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

SC1228 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 3.5 HOURS

This course explains principles and applications of diffuse optics in biology and medicine. Diffuse optical tools allow quantitative spectroscopic measurements in heavily scattering media, such as tissue, and 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:
1. define the regime in which diffuse optical techniques are applicable
2. describe diffuse optical data types, their relationships, and their limitations
3. explain the principle of diffuse correlation spectroscopy
4. summarize the current range of preclinical and clinical diffuse optical applications
5. determine the appropriate diffuse optical instrument for a particular application
6. discriminate between studies undertaken with various diffuse optical data types
7. access key resources for diffuse optical information

INTENDED AUDIENCE
Scientists, engineers, clinicians, technicians, or managers interested in expanding their knowledge of diffuse optics and its applications. Undergraduate training in engineering or science, a basic knowledge of optics and biomedical applications of optics, and an interest in clinical or preclinical applications is assumed.

INSTRUCTOR
David Busch is an assistant professor in the Departments of Anesthesiology & Pain Management and Neurology & Neurotherapeutics at the University of Texas Southwestern. He has designed and clinically deployed diffuse optical systems for 15 years at the University of Pennsylvania and Children's Hospital of Philadelphia. He has been both a Whitaker and Fulbright fellow and formerly chaired the Therapeutic Laser Applications group of the Optical Society of America. He received a Ph.D. in physics from the University of Pennsylvania in 2011.
Optics in the Hospital – Endoscope Specification and Design

SC1175 ∙ COURSE LEVEL: INTERMEDIATE ∙ COURSE LENGTH: 3.5 HOURS

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:
1. identify the types of medical procedures for which endoscopes can be deployed
2. classify the types of endoscope optics that are used in the body
3. explain the key specifications that define an endoscope design
4. describe the ISO specifications and FDA regulations pertinent to each endoscope design
5. identify at least three types of rigid endoscopes and two types of flexible endoscopes
6. identify elements of a substandard endoscope design and explain what needs to be improved
7. 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.
Interpreting Deep Learning Networks

Deep learning neural networks, or simply, deep neural networks (DNNs), have provided spectacular breakthroughs in the areas of artificial intelligence and machine learning with multiple applications in data science and analytics including scene recognition. One challenge faced by various end user communities is that of interpreting decisions made by DNNs. There is a prevalent notion of DNNs being “black boxes.” These can be particularly confounding when erroneous decisions are made by the DNN. However, several recent investigations have proposed methods for interpreting DNNs. Methods have also been proposed for reducing the likelihood of incorrect decisions. This course will provide insights into how these methods approach the problem and into future possibilities for interpreting DNNs. Topics: • DNN examples: training & classification • The different definitions of interpretability • Interpreting weights of converged DNNs • Saliency maps in convolutional neural networks (CNNs) • Layer hierarchy and interpreting layer outputs • Interpretability vs. Explainability • Interpreting DNNs through activation analysis & deep visualization • Use of generative adversarial network models for interpretation • Correlation across layers and networks • Sensitivity analysis and Garson’s algorithm • Relating classification to image features • DNN architectures to enable interpretability • Approaches for reducing likelihood of erroneous decisions through rank-N classification considerations • Future directions

LEARNING OUTCOMES
This course will enable you to:
1. frame the interpretability problem in deep neural networks
2. relate DNN decision making to contributions of direct and derived features in images
3. identify quantitative and qualitative approaches to interpreting DNNs
4. explore flow modification in DNNs to enable interpretability
5. compare and interpret performance of multiple DNNs

INTENDED AUDIENCE
Engineers and scientists interested in deep neural networks.

INSTRUCTOR
Raghuveer Rao is Chief of the Image Processing Branch at the U.S. Army Research Laboratory overseeing efforts in image understanding and computer vision with applications to autonomous systems and scene perception. He was previously a professor of Electrical Engineering and Imaging Science at the Rochester Institute of Technology. His other long term and visiting appointments include Advanced Micro Devices Inc., Philips Healthcare, U.S. Naval Surface Warfare Center, U.S. Air Force Research Laboratory, the Indian Institute of Science and Princeton University. Dr. Rao is an author of multiple research publications in signal processing, image processing and communications, and has served on the editorial boards of several signal and image processing journals. He is an elected Fellow of SPIE and IEEE.
Introduction to CCD and CMOS Imaging Sensors and Applications

SC504 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

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:

1. describe operating CMOS and CCD arrays and camera systems for commercial and scientific imaging applications
2. explain how CCD and CMOS arrays are designed, fabricated, tested and calibrated
3. know how to apply test methodologies and performance standards
4. list specifications and requirements to select a sensor for your imaging application
5. recognize performance differences between CMOS and CCD technologies
6. describe how video signals are processed for optimum signal-to-noise performance
7. 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
Richard Crisp is currently vice president of new technology development and chief scientist for Etron America where he is engaged in developing multiaperture imaging systems and advanced DRAM architectures. Mr Crisp has designed Imaging Systems, CPUS, Memories, and miniaturized semiconductor packaging for over 40 years. He has worked for Intel, Motorola, MIPS, Rambus and Tessera where he has received over 99 patents for his work. He was a member of the ISSCC Program Committee from 1991 – 2000 serving as the Program Committee Chair in 2000, Vice Chair in 1999 and Subcommittee Chair 1997-98. He has published many peer-viewed papers in journals and conferences such as the ISSCC, IEEE JSSC, SPIE Electronic Imaging, ISMP, ICEP and IS&T including recent work published in the area of using Photon Transfer methods to quantify thermally dependent image lag in cooled scientific imaging systems. Mr. Crisp is also an avid astrophotographer with many published images including with the OSA, Smithsonian and Space Telescope Science Institute.

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Biomedical Applications of Specialty Optical Fibers and Fiber Sensors

SC981 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

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:
1. describe the operating principles, features and advantages of fiber optic sensors
2. review a wide range of sensor types for physiological, bio-chemical and imaging applications
3. learn how specialty optical fibers are used in diverse biomedical devices and sensors
4. state some of the special biomedical considerations such as materials biocompatibility and related industry standards
5. illustrate specific sensing solutions and their clinical impact through case-study analysis
6. 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.
Biomedical Applications of Specialty Optical Fibers and Fiber Sensors (CONTINUED)

INSTRUCTORS

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.

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 Specialty Optical Fibers Handbook and co-author of the textbook Fiber Optic Sensors: Fundamentals and Applications. 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.

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Introduction to Nonlinear Optics

SC047 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

This introductory-level course provides the basic concepts of bulk media nonlinear optics. Although some mathematical formulas 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.

LEARNING OUTCOMES
This course will enable you to:
1. explain to another person the origins and concepts behind the Slowly-Varying Envelope Approximation (SVEA)
2. recognize what nonlinear events come into play in different effects
3. appreciate the intimate relationship between nonlinear events which at first appear quite different
4. appreciate how a variety of different nonlinear events arise, and how they affect the propagation of light
5. comprehend how wavematching, phase-matching, and index matching are related
6. explain to others how self-phase modulation impresses “chirping” on pulses, without using equations
7. describe basic two-beam interactions in photorefractive materials
8. 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 Music Association’s award “Mentor of the Year.”
Basic Laser Safety

SC1256 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

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:
1. identify elements for effective eyewear selection
2. determine what access control is most effective in one's laser use setting
3. explain laser hazard classification scheme
4. explain the role of laser safety officer
5. 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. People who need to be aware of laser hazards and control measures.

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.

“This is a great course led by a fantastic instructor. Information was conveyed in a clear & concise matter. This course should be taken by anyone involved with operating laser systems.”

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Laser Lab Design, Do’s and Don’ts

SC1257 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

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:
1. explain Laser Control Area requirements for Class 4 lasers
2. identify possible space restrictions from building and safety codes
3. explain the need for lab designers to know about laser equipment properties and needs, and how critical
4. temperature control and air down drafts can be
5. explain common errors made in laser lab design, how to avoid them, and the importance of avoiding them
6. 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.
Introduction to Vertical-Cavity Surface-Emitting Lasers (VCSELs) and Applications

SC1259 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

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:
1. explain the differences between edge emitting and vertical cavity lasers
2. recognize design issues pertaining to the laser mirrors and active region
3. describe the fabrication techniques and resulting device structures
4. recognize typical optical and electrical properties of VCSELs
5. discuss the performance of commercial VCSELs
6. 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 course is a comprehensive look at laser technology as applied to precision micromanufacturing. A brief background discussion on laser history, technology and definition of important terms will be presented. Then, available laser sources will be compared and contrasted including CO2, excimer, Nd:YAG, fiber and short pulse lasers. IR and UV material/photon interaction, basic optical components and system integration are also crucial to getting good processing results and these will all be examined in detail. Finally, real applications from the medical, microelectronics, aerospace and other fields will be presented. This course has been greatly expanded to include detailed discussions on short pulse lasers (ps and fs) and their applications, both present and future. Also, MicroManufacturing includes technologies such as welding, joining and additive technologies. While the main emphasis of the course is still MicroMachining (material removal), additive technologies will be discussed also – especially 3D LAM (Laser Additive Manufacturing).

LEARNING OUTCOMES
This course will enable you to:
1. compare UV, IR and other laser sources to each other and learn where each is best applied
2. describe and be familiar with several kinds of microprocessing lasers on the market
3. describe material/photon interaction and why and how UV lasers for instance are different than IR lasers
4. analyze a potential manufacturing application to identify it as a possible candidate for laser processing
5. familiarize yourself with ‘real world’ opportunities for laser micromanufacturing
6. identify marketplace growth opportunities

INTENDED AUDIENCE
The course will benefit anyone with an interest in small-scale industrial laser processing and achieving the best part quality, highest resolution and cost effectiveness. Engineers will benefit from the technical discussions. Project Managers will benefit from cost considerations and risk reduction scenarios.

INSTRUCTOR
Ronald Schaeffer is Chief Executive Officer of PhotoMachining, Inc. He has been involved in laser manufacture and materials processing for over 30 years, working in and starting small companies. He has over 150 publications, has written monthly web and print columns and is on the Editorial Advisory Board of Industrial Laser Solutions magazine where he also writes an ongoing BLOG. He is the author of the textbook “Fundamentals of Laser Micromachining”. He is also a past member of the Board of Directors of the Laser Institute of America and is affiliated with the New England Board of Higher Education. He has a Ph.D. in Physical Chemistry from Lehigh University and did graduate work at the University of Paris, after which he worked for several major laser companies. He is a US Army veteran of the 172nd Mountain Brigade and the 101st Airborne division. In his spare time, he farms, collects antique pocket watches, plays guitar and rides a motorcycle.
Micromachining with Femtosecond Lasers

SC743 · COURSE LEVEL: INTERMEDIATE · COURSE LENGTH: 3.5 HOURS

This course provides attendees with the knowledge necessary to understand and apply femtosecond 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 metals, 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:
1. summarize the linear and non-linear interaction mechanisms of femtosecond laser pulses with metals, semiconductors, and transparent materials
2. explain mechanisms for material removal and modification, as well as factors affecting precision and degree of collateral damage
3. describe unique capabilities afforded by femtosecond pulses for micromachining bulk transparent materials
4. determine appropriate femtosecond laser parameters for a micromachining task
5. 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.

INSTRUCTORS
Christopher Schaffer is an Associate Professor at Cornell University, where his current research focuses on applications of femtosecond laser ablation in biology. He has been actively engaged in research on femtosecond laser micromachining since the field’s inception in the mid-1990s.

Stefan Nolte is a Professor at the Friedrich Schiller University and at the Fraunhofer IOF in Jena, Germany. His research topics include ultrashort pulse 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.
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:
1. describe the overall inner workings of any laser
2. describe the functionality of the key laser components
3. explain the difference between how acousto- and electro-optic Q-switches work
4. explain how each key component in a laser may contribute to laser performance
5. intelligently engage your clients or customers using proper laser terminology
6. build stronger relationships with clients and customers by demonstrating product knowledge
7. 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.
Splicing of Specialty Fibers and Glass Processing of Fused Components for Fiber Laser and Medical Probe Applications

SC1020 · COURSE LEVEL: INTERMEDIATE · COURSE LENGTH: 3.5 HOURS

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 medical imaging.

LEARNING OUTCOMES
This course will enable you to:
1. become familiar with fiber processing fundamentals and state-of-the-art fiber splicing and fusion processing tools and hardware
2. explain specialty fiber basics and waveguide coupling optics between dissimilar fibers
3. gain in-depth knowledge of the fiber fusion splicing process and fiber glass processing techniques
4. describe 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
5. 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.
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:

1. identify the primary goals of reliability testing
2. define a complete reliability specification
3. differentiate between parametric and non-parametric reliability lifetests
4. list the models used to describe reliability and select the best for a given population
5. define a FIT score and explain why it is not a good measure of reliability
6. estimate reliability model parameters from real data
7. analyze cases which include insufficient, problematic, and/or uncertain data
8. compute confidence bounds and explain their importance
9. differentiate between failure modes and root causes
10. identify infant mortalities, random failures, and wear-out in the data
11. compare competing failure modes
12. analyze cases in which slow degradation is present
13. state the goal of accelerated lifetesting and identify when it is (and is not) appropriate
14. list common stresses used in accelerated lifetesting and explain how to treat these quantitatively
15. differentiate between step-stress and multicell accelerated lifetesting
16. use accelerated lifetest data to simultaneously extract acceleration parameters and population reliability
17. 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.
Fundamentals of Reliability Engineering for Optoelectronic Devices (CONTINUED)

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 a 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.
Additive Manufacturing of Metals – Powder Bed Fusion and Directed Energy Deposition

SC1237 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

Additive manufacturing (AM) is rapidly being adopted by industry as a means to fabricate once-impossible components in a matter of days and weeks rather than months. This course presents the key elements of powder bed fusion and directed energy deposition AM. With a focus on these two, most popular AM processes, the course will first guide the audience through the digital thread for component fabrication, then to the consequences of hardware implementations and the effects of post-processing on part quality. In-process sensing and post-process non-destructive evaluation methods will also be covered. Audience members will leave with a high-level understanding of the technology and an appreciation for the many benefits and challenges of metals additive manufacturing.

LEARNING OUTCOMES

This course will enable you to:
1. identify the key digital-processing steps in transforming a design to a printed component
2. determine essential process variables and their impact on part quality
3. evaluate in-situ sensing and control methodologies and commercially-available solutions
4. summarize necessary post-processing procedures for metal components
5. appreciate the role of in-process and post-process sensing in evaluating part quality
6. estimate the cost of component fabrication via available AM techniques
7. recognize good versus bad use-cases for the technology

INTENDED AUDIENCE

Sales staff, executives, marketing staff, engineers, technicians, or managers who wish to learn more about the state-of-the-art of metals additive manufacturing. Some undergraduate training in science or engineering may be helpful but is not necessary.

INSTRUCTOR

Abdalla Nassar PhD. is an expert in additive manufacturing (AM) of metal and laser-materials processing. As a Research Associate with the Applied Research Laboratory at Penn State and a member of the Gradate Faculty of the Engineering Science Department at Penn State, he has led and worked on programs addressing many topics relevant to AM, including the digital thread concept, process-microstructure relations, thermal and optical sensing, support removal, closed-loop control, and spectroscopy for defect detection. His work has led to six patent filings along with numerous publications.

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Photodetectors: Theory, Practice, and Applications

SC1277 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 3.5 HOURS

Many new and trending photonics applications (PET for medical imaging, LiDAR for autonomous vehicles, flow cytometry for medical point-of-care) require the use of photodetectors. This course discusses the selection process of an optimal photodetector from a pool of four (photomultiplier tube, photodiode, avalanche photodiode, and silicon photomultiplier) using the WITS$ methodology. The approach is based on four fundamental properties of light − wavelength (W), intensity (I), temporal behavior (T), and spatial characteristics (S) − and cost ($). After reviewing the basic concepts of the detectors’ optoelectronic characteristics, operation, and noise, the course presents realistic case studies of the selection process for a wide range of experimental setups. Anyone who wants to answer questions such as, “Should I switch from PMT to SiPM?” or “What are the advantages and weaknesses of each photodetector technology?” will benefit from taking this course.

LEARNING OUTCOMES

This course will enable you to:
1. explain the fundamental and physics of operation of the four photodetectors
2. explain the origin and assess the importance of noise sources (e.g., shot, Johnson, multiplication, etc.) in the photodetectors and the detection electronics
3. identify the main applications of the four photodetectors
4. describe the key properties of the detected light used in the WITS$ methodology
5. estimate S/N for the given input light, photodetector, and readout electronics
6. compare the performance of the photodetectors in terms of S/N
7. incorporate detector cost in the selection process summarize realistic examples of the selection process for a wide range of input light characteristics

INTENDED AUDIENCE

Scientists, engineers, technicians, and graduate students who wish to learn how to select an optimal point photodetector for their optical system designs and experiments. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Slawomir Platek has been measuring proper motions of nearby galaxies using images obtained with the Hubble Space Telescope as senior university lecturer of physics at New Jersey Institute of Technology. Additionally, he has developed a photonics training program for engineers at Hamamatsu Corporation in New Jersey in the role of a science consultant. He has presented at various international conferences and webinars on important topics such as automotive LiDAR, flow cytometry, selection of photodetectors and more. He earned his Ph.D. in Physics at Rutgers, the State University of New Jersey.
Optical Materials, Fabrication and Testing for the Optical Engineer

SC1086 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

This course is designed to give the optical engineer or lens designer an introduction to the technologies and techniques of optical materials, fabrication and testing. This knowledge will help the optical engineer understand how the choice of optical specifications and tolerances can either lead to more cost effective optical components, or can excessively drive the price up. Topics covered include optical materials, traditional, CNC and novel optical fabrication technologies, surface testing and fabrication tolerances.

LEARNING OUTCOMES
This course will enable you to:
1. identify key mechanical, chemical and thermal properties of optical materials (glass, crystals and ceramics) and how they affect the optical system performance and cost of optical components
2. describe the basic processes of optical fabrication
3. define meaningful surface and dimensional tolerances
4. communicate effectively with optical fabricators
5. design optical components that are able to be manufactured and measured using state of the art optical fabrication technologies
6. choose the optimum specifications and tolerances for your next project

INTENDED AUDIENCE
Optical engineers, lens designers, or managers who wish to learn more about how optical materials, fabrication and testing affect the optical designer. Undergraduate training in engineering or science is assumed.

INSTRUCTOR
Jessica DeGroote Nelson is the Director of Technology and Strategy at Optimax Systems, Inc. She is an adjunct faculty member at The Institute of Optics at the University of Rochester teaching both an undergraduate and graduate course on Optical Fabrication and Testing, and has given several guest lectures on optical fabrication and metrology methods. She earned a Ph.D. in Optics at The Institute of Optics at the University of Rochester. Dr. Nelson is a member of both OSA and SPIE.

“Absolutely fantastic. She is passionate and knowledgeable and a skilled instructor. I would take another class from her in a heartbeat.”

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Multispectral Image Fusion and Night Vision Colorization

SC1135 • COURSE LEVEL: INTRODUCTORY • COURSE LENGTH: 3.5 HOURS

This course presents methods and applications of multispectral image fusion and night vision colorization organized into three areas: (1) image fusion methods, (2) evaluation, and (3) applications. Two primary multiscale fusion approaches, image pyramid and wavelet transform, will be emphasized. Image fusion comparisons include data, metrics, and analytics. Fusion applications presented include off-focal images, medical images, night vision, and face recognition. Examples will be discussed of night-vision images rendered using channel-based color fusion, lookup-table color mapping, and segment-based method colorization. These colorized images resemble natural color scenes and thus can improve the observer’s performance. After taking this course you will know how to combine multiband images and how to render the result with colors in order to enhance computer vision and human vision especially in low-light conditions. In addition to the course notes, attendees will receive a set of published papers, the data sets used in the analysis, and MATLAB code of methods and metrics for evaluation. An FTP website is established for course resource access.

LEARNING OUTCOMES

This course will enable you to:
1. review the applications and techniques of image fusion and night vision enhancement
2. categorize multiscale image fusion methods: image pyramid vs. wavelet transform
3. apply quantitative vs. qualitative evaluation
4. investigate advanced fusion applications: target recognition, color fusion and face recognition
5. obtain an overview of colorization methods: color mapping, segment-based, and channel-based
6. evaluate colorized images: qualitative vs. quantitative, and correspondence with the NIIRS (National Imagery Interpretability Rating Scale) ratings
7. explore information fusion applications to a multispectral stereo face recognition systems at four levels: image, feature, score, and decision; to qualitatively evaluate performance improvement
8. recognize and discuss challenges for future development and applications

INTENDED AUDIENCE

Scientists, engineers, practitioners, students, and researchers who wish to learn more about how to combine multiband images to enhance computer vision and human vision for applications such as face recognition and scene understanding. Undergraduate training in engineering or science is assumed.
INSTRUCTORS

Yufeng Zheng received his PhD in optical engineering/image processing from the Tianjin University in Tianjin, China, in 1997. He is currently an tenured professor at Alcorn State University in Lorman, Mississippi. He is the principle investigator of several federal research grants in the areas of night vision enhancement, multispectral face recognition and deep learning neural networks. He holds three patents in glaucoma classification and face recognition, and has published more than 80 peer-reviewed papers. His research interests include deep learning for classification, biometrics, information fusion, and computer-aided detection and diagnosis. He is a Cisco Certified Network Professional (CCNP), and a senior member of SPIE, and IEEE Computer Society & Signal Processing.

Erik Blasch received his B.S. in mechanical engineering from the Massachusetts Institute of Technology in 1992 and M.S. degrees in mechanical engineering, health science, and industrial engineering (human factors) from Georgia Tech. He completed an M.B.A., M.S.E.E., M.S. econ, M.S./Ph.D. psychology (ABD), and a Ph.D. in electrical engineering from Wright State University and is a graduate of Air War College. From 2000-2010, Dr. Blasch was the information fusion evaluation tech lead for the Air Force Research Laboratory (AFRL) Sensors Directorate—COMprehensive Performance Assessment of Sensor Exploitation (COMPASE) Center, and adjunct professor with Wright State University. From 2010-2012, Dr. Blasch was an exchange scientist to Defence R&D Canada at Valcartier, Quebec in the Future Command and Control (C2) Concepts group. He is currently with the AFRL Information Directorate supporting information fusion developments. He received the 2009 IEEE Russ Bioengineering, 2012 IEEE AESS Magazine Mimno, and 2014 Military Sensing Symposium Mignogna Data Fusion awards. He is a past President of the International Society of Information Fusion (ISIF), a member of the IEEE Aerospace and Electronics Systems Society (AESS) Board of Governors, and a SPIE Fellow. His research interests include target tracking, information/sensor/image fusion, pattern recognition, and biologically-inspired applications.
Introduction to Performance Budgeting

SC1229 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

A performance budget is fundamental to understanding the likely outcome of a design or measurement process. The budget also gives insight into the distribution of likely performance and how it is affected by design. Because of the clear link between performance and design, the performance or error budget is the central tool in systems engineering, design and measurement. The ability to construct such a budget should be in every scientist’s and engineer’s tool kit regardless if the system is a simple measurement, component or something vastly more complex. This course explains the basic principles of the construction of a rigorous performance budget and understanding the distribution of outcomes. The problem of allocation of performance among components or subsystems is also introduced and explained. Examples of performance budgets and allocations are taken from various problems in the systems engineering of astronomical and laser systems are used to illustrate application of these techniques. This course will be of benefit, scientists, engineers and managers who want to answer the questions, “what are the chances of success of my project?” and “how can I maximize the probability of success?”

LEARNING OUTCOMES
This course will enable you to:
1. compose a performance or error budget and explain its construction
2. calculate the distribution of likely outcomes of a design or measurement process
3. determine how to allocate performance among components or subsystems
4. calculate the most likely value for the performance of a component or system
5. identify the sensitivity of performance to all parameters in the system
6. explain the probability of the success of design project

INTENDED AUDIENCE
Scientists, engineers, technicians, or managers who wish to learn more about performance and error budgeting and allocation. Undergraduate training in engineering or science is assumed.

INSTRUCTOR
Jonathan Arenberg has been working as an optical and systems engineer for over 35 years. His work experience has included tactical and high-power laser components and systems and major space astronomical projects such as Chandra and the James Webb Space Telescope and numerous technology efforts. He holds degrees in physics and engineering from the University of California, Los Angeles and currently the Chief Engineer for Northrop Grumman Aerospace Systems on the James Webb Space Telescope and for Space Science Missions. Dr. Arenberg is an SPIE fellow.
Designing and Specifying Digital Cameras

SC1231 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 3.5 HOURS

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

INTENDED AUDIENCE

Scientists, engineers, technicians, or managers who wish to learn how to specify a camera, the lens and the sensor, from a system perspective to satisfy a particular requirement. Managers and engineers who want to talk to lens designers or camera vendors with a higher level of understanding. No prerequisites.

INSTRUCTOR

Leo Baldwin is a physicist, a futurist, and an inventor with 89 US patents. He has delved into nuclear reactor core design, submarine design, plastic waste processing, and utility-scale solar power. The majority of his career has been in photonics. Leo has designed cameras including lenses, pixels, and sensors; illumination systems, lasers including beam-shaping and delivery systems, machine vision and robotic guidance systems. His original designs can be found with the armed forces of 26 countries, on ship decks and helicopters, in glass plants and breweries, in semiconductor fabs and on manufacturing floors, on iPhones and iPads, in the Amazon Go store and in Amazon consumer products. Leo is currently working on the Scout autonomous delivery robot for Amazon. Fun fact: Leo was deemed an Expert Witness on the subject of Beer Foam (and its measurement) in Judge Ito’s court.
From near-infrared security cameras above your front door, to thermal infrared camera accessories that mount to smartphones, infrared imaging technology is everywhere in 2017. But there is still confusion and misinformation about what it is and what it can and cannot do. This 2-hour, high-level introduction to the topic, with minimal math or physics knowledge required, is for the growing number of non-specialists who need to understand infrared imaging technology and its many applications. The presentation materials consist of infrared images from the instructor's extensive library, the stories these images tell us, how they are made and how the technology and the phenomena it captures relates to the more familiar realm of visible-light cameras and human vision.

LEARNING OUTCOMES
This course will enable you to:
1. discuss infrared imaging technology with engineers, scientists, and customers.
2. explain and understand the terminology of infrared radiation science and technology
3. explain understand how object emit and reflect infrared energy and how cameras detect it

INTENDED AUDIENCE
Executives, personnel in sales and business development, and non-technical employees of companies that make infrared cameras.

INSTRUCTOR
Austin Richards is a senior research scientist at FLIR Systems in Santa Barbara, CA. He holds a PhD in astrophysics from UC Berkeley, and has worked in the commercial infrared industry for over 20 years. He is also the principal of Oculus Photonics, a small company devoted to near-ultraviolet imaging systems manufacturing, sales and support. Richards is the author of the SPIE monograph Alien Vision: Exploring the Electromagnetic Spectrum with Imaging Technology. He is a SPIE Senior Member.

“Instructor Austin Richards was excellent; clear; informed, and concise. The course material was interesting, well presented, and educating.”
Infrared Systems Architecture and Design for Future Market Trends

SC1269 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

This course explains basic technology and new market trends for infrared sensors for commercial and military applications. The course starts with a brief introduction to Infrared physics, phenomenology and history. Typical systems architectures will be discussed and how they may be changed by emerging technologies. The difficulties and barriers of introducing a new technology into Infrared cameras and systems will be covered. Potential disruptive technologies and embryonic technologies will be described, forecasted and applied to future markets and applications. New emerging applications and markets that are untouched, or little penetrated by the technology will be described, and the barriers that have prevented this technology to sufficiently enter these markets. The subject matter concentrated on infrared imagers (both commercial and military); although the images may not be presented to a human, but a computer, car or robot. Some non-imaging systems such as IRSTs, hyperspectral and sparse FPAs for certain applications are also discussed. Classic IR spectrometry, near-IR (as detected by silicon) and IR microscopy are not addressed.

LEARNING OUTCOMES
This course will enable you to:
1. describe the emerging technologies
2. explain the current and future market forces
3. identify the role of potentially disruptive technologies to the infrared imaging industry
4. be familiar with new potential applications
5. explain the top-level state of the art infrared technology for commercial and military systems
6. describe the developing technology trends
7. summarize the existing and future marketing trends and judge how this will impact commercial and military products
8. Identify embryonic technologies that are potentially disruptive and judge what existing technologies are threatened

INTENDED AUDIENCE
Executives, sales, scientists, engineers, and managers who wish to learn more and understand how technology trends and market forces are and will interact in the future of the infrared imaging industry. Especially those that have less than 10 years of experience in the industry.
COURSE RECORDINGS

Infrared Systems Architecture and Design for Future Market Trends (CONTINUED)

INSTRUCTOR
John Lester Miller is a SPIE Fellow with 40 years of experience in the design, development and marketing of infrared systems for commercial, military, industrial and scientific applications. He has worked at Mt. Wilson & Palomar Observatories, Rockwell International, NASA’s Infrared Telescope Facility (on Mauna Kea), Lockheed Martin, and was with FLIR systems for 19 years including serving as Chief Technology Officer for FLIR’s Government Division. Mr. Miller joined FLIR when it had sales of $35 million per year, and left when it had reached $1.6 billion. He is now the founder and principle of Cascade Electro Optics, and sits on several boards of directors for photonic companies. He regularly consults on sensor system design, architecture, markets and phenomenology. He has written more than 100 papers, and five books on electro-optical technology, holds 8 patents and served as an expert witness in federal court and regularly consults. John is a conference for SPIE’s “Infrared Technology and Application Conference”, sits on SPIE’s executive committee and previously the Military Sensor Symposium’s Passive and National program committees. He has degrees in Physics, Astronomy and an MBA in management of technology.

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Fabrication Technologies for Micro- and Nano-Optics

SC454 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

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:
1. describe example applications and key ‘rules of thumb’ for micro- and nano-optics
2. explain basic principles of photolithography and how they apply to the fabrication of micro- and nano-optics
3. identify and explain multiple techniques for micro- and nano-optics fabrication
4. compare the advantages and disadvantages of different manufacturing methods
5. describe and compare performance and metrological testing methods for micro- and nano-optics
6. 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 Diffractive Optics: Design, Fabrication, and Test (SPIE Press), and has served as Senior Editor for JM3, 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.
NIR and SWIR Imaging Applications

SC710 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 3.5 HOURS

This course provides attendees with an overview of the diverse range of applications for NIR and SWIR imaging systems and how these systems are calibrated and characterized. The emphasis is on the capabilities of InGaAs and InSb sensors operating in the 0.7 to 3.0 micron NIR and SWIR bands with discussions of optics and tunable filter technology. Discussion will also include extended InGaAs and VisGaAs, a sensor material with both visible and NIR response.

LEARNING OUTCOMES
This course will enable you to:
1. learn about the many applications for NIR/SWIR imaging technology
2. specify a detector type and optics for various NIR/SWIR applications
3. calibrate NIR/SWIR camera systems and characterize their performance
4. describe spectral selection in the NIR/SWIR bands

INTENDED AUDIENCE
This material is intended for anyone wishing to become familiar with NIR/SWIR technology and imaging applications.

INSTRUCTOR
Austin Richards is a senior research scientist at FLIR Systems in Santa Barbara, CA. He holds a PhD in astrophysics from UC Berkeley, and has worked in the commercial infrared industry for over 20 years. He is also the principal of Oculus Photonics, a small company devoted to near-ultraviolet imaging systems manufacturing, sales and support. Richards is the author of the SPIE monograph Alien Vision: Exploring the Electromagnetic Spectrum with Imaging Technology. He is a SPIE Senior Member.
Cost-Conscious Tolerancing of Optical Systems

SC720 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

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:
1. define variability and comprehend its impact on nominal systems
2. utilize fundamental applied statistics in tolerancing
3. construct tolerance analysis budgets
4. perform detailed tolerance analysis
5. 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.
The Seven Habits of Highly Effective Project Managers

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:
1. manage scope, quality, budgets, and schedule in the most efficient and effective ways
2. identify what’s important in procurements and contract management—and recognize what’s not
3. identify the vital importance of proactive risk management, including how to turn realized problems into beneficial opportunities
4. build and maintain the most powerful asset you have as the PM—your project team
5. engage and leverage the power of your key external stakeholders
6. explain communication techniques that ensure your team is working and collaborating in the most efficient and effective ways possible
7. 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.
Quantum Computing

SC1210 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 3.5 HOURS

Quantum computing, one of the most recent joint ventures between physics and the theory of computation, can be defined as the scientific field whose purpose is to develop hardware and algorithms based on quantum mechanical phenomena. In addition to further advance the mathematical and physical foundations of quantum computing, scientists and engineers who work in this field focus on developing cutting-edge quantum algorithms in areas like artificial intelligence, cryptanalysis, machine learning, database search, chemical simulations, and image processing. The course summarizes recent theoretical and experimental results that showcase the feasibility of large-scale quantum computation. In addition, the course describes the potential applications of quantum computing to signal analysis, sensor fusion, and computer vision.

LEARNING OUTCOMES
This course will enable you to:
1. explain the difference between classical and quantum information
2. explain the difference between classical and quantum computing
3. identify key quantum mechanical properties as computational resources
4. describe the fundamental quantum algorithmic techniques
5. describe the potential applications and advantages of quantum computation applied to problems from signal analysis, communications, sensor fusion, and computer vision

INTENDED AUDIENCE
Scientists, engineers, technicians, or managers who wish to learn more about quantum computing and its potential applications to signal analysis, communications, sensor fusion, and computer vision. Undergraduate training in engineering or science is assumed.

INSTRUCTORS
Salvador Elias 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, has been a visiting professor at Harvard University (USA), Bahia Blanca University (Argentina), Sergio Arboleda University (Colombia) and del Valle University (Colombia). Dr Venegas-Andraca is a Senior Member of ACM and Fellow of the Mexican Academy of Sciences.

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.
The international society for optics and photonics

Introduction to LIDAR for Autonomous Vehicles

SC1232 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 3.5 HOURS

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:
1. explain the parameters that determine the size and weight of a LIDAR system
2. identify application-specific requirements that drove the design of state-of-the-art LIDAR systems for use in emerging applications
3. describe the advantages and disadvantages of staring and scanning LIDAR systems
4. estimate the maximum detectable range and the range resolution for a LIDAR instrument
5. distinguish between various LIDAR system designs for use on autonomous vehicles
6. compare advantages and disadvantages of different designs for small, portable LIDAR systems
7. 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 optical remote sensing systems and using them in environmental and military sensing for three decades, first at NOAA and currently as professor of electrical engineering and physics at Montana State University. Recognition for his work in this field includes NOAA research awards, a Presidential Early Career Award for Scientists and Engineers, the World Meteorological Organization's Vaisala Prize, and the SPIE Stokes Award. He earned a Ph.D. in Optical Sciences at the University of Arizona. Dr. Shaw is a Fellow of both the OSA and SPIE.

“Very good content, very clear and organized. I’d definitely recommend.”

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Multispectral and Hyperspectral Image Sensors

SC194 ∙ COURSE LEVEL: ADVANCED ∙ COURSE LENGTH: 3.5 HOURS

This course will describe the imaging capabilities and applications of the principal types of multispectral (MS) and hyperspectral (HS) sensors. The focus will be on sensors that work in the visible, near-infrared and shortwave-infrared spectral regimes, but the course will touch on longwave-infrared applications. A summary of the salient features of classical color imaging (human observation) will also be provided in an appendix.

LEARNING OUTCOMES

This course will enable you to:

1. explain many of the applications and advantages of multispectral (MS) and hyperspectral (HS) imaging
2. describe and categorize the properties of the principal MS / HS design types (multi-band scanner, starers with filter wheels, dispersive, wedge, and Fourier transform imagers with 2D arrays, etc.)
3. list and define the relevant radiometric radiometric quantities, concepts and phenomenology
4. describe the process of translating system requirements into sensor hardware constraints and specifications
5. analyze signal-to-noise ratio, modulation-transfer-function, and spatial / spectral sampling for MS and HS sensors
6. define, understand and apply the relevant noise-equivalent figures-of-merit (Noise-equivalent reflectance difference, Noise-equivalent temperature difference, Noise-equivalent spectral radiance, Noise-equivalent irradiance, etc.)
7. describe the elements of the image chain from photons-in to bits-out (photon detection, video signal manipulation, analog processing, and digitization)
8. list and review key imager subsystem technology elements (optical, focal plane, video electronics, and thermal)
9. formulate a detailed end-to-end design example of a satellite imaging scanning HS sensor
10. provide an appendix that summarizes color imaging principles and sensor associated elements for human observation applications (e.g. color television, still cameras, etc.)

INTENDED AUDIENCE

Engineers, scientists, and technical managers who are interested in understanding and applying multispectral and hyperspectral sensors in advanced military, civil, scientific and commercial applications.

INSTRUCTOR

Terrence Lomheim holds the position of Distinguished Engineer at The Aerospace Corp. He has 41 years of hardware and analysis experience in visible and infrared electro-optical systems, focal plane technology, and applied optics, and has authored and co-authored 66 publications in these technical areas. He is a Fellow of the SPIE.
Introduction to Optical Remote Sensing Systems

This course provides a broad introduction to optical remote sensing systems, including both passive sensors (e.g., radiometers and spectral imagers) and active sensors (e.g., laser radars or LIDARs). A brief review of basic principles of radiometry and atmospheric propagation (absorption, emission, and scattering) is followed by a system-level discussion of a variety of ground-, air-, and space-based remote sensing systems. Key equations are presented for predicting the optical resolution and signal-to-noise performance of passive and active sensing systems. Sensor system examples discussed in the class include solar radiometers, passive spectrometers and hyperspectral imagers, airborne imaging spectrometers, thermal infrared imagers, polarization imagers, and active laser radars (LIDARs and LADARs). The course material is directly relevant to sensing in environmental, civilian, military, astronomical, and solar energy applications.

LEARNING OUTCOMES
This course will enable you to:

1. review the principles of optical radiometry used to describe and calculate the flow of optical energy in an optical sensor system or solar energy system
2. describe how the atmosphere affects the propagation of optical radiation
3. explain how optical atmospheric effects influence remote sensing measurements or solar energy
4. use system parameters in basic radiometric calculations to predict the signal received by passive and active sensors
5. compare systems at the block-diagram level remote sensing measurements
6. explain the difference between passive imaging based on reflection and emission
7. acquire the operating principles of laser radar (lidar/ladar) systems for distributed and solid target sensing

INTENDED AUDIENCE
Scientists, engineers, technicians, or technical managers who find themselves working on (or curious about) optical remote sensing systems or data. Undergraduate training in engineering or science is assumed.

INSTRUCTOR
Joseph Shaw is a professor of electrical engineering and physics at Montana State University and previously worked at the NOAA research labs. He is a recognized expert in development, calibration, and analysis of optical remote sensing systems used in environmental and military sensing. Recognition for his work in this field 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.
Modern Optical Testing

SC212 ∙ COURSE LEVEL: INTERMEDIATE ∙ COURSE LENGTH: 3.5 HOURS

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 wavefront-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:
1. better specify optical components and systems
2. produce higher-quality optical systems
3. determine if an optics supplier can actually supply the optics you are ordering
4. evaluate optical system performance
5. explain basic interferometry and interferometers for optical testing
6. analyze interferograms
7. test flat and spherical surfaces
8. test ground and aspheric surfaces
9. make absolute measurements
10. 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 Sciences 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.
Fundamentals of Medical Image Processing and Analysis

SC086 · COURSE LEVEL: INTERMEDIATE · COURSE LENGTH: 7 HOURS

This course gives an overview of medical image formation, enhancement, analysis, visualization, and communication with many examples from medical applications. It starts with a brief introduction to medical imaging modalities and acquisition systems. Basic approaches to display one-, two-, and three-dimensional (3D) biomedical data are introduced. As a focus, image enhancement techniques, segmentation, texture analysis and their application in diagnostic imaging will be discussed. To complete this overview, storage, retrieval, and communication of medical images are also introduced. In addition to this theoretical background, a 45 min practical demonstration with ImageJ is given. ImageJ is a Java-based platform for medical image enhancement and visualization. It is developed by the National Institutes of Health, USA, open source and freely available in the public domain. For this course, ImageJ is appropriately configured with useful plug-ins (e.g. DICOM import, 3D rendering) and distributed on CD-ROM. Attendees are welcome to perform on their own laptop computers.

LEARNING OUTCOMES

This course will enable you to:
1. identify major processes involved in formation of medical images
2. recognize the imaging modality from their visualization
3. classify the various medical image processing algorithms
4. describe fundamental methods of image enhancement
5. enhance medical images using appropriate software
6. visualize all types of medical image data
7. appraise efficacy and drawbacks of several techniques of image segmentation
8. get familiar with the fundamental concepts of texture analysis
9. explain the basic principles of medical image communication
10. get started with ImageJ and self-perform fundamentals of medical image processing

INTENDED AUDIENCE

Engineers, scientists, biomedical researchers and managers who need a basic understanding of medical image processing technologies and methods. Some prior background with image processing and computer technology will be helpful.

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Fundamentals of Medical Image Processing and Analysis (CONTINUED)

INSTRUCTOR
Thomas M. Deserno (né Lehmann), PhD, is full professor of Medical Informatics at TU Braunschweig University, Germany, where he heads the Peter L. Reichertz Institute for Medical Informatics of TU Braunschweig and Hannover Medical School. He lectures undergraduate and graduate courses on biomedical signal and image acquisition and processing, co-authored the textbook Image Processing for the Medical Sciences (1997), and edited the Handbook of Medical Informatics (2005) and Biomedical Image Processing (2011). His research interests include signal and image analysis for computer-assisted diagnoses and event prediction as well as eHealth applications, where he has authored over 100 scientific publications. Dr. Deserno is Senior Member of IEEE and SPIE, where he is member of the Program Committee of the Medical Imaging Symposium (both, computer-aided diagnosis and imaging informatics tracks). He is a member of the International Association of Dentomaxillofacial Radiology (IADMFR), and serves on the International Editorial Boards of PLOS ONE, the European Journal for Biomedical Informatics, Methods of Information in Medicine, Dentomaxillofacial Radiology, World Journal of Radiology, Acta Informatics Medica, and GMS Medical Informatics, Biometry and Epidemiology (MIBE). He is Co-editor Europe of the International Journal of Healthcare Information Systems and Informatics and Associated Editor of the SPIE Journal of Medical Imaging. He is the German representative in the International Medical Informatics Association (IMIA).

“Excellent depth and breadth
- I really enjoyed the course.”
Principles and Advancements in X-ray Computed Tomography

SC471 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 4 HOURS

This course will present a description of the fundamental physics and mathematical principles of CT. Key system performance parameters and design tradeoffs are reviewed. Causes and corrections of various image artifacts are extensively discussed. Potential impact of image artifacts and performance parameters on other computer-based algorithms, such as CAD and 3D volume rendering, is outlined. The second part of the tutorial will focus on the recent technology advancements in CT. Basic principles, benefits, and inherent issues associated with the helical (spiral) CT, multi-slice CT, and volumetric CT will be described. Different reconstruction approaches to combat artifacts associated with cone beam and helical interpolation are examined. The tutorial will conclude with a discussion on the recent advancements in CT applications, such as cardiac imaging, perfusion, dual energy, and fluoroscopy.

LEARNING OUTCOMES
This course will enable you to:
1. acquire the fundamental principles of CT
2. explain mathematical foundations of CT image reconstruction
3. identify and analyze major system performance parameters and tradeoffs
4. describe the major causes and corrections of image artifacts, such as aliasing, beam hardening, off-focal radiation, patient motion, metal artifacts, detector non-ideal response, projection truncation, 3D artifacts, and others
5. discuss recent advancement in CT technology
6. assess recent advancement in clinical applications

INTENDED AUDIENCE
Engineers, physicists, biomedical scientists, radiologists, and managers who need to understand the fundamentals and the state-of-the-art of CT. No special knowledge on CT is required, although basic knowledge of x-ray physics and Fourier transform is a plus.

INSTRUCTOR
Jiang Hsieh is a Chief Scientist of GE Healthcare Technologies and an adjunct professor in the Medical Physics Department of the University of Wisconsin-Madison. He has nearly 30 years of experience in medical imaging. He holds over 220 US patents, has co-authored more than 200 articles, book chapters, and textbook. He taught AAPM summer school, refresher courses at RSNA, short courses at IEEE Medical Imaging Conference, AAPM annual meeting, and SPIE Medical Imaging Conference. His research interests include tomographic reconstruction, CT image artifact reduction and correction, signal processing, image processing, and advanced CT applications.

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Certificate in Understanding Basic Laser Technology: 5-Part Series

SC369 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 15 HOURS

Lasers are becoming increasingly important in our high-technology environment. Many technicians and engineers who sell, install, operate, and maintain them have limited training in the field of electro-optics. The result can be less efficient usage of these important tools. This 5-part series seeks to rectify that problem by presenting the fundamental operating principles of lasers in an intuitive, non-mathematical manner. This Certificate Series includes all 5 online courses from SPIE: SC364 - What Are Lasers Good For?; SC365 - How Light Works; SC366 - How Lasers Work; SC367 - Modifying Lasers; SC368 - Today's Commercial Lasers. See individual course descriptions for more details on the contents of each course.

LEARNING OUTCOMES
This course will enable you to:
1. describe the broad range of laser applications
2. explain the two basic concepts needed to understand lasers
3. describe the basic modifications that can be made to a laser to change its output characteristics
4. explain the fundamental motivation for pulsing lasers
5. explain how nonlinear optics enhances the utility of lasers

INTENDED AUDIENCE
This course is intended for engineers whose background is lacking in laser technology, technicians working with lasers, and anybody else who desires an understanding of the basic principles of laser technology. Participants should have a basic understanding of the principles of science (e.g., conservation of energy, cause and effect) and be at least somewhat comfortable with elementary algebra.

INSTRUCTOR
C. Breck Hitz served for 20 years as the executive director of LEOMA—the Laser and Electro-Optics Manufacturers’ Association—and organized much of the U.S. laser industry’s political activities during that period. He is the current chairman of the ISO Laser Standards Committee, and has represented the U.S. laser industry at export-control negotiation at both COCOM (Paris) and Wassenaar (Vienna). During the past 25 years, he has presented the course to literally thousands of engineers, scientists, technicians, and business people. He holds Bachelor and Master degrees in physics from the Pennsylvania State University and the University of Massachusetts, respectively.
Lasers are becoming increasingly important in our high-technology environment. Many technicians and engineers who sell, install, operate, and maintain them have limited training in the field of electro-optics. The result can be less efficient usage of these important tools. This 5-part series seeks to rectify that problem by presenting the fundamental operating principles of lasers in an intuitive, non-mathematical manner. Part 1 of this 5-part series addresses what lasers are good for by explaining what a laser is and addressing the many various applications.

LEARNING OUTCOMES
This course will enable you to:
1. name several different types of lasers and explain basic laser operation
2. describe the characteristics of a laser beam and explain the two basic concepts needed to understand a laser
3. describe the basic modifications that can be made to a laser to change its output characteristics
4. explain the advantages and limitations of laser material processing
5. explain various applications of lasers, such as color printing, defect detection, and fiber optic communication

INTENDED AUDIENCE
Intended for engineers who want to increase their knowledge of laser technology and technicians working with lasers, viewers should have a basic understanding of scientific principles and elementary algebra.

INSTRUCTOR
C. Breck Hitz served for 20 years as the executive director of LEOMA—the Laser and Electro-Optics Manufacturers’ Association—and organized much of the U.S. laser industry’s political activities during that period. He is the current chairman of the ISO Laser Standards Committee, and has represented the U.S. laser industry at export-control negotiation at both COCOM (Paris) and Wassenaar (Vienna). During the past 25 years, he has presented the course to literally thousands of engineers, scientists, technicians, and business people. He holds Bachelor and Master degrees in physics from the Pennsylvania State University and the University of Massachusetts, respectively.
How Light Works  
(Part 2 of a 5-Part Series)  

Lasers are becoming increasingly important in our high-technology environment. Many technicians and engineers who sell, install, operate, and maintain them have limited training in the field of electro-optics. The result can be less efficient usage of these important tools. This 5-part series seeks to rectify that problem by presenting the fundamental operating principles of lasers in an intuitive, non-mathematical manner. Part 2 of this 5-part series addresses how light works by covering such topics as: waves and photons, refractive index, polarization, birefringence, and interference.

LEARNING OUTCOMES
This course will enable you to:
1. describe what radio waves, visible light, and x-rays have in common
2. explain what is meant by refractive index and how it affects light propagation in materials
3. describe what is meant by polarization of a light wave
4. explain how light can be transmitted through crossed polarizers
5. describe the effect of a medium’s refractive index on light passing through it
6. explain birefringence and describe its applications in lasers and photonics
7. explain optical polarization and how it can be used to manipulate light
8. list examples of when light must be viewed as a wave, and when it must be viewed as a particle
9. explain the operation of a Fabry-Perot interferometer

INTENDED AUDIENCE
Intended for engineers who want to increase their knowledge of laser technology and technicians working with lasers, viewers should have a basic understanding of scientific principles and elementary algebra.

INSTRUCTOR
C. Breck Hitz served for 20 years as the executive director of LEOMA—the Laser and Electro-Optics Manufacturers’ Association—and organized much of the U.S. laser industry’s political activities during that period. He is the current chairman of the ISO Laser Standards Committee, and has represented the U.S. laser industry at export-control negotiation at both COCOM (Paris) and Wassenaar (Vienna). During the past 25 years, he has presented the course to literally thousands of engineers, scientists, technicians, and business people. He holds Bachelor and Master degrees in physics from the Pennsylvania State University and the University of Massachusetts, respectively.
Lasers are becoming increasingly important in our high-technology environment. Many technicians and engineers who sell, install, operate, and maintain them have limited training in the field of electro-optics. The result can be less efficient usage of these important tools. This 5-part series seeks to rectify that problem by presenting the fundamental operating principles of lasers in an intuitive, non-mathematical manner. Part 3 of this series addresses how lasers work, covering such topics as: spontaneous emission, stimulated emission, laser pumping mechanisms, resonators, intracavity dynamics, longitudinal modes of a resonator, transverse modes and Gaussian Beams.

**LEARNING OUTCOMES**
This course will enable you to:
1. explain the two basic principles of laser operation
2. explain the concepts of spontaneous and stimulated emission
3. list several techniques for exciting an atom
4. describe the common (and uncommon) techniques for pumping lasers
5. list the three basic functions of a laser resonator
6. explain how a laser can simultaneously oscillate in more than one longitudinal mode
7. explain which transverse modes would extract the most power from a resonator and why

**INTENDED AUDIENCE**
Intended for engineers who want to increase their knowledge of laser technology and technicians working with lasers, viewers should have a basic understanding of scientific principles and elementary algebra.

**INSTRUCTOR**
C. Breck Hitz served for 20 years as the executive director of LEOMA—the Laser and Electro-Optics Manufacturers’ Association—and organized much of the U.S. laser industry’s political activities during that period. He is the current chairman of the ISO Laser Standards Committee, and has represented the U.S. laser industry at export-control negotiation at both COCOM (Paris) and Wassenaar (Vienna). During the past 25 years, he has presented the course to literally thousands of engineers, scientists, technicians, and business people. He holds Bachelor and Master degrees in physics from the Pennsylvania State University and the University of Massachusetts, respectively.
Modifying Lasers  
(Part 4 of a 5-Part Series)

SC367 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 3 HOURS

Lasers are becoming increasingly important in our high-technology environment. Many technicians and engineers who sell, install, operate, and maintain them have limited training in the field of electro-optics. The result can be less efficient usage of these important tools. This 5-part series presents the fundamental operating principles of lasers in an intuitive, non-mathematical manner. Part 4 of the series addresses how lasers can be modified by covering such topics as: Q-switching, cavity dumping, mode locking, laser bandwidth, along with an introduction to nonlinear optics.

LEARNING OUTCOMES
This course will enable you to:
1. explain the relationship between power, energy and time
2. calculate the average and peak power of a laser
3. describe the operation of acousto-optic, electro-optic, and passive Q-switches
4. describe cavity dumping and explain why it’s a variation of Q-switching
5. describe what modelocking is and explain why it generates shorter pulses than Q-switching
6. discuss the common techniques of reducing laser bandwidth
7. discuss nonlinear effects including mixing, optical parametric oscillation, harmonic generation, and upconversion
8. describe what phasematching is, and why it’s essential in nonlinear optics

INTENDED AUDIENCE
Intended for engineers who want to increase their knowledge of laser technology and technicians working with lasers, viewers should have a basic understanding of scientific principles and elementary algebra.

INSTRUCTOR
C. Breck Hitz served for 20 years as the executive director of LEOMA—the Laser and Electro-Optics Manufacturers’ Association—and organized much of the U.S. laser industry’s political activities during that period. He is the current chairman of the ISO Laser Standards Committee, and has represented the U.S. laser industry at export-control negotiation at both COCOM (Paris) and Wassenaar (Vienna). During the past 25 years, he has presented the course to literally thousands of engineers, scientists, technicians, and business people. He holds Bachelor and Master degrees in physics from the Pennsylvania State University and the University of Massachusetts, respectively.
Lasers are becoming increasingly important in our high-technology environment. Many technicians and engineers who sell, install, operate, and maintain them have limited training in the field of electro-optics. The result can be less efficient usage of these important tools. This 5-part series presents the fundamental operating principles of lasers in an intuitive, non-mathematical manner. Part 5 of the series provides examples of different kinds of lasers such as: semiconductor lasers, solid state lasers, and gas lasers and discusses their applications.

**LEARNING OUTCOMES**

This course will enable you to:

1. discuss the advantages and disadvantages of semiconductor lasers compared to other lasers
2. discuss the advantages of a vertical-cavity, surface-emitting laser (VCSEL), compared to a conventional edge emitter
3. explain the growth technique for Nd:YAG and other common solidstate laser crystals
4. describe the deleterious effects in a solidstate laser of waste heat generated in the laser process
5. explain what holey fibers are and describe their advantages over conventional fiber lasers
6. explain why a thin-disk laser can avoid many of the thermal problems of conventional solidstate lasers
7. describe what ultrafast lasers are and what their applications can be

**INTENDED AUDIENCE**

Intended for engineers who want to increase their knowledge of laser technology and technicians working with lasers, viewers should have a basic understanding of scientific principles and elementary algebra.

**INSTRUCTOR**

C. Breck Hitz served for 20 years as the executive director of LEOMA—the Laser and Electro-Optics Manufacturers’ Association—and organized much of the U.S. laser industry’s political activities during that period. He is the current chairman of the ISO Laser Standards Committee, and has represented the U.S. laser industry at export-control negotiation at both COCOM (Paris) and Wassenaar (Vienna). During the past 25 years, he has presented the course to literally thousands of engineers, scientists, technicians, and business people. He holds Bachelor and Master degrees in physics from the Pennsylvania State University and the University of Massachusetts, respectively.
Practical Optical System Design
SC003 ∙ COURSE LEVEL: INTERMEDIATE ∙ COURSE LENGTH: 10 HOURS

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:
1. develop a complete optical system design specification
2. highlight fundamental physics and engineering related to optical design
3. establish a general basis for modeling optical systems using computer-aided methods
4. analyze and organize system considerations to incorporate such as environmental factors
5. design for manufacture, alignment, and testing
6. 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 N. 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.
Introduction to Optomechanical Design

SC014 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 13 HOURS

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:

1. select materials for use in optomechanical systems
2. determine the effects of temperature changes on optical systems, and develop design solutions for those effects
3. design high performance optical windows
4. design low stress mounts for lenses
5. select appropriate mounting techniques for mirrors and prisms
6. 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.

“Great course. Wish I’d taken it sooner.
Vukobratovich is well prepared and unbelievably knowledgeable on the subject.”
Fastening Optical Elements with Adhesives

SC015 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 5.5 HOURS

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:
1. describe and classify adhesives and how they work (epoxy, urethane, silicone, acrylic, RTV, VU-cure, etc.)
2. obtain guidance in: adhesive selection, surface preparation, application, and curing
3. develop a basis for analysis of stress and thermal effects
4. recognize contamination/outgassing and how to avoid it
5. review design options
6. 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 G. 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.
ONLINE COURSES

Optical Materials, Fabrication and Testing for the Optical Engineer

SC1086 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 3.5 HOURS

This course is designed to give the optical engineer or lens designer an introduction to the technologies and techniques of optical materials, fabrication and testing. This knowledge will help the optical engineer understand how the choice of optical specifications and tolerances can either lead to more cost effective optical components, or can excessively drive the price up. Topics covered include optical materials, traditional, CNC and novel optical fabrication technologies, surface testing and fabrication tolerances.

LEARNING OUTCOMES

This course will enable you to:

1. identify key mechanical, chemical and thermal properties of optical materials (glass, crystals and ceramics) and how they affect the optical system performance and cost of optical components
2. describe the basic processes of optical fabrication
3. define meaningful surface and dimensional tolerances
4. communicate effectively with optical fabricators
5. design optical components that are able to be manufactured and measured using state of the art optical fabrication technologies
6. choose the optimum specifications and tolerances for your next project

INTENDED AUDIENCE

Optical engineers, lens designers, or managers who wish to learn more about how optical materials, fabrication and testing affect the optical designer. Undergraduate training in engineering or science is assumed.

INSTRUCTOR

Jessica DeGroote Nelson is the Director of Technology and Strategy at Optimax Systems, Inc. She is an adjunct faculty member at The Institute of Optics at the University of Rochester teaching both an undergraduate and graduate course on Optical Fabrication and Testing, and has given several guest lectures on optical fabrication and metrology methods. She earned a Ph.D. in Optics at The Institute of Optics at the University of Rochester. Dr. Nelson is a member of both OSA and SPIE.
Mounting of Optical Components

SC1019 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 8 HOURS

This course introduces the optomechanical engineering principles for the mounting of optical components such as lenses, mirrors, windows, prisms, and filters. Oriented towards practicing engineers and managers, case studies are used to show how mount design is driven by a combination of environmental, performance, and cost requirements. Standard industry practices and common mounting techniques are reviewed, including:

- Mounting of lenses into barrels using adhesives or retaining rings
- Mounting of prisms and small mirrors using adhesives or clamps
- Mounting of assemblies using flexures
- Mounting and sealing of windows

Without using finite-element analysis (FEA), first-order engineering estimates are used to predict the performance of various mount types.

LEARNING OUTCOMES

This course will enable you to:

1. isolate the effects of the environment on optics
2. identify critical aspects of the optic-to-mount interface
3. compare alternate low-strain mounting techniques for common types of elements
4. estimate survivability for vibration and thermal loading
5. design mounts that balance performance, survivability, and cost
6. estimate optomechanical tolerances for optical assemblies using standard designs

INTENDED AUDIENCE

Intended for engineers (mechanical, optical, electrical, and systems), scientists, technicians, and managers who are developing, specifying, or purchasing optical, electro-optical, infrared, or laser systems. The material is at an introductory level, but a basic familiarity with optomechanical engineering principles is useful.

INSTRUCTOR

Keith J. 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 SENSIAAC, and an Instructor for the Optical Engineering Certificate Program at Univ. of California – Irvine.
Optical System Design: First Order Layout - Principles and Practices

SC1102 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 9 HOURS

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:
1. specify the requirements of an optical system for your application including magnification, object-to-image distance, and focal length
2. diagram ray paths and do simple ray tracing
3. describe the performance limits imposed on optical systems by diffraction and the human eye
4. predict the imaging characteristics of multi-component systems
5. determine the required element diameters
6. apply the layout principles to a variety of optical instruments including telescopes, microscopes, magnifiers, field and relay lenses, zoom lenses, and afocal systems
7. adapt a known configuration to suit your application
8. 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
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.

Table of Contents
The Proper Care of Optics: Cleaning, Handling, Storage and Shipping

SC1114 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 8 HOURS

There are many ways to clean optics; some are learned from experience and/or failure. This course explains the proper cleaning methods for optics that are used by professional optical technicians and engineers. How to clean optics has always been a challenging and controversial subject. Searching the Internet will yield hundreds of articles and videos that claim to know the best methods. This course will explain the simple steps used in cleaning optics. It will also describe the proper handling, storage and shipping of optical components. The course is designed for a diverse audience, from a first-time optical cleaner to an engineer searching for methods of handling and packaging optics. An in-class demonstration on inspecting and cleaning optics will be presented.

LEARNING OUTCOMES
This course will enable you to:
1. identify proper cleaning tools and their use
2. explain safety guidelines, personal protection equipment and basic worktable layout
3. compare lighting types required for inspection and cleaning
4. identify solvents and cleaning liquids used for removing contaminates
5. describe hand techniques used for applicators, wipes, and how to fold wipes
6. explain inspection methods for optical surfaces
7. list the types of contaminants and describe a short history of scratch and dig
8. describe visual methods used: unaided eye, eye loupe, microscope (light and digital)
9. describe types of optical coatings
10. explain proper cleaning of small, large and infrared optics
11. describe special cleaning techniques
12. explain techniques used for instrument inspection, disassembly, assembly, and cleaning
13. describe various instrument types
14. describe the tricks of the trade: edge cleaning, protection, black paint and removing glue
15. describe handling of optics using tweezers, cups, trays, storage and protection methods
16. summarize shipping containment methods
17. explain outdoor field cleaning

INTENDED AUDIENCE
Technicians, engineers, scientists and managers who wish to learn the methods of cleaning, handling, storage and shipping of optics. High school to graduate degree.
INSTRUCTOR

Robert Schalck is an Optical Engineer with 50 years experience in the optical industry. He is the author of the book “The Proper Care of Optics” (SPIE Press, 2019) as well as an SPIE Online Course of the same title. He presented his first paper on cleaning optics at the OSA OF&T workshop in 1975. In 1989, he delivered a paper on Classical Optical Cleaning at the OSA “How to Conference.” Over several decades, he has given presentations on how to care for optics at universities, colleges, groups and organizations. He has presented several papers on optical designs and the testing of optics. He is a Senior Member of OSA (Emeritus) and SPIE (Emeritus).
Basic Optics for Engineers

SC156 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 8 HOURS

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:
1. compute the following image properties: size, location, fidelity, brightness
2. estimate diffraction-limited imaging performance
3. explain optical diagrams
4. describe the factors that affect flux transfer efficiency, and their quantitative description
5. compute the spectral distribution of a source
6. describe the difference between photon and thermal detectors
7. calculate the signal to noise performance of a sensor (D* and noise equivalent power)
8. differentiate between sensitivity and responsivity
9. 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
Alfred Ducharme is a professor of optics and electrical engineering in the College of Engineering and Computer Science at the University of Central Florida. He received a B.S. in Electrical Engineering from the University of Massachusetts - Lowell, and both a M.S. and Ph.D. in Electrical Engineering from the University of Central Florida - School of Optics (CREOL). Dr. Ducharme is the Program Coordinator for the 4-year undergraduate program in Photonics (BSEET-Photonics) offered by the Engineering Technology Department.

“Great introductory course for optics. Very well structured and in a presentable format. The slide visuals and the examples used in the modules helped support my understanding of the content. As well the additional references provided at the end of each module is useful.”
Basic Optics for Non-Optics Personnel

SC609 · COURSE LEVEL: INTRODUCTORY · COURSE LENGTH: 2.5 HOURS

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:
1. read optical system descriptions and papers
2. ask the right questions about optical component performance
3. describe basic optical specifications for lenses, filters, and other components
4. assess differences in types of filters, mirrors and beam directing optics
5. 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 G. Harding has been active in the optics industry for over 38 years, and has taught machine vision and optical methods for over 30 years in over 70 workshops and tutorials, including engineering workshops on 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.
Radiometry Revealed

SC915 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 7 HOURS

This course explains basic principles and applications of radiometry and photometry. A primary goal of the course is to reveal the logic, systematic order, and methodology behind what sometimes appears to be a confusing branch of optical science and engineering. Examples are taken from the ultraviolet through the long-wave infrared portions of the electromagnetic spectrum. Anyone who wants to answer questions such as, “how many watts or photons do I have?” or “how much optical energy or radiation do I need?” will benefit from taking this course.

LEARNING OUTCOMES
This course will enable you to:
1. describe the fundamental units and quantities used to quantify electromagnetic radiation at wavelengths from the ultraviolet through the visible and infrared
2. use, understand, and convert between radiometric and photometric quantities
3. apply radiometry to typical applications, such as calibrating an imaging system, determining human-perceived brightness of a display, or calculating electricity produced by a solar cell
4. quantify the radiant energy in optical images from point and extended sources
5. explain the role of rays, stops, and pupils in defining the field of view and light-gathering capability of an optical system
6. determine the throughput of an optical system and use it in radiometric calculations
7. quantify the radiant energy in optical images from point and extended sources
8. transfer radiant energy into and throughout optical systems
9. identify radiometric standards and calibration methods
10. be familiar with radiometers and photometers

INTENDED AUDIENCE
Scientists, engineers, technicians, or technical managers who wish to learn more about how to quantify radiant energy in optical systems and measurements. Undergraduate training in engineering or science is assumed.

INSTRUCTOR
Joseph A. Shaw is Director of the Optical Technology Center and Professor of Electrical Engineering and Physics at Montana State University in Bozeman, Montana. He previously worked at the NOAA research labs in Boulder, Colorado. He is a widely recognized expert in the development, calibration, and analysis of optical systems used in environmental and military sensing. Recognition for his work in this field 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 and is a Fellow of both the OSA and SPIE.
Introduction to Lens Design

SC935 ∙ COURSE LEVEL: INTRODUCTORY ∙ COURSE LENGTH: 8 HOURS

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:
1. specify and evaluate a lens system
2. describe the source and correction of aberrations
3. interpret ray-intercept plots
4. classify the limits imposed by aberration theory
5. determine how to improve a design
6. use optical design software to its best advantage
7. 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.
# Conferences and Exhibitions

## 2020/21

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SPIE is the international society for optics and photonics, an educational not-for-profit organization founded in 1955 to advance light-based science and technology. The Society serves more than 255,000 constituents from 183 countries, offering conferences and their published proceedings, continuing education, books, journals, and the SPIE Digital Library in support of interdisciplinary information exchange, professional networking, and patent precedent. SPIE provided more than $5 million in support of education and outreach programs in 2019.