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structures while leaving the rest of the cell intact. All that has changed, however. Eric Mazur and colleagues at Harvard University (Cambridge, MA) and Harvard Medical School have used tightly focused femtosecond laser pulses to vaporize individual organelles and other subcellular structures with submicrometer precision—without disturbing the rest of the cell.

"Although they've been around since the '80s, it's not until the last five years that femtosecond lasers have been simple enough to operate to encourage this kind of cross-disciplinary work," says Chris Schaffer of the University of California at San Diego's biochemistry department and organizer of the Commercial and Biomedical Applications of Ultrafast Lasers IV Conference at Photonics West 2002 (19–25 January; San Jose, CA), where Mazur's group will present its latest work (paper #4633-29). "Sometimes you want to genetically or immunicalogically affect all of one type of substructure, but other times you just want to affect a few substructures of one type within a cell and see how the rest react. This is the only way to accomplish that."

Nan Shen, lead researcher for Mazur's group, uses a continuous-wave (CW) 5-W diode-pumped solid-state laser (Coherent Inc.; Santa Clara, CA) to pump a titanium-doped sapphire (Ti:sapphire) oscillator (Kapteyn-Murnane Laboratories L.L.C.; Boulder, CO). The setup also includes a neodymium-doped yttrium lithium fluoride (Nd:YLF) second-stage amplifier that produces a 1-kHz pulse train, but Shen intends to remove the amplifier from the setup as soon as possible and use software to control the repetition rate of the Ti:sapphire. "It's only there because we share the setup with other experiments," Shen says. "For our purposes, we only need 2 nJ per pulse, so a second-stage amplifier isn't necessary." An epifluorescent microscope with high numerical aperture (NA 1.4), oil-immersed objective delivers the pulses to the cell.

The trick, according to Shen, is to deliver just the right amount of energy: too much and you disrupt the entire cell, too little and the 800-nm light from the Ti:sapphire passes right through the sample. Each 100-fs pulse is focused down to an hour-glass shaped area some 400 nm in diameter at the waist and 1 µm deep. The high

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improved SiC growth method provides basis for blue lasers

A new method for growing bulk single-crystal silicon carbide (SiC) can produce high-quality SiC wafers for optoelectronics applications, say engineers at Okmetic AB (Linköping, Sweden), a member of the Okmetic group (Vantaa, Finland). "We have been building on our long-term work with Linköping University," says Asko Vehanen of Okmetic. "This has borne fruit in the form of a radically new method for SiC crystal growth, high-temperature chemical vapor deposition (HTCVD)." Using a continuous flow of pure gases containing silicon and carbon species, the HTCVD method produces SiC crystals with tightly controlled electrical and optical properties (see figure on page 12). According to Vehanen, the group has developed the first high-purity semi-insulating SiC wafers. "The main advantage is a significant increase in ingot quality—micropipes, background doping levels, etc.—and the degree of process control," says Vehanen. "We have also demonstrated SiC wafers that so far cannot be produced with sublimation, for example p-type wafers."

Okmetic is refining its relationship with Aixtron group (Aachen, Germany) member Epigress AB (Lund, Sweden), which produces the reactors for the HTCVD process. That company also has ties to the university. "In 10 years Linköping University has developed SiC growth technologies together with Okmetic, ABB, and Epigress," says Erik Janzén at Linköping University. "We will also expand our research on nitrides grown on SiC substrates."

Epigress is slated to supply Okmetic with a gas foil rotation (GFR) hot-wall SiC CVD system, says Goran Berg of Epigress. This system can accommodate three 2-in. or single 3- and 4-in. wafers.

SiC is a strong contender for the development of short-wavelength, high-brightness devices, say Reed Electronics Research (Sutton, UK) analysts in `Optoelectronics: A Study of the Worldwide Semiconductor Optoelectronic Component Industry 2005`. "The total market for these type of devices will reach U.S. $714 million for blue lasers and light-emitting diodes (LEDs) by 2005," the report says. "White LEDs based on these wide

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bandgap semiconductors could add an additional U.S. $806 million by 2005."

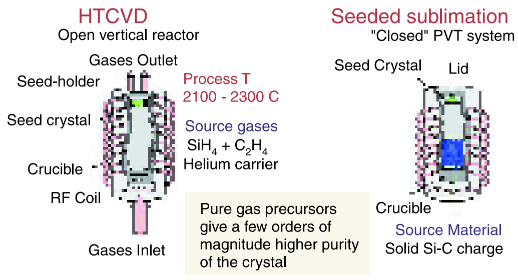
In a related story, Osram Opto Semiconductors GmbH (Regensburg, Germany) has demonstrated a continuous-wave (CW), blue-emitting indium gallium nitride (InGaN) laser. The work is the culmination of a research project funded by the German government and includes collaborators at the Fraunhofer Institut für Angewandte Festkörperphysik (Freiburg, Germany) and the universities of Stuttgart, Braunschweig, and Ulm.

Success did not happen overnight. "Even the first pulsed blue laser we developed in our labs in Regensburg represented a huge success for us," recalls Alfred Lell, project manager for the blue laser project at Osram Opto. The laser emitted microsecond pulses at approximately 410 nm but required a current of 1200 mA and a voltage of 33 V.

"This corresponds to an electric power of around 40 W, and a lot of heat is generated in the process," says project coordinator Volker Härle of Osram Opto. "In order to achieve a CW blue laser, we had to find ways and means to reduce the current, voltage, and therefore the power required to operate the laser."

To build the 0.5-mm × 0.3-mm × 0.1-mm laser chip, the group deposited various layers onto the SiC substrate using metal-oxide vapor phase epitaxy (MOVPE). Reducing the threshold current of the laser was a key step to reducing power consumption. It became evident that one efficient way of doing this was to optimize the InGaN quantum well (QW) active zone in which the light is generated. Specific coordination and adaptation of the composition and the thickness and the spacing of the QWs, combined with a precise definition of their quantity, ultimately led to success. With the aid of ridge waveguide technology, it was possible to limit the light-emitting range to a width of 3 µm, thus keeping the threshold current within defined limits.

—Roy Szweda



The HTCVD process involves exposing a seed crystal to a continuous flow of high-purity gases containing Si and C species to produce multiwafer ingot.

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NA lens creates an 80° cone angle for each laser pulse, compressing the bulk of the laser light to a focal point smaller than the wavelength of the laser light. The sheer number of photons at the focal point encourages nonlinear multiphoton absorption of the photons by the electrons in the subcellular structure. After a few pulses, enough light is absorbed to either vaporize or disrupt the structure. Shen can then view the results on the epifluorescent microscope or take the sample to a nearby lab for confocal imaging.

Early results are encouraging. With greater control of the pulse repetition rate, Shen intends to move from epifluorescent imaging to a high-resolution real-time multi-photon microscope, using some of the pulses for disruption and the rest to excite longer-lived fluorescent dyes that will allow her to watch the disruption in real time.

"There are confocal microscopes that operate at full video rate," Schaffer adds. "All the pieces are there to watch cell repair mechanisms and intracellular signal transduction processes in real time."

—Winn Hardin

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detectors

accident halts KamLAND

Yoji Totsuka, director of the Kamioka Observatory (Kamioka, Japan), confirms that a severe accident damaged a significant part of the Super-Kamiokande detector, which is designed to track the elusive neutrino. Located a mile deep in an abandoned zinc mine 180 miles northwest of Tokyo, the detector consists of a tank holding 12.5 million gallons of pure water and is lined with 11,242 photomultiplier tubes spaced about 1 m apart (see *oemagazine*, June 2001, page 20). These tubes detect a bluish streak of light in the water when a high-speed particle passes through. The accident reportedly occurred as the water in the tank was being changed, but the exact cause is

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