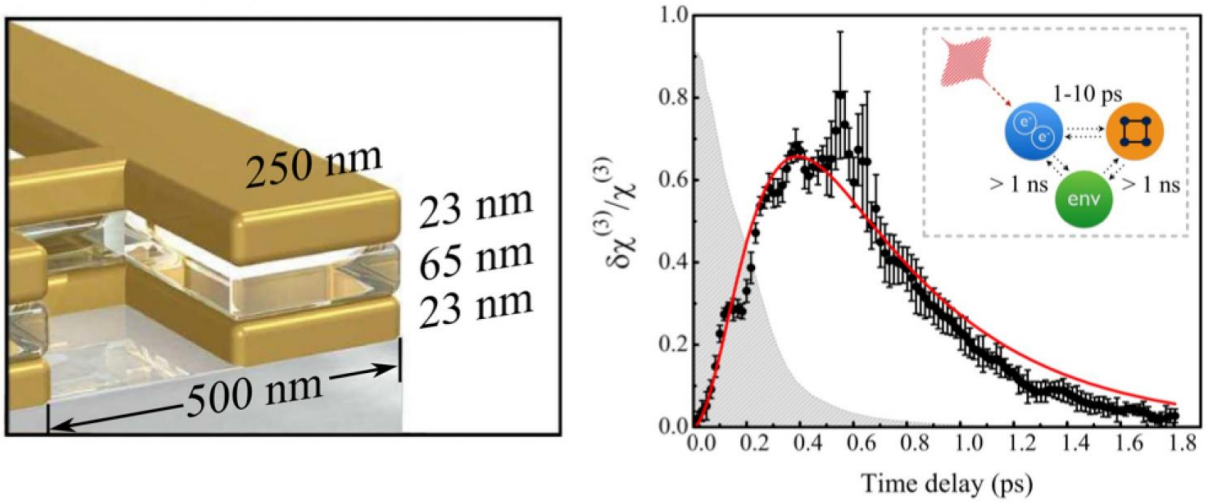
Ultrasensitive nonlinear metamaterials for data transfer

June 24 2016



Schematic illustration of the studied fishnet metamaterial (left). The relative change in the effective third-order nonlinear susceptibility of the fishnet metamaterial as a function of the time delay between the pump and probe pulses (black dots) and its fit to Eq. (7) (red curve). The gray dashed area represents the normalized cross-correlation function of the laser pulses. Inset: illustration of the photoinduced relaxation processes occurring in the structure (right). Credit: *Scientific Reports*.

Scientists have demonstrated the effect of all-optical switching between streams of photons, born during the third harmonic generation process, using non-linear metamaterials. Researchers at Lomonosov Moscow

State University planned the study and conducted calculations and experiments, while their German colleagues made samples of metamaterials. The results are published in *Scientific Reports*. According to Maxim Scherbakov, researcher at MSU's Laboratory of Nanophotonic metamaterials, the work will make it possible to use the metamaterials to create high-speed communication technologies in future.

Metamaterials: When 1 + 1 = 3

Sometimes, a small team can achieve far more than the sum of their individual abilities, as if, teaming up, they acquire new and useful properties. The same is true for metamaterials, which have 'super-powers' such as invisibility in the microwave range and two-dimensional space, seeing through walls, optical zooming and negative refractive index. These abilities are created artificially by the ordered structure of alternating layers of quite common substances. However, if combined, they behave as a completely new material with unique electromagnetic properties that can manipulate photons, i.e. light, in a new way.

The metamaterials that the authors worked with have a fishnet-looking structure with the main 'threads' consisting of gold and magnesium oxide. They belong to a class of nonlinear metamaterials, whose unusual optical properties can be used, for example, to simplify the processing of information and to create new devices that operate much faster than contemporary electronic devices.

Masters of light

Photons, unlike electrons that move through the wires of electronic devices, have no charge and rest mass, so they can perform in formation transfer much faster. The problem is developing photonic transistors as compact as modern electronic ones.

For this purpose, metal and semiconductor nanoparticles, microcavities, photonic crystals, and other man-made structures were considered. The disadvantage is that powerful laser radiation is required for observing all-optical switching. However, the nonlinear metamaterials, as reported in the article, have a higher sensitivity to femtosecond laser pulses than linear metamaterials. This gives nonlinear metamaterials an advantage in the management of light flows by the means of these pulses.

'In the conventional all-optical switching devices, one photon flux controls another thread about the same as it happens in electronic transistors with electron flows. In our previous work, we irradiated a silicon nanostructure with two laser pulses, and the transmission of a pulse varied depending on whether the second pulse is present,' says study co-author Maxim Shcherbakov.

Birth of photons

The experiments demonstrated that photon flow scan control the processes of photon merging with one another. 'There is an interesting effect in optics that can occur when three photons merge into one with tripled energy—almost as during thermonuclear fusion. This effect is called the third harmonic generation. In our work, we observed both effects: all-optical switching and third-harmonic generation. In other words, we control the process of photon synthesis with an external optical pulse. It is very important for integrated photonics, where the full control over all possible processes involving light is required,' Maxim Scherbakov notes, emphasizing that the high sensitivity of nonlinear metamaterials has applications for high-speed communications technologies in the future.

More information: Alexander S. Shorokhov et al, Ultrafast control of third-order optical nonlinearities in fishnet metamaterials, *Scientific Reports* (2016). DOI: 10.1038/srep28440

Provided by Lomonosov Moscow State University