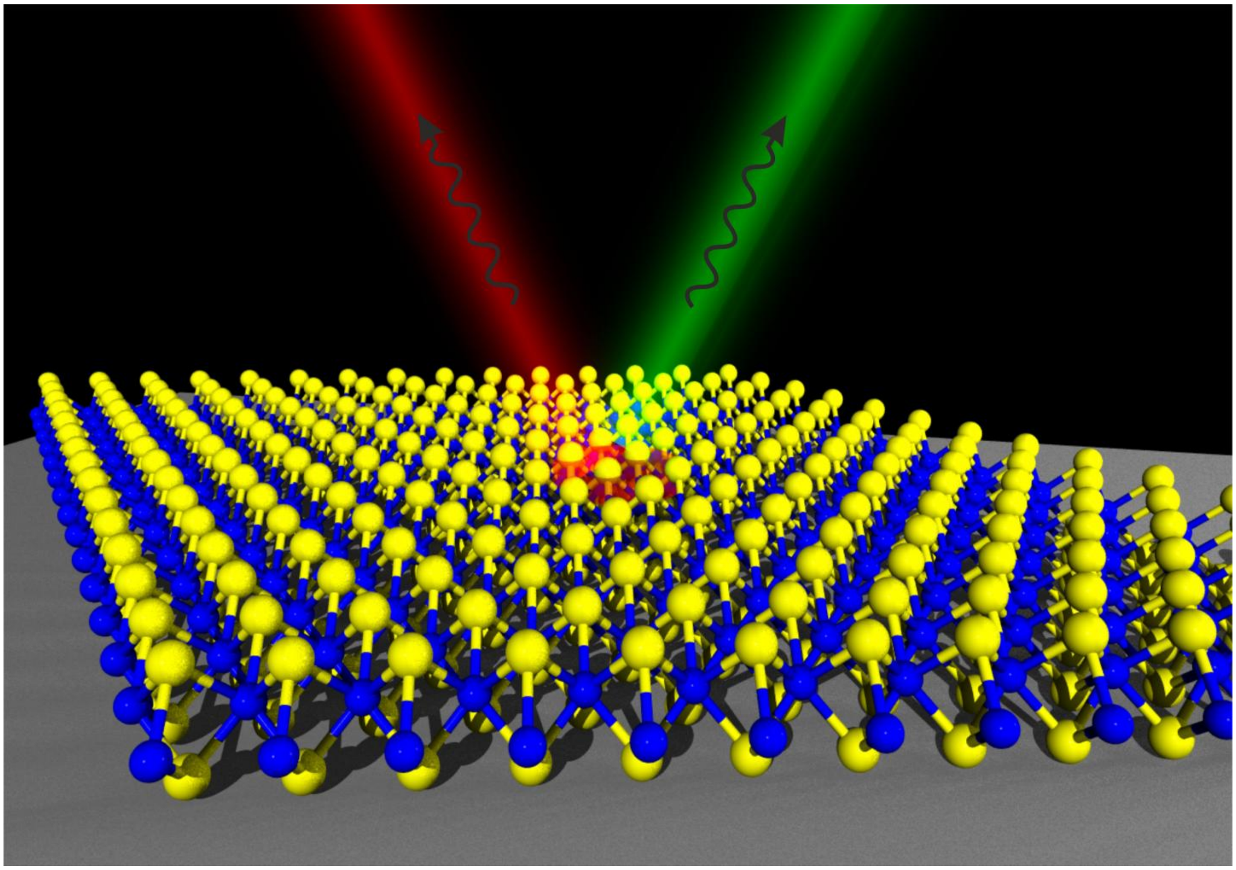
Novel light sources made of 2-D materials

October 28 2016



Artistic representation of a two-photon source: The monolayer (below) emits exactly two photons of different frequencies under suitable conditions. They are depicted in red and green in the picture. Credit: Karol Winkler

Physicists from the University of Würzburg have designed a light source that emits photon pairs, which are particularly well suited for tap-proof data encryption. The experiment's key ingredients: a semiconductor crystal and some sticky tape.

So-called monolayers are at the heart of the research activities. These so-called "super materials" have been surrounded by hype over the past decade. This is because they show great promise to revolutionise many areas of physics.

In physics, the term "monolayer" refers to solid materials of minimum thickness. Occasionally, it is only a single layer of atoms thick; in crystals, monolayers can be three or more layers. Experts also speak of two-dimensional materials. In this form, monolayers can exhibit unexpected properties that make them interesting for research. The so-called transition metal dichalcogenides (TMDC) are particularly promising. They behave like semiconductors and can be used to manufacture ultra-small and energy-efficient chips, for example.

Moreover, TMDCs are capable of generating light when supplied with energy. Dr. Christian Schneider, Professor Sven Höfling and their research team from the Chair of Technical Physics of the Julius-Maximilians-Universität Würzburg (JMU) in Bavaria, Germany, have harnessed exactly this effect for their experiments.

Experiments started with sticky tape

First, a monolayer was produced using a simple method. The researchers used a piece of sticky tape to peel a multi-layer film from a TMDC crystal. Using the same procedure, they stripped increasingly thin layers from the film, repeating the process until the material on the tape was only one layer thick.

The researchers then cooled this monolayer to a temperature of just above absolute zero and excited it with a laser. This caused the monolayer to emit single photons under specific conditions. "We were now able to show that a specific type of excitement produces not one but exactly two photons," Schneider explains. "The light particles are generated in pairs, so to speak."

Such two-photon sources can be used to transfer 100 percent tap-proof information. For this purpose, the light particles are entangled. The state of the first photon then has a direct impact on that of the second photon, regardless of the distance between the two. This state can be used to encrypt communication channels.

Monolayers enable novel lasers

In a second study, the JMU scientists demonstrated another application of exotic monolayers. They mounted a monolayer between two mirrors and again stimulated it with a laser. The radiation excited the TMDC plate itself to emit photons. These were reflected back to the plate by the mirrors, where they excited atoms to create new photons.

"We call this process strong coupling," Schneider explains. The light particles are cloned during this process, in a manner of speaking. "Light and matter hybridise, forming new quasi particles in the process: exciton polaritons," the physicist says. For the first time, it is possible to detect these polaritons at room temperature in atomic monolayers.

In the short term, this will open up interesting new applications. The "cloned" photons have properties similar to laser light. But they are manufactured in completely different ways. Ideally, the production of new light particles is self-sustaining after the initial excitation without requiring any additional energy supply. In a laser, however, the light-producing material has to be excited energetically from the outside on a permanent basis. This makes the new light source highly energy efficient. Moreover, it is well suited to study certain quantum effects.

More information: *Nature Communications*, DOI: 10.1038/ncomms13328

Provided by University of Würzburg