Temporal control of light echoes

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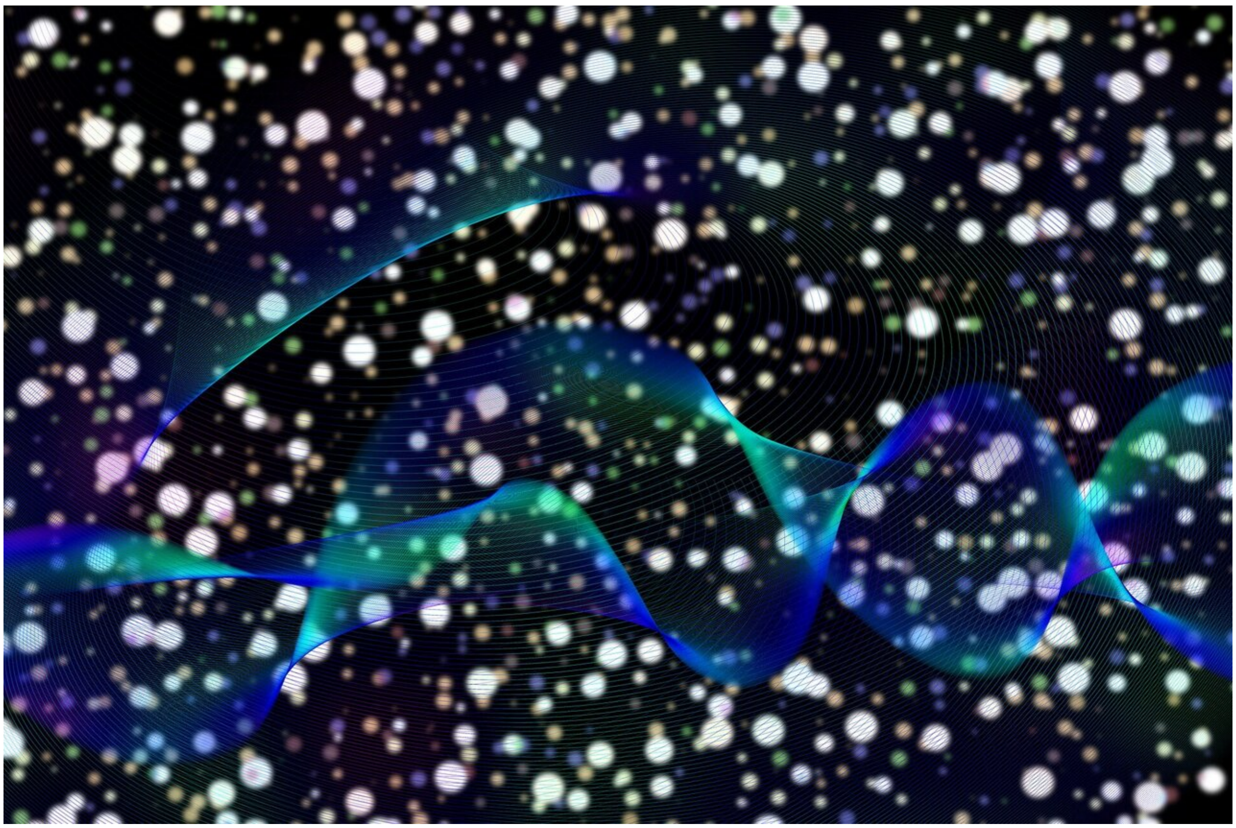

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Scientists at Paderborn University, the Technical University of Dortmund and the University of Würzburg have for the first time used laser pulses to precisely control photon echoes, which can occur when light waves superimpose on each other. The findings of the research have now been published in scientific journal *Communications Physics*.

Professor Torsten Meier from Paderborn University says, "'Shout into the forest and a similar echo will return," or 'what goes around comes around' is not only a well-known German proverb, but is also literally true. When a sound wave is reflected, an echo results. When exactly it comes back, however, depends on the forest, but first and foremost on the distance between the caller and the place of reflection. Just imagine that you could tailor when you wanted the echo to come back to you."

A team of scientists has now achieved this result for optical signals: The scientists found a way to control photon echoes emitted by semiconductor quantum dots with sub-second precision.

Meier explains: "Optical echoes are somewhat different from conventional acoustic echoes, because they are not generated by the reflection of waves, but rather in a non-linear optical process. Two short laser pulses are sent to a sample: The first represents the signal and the second the forest. This provides for the reflection. When the lag time of these pulses is doubled, a new light pulse, the photon echo, is emitted by the system exposed to the light."

Using a further control pulse, the researchers were able to control this photon echo within the picoseconds range (i.e. 10^{-12} seconds), and thereby delay it to a desired point in time. Such control is particularly pertinent for nanophotonic circuits in which multiple optical systems need to be precisely synchronized with each other.

The theoretical prediction of the effect was developed in Professor Torsten Meier's research group. A big challenge was the experimental implementation, which was carried out in the research group led by Professor Ilya Akimov of Technical University of Dortmund: "The temporal control of optical echoes is a highly dynamic effect, whereby the control pulse virtually pauses the system," says Hendrik Rose, a Ph.D. student in Paderborn. Alexander Kosarev, a Ph.D. student at the

Technical University of Dortmund, adds: "This effect was recently theoretically predicted, was successfully experimentally implemented by us and offers a wealth of possibilities for manipulating light emissions from semiconductor systems." The samples used were produced in Professor Sven Höfling's (University of Würzburg) research group.

Based on this first demo, the scientists now want to optimize the effect, for example, by increasing the time lags. The phenomenon is set to be further developed for novel applications in the field of photonic quantum technologies, which are the subject of intensive research at the Institute for Photonic Quantum Systems (PhoQS) at Paderborn University.

More information: Alexander N. Kosarev et al. Accurate photon echo timing by optical freezing of exciton dephasing and rephasing in quantum dots, *Communications Physics* (2020). DOI: 10.1038/s42005-020-00491-2

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