Defects are no threat: scientists study unexpected properties of disordered nanolattices

Researchers of Siberian Federal University and their colleagues from Royal Institute of Technology (Stockholm, Sweden), Federal Bio-Medical Agency of Russia (Krasnoyarsk), Kirensky Institute of Physics of the SB RAS, Reshetnev Siberian State University of Science and Technology, and the University of Rochester (New York, USA) have studied the phenomenon of collective lattice resonance arising in the optical spectrum of ordered arrays of silicon nanoparticles.

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The team modelled several possible defects which emerge during the construction of these arrays and proposed methods enabling to cut down the materials necessary for nanoparticles production. The research results are assumed to help in creating dielectric photonic devices of the tomorrow (lasers, compact waveguides with fewer losses than those of the conventional fibres, optical data storages and optical logic gates, and displays. In their paper published in the Journal of the Optical Society of America B, the scientists told about how the routine optics is changing literally right here and right now.

A clock pendulum, violin or guitar strings, the sound of a human voice, lasers used in a medical centre, all these phenomena exist due to the general physical principle of resonance. Resonance is when a frequency of one oscillation coincides with a frequency of another, which leads to a leap of the intensity of the oscillations. All today's optical devices, television, and wireless devices have been successfully operating thanks to this phenomenon since the mid-20th century, but scholars assert that the resonance domain is becoming much wider.

> *“It is known that various periodic structures can be built from nanoparticles. If you play with the wavelength emitting these particles, or change the period between them, you can achieve an interesting effect when all particles become excited simultaneously, and a special high-quality resonance appears in the optical spectrum. This effect can be used to create highly sensitive sensors that will instantly respond to the presence of any particular biological compounds in the medium under the study, or, for example, gases (including toxic ones). The US has started production of supercompact lasers: a fluorescent layer is applied on the thinnest film of nanoparticles, and as a result, they obtain a tool for emitting very intense radiation. Imagine a square-ruled sheet of a school notebook, in your mind draw “points” in the corners of each square, and you will get an ordered system where the nanoparticles-points are separated by a strictly set distance from each other. Next, you need to direct light radiation to these “points” and adjust the distance between them and the frequency of the wave being emitted so that all particles get vibrating at the same time. It will turn out like in the good old example with a bridge and a battalion of soldiers —nanoparticles will "march in step", and we will get the strongest resonance. But, unlike the example with soldiers, it’s believed that it does not matter how the particles are located in relation to each other — each one should have got its own anchored position, and the particles themselves should be identical, otherwise the desired effect will not be achieved,”* — explained the research supervisor, professor at the Specialized Department of Photonics and Laser Technologies at SibFU School of Engineering Physics and Radio Electronics, Dr. Sci. in Physics and Mathematics, **Sergey Karpov**.

According to the researcher, during their study, his colleagues asked the question if it is possible to violate the rules this system abides, and what these violations will lead to? The researchers studied three types of defects that can occur in ordered nanolattices. It turned out that if you significantly change the position of the particles in the lattice relative to each other (their period), either an electric dipole or magnetic dipole bond will suffer. If you change the particle size, for example, significantly enlarge one or reduce other nanoparticles, only the magnetic bond will change. The most unexpected discovery is that if a significant amount of nanoparticles (up to 84 %) is randomly “knocked out” of an ordered array, a 2D-lattice will still work and produce the necessary high-quality structural resonance.

> *“We developed some recommendations for experimenters synthesizing nanoparticles of that kind. Tt turned out that there is no need to be particularly scrupulous as for the size of the particles, and even if some of them are lost, this is also not a big deal for the system. in a certain way, this knowledge will help save resources for if you can minimize the amount of silicon spent, and even more so silver or gold, which nanoparticles are often made from, and make not 500, but 100 of these “combat units”, why not take this opportunity with no prejudice to the final result?”* — noted co-author of the study, a graduate of Siberian Federal University, Postdoctoral Research Fellow of the Institute of Optics of the University of Rochester, **Ilia Rasskazov**.

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