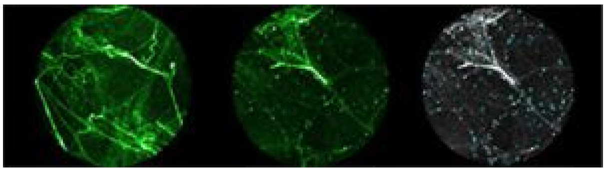
Real-Time Tracing of Hard-to-Diagnose Bacteria

Lung infections due to Gram-negative bacteria are notoriously difficult to diagnose rapidly for prompt treatment. A new procedure involving an optical probe and a fluorescent marker could make those pulmonary predators pop out on a display screen, leading to rapid diagnosis of potentially deadly pneumonia.



Engineering a fluorescent marker

So-called Gram-negative bacteria—the name comes from their lack of reaction to a crystal violet stain—have an outer cell membrane that contains an endotoxin with a component called lipid A. In small amounts, lipid A can provoke an attacking response from the human body’s immune system, but higher concentrations during an infection by Gram-negative bacteria can lead to septic shock, and even death, in the patient. Traditional methods for diagnosing Gram-negative pulmonary infections, from lung-tissue biopsy to sputum cultures that take days to produce results, have significant drawbacks. To get around those drawbacks, the Edinburgh team sought a fluorescent marker that would adhere specifically to Gram-negative bacteria. They found that an antimicrobial peptide called polymyxin selectively binds to the lipid A in the outer membrane of Gram-negative bacteria. Then, they attached the polymyxin to a fluorophore molecule. By testing the combination marker on several species of disease-causing bacteria, the scientists found that the marker produced fluorescent amplification with good signal-to-noise ratios when it hooked up with Gram-negative bacteria, but not with Gram-positive pathogens. The marker also distinguished between bacteria and mammalian cells *in vitro*.

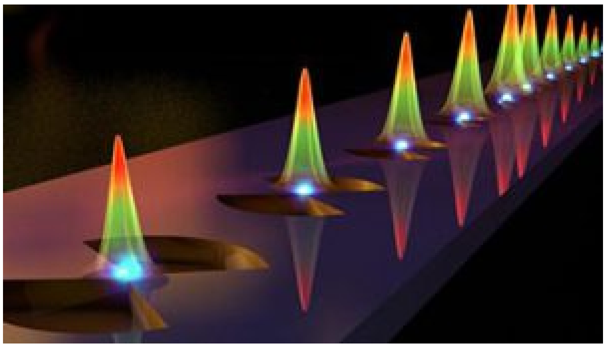
Animal and human testing

After toxicology tests to make sure that the fluorescent marker did not damage animal tissues, the team hooked up *ex vivo* sheep lungs to a mechanical ventilator. The researchers then tested the ability of their optical endomicroscope with an optical-fiber probe to detect the bacteria's fluorescence within tissues. The fluorescence confocal endomicroscope captured images at 12 frames/s and used a 488-nm laser as the illumination source. Finally, the researchers used their system on two small groups of humans: six patients with bronchiectasis, a chronic condition of airway enlargement with mucus production leading to frequent infections, and seven mechanically vented patients who were in the intensive care unit with suspected pneumonia. The clinical version of the optical endomicroscope had a circular field of view roughly 600 μm in diameter. Image-processing algorithms made the Gram-negative bacteria appear as bright spots.

For more information: doi:10.1126/scitranslmed.aal0033

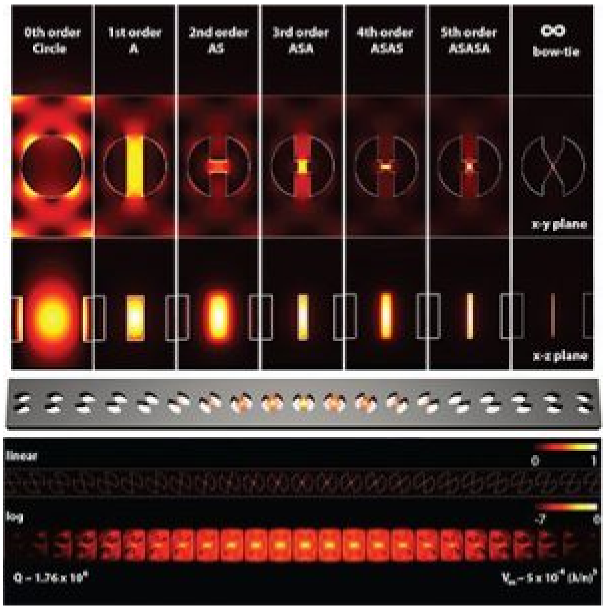
[Extreme Light Confinement in Nano-Bowties]()

A team led by OSA Fellow Sharon Weiss of Vanderbilt University, USA, has demonstrated an all-dielectric "bowtie" structure that combines the tight spatial light confinement of plasmonic resonators with the ultralow losses and long cavity lifetimes of photonic crystals.

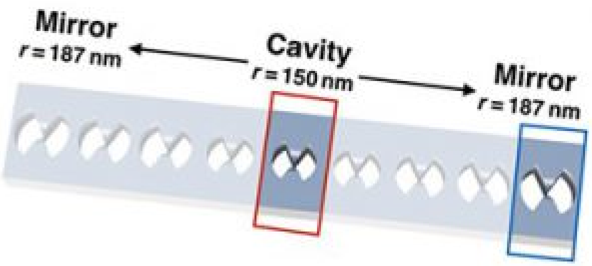


A long-standing conundrum of nanophotonics has been how to achieve deep-subwavelength light confinement (measured by a parameter called the mode volume, V_m) while holding the light in place in a cavity for long periods (an ability characterized by the cavity's quality factor, Q). Plasmonics—the enhancement of optical fields at metal-dielectric interfaces, using nanoscale metallic resonators or antennas—can give you very tight spatial confinement (low V_m). But plasmonic devices tend to be lossy, with anemic Q factors, and thus the spatially confined light energy quickly dissipates.

In a theoretical study in late 2016, Weiss, along with OSA member and then-grad-student Shuren Hu (now with the semiconductor fabrication firm GlobalFoundries), proposed an answer: combine the subwavelength-confinement properties of nanoscale dielectrics with the near-legendary Q values of photonic-crystal cavities. The process works in two steps. Incident light becomes localized in the photonic-crystal cavity air hole. Then, the cavity's bowtie geometry, and the energy concentration at the bowtie tips, funnels and squeezes the optical energy into the nanoscale dielectric bar. The result is deep subwavelength confinement of the light energy, combined with the photonic crystal's long cavity lifetime.



The result was a silicon photonic-crystal cavity consisting of unit-cell bowties with a radius of 150 nm, and with mirror unit cells of 187 nm radii on either end, arrayed in a 700-nm-wide waveguide. To put the structure through its paces, the team tied it, via lensed optical fiber, to a 1500-to-1630-nm tunable continuous-wave laser, and measured the field distribution using near-field scanning optical microscopy.The quality factor, on the order of $Q = 10^5$



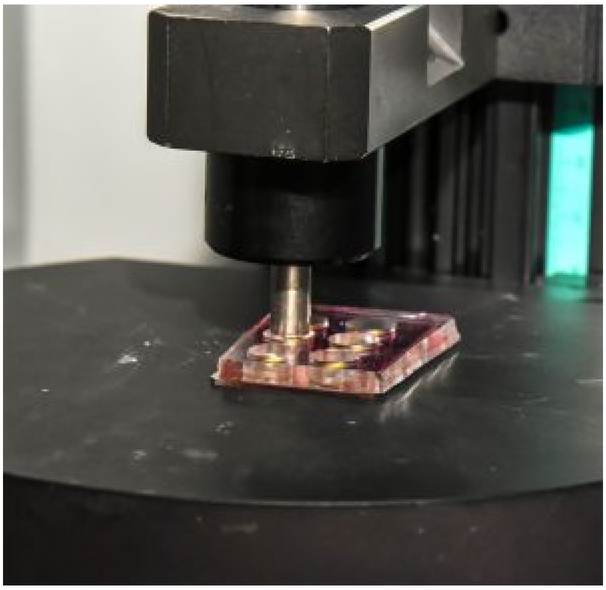
Realizing those possibilities will take a significant amount of work to scale up from these initial experiments, and to reproducibly create the exquisitely precise photonic-crystal structures required. Hu, at GlobalFoundries, is now co-P.I. with Weiss on a new project, funded by a U.S. National Science Foundation GOALI (Grant Opportunities for Academic Liaison with Industry) award, to work toward scale-up and proof-of-concept applications. Weiss notes that Hu began the work as a grad student in her lab under another GOALI grant, with IBM.

For more information: doi: 10.1126/sciadv.aat2355

Nanoplasmonics Enables Label-Free Measurement of Bacteria Formation

Using nanochip technology and a targeted beam of light, scientists have devised a real-time, label-free way to monitor biofilms, an important component in the search for alternatives to bacteria-resistant antibiotics. The team from the Okinawa Institute of Science and Technology (OIST) wanted to gain a better understanding of the biochemical reactions that allow bacteria to produce biofilms, which are slimy linked matrix structures. Finding no tools available that would allow them to monitor biofilm growth according to their requirements, the researchers modified an existing tool.

“We created little chips with tiny structures for *E. coli* to grow on,” said researcher Nikhil Bhalla. “They are covered in mushroom-shaped nanostructures with a stem of silicon dioxide and a cap of gold. When the researchers exposed the nanomushrooms to a beam of light, the nanostructures absorbed light through a localized surface plasmon resonance (LSPR) sensor. The sensor was able to capture the signatures of biofilm formation in real time by measuring the wavelength shift in the LSPR resonance peak with high temporal resolution. The researchers could observe the E. coli growing around the mushroom structures without damaging the sample.



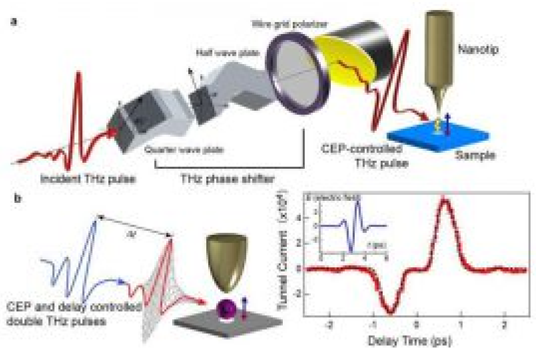
A nanomushroom chip undergoing testing with an localized surface plasmon resonance (LSPR) device. Courtesy of OIST and CC 2.0.

The researchers used the LSPR sensor to investigate how biofilm formation is affected by different drugs, including conventional antibiotics. To enable a constant stream of data from the LSPR-based tool, the researchers developed a program to automate the data analysis and processing so they could monitor biofilm growth in real time.The team believes that its benchtop tool could be used on a variety of clinically relevant bacteria for biofilm characterization and drug screening. It plans to miniaturize the technology to create a portable device that could be used in a range of biosensing applications.

For more information: (doi: 10.1021/acssensors.8b00287).

[Light switch: Scientists develop method to control nanoscale manipulation in high-powered microscopes]()

Researchers from Japan have taken a step toward faster and more advanced electronics by developing a a better way to measure and manipulate conductive materials through scanning tunneling microscopy. The team published their results in July in *Nano Letters*, an American Chemical Society journal. Scientists from the University of Tokyo, Yokohama National University, and the Central Research Laboratory of Hamamatsu Photonics contributed to this paper.



Scanning tunneling microscopy (STM) involves placing a conducting tip close to the surface of the conductive material to be imaged. A voltage is applied through the tip to the surface, creating a “tunnel junction” between the two through which electrons travel. The shape and position of the tip, the voltage strength, and the conductivity and density of the material’s surface all come together to provide the scientist with a better understanding of the atomic structure of the material being imaged. With that information, the scientist should be able to change the variables to manipulate the material itself. The researchers designed a custom terahertz pulse cycle that quickly oscillates between near and far fields within the desired electrical current.

"The characterization and active control of near fields in a tunnel junction are essential for advancing elaborate manipulation of light-field-driven processes at the nanoscale," said Jun Takeda, a professor in the department of physics in the Graduate School of Engineering at Yokohama National University. "We demonstrated that desirable phase-controlled near fields can be produced in a tunnel junction via terahertz scanning tunneling microscopy with a phase shifter."

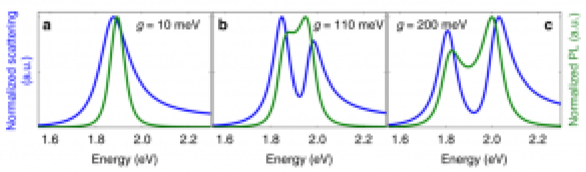
According to Takeda, previous studies in this area assumed that the near and far fields were the same—spatially and temporally. His team examined the fields closely and not only identified that there was a difference between the two, but realized that the pulse of fast laser could prompt the needed phase shift of the terahertz pulse to switch the current to the near field.

More information: Katsumasa Yoshioka et al, Tailoring Single-Cycle Near Field in a Tunnel Junction with Carrier-Envelope Phase-Controlled Terahertz Electric Fields, *Nano Letters* (2018). DOI: 10.1021/acs.nanolett.8b02161

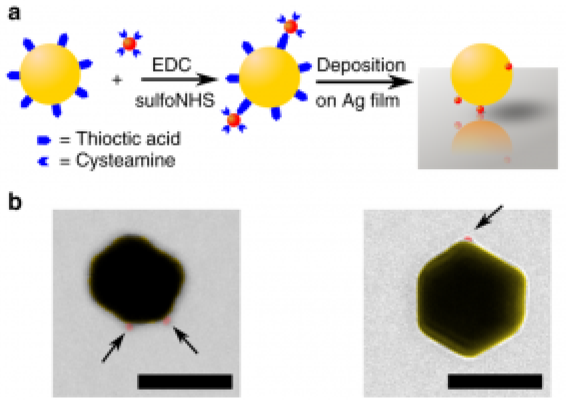
Strong coupling and induced transparency at room

[temperature with single quantum dots and gap plasmons]

Coherent coupling between plasmons and transition dipole moments in emitters can lead to two distinct spectral effects: vacuum Rabi splitting at strong coupling strengths, and induced transparency (also known as Fano interference) at intermediate coupling strengths. Achieving either strong or intermediate coupling between a single emitter and a localized plasmon resonance has the potential to enable single-photon nonlinearities and other extreme light–matter interactions, at room temperature and on the nanometer scale. Both effects produce two peaks in the spectrum of scattering from the plasmon resonance, and can thus be confused if scattering measurements alone are performed. Here we report measurements of scattering and photoluminescence from individual coupled plasmon–emitter systems that consist of a single colloidal quantum dot in the gap between a gold nanoparticle and a silver film. The measurements unambiguously demonstrate weak coupling (the Purcell effect), intermediate coupling (Fano interference), and strong coupling (Rabi splitting) at room temperature.



As shown in Fig. , however, a measurement of the photoluminescence (PL) spectrum can distinguish between the two regimes. Unlike scattering, PL is an incoherent process, and thus does not display Fano interference. Splitting in the PL spectrum thus occurs only in the strong-coupling regime, and has therefore been recognized as the definitive signature of Rabi splitting. So far, there has been only one report of PL splitting for a single emitter (a QD) coupled to a plasmonic metal nanostructure, but the PL spectrum showed an unexpected four-peak structure.



Fabrication of coupled quantum-dot / gap-plasmon systems. **a** Illustration of the synthesis process. Quantum dots (red) are linked to gold nanoparticles (yellow) through their capping molecules. The linked assemblies are then deposited on a silver film. **b** Electron-microscope images of linked assemblies. Quantum dots are colored in red and indicated by arrows. The left image was obtained by scanning transmission electron microscopy, and the right image was obtained by transmission electron microscopy. The scale bars are 100 nm

For more information: https://www.nature.com/articles/s41467-018-06450-4

[Impact of pump wavelength on](#)

[terahertz emission of a cavity-enhanced spintronic trilayer]

We systematically study the pump-wavelength dependence of terahertz pulse generation in thin-film spintronic THz emitters composed of a ferromagnetic Fe layer between adjacent nonmagnetic W and Pt layers. We find that the efficiency of THz generation is essentially flat for excitation by 150 fs pulses with center wavelengths ranging from 900 to 1500 nm, demonstrating that the spin current does not depend strongly on the pump photon energy. We show that the inclusion of dielectric overlayers of TiO2 and SiO2, designed for a particular excitation wavelength, can enhance the terahertz emission by a factor of of up to two in field.

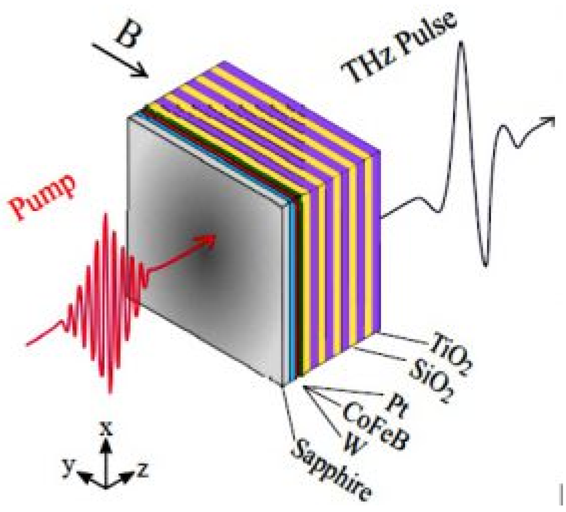


FIG. 1: Schematic of a spintronic trilayer with added dielectric cavity, grown on 0.5 mm of sapphire (Al2O3). The near-infrared pump pulse, incident through the substrate, is partially absorbed in the metallic layers, launching a spin current from the ferromagnetic (FM) layer into the nonmagnetic (NM) layers. The inverse spin Hall effect converts this ultrashort out-of-plane spin current into an in-plane charge current resulting in the emission of THz radiation into the

optical far-field. A weak in plane magnetic field (B) determines the magnetization direction, and the linear polarization of the emitted THz field.

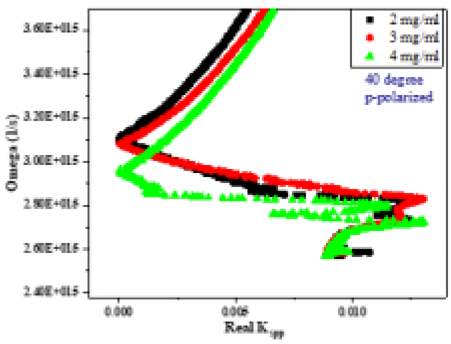
For more information: https://arxiv.org/abs/1808.00746

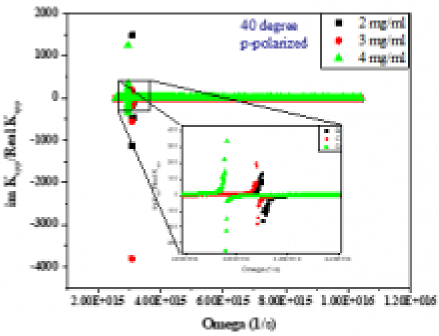
Our new paper in Superlattices and microstructures

Congratulations for the publication of paper " Fantastic Exciton-plasmon coupling in Dye-doped Poly (vinyl pyrrolidone) /Gold one-dimensional Nano-grating "

By Asgari, S. M. Hamidi

The present study aimed to investigate the coupling between the exciton in dye medium and plasmon in gold nano-grating. To this aim, at first, Polyvinylpyrrolidone (Rhodamine B) /Gold nano-grating samples were prepared with different concentrations and thicknesses of dye layer. Then, the spectroscopy of the selected samples was conducted under incident angle modulations and the dispersion diagrams were plotted based on the reflectance spectra. The results revealed the formation of new extra plexcitonic modes as a coupling between exciton and plasmon in the dispersion relation of samples. These new extra modes can be adjusted through the concentrations of the dye layer, the thickness of which is very useful for next generation of plexcitonic devices.

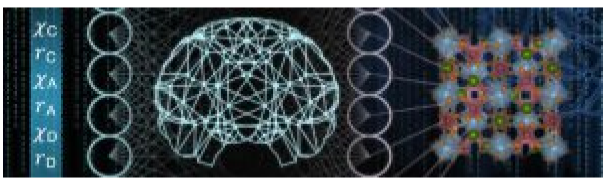




[Neural Networks Predict Crystal Stability]

SAN DIEGO, Sept. 21, 2018 — Researchers at the University of California, San Diego (UCSD) are using neural networks to predict the stability of materials in two classes of crystals: garnets and perovskites.

They trained artificial neural networks to predict a crystal's formation energy using just two inputs: electronegativity and ionic radius of the constituent atoms. Based on this work, they developed models that can identify stable materials in two classes of crystals. According to the team, its models are up to 10× more accurate than previous machine learning models and are fast enough to efficiently screen thousands of materials in a matter of hours on a laptop.



"Garnets and perovskites are used in LED lights, rechargeable lithium-ion batteries, and solar cells. These neural networks have the potential to greatly accelerate the discovery of new materials for these and other important applications," said researcher Weike Ye.

The team has made their models publicly accessible via a web application at http://crystals.ai so that others can use the neural networks to compute the formation energy of any garnet or perovskite composition on the fly.

"Predicting the stability of materials is a central problem in materials science, physics and chemistry," said professor Shyue Ping Ong. "On one hand, you have traditional chemical intuition such as Linus Pauling's five rules . . . On the other, you have expensive quantum mechanical computations to calculate the energy gained from forming a crystal . . . What we have done is to use artificial neural networks to bridge these two worlds."

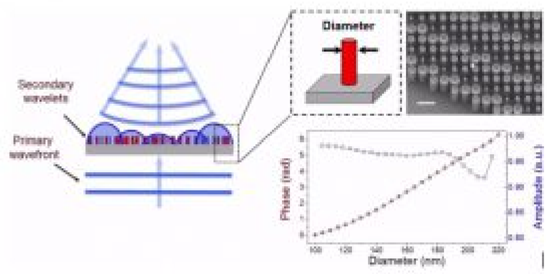
For more information: doi:10.1038/s41467-018-06322-x

Flat optics: from high-performance metalenses to structured light

In this keynote presentation, Federico Capasso, professor of applied physics at Harvard University, presents advances in dielectric metalenses in the visible, which correct spherical, coma, and chromatic aberrations.

Capasso begins his talk by reminding the audience that conventional lenses still require a very complex type of

technology as it takes several lenses to correct aberrations. “Basically, it’s 19th century technology perfected for the 21st century,” says Capasso. “So it’s really polishing, grinding, and so forth with some really expensive machines.”
Capasso describes metaoptics as a different way of looking at diffractive optics. “Metalenses have advantages over traditional lenses,” says Capasso, noting that metalenses are thin, easy to fabricate, and cost effective, and these advantages extend across the whole visible range of light.



Principle of metalenses: Controlling wavefront using nanostructures.

The metalenses developed by Capasso and his team use arrays of titanium dioxide nanofins to equally focus wavelengths of light and eliminate chromatic aberration. The metalenses are designed to provide spatially dependent group delays such that wavepackets from different locations arrive simultaneously at the focus and with the same width.
Metalens research seeks to achieve wavefront shaping of light using optical elements with thicknesses on the order of the wavelength. This miniaturization could to lead to compact, nanoscale optical devices with applications in cameras, lighting, displays, and wearable optics.

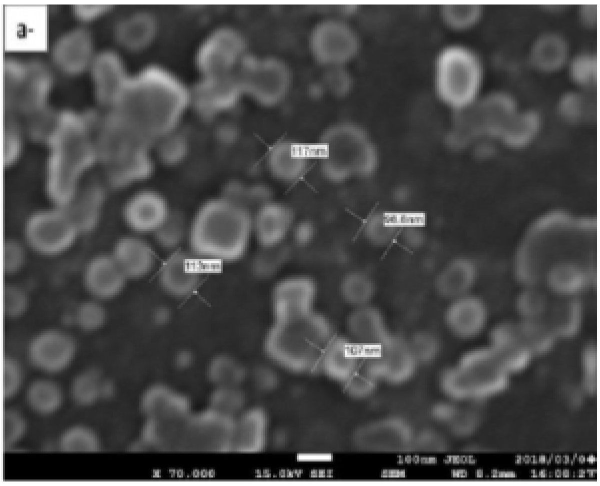
For more information: http://spie.org/newsroom/pw18_plenaries/pw18_capasso-

[Our new paper in Sylwan Nano Journal]

Congratulations for the publication of paper"Thermoplasmonic response of Au@SiO2 core–shell nanoparticles in deionized water and poly-vinylpyrrolidone matrix"

Maher Abdulfadhil Gatea, Hussein A. Jawad, M. Mosleh, S. M. Hamidi

Metal-dielectric core–shell nanoparticles strongly absorb light and convert into an efficient localized heat source in the presence of electromagnatic radiation at their plasmonic resonance. This process can be enhanced depending on the size, shape, structure, and surrounding media. This study theoretically and experimentally investigated the thermoplasmonic effects of Au@SiO2 core–shell nanoparticles immersed in water and poly-vinylpyrrolidone prepared through laser ablation in liquid. Two lasers (532 nm cw Nd:YAG and 520 nm fs pulsed ytterbium fiber) were used to illuminate the prepared samples. The theoretical thermoplasmonic response of the samples was estimated based on the finite element method of COMSOL multiphysics V5.2a. The generated heat difference of Au@SiO2 in both media with fs pulsed laser irradiation was higher than that of cw laser regarding the power used due to the heat confinement during the time of the pulse that cannot be disspated. This study can serve as a basis for using plasmonic core–shell nanoparticles as a nanoheat source in medical applications.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