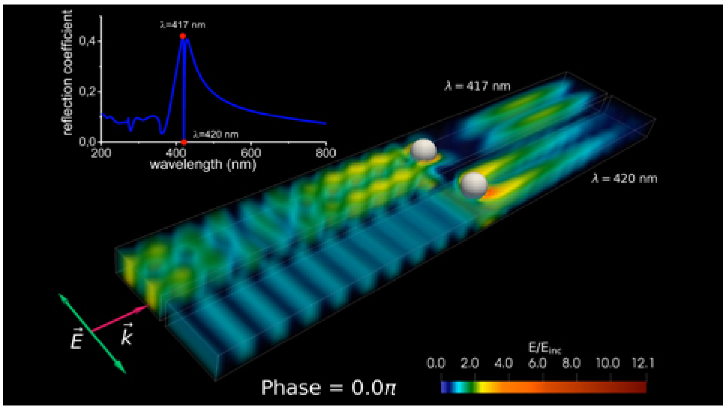
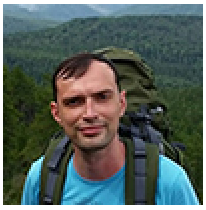
New material, new effect: aluminium in nanoplasmonics



Scientists of the International Research Center for Spectroscopy and Quantum Chemistry, Siberian Federal University, have reported about the possibility of suppressing backscattering of light (the so-called Kerker effect) when electromagnetic radiation interacts with plasmonic material in the form of a two-dimensional array of aluminium nanoparticles. The work was published in the top-rated international journal Physical Review B of the Nature Index group.

As the article explains, constructive interference of individual modes of the electric or magnetic field and lattice modes (Rayleigh anomalies) is responsible for implementing the predicted optical effect. The researchers were the first to show that complete suppression of backscattering of light can be observed even in plasmon materials not only in a narrow spectral range, as in classical plasmon materials (gold, silver), but in an extensive range of wavelengths, including ultraviolet and visible spectral ranges by simply changing the geometry of the gratings (radius of nanoparticles) and the distance between them.



"Earlier, the Kerker effect was observed in various hybrid dielectric and metal-dielectric nanostructures with strong electric and magnetic modes. The existence of both of these modes is a necessary condition for the Kerker effect. In classical plasmonic materials, magnetic modes are suppressed, which limits the use of classical plasmonic nanostructures. To overcome this limitation, we first investigated the possibility of the existence of the Kerker effect in a periodic array of nanoparticles of an alternative and cheap plasmonic material, aluminium, and discovered a substantially new and practically important effect. It should be said that for a single aluminium particle, the suppression of backscattering of light is not possible. That is, not only the material is important, but also its special nanostructure," said **Valery Gerasimov**, senior researcher at the International Research Center for Spectroscopy and Quantum Chemistry.

The Center employees numerically simulated the interaction of an external electromagnetic field with a two-dimensional lattice of aluminium nanoparticles with specified geometric dimensions (particle radius, structure period along one or the other axis) and studied the configurations of the electric and magnetic fields, as well as the transmittance spectra of this system. It was in the transmittance spectra of a two-dimensional array that the suppression of backscattering of light (the Kerker effect) was discovered.

"A few decades ago, it was theoretically predicted that ordered periodic structures of plasmonic nanoparticles interacting with electromagnetic radiation can show narrow optical resonances in the transmittance spectra, the Q factor of which is much higher compared to single nanoparticles that make up a periodic structure," explained the leading researcher of the International Research Center for Spectroscopy and Quantum Chemistry, Doctor of Physics and Mathematics, **Sergey Karpov**.

"These optical features are associated with the hybridization of the spectrum of a single plasmonic particle with vibrations propagating over the lattice structure. We studied these lattice resonances in a wide range of periodic nanostructures with different types of unit cells: single or paired nanodisks, cylinders with a core-shell structure, dimers, and more complex configurations," said **Alexander Ershov**

Today it has already become obvious that periodic arrays of nanoparticles can be used for both applied and research purposes: for example, in infrared spectroscopy, narrowband light absorption, sensorics, lasers and fluorescence, telecommunications and narrowband information transmission — wherever light streams manipulation is required. It is important to note that traditional nanoplasmonic materials (gold and silver) are gradually giving way to other alternative plasmonic materials, for example, conductive oxides (AZO, GZO, ITO), titanium nitride or the aforementioned aluminium.

The curiosity by the experts of the International Research Center for Spectroscopy and Quantum Chemistry in this material is due to the fact that the plasmon resonance of aluminium (in contrast to silver and gold) can be located in the ultraviolet (UV) range of the spectrum. This feature can be used, for example, in photocatalysis and to study organic and biological systems manifesting strong UV absorption. In addition, aluminium is relatively cheap and affordable, which opens up vast opportunities for fabrication and mass production in such promising areas as colour printing, photoelectricity, thermoplasmonics, and holography.

"The modern needs of research in the field of promising materials are focused on the possibility of manifesting unique physical properties in a given range by such materials, the simplicity of manufacturing new devices based on them, and their commercial prospects. As we showed in our work, in addition to traditional gold and silver, aluminum can become a promising new material for nanoplasmonics, in which a very beautiful and practically significant Kerker effect manifests itself," explained Sergey Polyutov, head of the International Research Center for Spectroscopy and Quantum Chemistry.

This video shows the dynamics of the electric field in a lattice of aluminium nanoparticles (for one unit cell of the lattice) at two wavelengths, which correspond to the maximum and minimum reflection of 417 and 420 nm. At a wavelength of 420 nm, the field is localized near the lattice particles, but the reflected wave does not appear.

Electric field dynamics in a lattice of aluminium nanoparticles

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