Beating the diffraction limit with nanoantennas

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A molecule being illuminated by two gold nanoantennas.

Plasmonic nanoantennas are among the hot topics in science at the moment because of their ability to interact strongly with light, which for example makes them useful for different kinds of sensing. But matching their resonances with atoms, molecules or so called quantum dots has been difficult so far because of the very different length scales involved. Thanks to a grant from the Engkvist foundation, Timur Shegai, assistant professor at Chalmers University of Technology, hopes to find a way to do this and by that open doors for applications such as safe long distance communication channels.

The diffraction limit makes it very hard for light to interact with the very smallest particles or so called quantum systems such as atoms, molecules or quantum dots. The size of such a particle is simply so much smaller than the wavelength of light that there cannot be a strong interaction between the two. But by using plasmonic nanoantennas, which can be described as metallic nanostructures that are able to focus light very strongly and in wavelengths smaller than those of the visible light, one can build a bridge between the light and the atom, molecule or quantum dot and that is what Timur Shegai is working on.

"Plasmonic nanostructures are themselves smaller than wavelengths of light, but because they have a lot of free electrons they can store the electromagnetic energy in a volume which is actually a lot smaller than the diffraction limit, which helps to bridge the gap between really small objects such as molecules and the larger wavelengths of light," he says.

Matching the harmonic with the un-harmonic

This might sound easy enough, but the problem with combining the two is that they behave in very different ways. The behaviour of plasmonic nanostructures is very linear, like a harmonic oscillator it will regularly move from side to side no matter how much energy or in other words how many excitations are stored in it. On the other hand, so called quantum systems like atoms, molecules or quantum dots are very much the opposite – their optical properties are highly un-harmonic. Here it makes a big difference if you excite the system with one or two or hundreds of photons.

"Now imagine that you couple together this un-harmonic resonator and a harmonic resonator, and add the possibility to interact with light much stronger than the un-harmonic system alone would have allowed. That opens up very interesting possibilities for quantum technologies and for non-linear optics for example. But as opposed to previous attempts that have been done at very low temperatures and in a vacuum, we will do it at room temperature."

Communication channels impossible to hack

One possible application where this technology could be useful in the future is to create channels for long distance communications that are impossible to hack. With the current technology this kind of safe communication is only possible if the persons communicating is within a distance of about one hundred kilometres from each other, because that is the maximum distance that an individual photon can run in fibres before it scatters and the signal is lost.

"The kind of ultra small and ultra fast technology we want to develop could be useful in a so called quantum repeater, a device that could be installed across the line from for example New York to London, that would repeat the photon every time it is about to be scattered," says Timur Shegai.

At the moment though, it is the fundamental aspects of merging plasmons with quantum systems that interest Timur Shegai. To be able to experimentally prove that the there can be interactions between the two systems, he first of all needs to fabricate model systems at the nano level. This is a big challenge, but with the grant of 1,6 million SEK over a period of two years that he just received from the Engkvist foundation, the chances of success have improved.

"Since I am a researcher at the beginning of my career every person is a huge improvement and now I can hire a post doc to work with my group. This means that the project can be divided into sub parts and together we will be able to explore more possibilities about this new technology."

Provided by Chalmers University of Technology