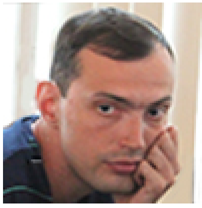
To replace the "sandwich": scientists develop a super-miniature optical filter

A research team, which included scientists from Siberian Federal University and Krasnoyarsk Research Centre SB RAS, as well as scientists from Sweden and the USA, has proposed ultra-miniature devices allowing to isolate the ultra-narrow spectral line in the visible and infrared ranges of the spectrum from the broadband optical radiation and to control its location.

It is worth noting that production of high-quality emission filters for various spectral ranges, which have advantages over the existing devices, is one of the priority tasks of modern optics.

The main results of the research are published in Optics Express, one of the reputable international scientific journals. These results can be used both in advanced telecommunication devices and in medical diagnostics.



'The disadvantage of monochromators — the conventional devices designed for filtering optical radiation — are significant dimensions and formidable cost. In our work, we proposed a rather miniature design — a 3×3 millimetre plate consisting of several thousand periodically arranged nanosized particles in the form of disks. These nanodisks are located at the corners of an elementary square cell smaller than the wavelength of light. The aggregate of such cells forms a lattice containing thousands of similar elements. The action of this plate is based on manifesting the so-called collective lattice resonances occurring as a result of the synchronized interaction of electromagnetic fields from individual particles and an external field,' said **Valery Gerasimov**, senior researcher at SibFU and one of the authors of this work.

The scientists tell that the sizes of these plates can be increased from a few millimetres (for using in miniature spectral selectors of fiber-optic communication) to centimetres.

'In the latter case, in contrast to monochromators, we can not only measure the emitted energy flux of monochromatic radiation but can also obtain a two-dimensional bitmap image of the object at a certain wavelength. Furthermore, tilting the plate slightly, by several degrees, we can fine-tune the selected spectral line along the wavelength. Such advantages of the proposed filters open up prospects for their application, in particular, for the methods of medical bioluminescent diagnostics,' said **Ilya Rasskazov**, a co-author of the research, graduate of Siberian Federal University and post-doc of the Institute of Optics, the University of Rochester.

The team testes a number of compounds: lithium niobate, titanium dioxide, gallium arsenide, as well as silicon and germanium a material of nanoparticles. Their feature is full transparency in the applied spectral range. And that is exactly where the secret of the success of the proposed mini-filter could not have been expected.

'If you fracture any of these materials into nanoparticles and then arrange them into a periodic structure, the whole set of particles will begin to work as a mirror, in other words, it completely reflects an exactly defined wavelength, though the material itself is not capable of this. After all, the typical basis of any mirror is still an opaque metal. This is amazing and proves once again that

the materials as we know them in ordinary life and the same materials at the nanoparticle level can behave very differently,' said **Sergei Polyutov**, a leading researcher at Siberian Federal University.

By replacing the particle material, it is possible to change the spectral range in which the filter is used. Having a set of such filters, one can cover the spectral range of the emitted monochromatic wavelengths from 500 to 5000 nm or more. The designed device is ultra-thin and single-layer, unlike the common interference filters, resembling a sandwich of many layers. What is more, these structures have large-scale invariance: by increasing the particle size by a factor of two, you can double the wavelength of the selected spectral line, which simplifies their manufacture for a particular wavelength.

'Today's fundamental science is often criticized due to the fact that new scientific developments collect dust and remain unimplemented in the applied areas of research. Authors of the designs do not always pay due attention to the practical significance of new ideas and the possibility of translating them into innovative products, the creation of which opens up new prospects in the production of high-tech products that improve the quality of people's life. The results of our basic research can be used here and now because modern technologies already allow us to synthesize such structures using the equipment of leading scientific centres of the world. Mass production is still a long way off, but prototypes appear and, of course, the possibility of practical application, for example, in medicine to improve diagnostic systems or in the field of telecommunication, is a huge advantage of our large-scale work in nanophotonics,' concluded the research director, professor of Siberian Federal University and leading researcher at the Institute of Physics of the FRC Krasnoyarsk Research Centre of SB RAS, **Sergey Karpov**.

The researched is supported by a grant from the Russian Science Foundation (project 18-13-00363).

Пресс-служба СФУ, 13 march 2020