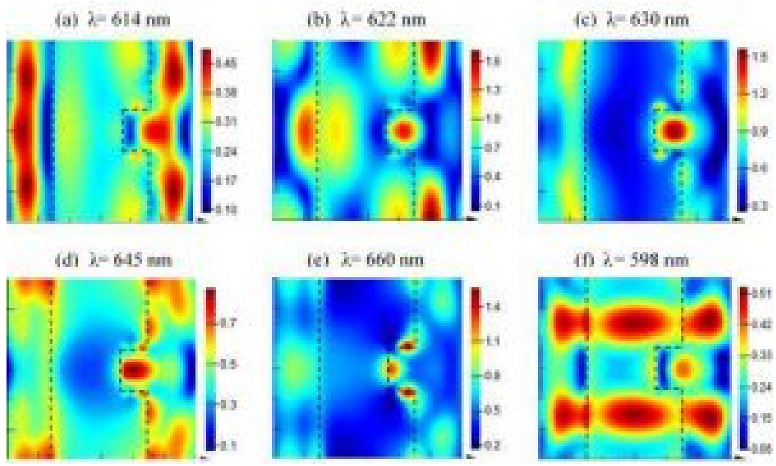
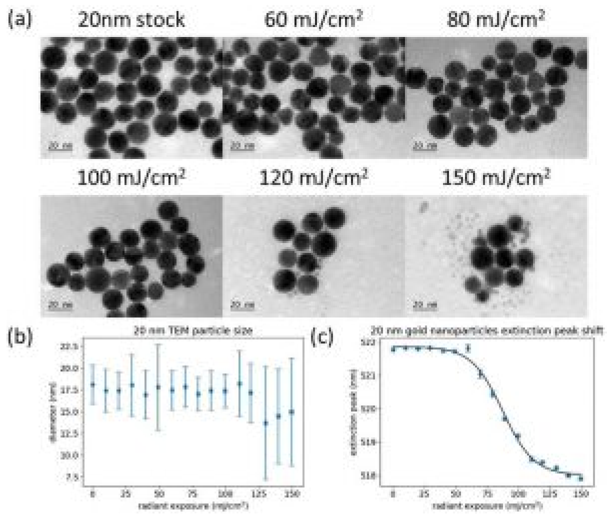
Our New paper in journal of magnetism and magnetic materials



Congratulations for the publication of paper “Enhanced Faraday rotation in one dimensional magneto-plasmonic structure due to Fano resonance” by **S. Sadeghi and S. M. Hamidi**.

Abstract
Enhanced Faraday rotation in a new type of Magneto-plasmonic structure with the capability of Fano resonance, has been reported theoretically. A magneto-plasmonic structure composed of a Gold corrugated layer deposited on a magneto-optically active layer was studied by means of Lumerical software based on finite-difference time-domain. In our proposed structure, plasmonic Fano resonance and localized surface plasmon induced enhancement in magneto-optical Faraday rotation. It is shown that the influence of geometrical parameters in Au layer offers a desirable platform for engineering spectral position of Fano resonance and enhancement of Faraday rotation.

Quantitative Evaluation of Nanosecond Pulsed Laser-Induced Photomodification of Plasmonic Gold Nanoparticles



Biophotonic application of plasmonic gold nanoparticles has become a highly active field of research in recent years due to their unique chemical and physical properties, such as high absorption cross sections and spectral tunability[1]. Many of the unique properties of gold nanoparticles are governed by the surface plasmon resonance (SPR) effect, a collective oscillation of electrons on the nanoparticle surface that occurs when excited with light at an appropriate wavelength. The SPR results in a strongly enhanced electromagnetic field near the particle surface, which causes unique, shape- and material-dependent spectral variations in light absorption and scattering. These properties allow nanoparticles to be used not only as therapeutic agents[2,3,4], but also for diagnostic imaging[5,6]. The therapeutic effects produced by laser-nanoparticle interaction can occur through a variety of mechanisms. Photothermal transduction causes rapid heating in a localized area around the irradiated nanoparticles and has been used for the treatment of solid tumors *in vivo*, with both continuous-wave and nanosecond-pulsed lasers[7,8,9]. Photomechanical effects, such as cavitation, can occur when exposing plasmonic nanoparticles to pulsed laser light (nanosecond-to-femtosecond), and the resultant bubbles are capable of disrupting cancer cell membranes[10,11,12]. Photochemical effects, like the production of reactive oxygen species, have also been observed from laser irradiation of gold nanoparticles, with pulsed lasers having a greater effect than continuous-wave lasers[13,14]. The properties that make gold nanoparticles so effective for laser-based therapeutics can also lead to unintended side-effects in diagnostic procedures.

One of the most promising diagnostic techniques that may employ gold nanoparticle contrast agents is photoacoustic imaging (PAI), a rapidly maturing biomedical modality capable of macro- and micro-scale imaging[5]. In PAI, tissue is illuminated with a nanosecond pulsed laser, typically a Q-switched Nd:YAG with pulse duration in the range of 5–10 ns, at exposures below standard safety limits[15]. This exposure causes rapid optical absorption and thermal expansion that produces acoustic waves, which can be detected using an ultrasonic transducer. The use of gold nanoparticles as contrast agents for PAI has the potential to generate photothermal, photomechanical, or photochemical effects that result in tissue injury. Furthermore, the spectral changes brought about by nanoparticle photomodification can cause spectral shifts in absorption that degrade PAI-nanoparticle product performance[16].

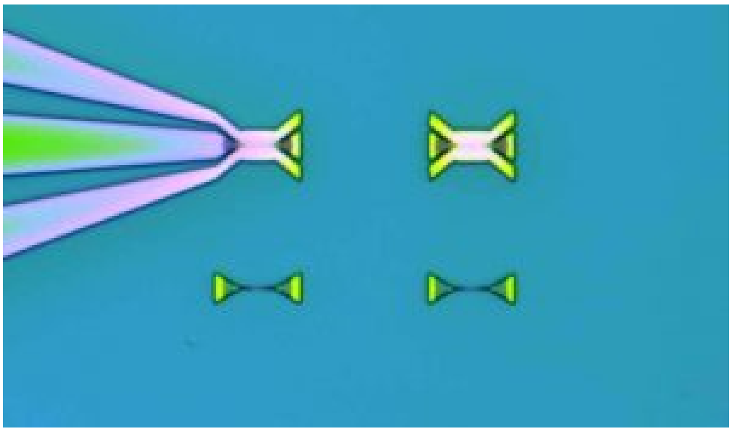
While there are well-established laser safety standards for the skin and eye, these standards are insufficient when exogenous chromophores such as nanoparticles are present. Additionally, no standards exist for evaluating the performance of laser-nanoparticle combination products for medicine. In recent years, a number of studies have contributed knowledge on the laser-nanoparticle interaction processes and resultant bioeffects, as well as test methods that could form the basis of new standards. One key step in elucidating laser-nanoparticle interactions is to understand the photostability of nanoparticles and characterize laser induced photomodification processes, including photothermally-induced melting/reshaping effects that have been documented for different types of metallic nanoparticles[16,17,18,19,20,21,22]. they chose to study spherical gold nanoparticles as their surface plasmon resonance is close to the wavelength (532 nm) of the second-harmonic Q-switched Nd:YAG laser, which is broadly employed in biophotonics and photomedicine[23,24,25], and because these nanoparticles possess well-defined morphological properties and their spherical shape is well-suited for theoretical investigation.

Several prior studies have evaluated the effect of pulsed laser irradiation on gold nanospheres – more accurately gold “pseudospheres” since most of the particles studied, as well as commercially available versions, have faceted rather than smooth edges. One such study by Takami *et al*. looked at the size reduction of approximately 50 nm gold nanospheres at different pulse energies[18]. Werner *et al*. investigated the effect of irradiation wavelength on 55 nm gold nanospheres and was mostly concerned with modeling the difference between interband and intraband excitation[22]. Another study used dynamic light scattering (DLS), electron microscopy and UV-Vis spectroscopy to examine the impact of a single laser pulse on particles of different sizes[26]. While results were presented for a range of energy levels, specific damage thresholds were not determined and comparison with theoretical results was not presented. These prior studies have provided significant insights, yet are deficient in terms of generating a standardized test methodology as they either only used a single nanoparticle size or provided a qualitative description of the damage with no well-defined threshold.

Our overall objective was to facilitate the optimization of safety and effectiveness in emerging biophotonic products incorporating nanoparticles. Previous works have not established a common approach for assessing laser damage thresholds in nanoparticles, and information on the role of particle size in nanosphere damage is typically spread across multiple reports with inconsistent experimental conditions. Therefore, the goals of this proof-of-concept study were to implement and assess methodologies to quantitatively determine nanoparticle photomodification thresholds, and to generate data on the melting process and damage thresholds that can be used to improve understanding of this process. Specifically, we have conducted quantitative experimental and analytical investigation of the interaction between nanosecond laser pulses at 532 nm and plasmonic gold nanoparticles with diameters from 20 to 100 nm over a wide range of laser radiant exposures.

More information: Andrew M. Fales et al. Quantitative evalution of nanosecond pulsed laser-induced photomodification of plasmonic gold nanoparticles, Scientific Reports(2017). 10.1038/s41598-017-16052-7.

Optoelectronics without glass

 [Microscopic image of a chip. Top left: functional modulator with electrical contacts; right: test modulator without electrical contact; below: test components.]

Researchers at ETH Zurich have developed the first opto-electronic circuit component that works without glass and is instead made of metal. The component, referred to as a modulator, converts electrical data signals into optical signals. It is smaller and faster than current modulators, and much easier and cheaper to make.

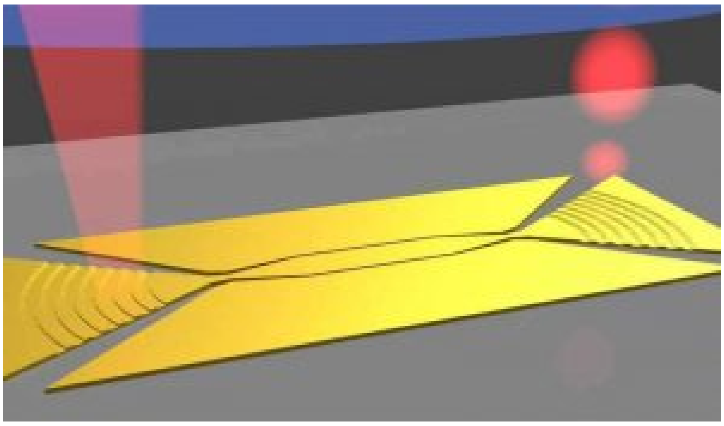
Optical components for microelectronics must be made of glass. Metals are not suitable for this purpose, since optical data can propagate only across roughly a distance of 100 micrometres. This was the general view of scientists until recently. A team of researchers headed by Juerg Leuthold, professor in the Department of Information Technology and Electrical Engineering, has now succeeded in doing what was thought to be impossible and developed a light-processing component made of metal. The researchers have presented their findings in the latest issue of the journal *Science*.

They accomplished this feat by building a small enough component: at just 3 x 36 micrometres, it is within a size range in which both optical and electrical information can propagate in metals.

Component for fibre optic networks

The component is a [modulator]: modulators convert electrical data signals into optical signals. They are installed in modern internet routers used for fibre optic networks and enable fibre optic data connections between computer units in data centres. However, the standard components used today function differently than the new modulators.

The new component works by aiming the light from a fibre optic source at the modulator, causing the electrons on its surface to oscillate. Experts refer to this as a surface plasmon oscillation. This oscillation can be changed indirectly by electrical data pulses. When the oscillation of the electrons is converted back into light, the electrical information is now encoded onto the optical signal. This means that the information is converted from an electrical into an optical data pulse that can be transmitted via fibre optics.


Schematic representation of the metallic modulator: Left: a continuous beam of light strikes a metallic lattice that deflects the light onto the chip. Right: an optical data pulse exits the component.

Faster and smaller

Two years ago, Leuthold and his colleagues developed one of these plasmonic modulators. At the time, it was the smallest and fastest modulator ever built, but the semiconductor chip still had various glass components.

By replacing all the glass components with metallic ones, the scientists have succeeded in building an even smaller modulator that works up to highest speed. “In metals, electrons can move at practically any speed, whereas the speed in glass is limited due to its physical properties," says Masafumi Ayata, a doctoral student in Leuthold's group and lead author of the study. In the experiment, the researchers succeeded in transmitting data at 116 gigabits per second. They are convinced that with further improvements, even higher data transfer rates will be possible.

Etched from a gold layer

The modulator prototype tested by the ETH researchers is made of a gold layer that lies on a glass surface. The scientists emphasised that the glass has no function. "Instead of the glasslayer, we could also use other suitable smooth surfaces," says Leuthold. It might also be possible to use less expensive copper instead of gold for industrial applications. The important point is that only one metallic coating is required for the new modulators. "This makes them much easier and cheaper to fabricate," says Leuthold.

The researchers are already working with an industrial partner in order to put the new modulator into practice, and talks with other partners are in progress. However, Leuthold believes that further development may be required before the technology is ready for the market; for example, he expects that the current loss of signal strength during modulation can be reduced further.

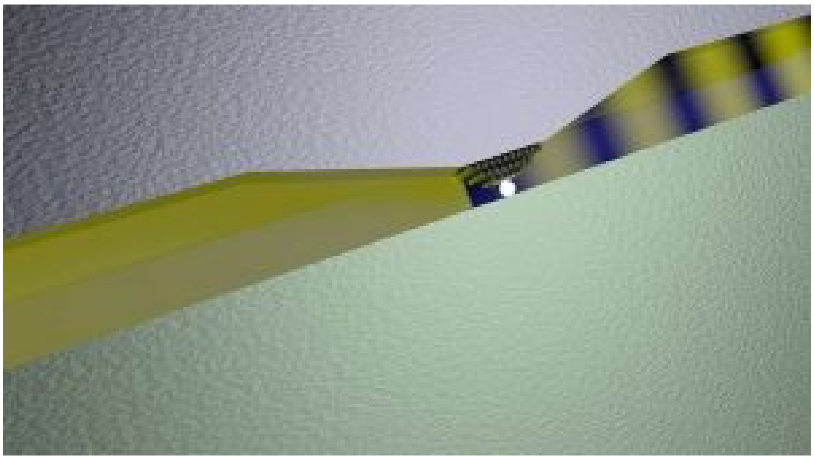
For computers and autonomous vehicles

The new modulator could one day be used not only for telecommunications applications, but for computers as well. "The computer industry is considering using fibre optics to transfer data between the individual chips inside computers," says Leuthold. However, this would require tiny modulators – such as Leuthold and his team have developed.

Ultimately, it is also conceivable that the modulators could be used in displays – including bendable ones – and optical sensors, such as those in the Lidar system for distance measurement that are used in (semi-) autonomous cars.

More information: Masafumi Ayata et al. High-speed plasmonic modulator in a single metal layer, *Science* (2017). DOI: 10.1126/science.aan5953

Switching light with a silver atom


The switch is based on the voltage-induced displacement of one or more silver atoms in the narrow gap between a silver and a platinum plate.

Researchers working under Juerg Leuthold, Professor of Photonics and Communications, have created the world's smallest integrated optical switch. Applying a small voltage causes an atom to relocate, turning the switch on or off.

The quantity of data exchanged via communications networks around the globe is growing at a breathtaking rate. The volume of data for wired and mobile communications is currently increasing by 23% and 57% respectively every year. It is impossible to predict when this growth will end. This also means that all network components must constantly be made more efficient.

These components include so-called modulators, which convert the information that is originally available in electrical form into optical signals. Modulators are therefore nothing more than fast electrical switches that turn a laser signal on or off at the frequency of the incoming electrical signals. Modulators are installed in data centres in their thousands. However, they all have the disadvantage of being quite large. Measuring a few centimetres across, they take up a great deal of space when used in large numbers.

From micromodulators to nanomodulators

Six months ago, a working group led by Jürg Leuthold, Professor of Photonics and Communications already succeeded in proving that the technology could be made smaller and more energy-efficient. As part of that work, the researchers presented a micromodulator measuring just 10 micrometres across – or 10,000 times smaller than modulators in commercial use.


Tiny plates made of silver (light grey) and platinum (mint) are placed on an optical waveguide (blue)

Leuthold and his colleagues have now taken this to the next level by developing the world’s smallest optical modulator. And this is probably as small as it can get: the component operates at the level of individual atoms. The footprint has therefore been further reduced by a factor of 1,000 if you include the switch together with the light guides. However, the switch itself is even smaller, with a size measured on the atomic scale. The team's latest development was recently presented in the journal *Nano Letters*.

In fact, the modulator is significantly smaller than the wavelength of light used in the system. In telecommunications, optical signals are transmitted using laser light with a wavelength of 1.55 micrometres. Normally, an optical device can not be smaller than the wavelength it should process. "Until recently, even I thought it was impossible for us to undercut this limit," stresses Leuthold.

New structure

But his senior scientist Alexandros Emboras proved the laws of optics wrong by successfully reconfiguring the construction of a modulator. This construction made it possible to penetrate the order of magnitude of individual atoms, even though the researchers were using light with a "standard wavelength".

Emboras's modulator consists of two tiny pads, one made of silver and the other of platinum, on top of an optical waveguide made of silicon. The two pads are arranged alongside each other at a distance of just a few nanometres, with a small bulge on the silver pad protruding into the gap and almost touching the platinum pad.

Set-up used in the lab to test the new type of switches.

Short circuit thanks to a silver atom

And here’s how the modulator works: light entering from an optical fibre is guided to the entrance of the gap by the optical waveguide. Above the metallic surface, the light turns into a surface plasmon. A plasmon occurs when light transfers energy to electrons in the outermost atomic layer of the metal surface, causing the electrons to oscillate at the frequency of the incident light. These electron oscillations have a far smaller diameter than the ray of light itself. This allows them to enter the gap and pass through the bottleneck. On the other side of the gap, the electron oscillations can be converted back into optical signals.

If a voltage is now applied to the silver pad, a single silver atom or, at most, a few silver atoms move towards the tip of the point and position themselves at the end of it. This creates a short circuit between the silver and platinum pads, so that electrical current flows between them. This closes the loophole for the plasmon; the switch flips and the state changes from “on” to “off” or vice versa. As soon as the voltage falls below a certain threshold again, a silver atom moves back. The gap opens, the plasmon flows, and the switch is “on” again. This process can be repeated millions of times.

ETH Professor Mathieu Luisier, who participated in this study, simulated the system using a high-performance computer at the CSCS in Lugano. This allowed him to confirm that the short circuit at the tip of the silver point is brought about by a single atom.

A truly digital signal

As the plasmon has no other options than to pass through the bottleneck either completely or not at all, this produces a truly digital signal – a one or a zero. “This allows us to create a digital switch, as with a transistor. We have been looking for a solution like this for a long time,” summarises Leuthold.

As yet, the modulator is not ready for series production. Although it has the advantage of operating at room temperature, unlike other devices that work using quantum effects at this order of magnitude, it still remains very slow for a modulator: so far, it only works for switching frequencies in the megahertz range or below. The ETH researchers want to fine-tune it for frequencies in the gigahertz to terahertz range.

Improving the lithography process

The researchers also want to further improve the lithography method, which was redeveloped by Emboras from scratch to build the parts, so that components like this can be produced reliably in future. At present, fabrication is only successful in one out of every six attempts. Nevertheless, the researchers consider this a success, as lithography processes on the atomic scale remain uncharted territory.

In order to continue his research into the nanomodulator, Leuthold has strengthened his team. However, he points out that greater resources would be required to develop a commercially available solution. Despite this, the ETH professor is confident that he and his team will be able to present a practicable solution within the next few years.

More information: Alexandros Emboras et al. Atomic Scale Plasmonic Switch, *Nano Letters* (2016). DOI: 10.1021/acs.nanolett.5b04537