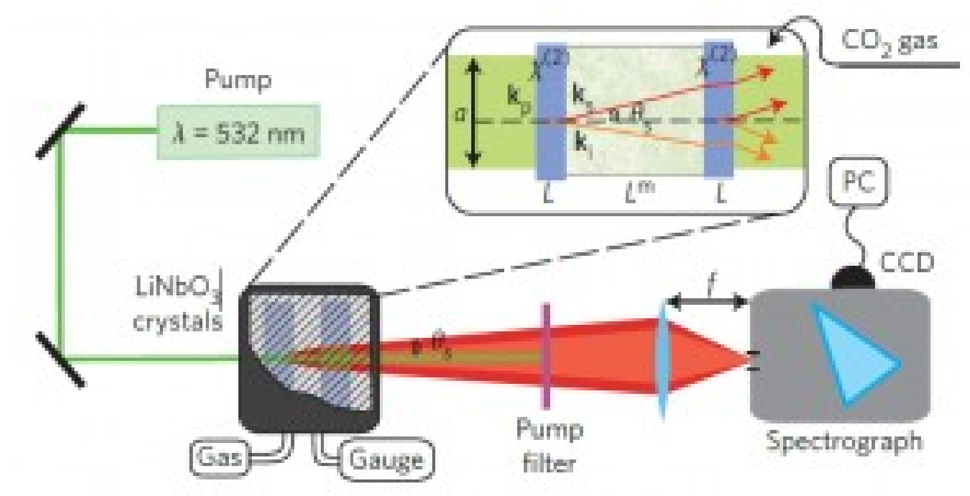
Infrared spectroscopy with visible light



Experimental set-up. A continuous-wave laser at 532 nm pumps two nonlinear crystals, where SPDC occurs. The crystals are placed in a vacuum chamber and CO2 is injected into the chamber. The interference pattern of the SPDC from the two crystals is imaged by a lens onto a slit of a spectrograph and recorded by a charge-coupled device (CCD) camera.

Spectral measurements in the infrared optical range provide unique fingerprints of materials, which are useful for material analysis, environmental sensing and health diagnostics[1]. Current infrared spectroscopy techniques require the use of optical equipment suited for operation in the infrared range, components of which face challenges of inferior performance and high cost. Here, Kalashnikov et al. develop a technique that allows spectral measurements in the infrared range using visible-spectral-range components. The technique is based on nonlinear interference of infrared and visible photons, produced via spontaneous parametric down conversion. The intensity interference pattern for a visible photon depends on the phase of an infrared photon travelling through a medium. This allows the absorption coefficient and refractive index of the medium in the infrared range to be determined from the measurements of visible photons. The technique can substitute and/or complement conventional infrared spectroscopy and refractometry techniques, as it uses well-developed components for the visible range

Reference:

Nature Photonics 10, 98–101 (2016) doi:10.1038/nphoton.2015.252 http://www.nature.com/nphoton/journal/v10/n2/full/nphoton.2015.252.html

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INTERNATIONAL YEAR OF LIGHT 2015

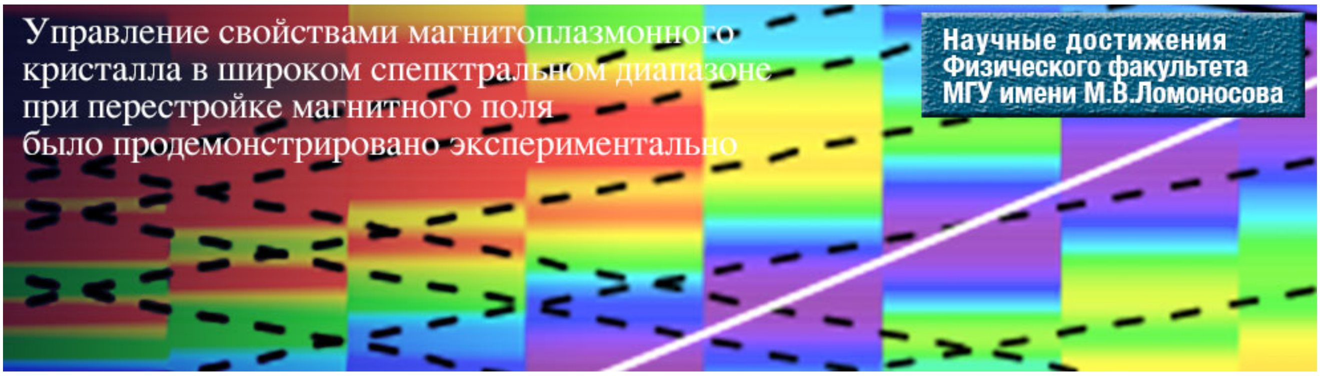
On 20 December 2013, The United Nations (UN) General Assembly 68th Session proclaimed 2015 as the **International Year of Light and Light-based Technologies (IYL 2015)**.

This International Year has been the initiative of a large consortium of scientific bodies together with UNESCO, and will bring together many different stakeholders including scientific societies and unions, educational institutions, technology platforms, non-profit organizations and private sector partners.

In proclaiming an International Year focusing on the topic of light science and its applications, the United Nations has recognized the importance of raising global awareness about how light-based technologies promote sustainable development and provide solutions to global challenges in energy, education, agriculture and health. Light plays a vital role in our daily lives and is an imperative cross-cutting discipline of science in the 21st century. It has revolutionized medicine, opened up international communication via the Internet, and continues to be central to linking cultural, economic and political aspects of the global society.

> *An International Year of Light is a tremendous opportunity to ensure that international policymakers and stakeholders are made aware of the problem-solving potential of light technology. We now have a unique opportunity to raise global awareness of this.*
>
> *John Dudley, Chairman of the IYL 2015 Steering Committee*

The tunable magnetic-field controlled behaviour of magnetoplasmonic crystals in a wide spectral range has been demonstrated experimentally



Researchers from the Faculty of Physics, Lomonosov Moscow State University, in collaboration with their colleagues from Minsk, Belarus, experimentally studied optical and magnetooptical effects in magnetoplasmonic crystals and demonstrated the tunable magnetic-field controlled behaviour of these crystals in a wide spectral range.

Magnetoplasmonic crystals (MPC) attract much attention due to their unique and pronounced ability to control the light flow. One of the efficient MPC compositions is the combination of a dielectric magnetic film with a thin perforated metal layer on top. It was demonstrated that MPC of such a type supports the resonant excitation of surface plasmon polaritons (SPP) with a relatively long SPP propagation length and reveals a strong magneto-optical response introduced by garnet films. This allows for a magnetic field control over the SPP excitation at the metal/garnet interface. An important point here is that the quality of the interfaces between the adjacent metal and dielectric layers should be smooth and free of defects. This restricts the number of accessible techniques for the MPC fabrication.

In most of the experimental papers methods involving the electron beam lithography were used to make the Au/gold MPC on a gallium gadolinium garnet (GGG) substrate. It was shown that such a structure supports the excitation of the SPP modes localized on two metal surfaces, as well as the waveguide (WG) modes in the dielectric slab. The necessity in use of a template limited the variety of structures that have been studied; besides, the minimal thickness of the gold layer in such MPC was about 70 nm.

In the work of scientists from Physics Department of MSU performed in collaboration with their colleagues from Scientific-Practical Materials Research Centre , Minsk, Belarus, optical and magnetooptical effects in magnetoplasmonic crystals (MPC) were studied. The MPCs were formed by a 1D gold grating on top of a magnetic garnet layer made by a novel method of combined ion-beam etching technique. We demonstrate that the proposed method allows to make high-quality MPC. It is shown that MPC with a 30-40 nm thick perforated gold layer provides an effective excitation of two surface plasmon-polariton modes and several numbers of waveguide modes in the garnet layer. An enhancement of the transversal magneto-optical effect up to the value of 1% is observed for all types of resonant modes that propagate in the magnetic layer, due to magnetic-field control over the mode excitation, which is promising for future photonic devices.

This work has been published in the paper: A. L. Chekhov, V. L. Krutyanskiy, A. N. Shaimanov, A. I. Stognij, T. V. Murzina, “Wide tunability of magnetoplasmonic crystals due to excitation of multiple waveguide and plasmon modes”, Opt. Express 22 (15) 17762-17768 (2014).

Surface Plasmons Enable

Tunable Color Filters

SINGAPORE, Aug. 30, 2012 — Combining a thin, perforated gold film with a liquid crystal layer makes a tunable, efficient color filter, engineers at A*STAR, the Agency for Science, Technology and Research in Singapore, report.

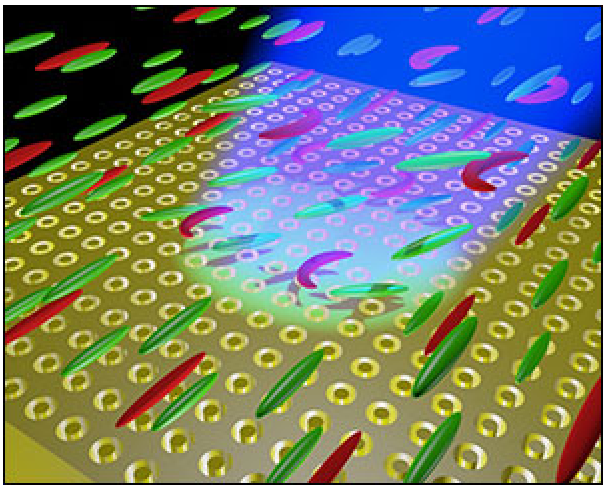
Flat panel displays and many digital devices require thin, efficient and low-cost light emitters. The pixels comprising the various colors on the display are typically wired to complex electronic circuits, but the A*STAR display technology requires a much simpler architecture.

“Our color filters are a lot thinner and more compact than conventional thin-film-based color filters,” said Jing Hua Teng of the A*STAR Institute of Materials Research and Engineering. “The colors of these filters can be tuned with ease, so they are very versatile in applications.”

Surface plasmons — the collective motion of electrons — on the surface of a patterned gold film absorb light at wavelengths dependent on the pattern details. If the patterns are narrow, nanometer-sized rings are cut out of the film. As the diameter of the rings changes, so, too, does the color of the metal film. Pixels of different colors can be realized by simply patterning the rings of varying sizes across the same gold film.

To realize a full display, however, each pixel must be turned on and off individually. This is where liquid crystals come in.

Liquid crystals can be switched between two different states by external stimuli, such as ultraviolet (UV) light. In their normal state, the crystals let visible light pass through so that the pixel is turned on. But when UV light is also present, the structure of the liquid crystal molecules changes so that it absorbs visible light, making the pixel go dark. This process can be repeated over many cycles without degrading the device itself.



Schematic of the tunable color filter. The combination of a gold film with ring-shaped holes and the use of liquid crystals (red and green) enables pixels of a defined color that can be turned on and off. ©2012 Y.J. Liu

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Although the device works in principle, it remains a concept on the drawing board for now, Teng's team said. There are still many issues to overcome, such as optimization of the switching speed and the contrast between "on" and "off" states. In future work, the team will need to extend its work so the device can serve a larger area and produce the fundamental colors red, green and blue.

Teng said he and his group are quite optimistic that they will achieve this soon.

A paper on their work, "Light-driven plasmonic color filters by overlaying photoresponsive liquid crystals on gold annular aperture arrays," appeared in *Advanced Materials.*

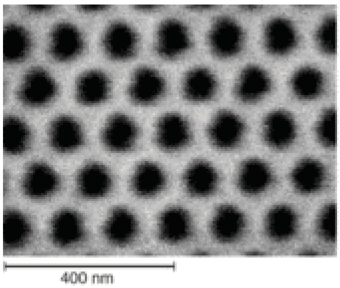
For more information, visit: www.a-star.edu.sg

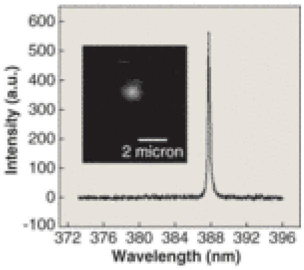
[ZnO photonic-crystal laser emits in the UV]

Although low-threshold lasing in the IR has been realized in photonic-crystal slabs made of III-V semiconductor materials, a UV photonic-crystal laser represents a special challengebecause of the different materials and the smaller feature sizes required for the crystal.

Although the small feature size is difficult to achieve in commonly used wide-bandgap materials such as gallium nitride (GaN) and zinc oxide (ZnO), demands for compact blue and UV light sources have prompted much research in this area. Building on a recent demonstration of photonic-crystal UV light-emitting diodes fabricated with III nitrides, a team of researchers from the Materials Research Center at Northwestern University (Evanston, IL) has demonstrated an optically pumped ZnO photonic-crystal laser operating in the near-UV at room temperature.

The photonic-crystal structure was prepared by growing 200-nm-thick ZnO films on c-plane sapphire substrates by plasma-enhanced metal-organic chemical-vapor deposition. Next, arrays of cylindrical columns were removed by focused-ion-beam (FIB) etching at 30 KeV (see figure). Structural damage caused by the FIB process was then removed by annealing the films in oxygen at 600°C for one hour. By adjusting the lattice constant a, and the radius of the air cylinders r, the ZnO gain spectrum can be made to overlap the photonic bandgap.





In the experimental setup, a 10×-microscope objective lens is used to focus a modelocked Nd:YAG laser (355-nm wavelength, 10-Hz repetition rate, 20-ps pulse length) at room temperature to a 4-µm spot on the patterned ZnO film. A beamsplitter routes the emission through another lens and into a UV fiber connected to a spectrometer with 0.13-nm spectral resolution. Because the sapphire substrate is transparent in both visible and UV frequencies, a 20×-microscope objective lens is placed at the backside of the sample for measurement of the spatial distribution of emission intensity. The sample was also illuminated by a white-light source to identify the position of the lasing modes in the photonic lattice.

Although the ZnO-patterned films had structures with lattice constants a varying from 100 to 160 nm, only the patterns witha = 115 nm and 130 nm were able to lase. The spectral emission from a pattern with a = 115 nm andr/a = 0.25 was a single sharp peak at 387.7 nm with a spectral width of 0.24 nm above the lasing threshold. The near-field image of the lasing mode showed spatial localization to a small region approximately 1 µm in diameter inside the 8 × 8-µm patterned region of the film (see figure).

Calculation of the photonic band structures using a 3-D plane-wave-expansion method revealed a bandgap from 396 to 415 nm for the structure with *a* = 130 nm and a narrower gap from 363 to 372 nm for the structure with *a* = 115 nm. With the gain spectrum for ZnO ranging from 373 to 397 nm, the calculated photonic bandgaps for these two structures do not exactly overlap the gain spectrum. The team surmised that the unavoidable imperfections in the structures created during the fabrication process broadened the bandgaps and made them shallower, allowing overlap and lasing modes to occur on the lower-frequency side of the bandgap (near the dielectric band edge) for the *a* = 115 nm structure and on the higher-frequency side of the bandgap (near the air band edge) for the *a* = 130 nm structure. The lasing threshold of the structure with *a* = 115 nm is lower than that of the latter because the defect modes are concentrated inside ZnO and experience more gain.

The research team now understands that the lasing modes are basically spatially localized defect states near the edge of the photonic bandgap that are formed by structural disorders unintentionally introduced during the fabrication process. “It is very difficult to make the intentionally introduced defect modes repeatable, especially in the UV regime,” says researcher Hui Cao. For this reason, the team plans to focus on minimizing the structure disorder so that they can get lasing in intentionally introduced defect modes.