summary
of the various types of lasers and their selection,
it reviews common laser specifications (peak
power, spatial coherence, etc.), Gaussian beam
characteristics and propagation, laser system
optics, beam control and scanning, radiometry
and power budgets, detectors specific to laser
systems, and the integration of these topics for
developing a complete laser system. The emphasis
is on real-world design problems, as well as the
commercial off-the-shelf (COTS) components
used to solve them.

LEARNING OUTCOMES

This course will enable you to:
• describe laser types, properties, and
  selection, including semiconductor, solid-
state, fiber, and gas lasers
• identify laser specifications such as average
  power, peak power, linewidth, pulse
  repetition frequency, etc. that are unique to
  specific applications such as manufacturing,
  biomedical systems, laser radar, laser
  communications, laser displays, and directed
  energy
• quantify Gaussian beam characteristics,
  propagation, and imaging; compare beam
  quality metrics [M2, beam-parameter product
  (BPP), and Strehl ratio]
• select laser system optics (windows, focusing
  lenses, beam expanders, collimators, beam
  shapers and homogenizers) and identify
critical specifications for their use, including
beam truncation, aberrations, surface figure,
surface roughness, surface quality, material
absorption, backreflections, coatings, and
laser damage threshold (LDT)
• distinguish between hardware elements
  available for beam control, including
  galvanometers, polygon scanners, MEMs
  scanners, and f-theta lenses
• develop power budgets and radiometric
  estimates of performance for point and
  extended objects; estimate signal-to-noise
  ratio (SNR) for active imaging, laser ranging,
  and biomedical systems
• select detectors appropriate for laser systems,
  including PIN photodiodes, avalanche
  photodiodes (APDs), and photomultiplier tubes
  (PMTs); estimate the performance limitations
  of noise sources (detector, speckle, etc.) and
  their effects on sensitivity and SNR

INTENDED AUDIENCE

Intended for engineers (laser, systems, optical,
mechanical, and electrical), scientists, technicians,
and managers who are developing, specifying, or
purchasing laser systems.
COURSES

INSTRUCTOR
Keith Kasunic has more than 30 years of experience developing optical, electro-optical, infrared, and laser systems. He holds a Ph.D. in Optical Sciences from the University of Arizona, an MS in Mechanical Engineering from Stanford University, and a BS in Mechanical Engineering from MIT. He has worked for or been a consultant to a number of organizations, including Lockheed Martin, Ball Aerospace, Sandia National Labs, and Nortel Networks. He is currently the Technical Director of Optical Systems Group, LLC. He is also the author of three textbooks [Optical Systems Engineering (McGraw-Hill, 2011), Optomechanical Systems Engineering (John Wiley, 2015), and Laser Systems Engineering (SPIE Press, 2016)], an Adjunct Prof. at Univ. of North Carolina – Charlotte, an Affiliate Instructor with Georgia Tech's SENSIAc, and an Instructor for the Optical Engineering Certificate Program at Univ. of California – Irvine.


Fundamentals of Reliability Engineering for Optoelectronic Devices
SC1091 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Sunday 8:30 am to 12:30 pm

Component reliability impacts the bottom line of every supplier and customer in the optics industry. Nevertheless, a solid understanding of the fundamental principles of reliability is often limited to a small team of engineers who are responsible for product reliability for an entire organization. There is tremendous value in expanding this knowledge base to others to ensure that all stakeholders (product engineers, managers, technicians, and even customers) speak a “common language” with respect to the topic of reliability.

This course provides a broad foundation in reliability engineering methods applied to lifetest design and data analysis. While the course focuses on the application of reliability engineering to optoelectronic devices, the underlying principles can be applied to any component.

LEARNING OUTCOMES
This course will enable you to:
• identify the primary goals of reliability testing
• define a complete reliability specification
• differentiate between parametric and non-parametric reliability lifetests
• list the models used to describe reliability and select the best for a given population
• define a FIT score and explain why it is not a good measure of reliability
• estimate reliability model parameters from real data
• analyze cases which include insufficient, problematic, and/or uncertain data
• compute confidence bounds and explain their importance
• differentiate between failure modes and root causes
• identify infant mortalities, random failures, and wear-out in the data
• compare competing failure modes
• analyze cases in which slow degradation is present
• state the goal of accelerated lifetesting and identify when it is (and is not) appropriate
• list common stresses used in accelerated lifetesting and explain how to treat these quantitatively
• differentiate between step-stress and multiecell accelerated lifetesting
• use accelerated lifetest data to simultaneously extract acceleration parameters and population reliability
• relate component reliability to module/system reliability

INTENDED AUDIENCE
The course targets a wide range of participants, including students, engineers, and managers and seeks to dispel common misconceptions which pervade the industry. A basic understanding of probability and statistics (high school level) may be helpful, but is not required.

INSTRUCTOR
Paul Leisher is a Senior Engineer with the Laser Systems Engineering and Operation Division at Lawrence Livermore National Laboratory (LLNL) in Livermore, California. Prior to joining LLNL, Dr. Leisher served as Associate Professor of Physics and Optical Engineering at Rose-Hulman Institute of Technology (Terre Haute, Indiana) and as the Manager of Advanced Technology at nLight Corporation (Vancouver, Washington). He received a B.S. degree in electrical engineering from Bradley University (Peoria, Illinois) in 2002, and M.S. and Ph.D. in electrical and computer engineering from the University of Illinois at Urbana-Champaign in 2004 and 2007, respectively. Dr. Leisher’s research interests include the design, fabrication, characterization, and analysis of high power semiconductor lasers and other photonic devices. His past responsibilities included the design and analysis of accelerated lifetests for assessing the reliability of high power diode lasers. He has authored over 200 technical journal articles and conference presentations and served as the principal investigator on 48 funded research projects. Dr. Leisher is a senior member of both SPIE and IEEE.

Semiconductor Photonics Device Fundamentals
SC747 • Course Level: Introductory • CEU: 0.7
$580 Members • $308 Student Members • $695 Non-Members USD
Sunday 8:30 am to 5:30 pm

Updated for 2018, this course presents a basic, in-depth description and explanation of the operation of the broad range of semiconductor photonic devices used for light generation, modulation, manipulation, detection, and application, covering the
optical spectral region extending from UV, visible, IR, through terahertz (sub-mm). The course begins with a review of the basics of semiconductor materials, with primary emphasis on their electrical and photonic properties. The motion of electrons and holes is discussed, and photon absorption and generation mechanisms are reviewed. The course describes and examines device structures such as p-n junctions, Schottky barriers, quantum wells, quantum wires and quantum dots, Bragg reflectors, quantum cascade lasers as tunable coherent infrared sources, VCSELs, distributed feedback lasers, avalancheing, tunneling and various photonic device effects. Current research as well as commercially-available photonic devices and representative systems are discussed. Course participants will gain an in-depth understanding of semiconductor photonic devices, their figures of merit, limitations, applications, and current areas of research.

**LEARNING OUTCOMES**

This course will enable you to:
- explain the basic operating principles of semiconductor photonic devices
- explain the operation of laser diodes, VCSELs, LEDs, OLEDs, quantum cascade lasers, light modulators, photodetectors, PIN and APD, multi-quantum well and quantum dot structures, CCDs, etc.
- explain the various device figures of merit and their limitations
- specify device characteristics required for your system applications
- explain the device manufacturer’s data sheet content relevant to your application
- identify what questions to ask device manufacturers

**INTENDED AUDIENCE**

Aimed at managers, engineers, system designers, R&D personnel, and technicians working on components and sub-assemblies as well as systems. No formal mathematics or physics background is necessary.

**INSTRUCTOR**

Kurt Linden received a PhD in Electrical Engineering, with primary emphasis on semiconductor photonics. With over 45 years of practical experience in the design, development, manufacture, testing, and application of a broad range of semiconductor photonic devices and systems, he is a pioneer in the development of visible, infrared, and far-infrared devices and is currently involved with their incorporation into operational systems. Dr. Linden has taught basic semiconductor physics and photonic courses at MIT, USPTO, and Northeastern University, and presents in-house as well as annual conference tutorials on photonics, received “best instructor” citations, and has served as an expert witness on this subject. He is currently a senior scientist at N2 Biomedical LLC, where he applies the basic concepts of semiconductor photonics to new biomedical systems.

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**Understanding Diffractive Optics**

**SC1071 • Course Level: Introductory • CEU: 0.7**

$615 Members • $322 Student Members • $730 Non-Members USD

**Saturday 8:30 am to 5:30 pm**

The course covers the fundamental principles of diffraction phenomena. It also includes numerous applications of diffractive components in optical and photonics systems, and covers recent developments and trends in the field. Attendees will be presented with optical field distributions and graphs to develop a qualitative understanding of diffraction and to establish the basis for fundamental relations and important trends. Attendees will also learn the important terminology employed in the field of diffractive optics. A comprehensive overview of the main types of diffractive optical components will be provided, including phase plates, diffraction gratings, binary optics, diffractive kinoforms, stepped-diffractive surfaces, holographic optical elements, meta-optics, and photonic crystals. Based on practical examples presented by the instructor, attendees will learn the benefit of incorporating diffractive optical components in optical and photonics instruments, such as augmented and virtual reality displays, optical data storage devices, imaging optics, optical tweezers, photonic sensors, and laser systems.

**LEARNING OUTCOMES**

This course will enable you to:
- explain the fundamentals of diffraction, including Fresnel and Fraunhofer diffraction, the Talbot effect, apodization, diffraction by multiple apertures, and superresolution phenomena
- explain terminology in the field of diffractive optics
- describe the operational principles of the major types of diffractive optical components in the scalar and resonant domains, the diffraction efficiency, and the blazing condition
- describe diffraction phenomena associated with the propagation of laser beams
- compare the major techniques for fabricating diffractive optics
- distinguish the various functions performed by diffractive optics components in optical systems
- compare the benefits and limitations of diffractive components
- learn about the recent developments and trends in meta-optics and sub-wavelength structures

**INTENDED AUDIENCE**

This material is intended for engineers, scientists, college students, and photonics enthusiasts who would like to broaden their knowledge and understanding of diffractive optics, as well as to learn the numerous practical applications of diffractive optical components in modern optical instruments.

**INSTRUCTOR**

Yakov Soskind is a renowned expert in physical optics and innovative photonics instrumentation development. For over 35 years, Dr. Soskind...
has made extensive contributions in the areas of diffractive optics and nano-photonics, optical engineering, laser resonators and beam shaping, fiber-optics, imaging, and illumination. He is a founding chair of the Photonic Instrumentation Engineering conference, an annual conference at OPTO/Photonics West providing an interdisciplinary forum for engineers and scientists to present their ideas, designs, case studies, and success stories in the field of photonic instrumentation. Dr. Sokind is the author of the Field Guide to Diffractive Optics (SPIE Press, 2011) and has been awarded more than 25 domestic and international patents in the field of photonics.


Volume Bragg Gratings—Optical Components Providing Unique Means

SC1204 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Sunday 1:30 pm to 5:30 pm

This course explains basic principles and applications of volume Bragg gratings (VBGs) that are holographic optical elements recorded in volume of photo-thermo-refractive optical glass. These elements enable dramatic increase of brightness of lasers and resolution of spectral analyzers. The goal of the course is to describe features of photosensitive optical glass, properties of VBGs, principles of gratings modeling and design, main types of optical components based on VBGs, and amazing results of their use in lasers and photonic devices. People who want to bring lasers and photonic devices to new level will benefit from taking this course.

LEARNING OUTCOMES

This course will enable you to:
- learn properties of holographic photo-thermo-refractive glass
- identify optical beams and pulses transformations produced by different types of VBGs
- describe VBGs’ applications
- determine the problems that could be solved by VBGs
- calculate parameters of VBGs that provide necessary functionality of laser and photonics systems
- use VBGs for spectral and angular selection, pulses stretching and compression, and spectral and coherent beam combining

INTENDED AUDIENCE

Scientists, engineers, and students who wish to learn about new optical elements that provide new functionality for laser and photonic devices. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Leonid Glebov is a co-inventor of volume Bragg gratings in photo-thermo-refractive glass. He earned Ph.D. and Doctor of Science degrees in Optics at State Optical Institute in Russia. Dr. Glebov is a Research Professor at CREOL/College of Optics and Photonics, University of Central Florida and a founder of OptiGrate Corp. He is a Fellow of SPIE, OSA, American Ceramic Society, and National Academy of Inventors. He is a recipient of SPIE Denice Gabor award in holography. Dr. Glebov conducts researches in photoinduced processes in glasses, holographic optical elements and lasers controlled by those elements.

Silicon Photonics

SCB17 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

Silicon Microphotonics is a platform for the large scale integration of CMOS electronics with photonic components. This course will evaluate the most promising silicon optical components and the path to electronic-photonic integration. The subjects will be presented in two parts: 1) Context: a review of optical interconnection and the enabling solutions that arise from integrating optical and electronic devices at a micron-scale, using thin film processing; and 2) Technology: case studies in High Index Contrast design for silicon-based waveguides, filters, photodetectors, modulators, laser devices, and an application-specific opto-electronic circuit. The course objective is an overview of the silicon microphotonics platform drivers and barriers in design or fabrication.

LEARNING OUTCOMES

This course will enable you to:
- identify trends in optical interconnection and the power of electronic-photonic convergence
- explain how the electronic, thermal and mechanical constraints of planar integration promote silicon as the optimal platform for micro photonics
- design application-specific photonic devices that take advantage of unique materials processing and device design solutions
- compute the performance of micron-scale optically passive/active devices
- judge the feasibility and impact of the latest silicon photonic devices

INTENDED AUDIENCE

This material is intended for anyone who needs to learn how to design integrated optical systems on a silicon platform. Those who either design their own photonic devices or who work with engineers and scientists will find this course valuable.

INSTRUCTOR

Jurgen Michel is a Senior Research Scientist at the MIT Microphotonics Center and a Senior Lecturer at the Department of Materials Science and Engineering at MIT. He has conducted research on silicon based photonic devices for more than 20 years. Sajan Saini received his doctoral degree in materials science at MIT in 2004, during which he investigated materials and device designs for optically pumped waveguide amplifiers in silicon micro photonics.

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MOEMS-MEMS in Photonics

Design Techniques and Applications Fields for Digital Micro-optics

SC125 • Course Level: Intermediate • CEU: 0.7
$580 Members • $308 Student Members •
$695 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course provides an overview of the various design and fabrication techniques available to the optical engineer for micro / nano optics, diffractive optics and holographic optics. Emphasis is put on DFM (Design For Manufacturing) for wafer scale fabrication, Diamond Turning Machining (DTM) and holographic origination. The course shows how design techniques can be tailored to address specific fabrication techniques’ requirements and production equipment constraints. The course also addresses various current application fields as in display, imaging, sensing and metrology.

It is built around 4 sections: (1) design, (2) modeling, (3) fabrication/mass production and (4) application fields.

1) The course reviews various design techniques used in standard optical CAD tools such as Zemax and CodeV to design Diffractive Optical Elements (DOEs), Micro-Lens Arrays (MLAs), hybrid optics and refractive micro-optics, Holographic Optical Element (HOE), as well as numerical design techniques for Computer Generated Holograms (CGHs).

2) Modeling single micro optics or complex micro-optical systems including MLAs, DOEs, HOEs, CGHs, and other hybrid elements can be a difficult task when using classical ray tracing algorithms. We review techniques using physical optics propagation to model all diffraction effects, along with systematic or random fabrication errors, multi-order propagation and other effects which cannot be modeled accurately through ray tracing.

3) Following the design (1) and modeling tasks (2), the optical engineer needs to perform a DFM process so that the resulting design can be fabricated by the desired manufacturing partner/vendor over a specific equipment. We will review such DFM for wafer fab via optical lithography (tape-out process), single point diamond turning (SPDT), or holographic recording specification. The course also reviews fracturing techniques to produce GDSII layout files for specific lithographic fabrication techniques and manufacturing equipment.

4) This section reviews current application fields for which micro-optics are providing an especially good match, quasi impossible to implement through traditional optics, such as depth mapping sensing (structured illumination based sensor) and augmented reality display (waveguide grating combiner optics). Applications examples in high resolution incremental/absolute optical encoders are also reviewed. Design and modeling techniques will be described for such applications fields, and optical hardware sub-system implementations and micro-optic elements will be shown and demonstrated at the end of the course.

LEARNING OUTCOMES

This course will enable you to:
- review the various micro-optics / diffractive optics design techniques used today in popular optical design software such as Zemax and CodeV
- decide which design software would be best suited for a particular micro-optics design task
- evaluate the various constraints linked to either ray tracing or physical optics propagation techniques, and develop custom numerical propagation algorithms
- model systematic and random fabrication errors, especially for lithographic fabrication
- compare the various constraints linked to mask layout generation for lithographic fabrication (GDSII)
- review the different GDSII fabrication layout file architectures, and how to adapt them to various lithographic fabrication techniques such as the ones described in SC454
- learn about current hot application fields in consumer products, targeted to Augmented and Mixed Reality headsets, and focus on two specific Microsoft consumer products: the Kinect 360 sensor and the Hololens V1 AR headset.

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about how to design, model and fabricate micro-optics, diffractive optics and hybrid optics, and how such optics can be integrated effectively in consumer products. Basic knowledge in optics is assumed. Attendees will benefit maximally by attending the companion SPIE short course SC454 “Fabrication Technologies for Micro- and Nano-Optics”.

INSTRUCTOR

Bernard Kress has made over the past two decades significant scientific contributions as an engineer, researcher, associate professor,
consultant, instructor, and author. He has been instrumental in developing numerous optical sub-systems for consumer electronics and industrial products, generating IP, teaching and transferring technological solutions to industry. Application sectors include laser materials processing, optical anti-counterfeiting, biotech sensors, optical telecom devices, optical data storage, optical computing, optical motion sensors, digital image projection, digital displays systems, computational imaging and display, depth map and gesture sensors, and head-up and head mounted displays (smart glasses, AR/MR and VR). Bernard is specifically involved in the field of micro-optics, wafer scale optics, holography and nanophotonics. Bernard has published numerous books and book chapters on micro-optics and has more than 35 patents granted worldwide. He is a short course instructor for the SPIE since a decade and has been involved in numerous SPIE conferences as technical committee member and conference co-chair and chair. He is an SPIE fellow since 2013 as has been recently elected to the board of Directors of SPIE. Bernard has joined Google [X] Labs in 2011 as the Principal Optical Architect, and is since 2015 the Partner Optical Architect at Microsoft Corp, working on the Hololens project.

**Fabrication Technologies for Micro- and Nano-Optics**

SC454 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Tuesday 8:30 am to 12:30 pm

Applications of micro and nano-scale optics are widespread in essentially every industry that uses light in some way. A short list of sample application areas includes communications, solar power, biomedical sensors, laser-assisted manufacturing, and a wide range of consumer electronics. Understanding both the possibilities and limitations for manufacturing micro- and nano-optics is useful to anyone interested in these areas. To this end, this course provides an introduction to fabrication technologies for micro- and nano-optics, ranging from refractive microlenses to diffractive optics to sub-wavelength optical nanostructures. After a short overview of key applications and theoretical background for these devices, the principles of photolithography are introduced. With this backdrop, a wide variety of lithographic and non-lithographic fabrication methods for micro- and nano-optics are discussed in detail, followed by a survey of testing methods. Relative advantages and disadvantages of different techniques are discussed in terms of both technical capabilities and scalability for manufacturing. Issues and trends in micro- and nano-optics fabrication are also considered, focusing on both technical challenges and manufacturing infrastructure.

**LEARNING OUTCOMES**

This course will enable you to:

- describe example applications and key ‘rules of thumb’ for micro- and nano-optics
- explain basic principles of photolithography and how they apply to the fabrication of micro- and nano-optics
- identify and explain multiple techniques for micro- and nano-optics fabrication
- compare the advantages and disadvantages of different manufacturing methods
- describe and compare performance and metrological testing methods for micro- and nano-optics
- evaluate fabrication trends and supporting process technologies for volume manufacturing

**INTENDED AUDIENCE**

Engineers, scientists, and managers who are interested in the design, manufacture, or application of micro/nano-optics, or systems that integrate these devices. A background in basic optics is helpful but not assumed.

**INSTRUCTOR**

Thomas Suleski has been actively involved in research and development of micro- and nano-optics since 1991 at Georgia Tech, Digital Optics Corporation, and since 2003, as a member of the faculty at the University of North Carolina at Charlotte. He holds over 140 technical publications, including 13 patents, in the areas of micro- and nanoscale optics, freeform and conformal optics, optical microsystems, and optical manufacturing. He is co-author of Diffactive Optics: Design, Fabrication, and Test (SPIE Press), and has served as Senior Editor for JMM, the Journal of Micro/Nanolithography, MEMS and MOEMS since 2004. Dr. Suleski is Site Director for the NSF I/UCRC Center for Freeform Optics (CeFO), and a Fellow of SPIE, the International Society for Optical Engineering.

**Advanced Quantum and Optoelectronic Applications**

**Quantum Sensors**

SC1191 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Sunday 8:30 am to 12:30 pm

Quantum sensors are sensing devices that exploit quantum phenomena in such a way that makes them perform substantially better than their classical counterparts. This course uses an information-theoretic approach to identify and explain the basic design principles and potential applications of quantum sensors. A primary goal of the course is to describe those aspects of quantum phenomena that can be harnessed in order to design and develop novel sensing devices. To this end, the course summarizes recent theoretical and experimental results that showcase the feasibility of quantum sensors. In addition, the course compares the theoretical performance of quantum sensors with their classical counterparts in the areas of radar, lidar, photo-detection, magnetometry, and gravimetry.

**LEARNING OUTCOMES**

This course will enable you to:

- explain the difference between classical and quantum information
- explain the difference between classical and quantum sensing
• describe the role played by quantum entanglement and superposition in the design of quantum sensors
• describe how the detrimental effects of environmental quantum noise can be mitigated
• explain the basic design principles to design and develop novel quantum sensors
• summarize recent research results that showcase the feasibility of quantum sensing
• describe the potential applications and advantages of quantum radar, lidar, photo-detection, magnetometry, and gravimetry
• compare the theoretical performance of quantum and classical sensing devices

INTENDED AUDIENCE
Scientists, engineers, technicians, or managers who wish to learn more about quantum sensors and their potential applications to radar, lidar, photo-detection, magnetometry and gravimetry. Undergraduate training in engineering or science is assumed.

INSTRUCTOR
Marco Lanzagorta is a Research Physicist at the US Naval Research Laboratory in Washington DC. Dr. Lanzagorta is a recognized authority on the research and development of advanced information technologies and their application to combat and scientific systems. Dr. Lanzagorta has over 100 publications in the areas of physics and computer science, and he authored the book Quantum Radar (2011), Underwater Communications (2012), and Quantum Information in Gravitational Fields (2014). Dr. Lanzagorta received a doctorate degree in theoretical physics from Oxford University in the United Kingdom. Before joining NRL, Dr. Lanzagorta was Technical Fellow and Director of the Quantum Technologies Group of ITT Exelis, and worked at the European Organization for Nuclear Research (CERN) in Switzerland, and at the International Centre for Theoretical Physics (ICTP) in Italy.

Salvador Venegas-Andraca is a scientist and entrepreneur devoted to scientific research, technology development, technology transfer and teaching. Dr. Venegas-Andraca is a Professor of Mathematics and Computer Science at Tecnologico de Monterrey and he is a leading scientist in the field of quantum walks as well as a cofounder of the field of Quantum Image Processing. Dr. Venegas-Andraca has published 25 scientific papers and has authored the book Quantum Walks for Computer Scientists (2008). Dr. Venegas-Andraca holds a PhD in physics awarded by the University of Oxford and has been a visiting professor at Harvard University (USA), Bahia Blanca University (Argentina) and Sergio Arboleda University (Colombia).

Quantum Cryptography New

SC1255 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members •
$390 Non-Members USD
Sunday 1:30 pm to 5:30 pm

Quantum cryptography is a scientific and engineering field devoted to harnessing physical objects whose behavior is governed by the rules of quantum mechanics to generate and distribute keys in order to convert ordinary plain text messages into meaningless (codified) messages and vice versa. In this paradigm, safe key distribution relies on the physical properties of quantum-mechanical systems rather than on mathematical conjectures. This course presents a succinct review of key generation & distribution and its role in symmetric and asymmetric cryptography protocols, followed by a concise yet complete introduction to the BB84 and E91 quantum key distribution (QKD) protocols (this section comprises the theoretical foundations and several computer simulations of both QKD protocols). We finish this course by showing some real-world applications of QKD protocols.

LEARNING OUTCOMES
This course will enable you to:
• identify the role of safe generation and distribution of private keys in cryptography protocols.
• describe the properties of quantum mechanical systems required to build the BB84 & E91 QKD protocols.
• describe the structure and assumptions of BB84 and E91 QKD protocols.
• identify the role of QKD protocols in symmetric cryptography.
• describe some real-world applications of QKD protocols.

INTENDED AUDIENCE
Scientists, engineers, technicians, or managers who wish to learn more about quantum cryptography and their potential applications.

INSTRUCTOR
Salvador Venegas-Andraca is a scientist and entrepreneur devoted to scientific research, technology development, technology transfer and teaching. Dr. Venegas-Andraca is a Professor of Mathematics and Computer Science at Tecnologico de Monterrey, a fellow of the Mexican Academy of Sciences, a leading scientist in the field of quantum walks as well as a cofounder of the field of Quantum Image Processing. Dr. Venegas-Andraca has published 40 scientific papers and has authored the book Quantum Walks for Computer Scientists (2008). Dr. Venegas-Andraca holds a PhD in physics awarded by the University of Oxford and has been a visiting professor at Harvard University (USA), Bahia Blanca University (Argentina), and del Valle University (Colombia).

Marco Lanzagorta is a Research Physicist at the US Naval Research Laboratory in Washington DC. Dr. Lanzagorta is a recognized authority on the research and development of advanced information technologies and their application to combat and scientific systems. Dr. Lanzagorta has over 100 publications in the areas of physics and computer science, and he authored the books Quantum...
Radar (2011), Underwater Communications (2012), and Quantum Information in Gravitational Fields (2014). Dr. Lanzagorta received a doctorate degree in theoretical physics from the University of Oxford. Before joining NRL, Dr. Lanzagorta was Technical Fellow and Director of the Quantum Technologies Group of ITT Exelis, and worked at the European Organization for Nuclear Research (CERN) in Switzerland, and at the International Centre for Theoretical Physics (ICTP) in Italy.

Semiconductor Lasers, LEDs, and Applications

Laser Diode Beam Basics, Characteristics and Manipulation

SC146 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Monday 1:30 pm to 5:30 pm

Laser diodes are the most widely used lasers and have several unique properties that are difficult to handle. This course first describes laser diode basic properties. Then, laser diode beam properties are extensively explained in detail. Attendees of the course will gain practical knowledge about laser diode beam characteristics, modeling and parameter measurement, learn about designing laser diode optics, and be able to effectively handle and utilize laser diodes.

LEARNING OUTCOMES
This course will enable you to:
• describe the unique properties of laser diodes
• describe the unique properties of laser diode beams
• model laser diode beams
• describe the operating principles of laser diode beam measurement instruments
• measure laser diode beam parameters
• design laser diode optics
• become familiar with laser diode, laser diode optics and laser diode module vendors
• tailor a diode laser beam to suit your own application

INTENDED AUDIENCE
Scientists, engineers, technicians, college students or managers who wish to learn how to effectively use laser diodes. Undergraduate training in engineering or science is assumed.

INSTRUCTOR
Haiyin Sun has thirty years’ engineering, research and management experience in optics and lasers. He held senior optical engineer or manager positions with L-3 Communications, Coherent, Oplink Communications, etc, working mainly on laser diode optics design, optical system design and laser diode physics. In these fields, he has authored four books, one book chapter and about thirty peer reviewed journal papers. His research works have been reported by Photonics Spectra and cited by Melles Griot Catalog. He is a fellow of SPIE, served as an adjunct faculty of optical science at the University of Arkansas, an editorial board member of the Journal of Optical Commu-

COURSES

Introduction to Vertical-Cavity Surface-Emitting Lasers (VCSELs) and Applications *New*

SC1259 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Wednesday 8:30 am to 12:30 pm

This course will review the principles of operation and technological advances of vertical cavity surface emitting lasers (VCSELs). The course will begin with an introduction to microcavity laser diode physics, the semiconductor gain media, and the underlying semiconductor fabrication technologies. Specific examples of infrared and visible VCSELs will be included. The major application areas of VCSELs in data communication and sensing will be covered, as well as recent advances in semiconductor microcavity lasers and their emerging commercial applications.

LEARNING OUTCOMES
This course will enable you to:
• explain the differences between edge emitting and vertical cavity lasers
• recognize design issues pertaining to the laser mirrors and active region
• describe the fabrication techniques and resulting device structures
• recognize typical optical and electrical properties of VCSELs
• discuss the performance of commercial VCSELs
• discuss recent VCSEL research topics and results

INTENDED AUDIENCE
Students, scientists, application engineers, and managers with interests and/or job responsibilities in optoelectronic systems, components, and devices. Basic device concepts will be taught, so only a general background in optics and physics will be assumed.

INSTRUCTOR
Kent Choquette is the Able Bliss Professor of Engineering in the Electrical and Computer Engineering Department at the University of Illinois. Prof. Choquette leads the Photonic Device Research Group and his research interests center around the design and characterization of VCSELs and other optoelectronic devices, as well as novel fabrication technologies. Professor Choquette has authored over 300 publications and has presented numerous invited talks and tutorials on VCSELs. He is a Fellow of SPIE, a Fellow of the IEEE, a Fellow of the Optical Society, and a Fellow of the American Association for the Advancement of Science.

THIS PDF PROGRAM IS CURRENT AS OF 1 OCTOBER 2018
Find complete, up-to-date information and create your personalized schedule at spie.org/pwcourses
Advanced Thermal Management Materials for Optoelectronic, Microelectronic and MEMS Packaging

SC386 • Course Level: Intermediate • CEU: 0.7
$550 Members • $308 Student Members • $695 Non-Members USD
Thursday 8:30 am to 5:30 pm

There are now a large and increasing number of production advanced materials designed to solve the critical problems in packaging of microelectronics, diode lasers, LEDs, displays, photovoltaics, sensors and MEMS. This course will examine materials to help alleviate issues including heat dissipation, thermal stresses, warpage, alignment, weight, size, cost, and manufacturing yield. Decades-old traditional low-coefficient-of-thermal-expansion (CTE) materials like tungsten/copper, molybdenum/copper, copper-Invar-copper, “Kovar”, etc., have thermal conductivities that are no better than that of aluminum. There are now many low-density, low-CTE advanced composite and monolithic materials with much higher thermal conductivities - some as high as 1700 W/m-K - resulting in a large, increasing number of production applications. Some are cheaper than traditional materials. Weight savings as high as 85% have been demonstrated.

LEARNING OUTCOMES
This course will enable you to:
• compare the advantages, disadvantages and properties of the numerous and increasing number of advanced thermal management materials compared to traditional ones
• greatly increase heat dissipation
• improve reliability, alignment, strength and stiffness
• reduce size, weight, thermal stresses and warpage
• improve and simplify thermal design and reduce battery power
• use hard solders
• select manufacturing processes to reduce cost and increase yield
• use current applications to guide your own designs and improve competitive position
• plan for future developments through a knowledge of key future trends, including carbon nanotubes, graphite nanoplatelets, graphene, etc.

INTENDED AUDIENCE
This course is designed for engineers, scientists and managers involved in design and manufacture of optoelectronic, microelectronic and MEMS systems; material development; and thermal management.

INSTRUCTOR
Carl Zweben PhD, now an independent consultant on advanced thermal materials and structural composites, was for many years Advanced Technology Manager and Division Fellow at GE. Dr. Zweben has over 40 years’ experience in development and application of many types of advanced materials. He is a Life Fellow of ASME, a Fellow of ASTM and SAMPE, and an Associate Fellow of AIAA. He is the first winner of the GE Engineer-of-the-Year and One-in-a-Thousand awards. He has published widely and taught over 250 classroom, satellite broadcast, video and Internet-based short courses in the U.S., Europe and Asia. This course replaces its previous versions, “Advanced Thermal Management and Packaging Materials”, “Advanced Materials for Optoelectronic and MEMS Packaging”, and “Advanced Thermal Management Materials for Optoelectronic, Microelectronic and MEMS Packaging”, and has been updated to include numerous recent advances in technology and applications.

Displays and Holography

Head-Mounted Display Requirements and Designs for Augmented Reality Applications

SC1096 • Course Level: Introductory • CEU: 0.7
$625 Members • $326 Student Members • $740 Non-Members USD
Tuesday 8:30 am to 5:30 pm

There has never been a more exciting time for augmented reality (AR). The advent of high resolution microdisplays, the invention of new optical designs like waveguide and freeform eyepieces, and the significant advances in optical manufacturing techniques mean that augmented reality head mounted displays can be produced now that were not possible five years ago. Key to the development and adoption of these systems is the understanding of the fundamental requirements, derived from a human factors-centric approach to AR system design. The authors, with a combined experience of over 50 years in the design of AR systems, will identify the key performance parameters necessary to understand the specification, design and selection of AR systems and help students understand how to separate the hype from reality in evaluating new AR displays. This course will evaluate the performance of various AR systems and give students the basic tools necessary to understand the important parameters in augmented reality displays, whether they are designing them or purchasing them. This is an introductory class and assumes no background in head mounted displays or optical design.

LEARNING OUTCOMES
This course will enable you to:
• define basic components and attributes of AR displays
• describe important features and enabling technologies of an AR system and their impact on user performance and acceptance
• evaluate tradeoffs for critical display
• classify current image source technologies
• identify key tradeoffs for monocular, binocular and biocular systems
• list basic features of the human visual system
• identify key user-oriented performance parameters

INTENDED AUDIENCE
Software developers, hardware engineers, scientists, engineers, researchers, technicians, or managers who wish to learn the fundamentals of the specification, design, and use of augmented reality head mounted displays.

INSTRUCTOR
Michael Browne is the General Manager of the Vision Products Division at SA Photonics in Los Gatos, California. He has a Ph.D. in Optical Engineering from the University of Arizona’s Optical Sciences Center. Mike has been involved in the design, test and measurement of augmented reality systems since 1991. At Kaiser Electronics, Mike led the design of numerous augmented reality head mounted displays systems including those for the RAH-66 Comanche helicopter and the F-35 Joint Strike Fighter. Mike also invented one of the first head-mounted “virtual workstations” for interacting with data in a virtual space. Mike leads SA Photonics’ programs for the design and development of person-mounted information systems, including body-worn electronics, head-mounted displays and night vision systems. Mike's current research includes investigations into the design of wide field of view augmented reality head mounted displays, binocular rivalry in head mounted displays, digital night vision and smear reduction in digital displays.

James Melzer is the Technical Director for Advanced Projects at Thales Visionix, Inc, (TVI). He was previously a Technical Fellow with Rockwell Collins, where he designed head- and helmet-mounted displays for flight, simulation, medical, professional and space applications for over 30 years. He holds a BS from Loyola University of Los Angeles and an SM from the Massachusetts Institute of Technology. He has extensive experience in optical and displays engineering, visual human factors, and is an expert head-mounted display and sensor systems. His research interests are in visual and auditory perception and in bio-inspired applications of invertebrate vision and animal navigation. He has authored over 50 technical papers, books and book chapters and holds eight patents in head-mounted display design.


ATTENDEE TESTIMONIAL:
I was able to apply a lot of the material to my PhD research, and was also able to meet many industry leaders that were extreme experts in the field.

Definite bonus! THIS PDF PROGRAM IS CURRENT AS OF 1 OCTOBER 2018 Find complete, up-to-date information and create your personalized schedule at spie.org/pwcourses

**Optical Technologies and Architectures for Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) Head-Mounted Displays (HMDs)**

**SC1218 • Course Level:** Intermediate • CEU: 0.7
• $580 Members • $308 Student Members • $695 Non-Members USD
**Wednesday 8:30 am to 5:30 pm**

The course provides an extensive overview of the current product offerings as well as the various optical architectures, as in:
• Smart Glasses and Digital Eyewear
• Augmented Reality (AR) and Mixed Reality (MR) headsets
• Virtual Reality (VR) and Merged Reality headsets

The course describes the optical backbone of existing systems, as well as the various optical building blocks, as in:
• Display engines including microdisplay panel architectures, scanner based light engines and phase panels
• Optical combiners integrated either in free space or waveguide platforms
• Depth mapping sensors either though structured illumination or time of flight
• Head tracking, gaze tracking and gesture sensors

Emphasis is set on the design and fabrication techniques to provide the best display immersion and comfort:
• Wearable comfort (size/ weight, CG)
• Visual comfort (eye box size and IPD coverage, angular resolution, FOV, distortion, dynamic range, contrast,...)
• Passive and active foveated rendering and peripheral displays
• VAC (Vergence Accommodation Conflict) mitigation through varifocal, multifocal, spatial and temporal light fields and per pixel depth holographic displays.

The features and limitations of current optical technologies addressing such specifications are reviewed.

In order to design next generation head worn systems, one needs to fully understand the specifics and limitations of the human visual system, and design the optics and the optical architecture around such.

Challenges for next generation systems are reviewed, where immersion and comfort need to be addressed along with consumer level costs requirements.

Finally, the course reviews market analysts’ expectations, projected over the next 5 to 10 years, and lists the major actors (major product design vendors, and current investment rounds in such). Demonstration of some of the state of the art AR, MR and VR headsets will be offered to attendees at the end of the course.

NOTE: This course emphasizes on markets, enterprise and consumer applications, differentiation analysis over existing AR/MR/VR headsets as well
as remaining hardware challenges to overcome for next generation MR headsets, with special focus on optical waveguide combiners architectures and technologies and vergence accommodation conflict (VAC) mitigation techniques and technol-
gies. The course will end in an optical teardown and demo of two major AR/MR headsets available
today. People interested in requirements, specifi-
cations, free space design and components, along
with some human factors should take SC1096
Head-Mounted Displays for Augmented Reality
Applications. SC1096 and SC1218 are compli-
mentary courses, and people interested in learning
about AR/VR would benefit from taking both.

LEARNING OUTCOMES
This course will enable you to:
• identify the various consumer and enterprise
head worn systems available in industry today,
defined as smart glasses, digital eyewear,
AR, MR and VR HMDs, and understand their
fundamental differences and specifics
• explain the current optical technologies and
sub-systems, their advantages and limitations.
• describe the relations and implications
between FOV, resolution, MTF, pupil size,
effective IPD coverage, screen door effects,
pupil swim, vergence/accommodation
disparity, foveated rendering, peripheral
displays,
• examine the human visual system, its specifics
and limitations.
• identify the limitations of current optical
architectures and how some can be overcome
by designing the optics around the human
visual system.
• describe the feature and functionality
requirement for next generation systems, and
review the key enabling technologies.
• examine the current AR/VR market status as
well as the upcoming market expectations for
each field (smart glasses, AR and VR)

INTENDED AUDIENCE
Optical, mechanical and electrical engineers
involved in the design and development of Enter-
prise and Consumer HMDs in all their declinations.
Product and project managers involved in defining
current and next generation HMD products, tech-
ology product roadmaps and next generation
optical sub-systems.

INSTRUCTOR
Bernard Kress Over the past two decades,
Bernard Kress has made significant scientific
contributions as an engineer, researcher, associate
professor, consultant, instructor, and author. He
has been instrumental in developing numerous
optical sub-systems for consumer and industrial
products generating IP, teaching and transferring
technological solutions to industry. Application
sectors include laser materials processing, opti-

cal anti-counterfeiting, biotech sensors, optical
telecom devices, optical data storage, optical
computing, optical motion sensors, digital displays
systems, and eventually HUD and HMD displays
(smart glasses, AR/MR/VR). Bernard has been
specifically involved in the field of micro-optics,
waver scale optics, holography and nano-pho-
tonics. He has published half a dozen books and
has more than 35 patents granted. He is a short
course instructor for the SPIE and has been chair
of various SPIE conferences. He is an SPIE fellow
since 2013 and has been elected to the board of
Directors of SPIE (2017-19). Bernard has joined
Google [X] Labs. in 2011 as the Principal Optical
Architect on the Google Glass project, and is since
2015 the Partner Optical Architect at Microsoft
Corp. on the Hololens project.

Introduction to VR, AR, MR
and Smart Eyewear: Market
Expectations, Hardware
Requirements and Investment
Patterns

SC1234 • Course Level: Introductory • CEU:
0.2 $185 Members • $114 Student Members •
$210 Non-Members USD
Sunday 8:30 am to 10:30 am

This course serves as a high level introduction to
the various categories of Head Mounted Displays
(HMDs) available today: Smart Glasses or Smart
Eyewear, Virtual Reality (VR), Augmented Reality
(AR), Mixed Reality (MR), and provides a synthetic
overview of both current hardware architectures
and related markets (enterprise and consumer).
Products limitations and next generation hardware
and functionality requirements to fulfill the expect-
ed market will be reviewed in a synthetic way.

LEARNING OUTCOMES
This course will enable you to:
• explain the current product offerings and be
able to compare performances of different
products as in visual and wearable comfort,
display immersion and costs.
• describe current HMD optical sensors,
including head tracking, gaze tracking,
gesture sensing and depth mapping,
• explain current HMD hardware ecosystem,
from end product design houses, to product
integrators, contract manufacturers, optical
building blocks vendors, down to mass
fabrication equipment providers.
• explain the shortcomings of current immersive
3D display architectures.
• anticipate next generation HMD hardware
revisions and product re-definitions.
• explain why it is going to be a long ride
towards the ultimate consumer product.
• anticipate the rise of new optical building
block technologies able to sustain successive
hardware revs.
• anticipate the fall of existing optical building
block technologies unable to sustain
successive hardware revs.
• identify new niche market segment growths
based on next generation features and
functionality expectations

INTENDED AUDIENCE
This 2 hours course is structured to be synthetic
with a broad overview of the topics. It is intended
for a wide audience, ranging from marketing and
business development managers, market analysts
and venture capital bankers, to product/project
managers and engineers in various fields (OE, EE,
ME, CR, SWE).
The companion day-long course (SC1218) is more specifically intended for Optical Engineers.

**INSTRUCTOR**

Bernard Kress  
Over the past two decades, Bernard Kress has made significant scientific contributions as an engineer, researcher, associate professor, consultant, instructor, and author. He has been instrumental in developing numerous optical sub-systems for consumer and industrial products, generating IP, teaching and transferring technological solutions to industry. Application sectors include laser materials processing, optical anti-counterfeiting, biotech sensors, optical telecom devices, optical data storage, optical computing, optical motion sensors, digital displays systems, and eventually HUD and HMD displays (smart glasses, AR/MR/VR). Bernard has been specifically involved in the field of micro-optics, wafer scale optics, holography and nano-photonics. He has published half a dozen books and has more than 35 patents granted. He is a short course instructor for the SPIE and has been chair of various SPIE conferences. He is an SPIE fellow since 2013 and has been elected to the board of Directors of SPIE (2017-19). Bernard has joined Google [X] Labs. in 2011 as the Principal Optical Architect on the Google Glass project, and is since 2015 the Partner Optical Architect at Microsoft Corp. on the Hololens project.

**Practical Optical System Design**

SC003 • Course Level: Intermediate • CEU: 0.7  
$685 Members • $350 Student Members •  
$800 Non-Members USD  
Monday 8:30 am to 5:30 pm

This course will provide attendees with a basic working knowledge of optical design and associated engineering. The information in this course will help novice and experienced designers, as well as people who interact with optical designers and engineers, sufficiently understand these problems and solutions to minimize cost and risk. The course includes background information for optical design and an array of pragmatic considerations such as optical system specification, analysis of optical systems, material selection, use of catalog systems and components, ultraviolet through infrared system considerations, environmental factors and solutions, Gaussian beam optics, and production considerations such as optical testing and alignment. The course includes practical and useful examples emphasizing rigorous optical design and engineering with an emphasis on designing for manufacture. Even if you have never used an optical design program before, you will become fluent with how to estimate, assess, execute, and manage the design of optical systems for many varied applications.

This course is a continuation of the long-running Practical Optical Systems Design course established and taught by Robert E. Fischer.

**LEARNING OUTCOMES**

This course will enable you to:

- develop a complete optical system design specification
- highlight fundamental physics and engineering related to optical design
- establish a general basis for modeling optical systems using computer-aided methods
- analyze and organize system considerations to incorporate such as environmental factors
- design for manufacture, alignment, and testing
- describe multiple key aspects of optical engineering for successfully transitioning from concept to production

**INTENDED AUDIENCE**

This course is intended for anyone who needs to learn how to engineer optical systems. It will be of value to those who either design their own optics or those who work directly or indirectly with optical designers, as you will now understand what is really going on and how to ask the right questions of your designers.

**INSTRUCTOR**

Richard Youngworth, Ph.D. is Founder and Chief Engineer of Riyo LLC, an optical design and engineering firm providing engineering and product development services. His industrial experience spans diverse topics including optical metrology, design, manufacturing, and analysis. Dr. Youngworth has spent significant time working on optical systems in the challenging transition from ideal design to successful volume manufacturing. He is widely considered an expert, due to his research, lectures, publications, and industrial work on the design, producibility, and tolerance analysis of optical components and systems. Dr. Youngworth teaches “Practical Optical System Design” and “Cost-Conscious Tolerancing of Optical Systems” for SPIE and is a Fellow of the society. He has a B.S. in electrical engineering from the University of Colorado at Boulder and earned his Ph.D. in optics at the University of Rochester by researching tolerance analysis of optical systems.


This course is also available in online format.

**Design of Efficient Illumination Systems**

SC011 • Course Level: Intermediate • CEU: 0.4  
$330 Members • $186 Student Members •  
$390 Non-Members USD  
Sunday 1:30 pm to 5:30 pm

Illumination systems are included in fiber illuminators, projectors, and lithography systems. The design of an illumination system requires balancing uniformity, maximizing the collection efficiency from the source, and minimizing the size of the optical package. These choices are examined for systems using lightpipes, lens arrays, faceted optics, tailored edge rays designs, and integrating spheres through a combination of computer simulations, hardware demonstrations and discussions.
LEARNING OUTCOMES
This course will enable you to:
• describe the differences between illuminance, intensity and luminance
• compute the required source luminance given typical illumination system specifications
• compute the change in luminance introduced by an integrating sphere
• distinguish between a Kohler illuminator and an Abbe illuminator
• explain the difference in uniformity performance between a tailored edge ray reflector and a standard conic reflector
• design a lightpipe system to provide uniform illuminance
• design a lens array system to create a uniform illuminance distribution
• design a reflector with facets to create a uniform illuminance distribution
• explain the difference in uniformity
• differentiate between a Kohler illuminator and an Abbe illuminator
• explain the difference in intensity and luminance
• design a reflector with facets to create a uniform illuminance distribution

INTENDED AUDIENCE
Individuals who design illumination systems or need to interface with those designers will find this course appropriate. Previous exposure to Optical Fundamentals (Reflection, Refraction, Lenses, Reflectors) is expected.

INSTRUCTOR
William Cassarly is a Synopsys Scientist at Synopsys (formerly Optical Research Associates). Before joining ORA 19 years ago, Cassarly worked at GE for 13 years, holds 48 US patents, and has worked extensively in the areas of illumination system design, sources, photometry, light pipes, and non-imaging optics. Bill was awarded the GE Corporate “D. R. Mack Advanced Course Supervisor Award” for his efforts in the training of GE Engineers and is an SPIE Fellow.

ATTENDEE TESTIMONIAL:
This was the most illumination info I’ve had in one place!

Practical Guide to Spectral Measurements
SC1177 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Monday 8:30 am to 12:30 pm

Have you asked questions such as: “Is there a less expensive alternative to costly laboratory spectro-photometers?” or “What components should I use to build my own spectral measurement system?” If so, you will benefit from this course. In it, you will learn the fundamentals for designing, building and using a custom system for spectroscopic measurements using off-the-shelf components. The course will begin with a short introduction on spectroscopy theory, review basic optical components and their use, and conclude with examples of hardware setups ranging from the ultraviolet to the near infrared. A primary goal of this course is to demystify the creation of an effective spectroscopic solution optimized for your needs.

LEARNING OUTCOMES
This course will enable you to:
• identify optimal off-the-shelf hardware for your spectroscopic application
• differentiate between grating spectrometers, monochromators, and interference-based spectrometers
• calibrate, maintain and troubleshoot your spectral system
• explain common specifications for spectrometer systems
• use fundamental geometric optics to choose optical components as needed
• communicate concepts in spectral sensing with optical engineers
• discriminate between different light sources
• know sources for common optical components such as lenses, prisms, gratings, filters and mounting hardware

INTENDED AUDIENCE
Scientists, engineers, technicians, or managers who need to make spectroscopic measurements for which expensive, pre-packaged systems are impractical.

INSTRUCTOR
Eric Kaltenbacher has been developing optical sensors and instruments and using them in environmental, commercial and military applications for more than two decades. His career began developing optical instruments for gauging and 3D measurements and then transitioned to developing optics for inspection of glass and plastic containers. Currently, Mr. Kaltenbacher’s activities are focused on designing spectroscopic sensors for highly precise quantification of chemicals in aqueous solutions. Recognition for his work in this field includes numerous federal research awards, and several patents. He earned a M.S. in Electro-Optics at the University of Dayton. Mr. Kaltenbacher is a member of SPIE.

Stray Light Analysis and Control
SC1199 • Course Level: Introductory • CEU: 0.7
$625 Members • $326 Student Members • $740 Non-Members USD
Tuesday 8:30 am to 5:30 pm

This course explains the basic principles of designing, building, and testing optical systems whose stray light performance is adequate for their intended purpose. It teaches methods to identify stray light problems in the design phase when they can be most easily and inexpensively fixed, and does not emphasize the use of any particular stray light analysis software, but rather the fundamental principles of radiometry and optical design necessary to use such software effectively. Application of the course material is demonstrated in class by measuring the stray light performance of a simple camera system and comparing the measurement to both first order estimates and detailed ray tracing results.

LEARNING OUTCOMES
This course will enable you to:
• explain the meaning of the phrase “Move it or block it”
• differentiate between in-field and out-of-field stray light
• differentiate between internal and external stray light
• explain the pros and cons of basic radiometric analysis vs. detailed ray tracing analysis
• quantify stray light in an optical system using standard metrics such as Point Source Transmittance and Veiling Glare
• quickly estimate the stray light performance of a simple optical system using basic radiometry
• identify problematic stray light paths in an optical system by performing a backwards ray trace in stray light analysis software
• use techniques such as ray aiming and statistical analysis to reduce the time required to complete a ray trace
• verify the result of a ray tracing analysis with basic radiometry
• list the primary mechanisms of stray light
• predict the BSDF of a contaminated optical surface from its IEST-1246C cleanliness level
• predict the BSDF of an optical surface from its surface roughness statistics
• measure the BSDF of a surface
• list popular black surface treatments (such as anodize) used to control stray light
• use anti-reflection coatings to reduce stray light due to ghost reflections
• explain the root cause of large unit-to-unit variability in stray light performance
• design an optimal set of baffle vanes
• design primary mirror baffles for Cassegrain telescopes
• design stray light control features such as field stops and relayed pupils
• measure the stray light performance of an optical system
• define meaningful stray light performance requirements
• explain the benefit of having a stray light model whose predictions have been correlated with measurements

INTENDED AUDIENCE
Designers, builders, testers, and users of optical systems who wish to learn more about the causes of stray light and the best methods to control it. Undergraduate training in engineering or science is assumed.

INSTRUCTOR
Eric Fest has been developing stray light control systems for the optics industry for 25 years, and is currently an Optical Scientist at Facebook Reality Labs. He is the author of numerous publications on the topic of stray light, including the SPIE Press best-selling book Stray Light Analysis and Control. He has a Ph.D. in Optical Sciences from the University of Arizona.

COURSE PRICE INCLUDES the textbook Stray Light Analysis and Control (SPIE Press) by Eric Fest.

Introduction to LIDAR for Autonomous Vehicles

SC1232 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

This course provides an introduction to the exciting and rapidly growing field of light detection and ranging (LIDAR) on autonomous vehicles. The rapid growth of new lasers and detectors, along with miniaturization of computers and high-speed data acquisition systems, is opening many new opportunities for LIDAR systems in applications that require smaller and more portable instruments. Since the invention of LIDAR in the 1960s, systems have evolved from large instruments mounted in unmovable laboratories or on trucks and trailers, to smaller and dramatically more portable instruments. This course reviews the basic principles that govern the design of any LIDAR system, emphasizing how these principles can be used to design and analyze small, portable LIDAR systems uniquely tailored to guiding and performing remote sensing measurements from autonomous vehicles on the road, in the air, and in the water.

LEARNING OUTCOMES
This course will enable you to:
• explain the parameters that determine the size and weight of a LIDAR system
• identify application-specific requirements that drove the design of state-of-the-art LIDAR systems for use in emerging applications
• describe the advantages and disadvantages of staring and scanning LIDAR systems
• estimate the maximum detectable range and the range resolution for a LIDAR instrument
• distinguish between various LIDAR system designs for use on autonomous vehicles
• compare advantages and disadvantages of different designs for small, portable LIDAR systems
• recognize key technologies to watch or work on for achieving your dream miniature LIDAR.

INTENDED AUDIENCE
Engineers, scientists, technicians, or managers who want to understand how LIDAR works and what limits the size and capabilities of LIDAR instruments used for autonomous vehicles and other emerging applications. Undergraduate training in engineering or science is assumed.

INSTRUCTOR
Joseph Shaw has been developing and using optical remote sensing systems since 1989, first at NOAA and currently as professor of optics, electrical engineering, and physics at Montana State University. He has published about and patented LIDAR designs for applications ranging from traditional atmospheric measurements to nontraditional applications such as monitoring insects in flight. Recognition for his work includes NOAA research awards, a Presidential Early Career Award for Scientists and Engineers, and the World Meteorological Organization’s Vaisala Prize. He earned a Ph.D. in Optical Sciences at the University of Arizona. Dr. Shaw is a Fellow of both the OSA and SPIE. He believes that learning should be fun and uses that belief in designing and presenting courses.
Polarized Light and Optical Design

SC1247 • Course Level: Intermediate • CEU: 0.7
$580 Members • $308 Student Members • $695 Non-Members USD
Wednesday 8:30 am to 5:30 pm

Polarized Light and Optical Systems surveys polarization effects in optical systems and their simulation by polarization ray tracing. First polarized light is reviewed with Jones vector and Stokes parameter descriptions. Polarization elements and effects, including retardance and diattenuation, can be described by Jones matrices for coherent and ray tracing calculations, or with Mueller matrices for incoherent calculations. A framework for polarization ray tracing is presented for nearly spherical waves in optical systems to include the large set of polarization effects which occur: polarization elements, Fresnel equations, thin films, anisotropic materials, diffractive optical elements, stress birefringence, and thin films. These polarization aberrations adversely affect the point spread function/matrix and optical transfer function/matrix.

LEARNING OUTCOMES
This course will enable you to:
• explain fundamentals of polarized light and polarization elements in optical systems
• explain Jones and Mueller calculus
• describe polarized light propagating in 3D
• classify Fresnel aberrations, thin films, and polarization aberrations
• describe image formation with polarization aberrations
• identify anisotropic materials, crystal polarizers and retarders
• describe polarization of diffractive optical elements, gratings and wire grid polarizers
• distinguish stress birefringence
• identify polarization effects in liquid crystal cells
• compare the polarization ray trace and polarization aberrations of a telescope

INTENDED AUDIENCE
This is an intermediate level class is intended for educators, students, lens designers, optical engineers, scientists, and managers who need to understand and apply polarization concepts to optical systems. Prior exposure to optical design programs, polarization, and to linear algebra would be helpful.

INSTRUCTOR
Russell Chipman is Professor of Optical Sciences at the University of Arizona and a Visiting Professor at the Center for Optics Research and Education (CORE), Utsunomiya University, Japan. He founded Airy Optics Inc. which provides polarization analysis software. He teaches courses in polarized light, polarimetry, and polarization optical design at both Universities. Prof. Chipman received his BS in Physics from MIT and MS and Ph. D. in Optical Science from the University of Arizona. He is a Fellow of OSA and SPIE. He received SPIE’s 2007 G. G. Stokes award for research in Polarimetry and OSA’s Joseph Fraunhofer Award/Robert Burley Award for Optical Engineering in 2015. He is a Co-Investigator on NASA/JPL’s Multi-Angle Imager for Aerosols, a polarimeter scheduled for launch into earth orbit around 2021 for monitoring aerosols and pollution in metropolitan areas. He is also developing UV and IR polarimeters for other NASA exoplanet and remote sensing missions. He has recently focused on developing the Polaris-M polarization ray tracing code, available from Airy Optics, which analyzes optical systems with anisotropic materials, diffractive optical elements, stress birefringence, polarized scattered light, and many other effects.

Garam Young graduated with a BS in Physics from Seoul National University in Korea and received her doctorate from University of Arizona’s College of Optical Sciences, also earning Valedictorian and Outstanding Graduate Student honors. She then developed polarization features and optimization features for CODE V and LightTools with Synopsys in Pasadena, and she currently works as an optical and illumination engineer in the Bay Area. She is a co-author of the textbook “Polarized Light and Optical Systems” published by CRC Press in 2018.

RECOMMENDED text Polarized Light and Optical Systems [al (CRC Press, 2018) by Russell Chipman, Wai Sze Tiffany Lam, and Garam Young.

Fourier Optics

SC1254 • Course Level: Intermediate • CEU: 0.7
$580 Members • $308 Student Members • $695 Non-Members USD
Wednesday 8:30 am to 5:30 pm

This course aims to familiarize optics researchers with the power of the Fourier transform and its application in all branches of linear optics. We will cover concepts of field propagation in both time and space and employ useful properties of the Fourier transform to gain understanding into physical phenomena and simplify our calculations. The first part of the course will be dedicated to describing the Fourier transform in 1D, 2D, and 3D, along with its most important properties, relevant to optical signals. The second part will be focused on applying the Fourier transform to solving optical problems of practical interest, as follows. 1D: pulse propagation in dispersive media, plane wave propagation in space; 2D: light diffraction on arbitrary apertures, imaging of two-dimensional objects, spatial and temporal coherence, holography; 3D: light scattering under the Born approximation and tomographic reconstructions.

LEARNING OUTCOMES
This course will enable you to:
• list the most common properties of the Fourier transform in 1D, 2D, and 3D
• describe the spectral phase and its effects on wave propagation in both space and time
• name the Fourier properties of real, imaginary, even, and odd signals
• explain the concept of complex analytic signals and the Kramers-Kronig relationship
• define the uncertainty relation in both space and time, describe the effects of chirp on the pulse duration and effects of geometric aberrations on spatial resolution
• solve the wave equation in the (k,?) representation, explain the angular spectrum approximation, the Fresnel approximation, and the Fraunhofer approximation
• compute the diffraction pattern produced by a plane wave interacting with an arbitrarily-shaped aperture
• describe the Fourier properties of lenses and the resolution of 2D coherent imaging systems
• define spatial and temporal coherence in terms of the respective power spectra; the Wiener-Khinchin theorem
• perform phase extraction from an off-axis hologram; the Hilbert transform
• solve the inhomogeneous Helmholtz equation under the first-order Born approximation
• explain scattering by particles: the Rayleigh approximation, the Rayleigh-Gans approximation
• compute diffraction tomography

INTENDED AUDIENCE

Scientists and engineers who wish to broaden their research portfolio by exploiting the power of Fourier transforms. Undergraduate training in Optics or equivalent is assumed.

INSTRUCTOR

Gabriel Popescu is a Professor in Electrical and Computer Engineering, University of Illinois at Urbana-Champaign. He received his Ph.D. in Optics in 2002 from the School of Optics/CREOL (now the College of Optics and Photonics), University of Central Florida. He continued his training with Michael Feld at M.I.T., working as a postdoctoral associate. He joined Illinois in August 2007 where he directs the Quantitative Light Imaging Laboratory (QLI Lab) at the Beckman Institute for Advanced Science and Technology. Dr. Popescu served as Associate Editor of Optics Express and Biomedical Optics Express, Editorial Board Member for Journal of Biomedical Optics and Scientific Reports. He authored a book, edited another book, authored 150 journal publications, 200 conference presentations, 32 patents, gave 190 lecture/plenary/invited talks (http://light.ece.illinois.edu/). He founded Phil Optics, Inc., a start-up company that commercializes quantitative phase imaging technology. He is an OSA and SPIE Fellow.

Basic Optics for Engineers

SC156 • Course Level: Introductory • CEU: 0.7
$625 Members • $326 Student Members • $740 Non-Members USD
Sunday 8:30 am to 5:30 pm

This course introduces each of the following basic areas of optics, from an engineering point of view: geometrical optics, image quality, flux transfer, sources, detectors, and lasers. Basic calculations and concepts are emphasized.

LEARNING OUTCOMES

This course will enable you to:
• compute the following image properties: size, location, fidelity, brightness
• estimate diffraction-limited imaging performance
• explain optical diagrams
• describe the factors that affect flux transfer efficiency, and their quantitative description
• compute the spectral distribution of a source
• describe the difference between photon and thermal detectors
• calculate the signal to noise performance of a sensor (D* and noise equivalent power)
• differentiate between sensitivity and responsivity
• explain the main factors of laser beams: monochromaticity, collimation, and propagation

INTENDED AUDIENCE

This class is intended for engineers, technicians, and managers who need to understand and apply basic optics concepts in their work. The basics in each of the areas are covered, and are intended for those with little or no prior background in optics, or for those who need a fundamental refresher course.

INSTRUCTOR

Menelaos Poutous is an Asst. Professor of Interdisciplinary Optics in the Department of Physics & Optical Science, University of North Carolina at Charlotte. He previously held a Principal Development Engineer's position at Digital Optics Corporation, and before that, he was Lecturer with the Department of Physics at Emory University. He received his Doctorate from the School of Physics at Georgia Institute of Technology, Atlanta GA. He has been teaching Optics undergraduate and graduate courses of all levels for the last 25 years. His research interests are in spectroscopy, diffractive micro-optical elements, photo-lithographic fabrication processes, micro-optics in laser cavities and, artificial optical surfaces. He is a member of OSA and a senior member of SPIE.

COURSE PRICE INCLUDES the text Basic Electro-Optics for Electrical Engineers (SPIE Press, 1998) by Glenn D. Boreman.

This course is also available in online format.

Optical System Design: Layout Principles and Practice

SC690 • Course Level: Introductory • CEU: 0.7
$615 Members • $322 Student Members • $730 Non-Members USD
Sunday 8:30 am to 5:30 pm

This course provides the background and principles necessary to understand how optical imaging systems function, allowing you to produce a system layout which will satisfy the performance requirements of your application.

This course teaches the methods and techniques of arriving at the first-order layout of an optical system by a process which determines the required components and their locations. This process will produce an image of the right size and in the right location. A special emphasis is placed on understanding the practical aspects of the design of optical systems.

Optical system imagery can readily be calculated using the Gaussian cardinal points or by paraxial ray tracing. These principles are extended to the layout and analysis of multi-component systems. This course includes topics such as imaging with thin lenses and systems of thin lenses, stops and
pupils, and afocal systems. The course starts by providing the necessary background and theory of first-order optical design followed by numerous examples of optical systems illustrating the design process.

LEARNING OUTCOMES
This course will enable you to:
• specify the requirements of an optical system for your application including magnification, object-to-image distance, and focal length
• diagram ray paths and do simple ray tracing
• describe the performance limits imposed on optical systems by diffraction and the human eye
• predict the imaging characteristics of multi-component systems
• determine the required element diameters
• apply the layout principles to a variety of optical instruments including telescopes, microscopes, magnifiers, field and relay lenses, zoom lenses, and afocal systems
• adapt a known configuration to suit your application
• grasp the process of the design and layout of an optical system

INTENDED AUDIENCE
This course is intended for engineers, scientists, managers, technicians and students who need to use or design optical systems and want to understand the principles of image formation by optical systems. No previous knowledge of optics is assumed in the material development, and only basic math is used (algebra, geometry and trigonometry). By the end of the course, these techniques will allow the design and analysis of relatively sophisticated optical systems.

INSTRUCTOR
John Greivenkamp is a professor at the College of Optical Sciences of The University of Arizona where he teaches geometrical optics and optical system design to undergraduate and graduate students. John is the editor of the SPIE Field Guides and is the author of the Field Guide to Geometrical Optics (SPIE Press, 2004).


SPECIAL NOTE: This course is a continuation of Warren Smith's long-standing SPIE course SC001, Optical System Design: Layout Principles and Practice and incorporates many of the same approaches and material used for that course.

Cost-Conscious Tolerancing of Optical Systems

SC720 • Course Level: Introductory • CEU: 0.4
$330 Members • $186 Student Members • $390 Non-Members USD
Tuesday 8:30 am to 12:30 pm

The purpose of this course is to present concepts, tools, and methods that will help attendees determine optimal tolerances for optical systems. Detailed topics in the course apply to all volumes of systems being developed – from single systems to millions of units. The importance of tolerancing throughout the design process is discussed in detail, including determining robustness of the specification and design for manufacture and operation. The course also provides a background to effective tolerancing with discussions on variability and relevant applied statistics. Tolerance analysis and assignment with strong methodology and examples are discussed in detail. A short introduction is also provided for useful development and production tools like design of experiments and statistical process control. References and examples are included to help researchers, designers, engineers, and technicians practically apply the concepts to plan, design, engineer, and build high-quality cost-competitive optical systems.

LEARNING OUTCOMES
This course will enable you to:
• define variability and comprehend its impact on nominal systems
• utilize fundamental applied statistics in tolerancing
• construct tolerance analysis budgets
• perform detailed tolerance analysis
• summarize different design of experiment and statistical process control strategies

INTENDED AUDIENCE
This material is intended for managers, engineers, and technical staff involved in product design from concept through manufacturing.

INSTRUCTOR
Richard Youngworth Ph.D. is Founder and Chief Engineer of Riyo LLC, an optical design and engineering firm providing engineering and product development services. Dr. Youngworth is a research adjunct professor at The College of Optical Sciences at the University of Arizona and an adjunct teaching professor in the Physics Department at Boise State University. His industrial experience spans diverse topics including optical metrology, design, manufacturing, and analysis. Dr. Youngworth has spent significant time working on optical systems in the challenging transition from ideal design to successful volume manufacturing. He is widely considered an expert, due to his research, lectures, publications, and industrial work on the design, producibility, and tolerance analysis of optical components and systems. Dr. Youngworth regularly teaches “Practical Optical System Design” and “Cost-Conscious Tolerancing of Optical Systems” for SPIE. He has a B.S. in electrical engineering from the University of Colorado at Boulder and earned his Ph.D. in optics at the University of Rochester by researching tolerance analysis of optical systems.

Introduction to Lens Design

SC935 • Course Level: Introductory • CEU: 0.7
$675 Members • $346 Student Members
$790 Non-Members USD
Tuesday 8:30 am to 5:30 pm

Have you ever needed to specify, design, or analyze a lens system and wondered how to do it or where to start? Would you like a better understanding of the terminology used by lens designers? Are you interested in learning techniques to better utilize your optical design software? Have
you always wanted to know what the difference is between spherical aberration and coma or where those crazy optical tolerances come from? If your answer to any of these questions is yes, this course is for you!

This full day course begins with a review of basic optics, including paraxial optics, system layout, and lens performance criteria. A discussion of how different system specifications influence the choice of design form, achievable performance, and cost will be presented. Third-order aberration theory, stop shift theory, and induced aberrations are examined in detail. Factors that affect aberrations and the principles of aberration correction are discussed. Demonstrations of computer aided lens design are given accompanied by a discussion of optimization theory, variables and constraints, and local vs. global optimization. Techniques for improving an optical design are illustrated with easy-to-understand examples. The optical fabrication and tolerancing process is explored including an example comparison between a simple copier lens and a complex lithography lens (used to print computer circuit boards) to help explain why some optical designs require precision mechanics and precision assembly and some do not.

**LEARNING OUTCOMES**

This course will enable you to:

- specify and evaluate a lens system
- describe the source and correction of aberrations
- interpret ray-intercept plots
- classify the limits imposed by aberration theory
- determine how to improve a design
- use optical design software to its best advantage
- design tolerated, easily manufacturable lenses

**INTENDED AUDIENCE**

This course is intended for engineers, scientists, managers, technicians, and students whose main job function is not lens design, but are occasionally called upon to specify, design, analyze, or review an optical system and would like to have a better understanding of the subject. No previous knowledge of geometrical optics, optical design, and computer optimization is assumed.

**INSTRUCTOR**

Julie Bentley is an Associate Professor at The Institute of Optics, University of Rochester and has been teaching undergraduate and graduate level courses in geometrical optics, optical design, and product design for more than 15 years. She received her B.S., M.S., and PhD in Optics from the The Institute of Optics, University of Rochester. After graduating she spent two years at Hughes Aircraft Co. in California designing optical systems for the defense industry and then twelve years at Corning Tropel Corporation in Fairport, New York designing and manufacturing precision optical assemblies such as microlithographic inspection systems. She has experience designing a wide variety of optical systems from the UV to the IR, refractive and reflective configurations, for both the commercial and military markets.

**COURSE PRICE INCLUDES**


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**Optomechanics**

**Introduction to Optical Alignment Techniques**

**SC010 • Course Level: Introductory • CEU: 0.7 • $580 Members • $308 Student Members • $695 Non-Members USD**

Tuesday 8:30 am to 5:30 pm

This course discusses the equipment, techniques, tricks, and skills necessary to align optical systems and devices. You learn to identify errors in an optical system, and how to align lens systems.

**LEARNING OUTCOMES**

This course will enable you to:

- determine if errors in the optical system are due to misalignment errors or other factors such as fabrication, design, or mounting problems
- recognize and understand the fundamental imaging errors associated with optical systems
- diagnose (qualitatively and quantitatively) what is wrong with an optical system by simply observing these fundamental imaging errors
- use the variety of tools available for aligning optical systems, and more importantly, how to “tweak” logically the adjustments on these devices so that the alignment proceeds quickly and efficiently
- align basic lens systems and telescopes
- align more complex optical systems such as those containing off-axis aspheric surfaces, and maintain alignment using automatic mounting techniques

**INTENDED AUDIENCE**

This course is directed toward engineers and technicians needing basic practical information and techniques to achieve alignment of simple optical systems, as well as seemingly more complicated off-axis aspheric mirrors. To benefit most from this course you will need a basic knowledge of the elementary properties of lenses and optical systems (i.e. focal lengths, f/numbers, magnification, and other imaging properties) and a working knowledge of simple interferometry. Some familiarity with the basic aberrations such as spherical aberration, coma, and astigmatism will be helpful.

**INSTRUCTOR**

Kenneth Castle Ph.D. is president of Ruda–Cardinal, Inc., an optical engineering consulting firm located in Tucson, Arizona. Ken has worked with Mitch Ruda, the originator of this course, for 28 years. Mitch passed away August 31, 2013, and Ruda-Cardinal is continuing the tradition of this course in his memory.
COURSES

Introduction to Optomechanical Design
SC014 • Course Level: Introductory • CEU: 1.3
$1,150 Members • $578 Student Members •
$1,370 Non-Members USD
Sunday - Monday 8:30 am to 5:30 pm

This course will provide the training needed for the optical engineer to work with the mechanical features of optical systems. The emphasis is on providing techniques for rapid estimation of optical system performance. Subject matter includes material properties for optomechanical design, kinematic design, athermalization techniques, window design, lens and mirror mounting.

LEARNING OUTCOMES
This course will enable you to:
• select materials for use in optomechanical systems
• determine the effects of temperature changes on optical systems, and develop design solutions for those effects
• design high performance optical windows
• design low stress mounts for lenses
• select appropriate mounting techniques for mirrors and prisms
• describe different approaches to large and lightweight mirror design

INTENDED AUDIENCE
Engineers who need to solve optomechanical design problems. Optical designers will find that the course will give insight into the mechanical aspects of optical systems. The course will also interest those managing projects involving optomechanics. SPIE live course SC690 Optical System Design: Layout Principles and Practice or online course SC1102 Optical System Design: First Order Layout - Principles and Practices, or a firm understanding of their content, is required as background to this course.

INSTRUCTOR
Daniel Vukobratovich is a senior principal engineer at Raytheon. He has over 30 years of experience in optomechanics, is a founding member of the SPIE working group in optomechanics, and is fellow of SPIE. He has taught optomechanics in 11 countries, consulted with over 50 companies and written over 50 publications in optomechanics.

This course is also available in online format.

ATTENDEE TESTIMONIAL:
Class was excellent! I learned far more than I anticipated. Daniel Vukobratovich seems incredibly knowledgeable about a wide range of optomechanical topics and was able to answer questions and provide examples that were relevant and engaging.
- Conference Attendee

Fastening Optical Elements with Adhesives
SC015 • Course Level: Intermediate • CEU: 0.4
$330 Members • $186 Student Members •
$390 Non-Members USD
Monday 8:30 am to 12:30 pm

Optomechanical systems require secure mounting of optical elements. Adhesives are commonly used, but rarely addressed in the literature. This course has compiled an overview of these adhesives, their properties, and how to test them. How to use them is addressed in detail with guidelines and examples provided. A summary of common adhesives is presented with justification for their use. Consideration and analysis of adhesive strength, reliability, and stability are included. Different design approaches to optimize the application are presented and discussed. Many examples are described as well as lessons learned from past experience. Discussions are encouraged to address current problems of course attendees.

LEARNING OUTCOMES
This course will enable you to:
• describe and classify adhesives and how they work (epoxy, urethane, silicone, acrylic, RTV, VU-cure, etc.)
• obtain guidance in: adhesive selection, surface preparation, application, and curing
• develop a basis for analysis of stress and thermal effects
• recognize contamination/outgassing and how to avoid it
• review design options
• create and use an adhesive check list

INTENDED AUDIENCE
This course is for engineers, managers, and technicians. This course provides a foundation for the correct design for successful optical mounting; an understanding of the best options to employ for each application, and the selection and approach conducive to production. A bound course outline (that is a good reference text) is provided, including summaries of popular adhesives and their properties.

INSTRUCTOR
John Daly has 35 years of experience in lasers and optomechanics. Over this period, he has worked optical bonding problems since his thesis projects, as an employee of several major corporations, and now as a consultant. His academic background in mechanical engineering and applied physics compliments this discipline. His work experience has been diverse covering areas such as: military lasers, medical lasers, spectroscopy, point and standoff detection, and E-O systems. His roles over these years have included analysis, design, development, and production. He is an SPIE member, with numerous publications, and is a committee member of the SPIE Optomechanical Engineering Program.

ATTENDEE TESTIMONIAL:
That was an amazing amount of material!! Possibly the most applicable & easy to apply short course I’ve ever taken.
Optomechanical Systems Engineering

SC1085 • Course Level: Introductory • CEU: 0.7
$580 Members • $380 Student Members • $695 Non-Members USD
Thursday 8:30 am to 5:30 pm

This course emphasizes a systems-level overview of optomechanical engineering. Starting with the fundamentals of imaging, it reviews how optical system concepts flow down into optomechanical requirements on optical fabrication, alignment, structural design, mechanics of materials (metals, composites, and glasses), structural vibrations, thermal management, and kinematic mounts. The focus is on real-world design problems, as well as the commercial off-the-shelf (COTS) components used to solve them.

LEARNING OUTCOMES

This course will enable you to:

- utilize the basic concepts and terminology of optical engineering required for the development of optomechanical components
- read conventional and ISO-10110 drawings used for the fabrication of lenses
- develop an alignment plan with an emphasis on critical tolerances, alignment mechanisms, and “go-no go” decisions for adjusting tilt, decenter, despace, and defocus
- quantify the ability of a structural design to maintain alignment using efficient architectures and lightweight materials; compare low-strain lens and mirror mounts for reducing wavefront error (WFE)
- utilize the results of STOP (structural-thermal-optical) analysis for the deflection and distortion of optical components under static loads; estimate the impact of stress concentrations and contact stresses; select optical materials with appropriate structural properties
- estimate the effects of vibration environments on the alignment of optomechanical systems; select COTS components for vibration isolation
- predict the effects of conductive, convective, and radiative thermal environments on the performance of optical systems; select materials and off-the-shelf hardware to manage the effects of heat loads and temperature changes
- compare kinematic and semi-kinematic mounts and the limitations of COTS hardware

INTENDED AUDIENCE

Intended for engineers (systems, optical, mechanical, and electrical), scientists, technicians, and managers who are developing, specifying, or purchasing optical, electro-optical, infrared, or laser systems.

INSTRUCTOR

Keith Kasunic has more than 30 years of experience developing optical, electro-optical, infrared, and laser systems. He holds a Ph.D. in Optical Sciences from the University of Arizona, an MS in Mechanical Engineering from Stanford University, and a BS in Mechanical Engineering from MIT. He has worked for or been a consultant to a number of organizations, including Lockheed Martin, Ball Aerospace, Sandia National Labs, and Nortel Networks. He is currently the Technical Director of Optical Systems Group, LLC. He is also the author of three textbooks (Optical Systems Engineering (McGraw-Hill, 2011), Optomechanical Systems Engineering (John Wiley, 2015), and Laser Systems Engineering (SPIE Press, 2016)), an Adjunct Prof. at Univ. of North Carolina – Charlotte, an Affiliate Instructor with Georgia Tech’s SENSIAC, and an Instructor for the Optical Engineering Certificate Program at Univ. of California – Irvine.


Optics Surface Inspection Workshop

SC1017 • Course Level: Introductory • CEU: 0.4
$430 Members • $226 Student Members • $490 Non-Members USD
Tuesday 1:30 pm to 5:30 pm

Understanding the correct way to inspect optical surfaces is one of the most important skills anyone working with or around optics can have, including technicians, material handlers, engineers, managers, and buyers. While understanding the specifications is the first step, learning how to actually perform the inspection is just as important. This hands-on workshop will allow attendees to learn the “Best Practice” for cleaning and inspecting optical surfaces. The course has many demonstrations and labs and gives attendees practice handling and inspecting optics to develop a high level of proficiency.

This course was designed to bring photonics personnel up to an immediate working knowledge on the correct methods to conduct a surface inspection in accordance with MIL, ANSI, and ISO standards. It is designed to complement SC700 Understanding Scratch and Dig Specifications and provide hands-on experience applying the specification and inspection parameters covered in that course.

LEARNING OUTCOMES

This course will enable you to:

- perform a visual review of the surface
- create a surface map
- conduct a visual inspection according to MIL-PRF-13830B
- conduct a visual inspection according to ANSI OP1.002
- conduct a visual inspection according to ISO 10110-7 and ISO 14997 standards
- acquire and apply the accumulation rules
- review the tools available for microscope-based inspection to ANSI and ISO standards
- evaluate a surface and determine if a surface passes or fails

INTENDED AUDIENCE

This course is designed for all optical practitioners who need to handle and evaluate optics or optical
assemblies. Other suggested attendees include mechanical engineers, purchasing agents, quality assurance personnel and other persons working with or around optical components. SC700 Understanding Scratch and Dig Specifications is a pre-requisite for the course.

INSTRUCTOR
David Aikens a.k.a “the scratch guy”, is among the foremost experts on surface imperfection standards and inspection. Dave is President and founder of Savvy Optics Corp., and is the head of the American delegation to ISO TC 172 SC1.

COURSE PRICE INCLUDES a copy of the latest ANSI approved surface imperfections specification standard, if desired. Due to the hands-on nature of this course, class size is limited to 12 participants. Early registration is recommended.

ATTENDEE TESTIMONIAL:
Wonderful! I’ve learned many skills that I can use every day.

Modern Optical Testing
SC212 • Course Level: Intermediate • CEU: 0.4
$365 Members • $200 Student Members • $425 Non-Members USD
Monday 8:30 am to 12:30 pm

This course describes the basic interferometry techniques used in the evaluation of optical components and optical systems. It discusses interferogram interpretation, computer analysis, and phase-shifting interferometry, as well as various commonly used waveform-measuring interferometers. The instructor describes specialized techniques such as testing windows and prisms in transmission, 90-degree prisms and corner cubes, measuring index inhomogeneity, and radius of curvature. Testing cylindrical and aspheric surfaces, determining the absolute shape of flats and spheres, and the use of infrared interferometers for testing ground surfaces are also discussed. The course also covers state-of-the-art direct phase measurement interferometers.

LEARNING OUTCOMES
This course will enable you to:
• better specify optical components and systems
• produce higher-quality optical systems
• determine if an optics supplier can actually supply the optics you are ordering
• evaluate optical system performance
• explain basic interferometry and interferometers for optical testing
• analyze interferograms
• test flat and spherical surfaces
• test ground and aspheric surfaces
• make absolute measurements
• discuss state-of-the-art direct phase-measurement interferometers

INTENDED AUDIENCE
Engineers and technical managers who are involved with the construction, analysis or use of optical systems will find this material useful.

INSTRUCTOR
James Wyant is Professor Emeritus of Optical Sci-
ences at the University of Arizona. He is currently Chairman of the Board of 4D Technology. He was a founder of the WYKO Corporation and served as its president from 1984 to 1997. Dr. Wyant was the 1986 President of SPIE.


Understanding Scratch and Dig Specifications
SC700 • Course Level: Introductory • CEU: 0.4
$430 Members • $226 Student Members • $490 Non-Members USD
Tuesday 8:30 am to 12:30 pm

Surface imperfection specifications (i.e. Scratch-Dig) are among the most misunderstood, misinterpreted, and ambiguous of all optics component specifications. This course provides attendees with an understanding of the source of ambiguity in surface imperfection specifications, and provides the context needed to properly specify surface imperfections using a variety of specification standards, and to evaluate a given optic to a particular level of surface imperfection specification. The course will focus on the differences and application of the Mil-PRF-13830, ISO 10110-7, and ANSI OP1.002. Many practical and useful specification examples are included throughout, as well as a hands-on demonstration on visual comparison evaluation techniques.

The course is followed by SC1017 Optics Surface Inspection Workshop, which provides hands-on experience conducting inspections using the specification information provided in this course.

LEARNING OUTCOMES
This course will enable you to:
• describe the various surface imperfection specifications that exist today.
• compose a meaningful surface imperfection specification for cosmetic imperfections using ISO, ANSI, or MIL standards.
• identify the different illumination methods and comparison standards for evaluation.
• demonstrate a surface imperfection visual inspection.
• understand the options available for controlling surface imperfections in a vendor/supplier relationship.

INTENDED AUDIENCE
This material is intended for anyone who needs specify, quote, or evaluate optics for surface imperfections. Those who either design their own optics or who are responsible for optics quality control will find this course valuable.

INSTRUCTOR
David Aikens a.k.a “the scratch guy”, is among the foremost experts on surface imperfection standards and inspection. Dave is President and founder of Savvy Optics Corp., and is the head of the American delegation to ISO TC 172 SC1.

COURSE PRICE INCLUDES a copy of the latest ANSI approved surface imperfections specification standard.
Deep Learning and Its Applications in Image Processing

SCI222 • Course Level: Introductory • CEU: 0.7
$580 Members • $308 Student Members • $695 Non-Members USD
Sunday 8:30 am to 5:30 pm

This course provides a broad introduction to the basic concept of the classical neural networks (NN) and its current evolution to deep learning (DL) technology. The primary goal of this course is to introduce the well-known deep learning architectures and their applications in image processing for object detection, identification, verification, action recognition, scene understanding and biometrics using a single-modality or multimodality sensor information. This course will describe the history of neural networks and its progress to current deep learning technology. It covers several DL architectures such as the classical multi-layer feed forward neural networks, convolutional neural networks (CNN), restricted Boltzmann machines (RBM), auto-encoders and recurrent neural networks such as long term short memory (LSTM). Use of deep learning architectures for feature extraction and classification will be described and demonstrated. Examples of popular CNN-based architectures such as AlexNet, VGGNet, GooGleNet (Inception modules), ResNet, DeepFace, Highway Networks, FractalNet and their applications to defense and security will be discussed. Advanced architectures such as Siamese deep networks, coupled neural networks, auto-encoders, fusion of multiple CNNs and their applications to object verification and classification will also be covered.

LEARNING OUTCOMES

This course will enable you to:

• Identify the fundamental concepts of neural networks and deep learning
• Describe the major differences between neural network and current deep learning architectures
• Explain the stochastic gradient descent algorithm to train deep learning networks with different regularizations methods
• Describe the popular CNN-based architectures (i.e., AlexNet, VGGNet, GooGleNet, ResNet)
• Compare the relative merits of various deep learning architectures, MLP, CNN, RBM and LSTM
• Formulate CNN and auto-encoders for feature extraction
• Demonstrate the use of deep learning framework for object, face, pedestrian detection, pose estimation and face identification
• Differentiate between Siamese and coupled deep learning architectures and their use for object verification and identification
• Design multiple deep learning architectures for multi-view face identification and multimodal biometrics applications

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about deep learning architectures and their applications in image processing and machine learning. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Nasser Nasrabadi is a professor in the Lane Computer Science and Electrical Engineering Department at West Virginia University. He was senior research scientist (ST) at US Army Research Laboratory (ARL). He is actively engaged in research in deep learning, image processing, automatic target recognition and hyperspectral imaging for defense and security. He has published over 300 papers in journals and conference proceedings. He has been an associate editor for the IEEE Transactions on Image Processing, IEEE Transactions on Circuits and Systems for Video Technology and IEEE Transactions on Neural Networks. He is a Fellow of IEEE and SPIE.

Designing and Specifying Digital Cameras

SCI231 • Course Level: Introductory • CEU: 0.4
$350 Members • $186 Student Members • $390 Non-Members USD
Wednesday 8:30 am to 12:30 pm

This course teaches how to design a digital camera from a systems perspective with emphasis on the optical specification and how that relates to the sensor. Concepts are explained through graphics, animations and examples. Only simple math is presented. Rules of thumb are emphasized over rigorous theory.

LEARNING OUTCOMES

This course will enable you to:

• discuss the difference between rectilinear, fisheye, and telecentric lenses.
• explain how to calculate the required focal length to yield a desired field of view.
• explain how to calculate the field of view that a focal length will yield.
• explain how to specify the appropriate lens performance for a given sensor.
• discuss aliasing, Nyquist, oversampling, and the limits of oversampling.
• discuss terms like MTF, diffraction limited, PSF and how to specify them.
• explain how aperture affects lens performance.
• describe chief ray angle, and what happens when the CRA is mismatched.
• explain the difference between spherical lenses and aspherical lenses.
• discuss when to use stock lenses, and when to consider custom or semi-custom optics.
• gain familiarity with different lens production methods, and when to consider each.
• demonstrate the difference between rolling shutter and globally shuttered imagers.

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn more about design of a digital camera, the lens and the sensor, from a system perspective to satisfy a particular requirement. Managers and...
COURSES

engineers who want to talk to lens designers or camera vendors with a higher level of understanding. No prerequisites.

INSTRUCTOR
Leo Baldwin has been designing lenses and camera systems for three decades starting with Leitz (Leica) and including Indal Technologies (Curtiss-Wright), Emhart, Electro-Scientific Industries, GoPro and Amazon. Leo is the named inventor on 88 US patents and has delivered numerous presentations, keynote addresses, chaired conferences, moderated panels and taught courses from one hour to one week in duration. Leo’s expertise covers lens design and production, sensor design and integration, and camera design for defense applications, industrial machine vision, and for consumer products. Leo has designed products that have shipped in the dozens and in the millions. Some of Leo’s designs are still shipping after three decades.

Introduction to CCD and CMOS Imaging Sensors and Applications
SC504 • Course Level: Introductory • CEU: 0.4 $470 Members • $242 Student Members • $530 Non-Members USD

This course provides a review of general theory and operation for CCD and CMOS imaging technologies looking at the development and application statuses of both. Performance differences between CMOS and CCD imaging arrays are covered. Fundamental performance limits behind major sensor operations are presented in addition to image defects, shorts, device yield, popular chip foundries, chip cost; custom designed and off-the-shelf sensors. We discuss operation principles behind popular commercial and scientific CMOS pixel architectures, and various array readout schemes. We cover backside illuminated arrays for UV, EUV and x-ray applications; high QE frontside illuminated sensors; deep depletion CCDs, ultra large CMOS and CCD arrays; high speed/low noise parallel readout sensors. We describe the photon transfer technique in measuring performance and calibrating camera and chip systems, and charge transfer mechanisms. We review correlated double sampling theory used to achieve low noise performance and conclude with a look at future research and development trends for each technology.

LEARNING OUTCOMES
This course will enable you to:
• describe operating CMOS and CCD arrays and camera systems for commercial and scientific imaging applications
• explain how CCD and CMOS arrays are designed, fabricated, tested and calibrated
• know how to apply test methodologies and performance standards
• list specifications and requirements to select a sensor for your imaging application
• recognize performance differences between CMOS and CCD technologies

• understand how video signals are processed for optimum signal-to-noise performance
• become familiar with current and future imaging technologies and applications

INTENDED AUDIENCE
This course is for scientists, engineers, and managers involved with high performance CCD and CMOS imaging sensors and camera systems.

INSTRUCTOR

Basic Laser Safety
SC1256 • Course Level: Introductory • CEU: 0.2 $225 Members • $130 Student Members • $250 Non-Members USD
Monday 10:30 am to 12:30 pm

This course reviews the critical elements of laser safety in a non-medical setting and will concentrate on the items of greatest value to users. It will be presented as a mixture of presentations and performance based exercises. Topics such as eyewear selection, access control, training requirements, regulatory players, beam control, and the role of Laser Safety Officer will be discussed. This course will serve as both a review and introduction to the critical elements of laser safety.

LEARNING OUTCOMES
This course will enable you to:
• identify elements for effective eyewear selection
• determine what access control is most effective in one’s laser use setting
• explain laser hazard classification scheme
• explain the role of laser safety officer
• determine which regulatory agencies and standards apply to your laser application

INTENDED AUDIENCE
People working in a class 4 laser use area or laboratory. Laser users, engineers, graduate students, staff, and Principal Investigators.

INSTRUCTOR
Ken Barat is a former LSO for Lawrence Berkeley National Lab. and National Ignition Facility-LLNL. He is an SPIE Senior Member and author of two SPIE texts, Laser Safety in the Lab and How to Set up a Laser Lab. He is a Fellow of the Laser Institute of America (LIA), and a senior member in IEEE. He is an ANSI committee member and chair of ANSI R&D Standard Committee and the “Ask the Expert” for laser questions for the Health Physics Society.

Laser Lab Design, Do’s and Don’ts

New SC1257 • Course Level: Introductory • CEU: 0.2
$210 Members • $124 Student Members • $235 Non-Members USD
Monday 1:30 pm to 3:30 pm

Laser users and facilities managers commonly do not understand or appreciate each other’s needs. Labs are set up by scientists and engineers who are knowledgeable of experimental needs, but may not be aware of building restrictions and codes. Starting with the exterior of a laser control area and working inwards, we will review laser set-ups with an eye toward common mistakes made in laser control areas and lab use areas. Reasons for errors and solutions will be discussed. The goal is to allow scientists to have an intelligent discussion with their facilities manager.

LEARNING OUTCOMES
This course will enable you to:
• explain Laser Control Area requirements for Class 4 lasers
• identify possible space restrictions from building and safety codes
• explain the need for lab designers to know about laser equipment properties and needs, and how critical temperature control and air down drafts can be.
• explain common errors made in laser lab design, how to avoid them, and the importance of avoiding them.
• demonstrate why knowledge of building and life safety codes can save time and money

INTENDED AUDIENCE
People tasked with setting up, upgrading or designing a laser, including project managers, Principal Investigators, Engineers and Post Docs. People wanting to avoid common laser lab design errors.

INSTRUCTOR
Ken Barat is a former LSO for Lawrence Berkeley National Lab. and National Ignition Facility-LLNL. He is an SPIE Senior Member and author of two SPIE texts, Laser Safety in the Lab and How to Set up a Laser Lab. He is a Fellow of the Laser Institute of America (LIA), and a senior member in IEEE. He is an ANSI committee member and chair of ANSI R&D Standard Committee and the “Ask the Expert” for laser questions for the Health Physics Society.


The Very Least You Need To Know About Optics

New SC1170 • Course Level: Introductory • CEU: 0.2
$185 Members • $114 Student Members • $210 Non-Members USD
Monday 3:30 pm to 5:30 pm

This course is tailored to the thousands of professionals working in the optics industry who are not engineers. The curriculum develops a foundational understanding of the core principles of optics by relying on visual examples rather than mathematics. Upon completion of the course, students will be able to follow the thread of most technical optical presentations, and they will be well-positioned to study more specialized topics related to specific industries. The class size is limited to 20 participants. Early registration is recommended.

LEARNING OUTCOMES
This course will enable you to:
• define the law of reflection
• define the law of refraction (Snell’s Law)
• classify different types of optical elements visually
• explain the impacts of dispersion on optical systems

INTENDED AUDIENCE
This course is intended for non-engineers, particularly sales professionals, who need a rapid, non-mathematical introduction to the core principles of optics. No prior scientific or mathematical background is assumed.

INSTRUCTOR
Damon Diehl is the founder and owner of DIEHL Research Grant Services. He has a Ph.D. in optical engineering from the University of Rochester’s Institute of Optics and a B.A. in physics from the University of Chicago. He recently served as academic coordinator for the “reboot” of the Optical Systems Technology program at Monroe Community College in Rochester, NY — the oldest program of its type in the United States. This course is based on twenty years of research experience.

Fundamentals of Optical Engineering

New SC1224 • Course Level: Introductory • CEU: 0.2
$185 Members • $114 Student Members • $210 Non-Members USD
Monday 10:30 am to 12:30 pm

This course explains fundamental principles and applications of optics. The basic characteristics and the design of optical components and systems will be discussed. For perspective, general topics such as the history of optics and the presence of optical phenomenon in our everyday lives will be
Introduction to VR, AR, MR and Smart Eyewear: Market Expectations, Hardware Requirements and Investment Patterns

SC1234 • Course Level: Introductory • CEU: 0.2
$185 Members • $114 Student Members • $210 Non-Members USD
Sunday 8:30 am to 10:30 am

This course serves as a high level introduction to the various categories of Head Mounted Displays (HMDs) available today: Smart Glasses or Smart Eyewear, Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and provides a synthetic overview of both current hardware architectures and related markets (enterprise and consumer).

Products limitations and next generation hardware and functionality requirements to fulfill the expected market will be reviewed in a synthetic way.

LEARNING OUTCOMES
This course will enable you to:
• explain fundamental concepts of optics
• identify basic optical components
• describe basic optical systems
• compare relative optical performance
• describe how concepts in optics play a role in applications or devices found in modern society
• explain the functioning of the human visual system

INTENDED AUDIENCE
Engineers, technicians, sales professionals, and support staff interested in learning more about optics. Attendance will enhance the understanding and specification of basic optical principles, components, and systems.

INSTRUCTOR
Alexis Vogt Ph.D. is Endowed Chair and Associate Professor of Optics at Monroe Community College. In addition to teaching responsibilities, Dr. Vogt was appointed to her role at MCC in September 2015 to strengthen and grow the optics and photonics program – the nation’s oldest two-year degree program for training technicians to work in the optics and photonics industry. Dr. Vogt received her B.S. as well as her Ph.D. in Optics from the University of Rochester Institute of Optics where her research focused on polarization engineering, coherence theory, and microscopy. Prior to joining MCC, Dr. Vogt was the Applications & Business Development Manager at Melles Griot and previous to that, designed contact lenses and intraocular lenses for Bausch + Lomb. In addition to her industry experience, Dr. Vogt holds three patents and has authored numerous papers, presentations, and publications in the field, including the definitions of “light” and “polarization” for The World Book Encyclopedia.

The companion day-long course (SC1218) is more specifically intended for Optical Engineers.

INSTRUCTOR
Bernard Kress has made significant scientific contributions as an engineer, researcher, associate professor, consultant, instructor, and author. He has been instrumental in developing numerous optical sub-systems for consumer and industrial products, generating IP, teaching and transferring technological solutions to industry. Application sectors include laser materials processing, optical anti-counterfeiting, biotech sensors, optical telecom devices, optical data storage, optical computing, optical motion sensors, digital displays systems, and eventually HUD and HMD displays (smart glasses, AR/MR/VR). Bernard has been specifically involved in the field of micro-optics, wafer scale optics, holography and nano-photonics. He has published half a dozen books and has more than 35 patents granted. He is a short course instructor for the SPIE and has been chair of various SPIE conferences. He is an SPIE fellow since 2013 and has been elected to the board of Directors of SPIE (2017-19). Bernard has joined Google [X] Labs, in 2011 as the Principal Optical Architect on the Google Glass project, and is since 2015 the Partner Optical Architect at Microsoft Corp. on the Hololens project.

Included. All information will be presented in a conversational format, with no requirement for dealing with complex theories or mathematics. This course will include hands-on demonstrations of optics phenomena.

LEARNING OUTCOMES
This course will enable you to:
• explain the current product offerings and be able to compare performances of different products as in visual and wearable comfort, display immersion and costs.
• describe current HMD optical sensors, including head tracking, gaze tracking, gesture sensing and depth mapping.
• explain current HMD hardware ecosystem, from end product design houses, to product integrators, contract manufacturers, optical building blocks vendors, down to mass fabrication equipment providers.
• explain the shortcomings of current immersive 3D display architectures.
• anticipate next generation HMD hardware revisions and product re-definitions.
• explain why it is going to be a long ride towards the ultimate consumer product.
• anticipate the rise of new optical building block technologies able to sustain successive hardware revs.
• anticipate the fall of existing optical building block technologies unable to sustain successive hardware revs.
• identify new niche market segment growths based on next generation features and functionality expectations

INTENDED AUDIENCE
This 2 hours course is structured to be synthetic with a broad overview of the topics. It is intended for a wide audience, ranging from marketing and business development managers, market analysts and venture capital bankers, to product/project managers and engineers in various fields (OE, EE, ME, CR, SWE).

The companion day-long course (SC1218) is more specifically intended for Optical Engineers.

INTENDED AUDIENCE

For the past two decades, Bernard Kress has made significant scientific contributions as an engineer, researcher, associate professor, consultant, instructor, and author. He has been instrumental in developing numerous optical sub-systems for consumer and industrial products, generating IP, teaching and transferring technological solutions to industry. Application sectors include laser materials processing, optical anti-counterfeiting, biotech sensors, optical telecom devices, optical data storage, optical computing, optical motion sensors, digital displays systems, and eventually HUD and HMD displays (smart glasses, AR/MR/VR). Bernard has been specifically involved in the field of micro-optics, wafer scale optics, holography and nano-photonics. He has published half a dozen books and has more than 35 patents granted. He is a short course instructor for the SPIE and has been chair of various SPIE conferences. He is an SPIE fellow since 2013 and has been elected to the board of Directors of SPIE (2017-19). Bernard has joined Google [X] Labs, in 2011 as the Principal Optical Architect on the Google Glass project, and is since 2015 the Partner Optical Architect at Microsoft Corp. on the Hololens project.
Basic Optics for Non-Optics Personnel

SC609 • Course Level: Introductory • CEU: 0.2
$185 Members • $114 Student Members • $210 Non-Members USD
Monday 1:30 pm to 3:30 pm

This course will provide the technical manager, sales engineering, marketing staff, or other non-optics personnel with a basic, non-mathematical introduction to the terms, specifications, and concepts used in optical technology to facilitate effective communication with optics professionals on a functional level. Topics to be covered include basic concepts such as imaging, interference, diffraction, polarization and aberrations, definitions relating to color and optical quality, and an overview of the basic measures of optical performance such as MTF and wavefront error. The material will be presented with a minimal amount of math, rather emphasizing working concepts, definitions, rules of thumb, and visual interpretation of specifications. Specific applications will include defining basic imaging needs such as magnification, depth-of-field, and MTF as well as the definitions of radiometric terms.

LEARNING OUTCOMES
This course will enable you to:
• read optical system descriptions and papers
• ask the right questions about optical component performance
• describe basic optical specifications for lenses, filters, and other components
• assess differences in types of filters, mirrors and beam directing optics
• describe how optics is used in our everyday lives

INTENDED AUDIENCE
This course is intended for the non-optical professional who needs to understand basic optics and interface with optics professionals.

INSTRUCTOR
Kevin Harding has been active in the optics industry for over 40 years, and has taught machine vision and optical methods for over 30 years in over 75 workshops and tutorials, including engineering workshops on basic optics, machine vision, metrology, NDT, and interferometry used by vendors and system houses to train their own engineers. He has been recognized for his leadership in optics and machine vision by the Society of Manufacturing Engineers, Automated Imaging Association, and Engineering Society of Detroit. Kevin is a Fellow of SPIE and was the 2008 President of the Society. Kevin Harding is a partner in the consulting firm Optical Metrology Solutions.

This course is also available in online format.

How to Develop Profitable Technology Products

SC1253 • Course Level: Introductory • CEU: 0.4
$200 Members • $120 Student Members • $225 Non-Members USD
Monday 8:30 am to 12:30 pm

Product development is the exciting use of scientific knowledge to engineer a solution to a problem. Successful product development takes more than just strong technical skills, however. Successful products need to be scalable, reliable, and most of all, profitable. How do product development teams come together and turn science into things people need in an efficient and effective way? In this class you will learn some useful and proven systems and how to apply them at your own company.

LEARNING OUTCOMES
This course will enable you to:
• describe the 5 critical elements of a product (Definable, Scalable, Reliable, Viable, and Profitable) and be able to answer the question: “Do we have a product?” for their own company.
• explain the purpose and key elements of the Stage-Gate Product Development Process (PDP), and diagram a PDP for their own company.
• explain how a Failure Modes and Effects Analysis (FMEA) helps to identifying, prioritize, and mitigate product risks, and conduct an FMEA at their own company.
• outline the 8-Discipline (8D) approach to problem resolution and describe how this approach can be used to turn a customer issue in to an opportunity.

INTENDED AUDIENCE
This course is intended for early-career scientists and engineers who are new to developing technology products, but anyone who wants to learn more about industry standard product development tools is invited to attend.

INSTRUCTOR
David Giltner has spent his career commercializing new laser technology for companies such as JDS Uniphase, Ball Aerospace, and Zolo Technologies (now part of Koch Industries). His work in telecommunications and Datacom resulted in multiple successful products including the first cladding-pumped fiber laser device to be qualified to stringent Telcordia standards. Through this experience, David learned the value of the Product Manager role, a solid Product Development Process, and the One-Sheet System for coordinating product team activities. David has a BS and PhD in physics and holds six patents in the fields of laser spectroscopy and optical communications.
The Seven Habits of Highly Effective Project Managers

SC1208 • Course Level: Introductory • CEU: 0.4 $200 Members • $120 Student Members • $225 Non-Members USD
Monday 1:30 pm to 5:30 pm

Why do some engineering projects succeed, while others fail? There are many different factors that can influence the outcome of any given project, but one of the most important is the combined skills and qualifications of the project manager (PM) at its helm. But what exactly makes a project manager “skilled and qualified?” Asked another way, are there common best practices, philosophies, and/or techniques that the most successful PMs share, and if so, what are they? The short answer is yes, the majority of successful engineering project managers have many skills and character traits in common. The longer answer is there are at least seven of these key traits, or “habits” that many successful PMs implement within their respective projects.

This course explains what those habits are. More importantly, this course teaches a student how to implement these best practices into their own projects, large or small. From scope, quality, budget, and schedule management, to risk mitigation strategies, building a strong project team, engaged stakeholder management, and general leadership skills, this course will give both new and experienced project managers new tools and techniques to help them not only succeed, but excel within their projects.

LEARNING OUTCOMES
This course will enable you to:
• manage scope, quality, budgets, and schedule in the most efficient and effective ways
• identify what’s important in procurements and contract management—and recognize what’s not
• identify the vital importance of proactive risk management, including how to turn realized problems into beneficial opportunities
• build and maintain the most powerful asset you have as the PM—your project team
• engage and leverage the power of your key external stakeholders
• explain communication techniques that ensure your team is working and collaborating in the most efficient and effective ways possible
• identify the most important leadership techniques and traits that your project needs for its success

INTENDED AUDIENCE
Scientists, engineers, or managers—both new and experienced—who wish to learn simple but powerful techniques that highly effective PMs use to drive their projects to success.

INSTRUCTOR
Mark Warner PE, PMP is the Project Manager of the $350M Daniel K. Inouye Solar Telescope (DKIST) design-build construction project. He is a degreed and licensed professional engineer (PE), and has a project management professional (PMP) certification. His career spans 35 years as both engineer and engineering project manager. His expertise includes aerospace engineering, management of large-scale construction projects, design and fabrication of scientific instrumentation and precision machinery, and the oversight and management of complex large-scale science and engineering projects. Mark has lived and worked throughout North America, Europe, and Hawaii, and currently resides in Boulder, Colorado. His project management blog can be found at www.TheProjectManagementBlueprint.com

Think like an Entrepreneur

WS1250 • Course Level: Introductory • CEU: 0 $65 Members • $30 Student Members • $75 Non-Members USD
Sunday 10:30 am to 5:00 pm

Have you ever wondered if something you’ve developed in the lab could be the basis for a business? This workshop will introduce foundational concepts of entrepreneurship to optics & photonics researchers so that they understand the different mindsets and networks they may need to be successful with a business venture. This mindset is important whether you are building a business from nothing or trying to introduce a new product in an existing company. In a workshop setting with current entrepreneurs, you’ll explore the diverse skills and demands needed to do modern product development.

LEARNING OUTCOMES
• Think like a Founder – Starting something from nothing
• Think like a Customer – What will solve their real problems
• Think like a CEO – Building a team
• Think like a VC – Financing teams, getting a payoff
• Think like a Manufacturer – Prototyping, building lean, selling it quickly

INTENDED AUDIENCE
Early Career Professionals attending Optics and Photonics conference, Masters and PhD students, members of the local optics & photonics community.

INSTRUCTOR
Farzin Samadani has a diverse background in business and technology. As co-founder of Curious Me, LLC, he provides business modeling and advisory services for early stage startups. Farzin is also a member of the national teaching faculty of the National Science Foundation Innovation Corps
Photodetectors, Raman Spectroscopy, and SiPMs versus PMTs: One-day Workshop

WS9006 • Course Level: Introductory • CEU: 0
CEU Credits are NOT available for this workshop.
$0 Members • $0 Student Members •
$0 Non-Members USD
Wednesday 8:30 am to 5:00 pm

Hamamatsu is holding a free one-day workshop that covers three topics:

PART I - 8:30 to 10:00 am
Photodetectors: Theory, Practice, Applications, and Selection

PART II - 1:00 to 2:45 pm
Raman Spectroscopy: Theory and Practice

PART III - 3:00 to 5:00 pm
Single-photon detection: SiPMs versus PMTs

Come for each session or come for the entire day.

DAILY SCHEDULE

PART I - 8:30 to 10:00 am
Photodetectors: Theory, Practice, Applications, and Selection

Photodetectors are essential components in a vast array of modern scientific and commercial instruments and devices; technological progress will make them even more ubiquitous. Understanding their opto-electronic properties, regimes of operation, circuit requirements, and noise characteristics is essential to a practitioner to make a proper photodetector selection for a given application.

The purpose of this presentation is to provide guidance in this process by discussing the above considerations for the four most common point photodetectors: photomultiplier tube, photodiode, avalanche photodiode, and silicon photomultiplier.

PART II - 1:00 to 2:45 pm
Raman Spectroscopy: Theory and Practice

Information about the system under investigation may be contained in the spectrum of light received from it. Spectroscopy is an umbrella term referring to a multitude of measurement techniques that can be employed to access the information.

This presentation mentions several major dispersive and non-dispersive spectroscopic techniques such as, for example, fluorescence, Fourier transform, laser-induced breakdown, time-resolved, and mechanical engineers with OpticStudio and LensMechanix. This course will provide awareness and understanding of the tools Zemax provides to streamline engineering design workflow.

LEARNING OUTCOMES

This course will enable you to:
• Optimize, analyze, and tolerance a sequential system in OpticStudio

How to Reduce Errors Found Downstream of the Optical Design with Zemax Virtual Prototyping

WS9010 • Course Level: Introductory • CEU: 0
CEU Credits are NOT available for this workshop.
$0 Members • $0 Student Members •
$0 Non-Members USD
Wednesday 1:30 pm to 5:30 pm

Zemax virtual prototyping enables optical and mechanical engineers to design, communicate, and collaborate on building optical products right the first time. Optical engineers can continue to rely on OpticStudio for the reliable and accurate calculations. With LensMechanix, mechanical engineers can validate their mechanical designs by flagging potential problems early in the product development process without having to step out of the CAD platform. By maintaining the fidelity of the optical design throughout the design process, optical and mechanical engineers can create a complete, reliable, model of a product.

Learn how virtual prototyping from Zemax is improving the engineering design process for both optical and mechanical engineers with OpticStudio and LensMechanix. This course will provide awareness and understanding of the tools Zemax provides to streamline engineering design workflow.
COURSES

- Optimize a sequential design for conversion to non-sequential mode
- Load a sequential design into SOLIDWORKS using LensMechanix
- Package, analyze, and validate your complete optomechanical design
- Open a completed LensMechanix design in OpticStudio
- Optimize a complete optomechanical design

INSTRUCTORS
Thomas Pickering (Zemax, LLC) and Isis Peguero (Zemax, LLC)

SPONSORED BY
Zemax

High-power Laser Optics, Distance Measurement in LiDAR, and Infrared Detectors
WS9012 • Course Level: Intermediate • CEU: 0
CEU Credits are NOT available for this workshop.
$0 Members • $0 Student Members • $0 Non-Members USD
Wednesday 9:00 am to 4:30 pm

PART 1 - 9:00 am to 11:30 am
How to Specify Laser Optics and Polarizers

Specifying the correct optical component may determine the success of an application. This course focuses on laser damage thresholds, custom coatings, and polarizers, their functional principles, essential properties, and corresponding effects depending on the application.

The morning session is broken up in three parts and you are free to attend one or all presentations.

9:00 am to 9:30 am: LIDT and High-Power Laser Optics
- Specify Laser-Induced Damage Threshold (LIDT)
- Identify what influences LIDT
- Explain LIDT values

9:30 am to 10:00 am: Custom Coatings
- Determine the positive effects of low UV absorption in UV coated optics to increase lifetime and avoid damage of high-power short-pulse lasers
- Describe the golden rules for multi-wavelength coatings
- Evaluate the trade-off between reflectivity and transmission, and high laser damage threshold for complex coatings

11:00 AM - 11:30 AM: Polarizers
- Explain the matter of polarization and list different types of polarizers
- Characterize polarizers by their specifications
- Describe the polarizers mode of operation in various applications
- Define key parameters for a polarizer in an intended application

PART 2 - 11:30 AM - 2:30 PM
From Distance Measurement in LiDAR to Next-Gen White Light, Each Using Different Technologies: How to Set the Optimal Device Performance

The workshop explains the different working principles of (Flash) LiDAR-optimized Pulsed Laser Diodes, Single-Photon Avalanche Diodes, and optical Transimpedance Amplifiers for photodiodes. The primary goal is to understand the advantages and challenges of these technologies, as well as the trade-off between laser power and eye-safety. We will also illustrate various applications of laser-generated white light sources as well as optical design considerations when building high intensity, long throw spot lighting or fiber optic illumination.

11:30 AM - 12:00 PM: Flash LiDAR Detectors and Technology
- Describe the basic working principle of Flash LiDAR systems
- Identify the different system components
- Summarize the main advantages and challenges of Flash LiDAR
- Explain the role of the detector and the associated requirements
- Understand the critical role of sun and other environmental conditions in outside applications
- Be familiar with LiDAR for automotive and safety applications

1:30 PM - 2:00 PM: Driving FET-based Pulsed Laser Hybrid Circuits
Understanding of the various elements of field-effect transistors (FET) driver design for optimized device performance

2:00 PM - 2:30 PM: High performance lighting applications with LaserLight
- Identify to which applications laser white light sources, called LaserLight, bring unique value when compared to other solid-state lighting sources like LEDs
- Estimate the performance achieved with a LaserLight system using models
- Demonstrate systems expediently and generate new designs by using optics and complementary components

PART 3 - 4:00 PM - 4:30 PM
Important Factors to Consider When Selecting the Appropriate Infrared Detector

Infrared detectors are used in a wide variety of applications including spectroscopy, gas analysis, flame detection, moisture sensing, range finding, remote temperature measurement, and even gravitational wave measurements. Whatever your instrument design or research requirements, there are a few key parameters used to select the optimum IR detector. Attendees will learn the following:

Describe the importance of specifications such as wavelength range, detectivity, noise equivalent power, incident power levels, and desired operating frequency

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Distinguish and compare different types of IR detectors: photomultiplier tubes, InGaAs photodiodes, PbS and PbSe photoconductors, MCT detectors, bolometers, thermocouples, and pyroelectric detectors.

Specify the best optimized IR detector for your application.

INTENDED AUDIENCE

Part 1: Scientists, laser engineers, optical engineers, technicians, or managers
Part 2: Design/System engineers, project managers, directors, researchers, & contractors
Part 3: Scientists, Engineers, Technicians, Optical Engineers, System integrators, or Managers. Undergraduate training in engineering or science is assumed.

INSTRUCTORS

Barbara Herdt, Laser Components
Andre Volke, CODIXX AG
Ran Zhu, Laser Components
Julian Carey, SLD Laser
Susan T. Wells, Laser Components USA Inc
“The instructor was skilled and clear in his presentation. In contrast to some other courses I have taken there is value in using the higher definition of the videos where the video is available as the presenter actually gestures and contributes to the presentation.”

– Online course taker on Mounting of Optical Components

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SC014: Introduction to Optomechanical Design
Instructor: Daniel Vukobratovich
“Loved the stories and real life examples. Helped make the material interesting and practical.”

Course presentation recording videos from Photonics West available in Spring 2019.