

# Bright Solutions

## The Karlsruhe School of Optics & Photonics

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*Silizium-Nanopartikel unterschiedlicher Größe in Lösung.  
Die Partikel zeigen unter UV-Anregung Photolumineszenz  
bei unterschiedlichen Wellenlängen*

*Silicon nanoparticles of various sizes in solution.  
In case of UV excitation, the particles exhibit  
photoluminescence at variable wavelengths*

High speed, shortest pulses, focusing, high powers – light possesses amazing properties. Photonics – derived from photon for light particles – uses these properties. Optics and photonics stimulate fundamental research in physics, chemistry, life and engineering sciences and represent the key to innovative technologies in many areas, extending from data transmission to illumination to medical engineering. At KIT, the Karlsruhe School of Optics & Photonics (KSOP) established in 2006 under the Excellence Initiative offers first-class master and PhD programs in the area of optical technologies. At KSOP, KIT institutes on Campus North and Campus South cooperate closely. The program is of international character and combines expert qualification with the acquisition of key competencies. With about 20 professors, approximately 80 active PhD students, and more than 50 alumni, KSOP has established itself as an excellent research and training institution. Funding will continue in the second phase of the Excellence Initiative.

The KSOP programs are executed by the four KIT Departments of Physics, Chemistry and Biosciences, Electrical Engineering and Information Technology as well as Mechanical Engineering. KSOP spokesperson is Professor Uli Lemmer. Activities of KSOP concentrate on photonic materials and components, modern spectroscopy, biomedical photonics, optical systems, and solar energy. LookKIT presents two current PhD projects.

### Silicon Nanoparticles Emit Light

KSOP doctoral student Florian Maier-Flaig at the Light Technology Institute (LTI) of KIT studies so-called artificial atoms that can be tailored to various applications. Quantum dots (QD) consist of only a few hundred to a thousand atoms. In this dimension, material properties are not only influenced by chemical composition, but also by size and shape. Quantum dots have amazing physical qualities due to their nanoscopic dimensions. While charge carriers move freely in a conventional solid and may assume continuously distributed energy states, movement of charge carriers in all three spatial directions is limited in quantum dots, such that extremely sharp and discrete energy levels develop.

The spectrum of potential applications of quantum dots extends from simple chemical additives to new technologies in life sciences. In particular, quantum dots have a high potential in opto-electronics, as highly efficient light-emitting materials for LEDs (light-emitting diodes). In a quantum dot-LED (QDLED), the emission wavelength of the light emitted can be varied easily by a variation of particle size. Classical quantum dots, i.e. nanoparticles of cadmium selenide, have proved to be highly efficient light-emitting materials. These colloidal particles can be produced in a solvent and then processed from liquid phase at low cost.

An interesting alternative to cadmium selenide quantum dots are silicon nanoparticles. "In contrast to cadmium selenide, cadmium sulfide or lead sulfide, silicon is a non-toxic starting material for nanoparticles," explains Florian Maier-Flaig. "Silicon is readily available on earth and rather inexpensive." Thanks to the nanoscopic dimensions of silicon, light can be extracted. Together with other KIT institutes, LTI researchers characterize the QD produced by inorganic chemists and use them for light-emitting diodes. The first LEDs have already been manufactured on the lab scale. Only few research groups worldwide have succeeded in doing so. LTI's performance is at the top.

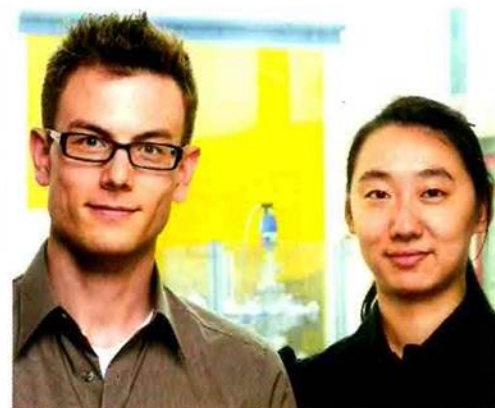
*Thema der Doktorandin Xin Liu: Der Nachweis von tumorspezifischen Prozessen in der DNA oder RNA anhand von geringen Mengen biologischer Proben*

*Work of Liu Xin focuses on the detection of tumor-specific processes in the DNA or RNA using small volumes of biological samples*

Maier-Flaig studies opto-electronic applications of silicon nanoparticles. The opto-electronics specialist reports that the nanoparticles are characterized by a high quantum yield, above all in the red visible spectral range and in the near infrared (NIR). "It is therefore only logical to use the particles as emitters in opto-electronic components. For the first time, they are excited electrically with high efficiency." Apart from use in light-emitting diodes, using NIR-emitting silicon nanoparticles as markers in biological samples is feasible. Such a marker could be coupled to a medical substance to track the movement of medicine through the body. The particles might also be heated up optically to destroy tissues, such as tumor cells.

### Organic Lasers Detect Molecules

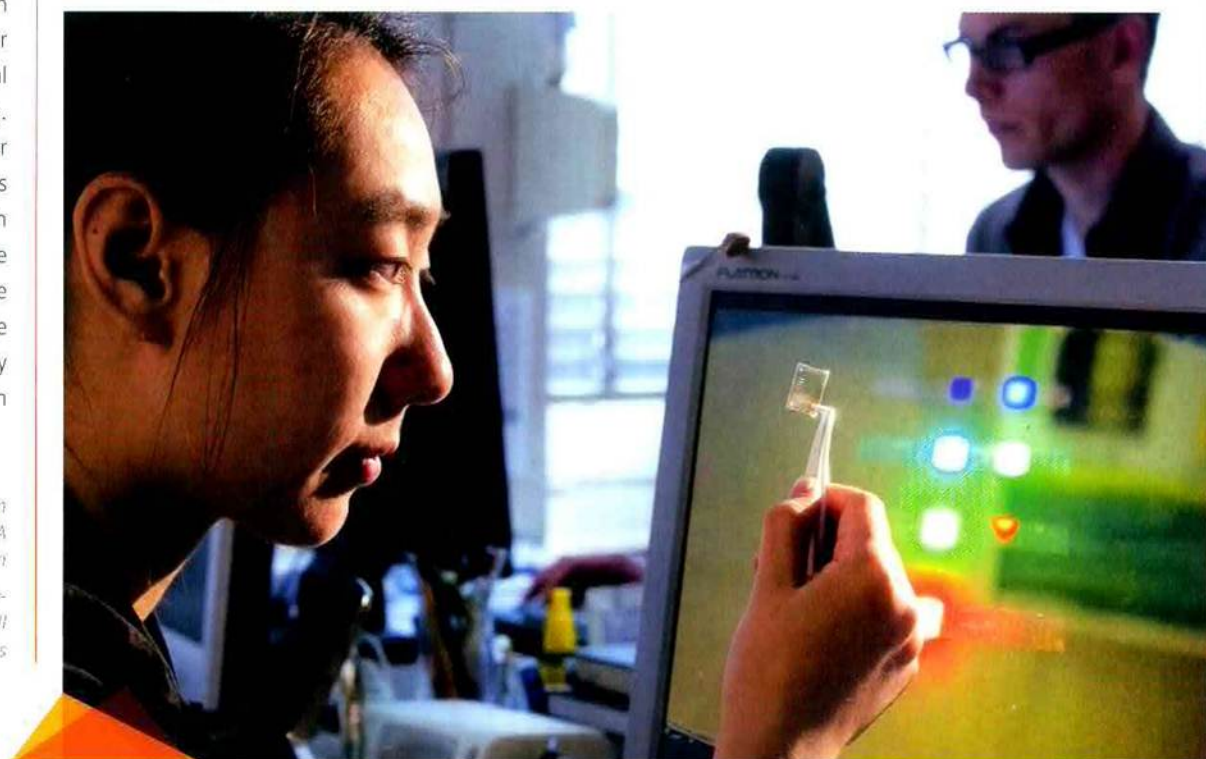
Application of so-called surface-enhanced Raman scattering (SERS) for the detection of tumor cells or tumor-specific processes in DNA or RNA using small volumes of biological samples is the focus of electrical engineer Xin Liu at LTI. Raman scattering generally stands for inelastic scattering of light by atoms, molecules, and solids. Compared to the incident light beam, the scattered light emitted has a higher or lower frequency and is specific to the atom or molecule that does the scattering. "In case of a molecule, specific wavelengths of the scattered light allow conclusions to be drawn with respect to certain chemical bonds within the



*KSOP-Doktoranden Florian Maier-Flaig und Xin Liu*  
*KSOP doctoral students Florian Maier-Flaig and Xin Liu*

molecule," explains Xin Liu. "Raman scattering allows us to take a unique fingerprint of every molecule." Several molecules can be identified simultaneously in a single solution. Normally, the scattered light is rather weak. However, the signal can be amplified by small metal particles near the molecule analyzed. SERS represents a highly sensitive marker-free analysis method.

In surface-enhanced Raman scattering, the excitation light must have an appropriate wavelength. Usually, lasers are applied. Laser



light sources, whose wavelengths can be varied continuously over a wide range of visible light, however, are rather large and accordingly expensive. Adjustable organic semiconductor lasers represent an alternative. Together with so-called microfluidic channels, in which liquids are handled in a small space, they allow for new SERS measurements in a small laboratory accommodated on a single chip. Xin Liu studies such lab-on-a-chip systems in her PhD project.

"For these studies, laser power has to be sufficient for inelastic scattering. In addition, local field enhancement caused by directly adjacent metallic nanostructures must be reproducible any time," explains the young scientist. Lasers with distributed feedback (DFB) have proved to be highly efficient.

Xin Liu analyzes how the performance of organic DFB lasers can be influenced by varying the grating parameters. This also includes theoretical studies of optically pumped organic lasers, i.e. lasers excited by light.

Xin Liu produced the lab-on-a-chip system at the Institute of Microstructure Technology (IMT) of KIT. This process included molding of the grating by electron beam lithography, waveguide structurization by ultraviolet lithography, and encapsulation. "As a PhD student at the Karlsruhe School of Optics & Photonics, I have many opportunities to cooperate with colleagues at other institutes and to use their infrastructure. This is one of the big chances offered by this PhD program." ■



*Florian Maier-Flaig untersucht die optoelektronischen Anwendungen der Silizium-Nanopartikel*

*Florian Maier-Flaig studies opto-electronic applications of silicon nanoparticles*

## Lichte Lösungen

Karlsruhe School of Optics & Photonics

Optik und Photonik ermöglichen innovative Technologien in vielen Bereichen – von der Datenübertragung über die Beleuchtung bis hin zur Medizintechnik. Am KIT bietet die Karlsruhe School of Optics & Photonics (KSOP) erstklassige Master- und Doktorandenprogramme im Bereich der optischen Technologien. Mit rund 20 Professoren, circa 80 aktiven Doktoranden und über 50 Alumni hat sich die international ausgerichtete KSOP als herausragende Forschungs- und Ausbildungseinrichtung etabliert. Als Sprecher fungiert Professor Ull Lemmer. Die Aktivitäten konzentrieren sich auf die Forschungsfelder Photonische Materialien und Bauelemente, Moderne Spektroskopie, Biomedizinische Photonik, Optische Systeme sowie Solarenergie. lookKIT stellt zwei aktuelle Promotionsprojekte vor:

### Silizium-Nanopartikel emittieren Licht

Mit Silizium-Quantenpunkten befasst sich der KSOP-Doktorand Florian Maier-Flaig am Lichttechnischen Institut (LTI) des KIT. Als hocheffiziente lichtemittierende Materialien für Leuchtdioden (Light-Emitting Diode – LED) besitzen Quantenpunkte großes Potenzial. Die Emissionswellenlänge lässt sich durch Änderung der Partikelgröße variieren. Dabei besitzt Silizium als Ausgangsmaterial wesentliche Vorteile: Es ist nicht toxisch, reichlich verfügbar und kostengünstig. Silizium-Nanopartikel zeichnen sich durch eine hohe Quantenausbeute vor allem im roten-sichtbaren Spektralbereich und

im Bereich des Nahen Infrarot (NIR) aus. Daraus Leuchtdioden herzustellen, gelingt bis jetzt nur wenigen Forschergruppen weltweit; die am LTI erreichte Performance ist dabei führend. Neben dem Einsatz in Leuchtdioden ist auch eine Anwendung als Marker in biologischen Proben denkbar.

### Organische Laser detektieren Moleküle

Tumorzellen oder tumorspezifische Prozesse in der DNA oder RNA anhand von geringen Mengen biologischer Proben nachzuweisen, ist eine mögliche Anwendung der sogenannten oberflächenverstärkten Raman-Streuung (Surface Enhanced Raman Scattering – SERS), mit der sich die KSOP-Doktorandin Xin Liu am LTI befasst. Raman-Streuung heißt die inelastische Streuung von Licht an Atomen, Molekülen und Festkörpern. Bei einem Molekül lassen die spezifischen Wellenlängen des gestreuten Lichts direkt auf bestimmte chemische Bindungen innerhalb des Moleküls schließen. Winzige Metallpartikel in der Nähe des zu analysierenden Moleküls verstärken das Signal. Durchstimmbare organische Halbleiterlaser ermöglichen in Verbindung mit sogenannten Mikrofluidik-Kanälen, mit denen sich Flüssigkeiten auf kleinstem Raum handhaben lassen, neue SERS-Messansätze in winzigen, auf einem einzigen Chip untergebrachten Labors (Lab-on-a-Chip-Systeme).