Machine learning helps improving photonic applications

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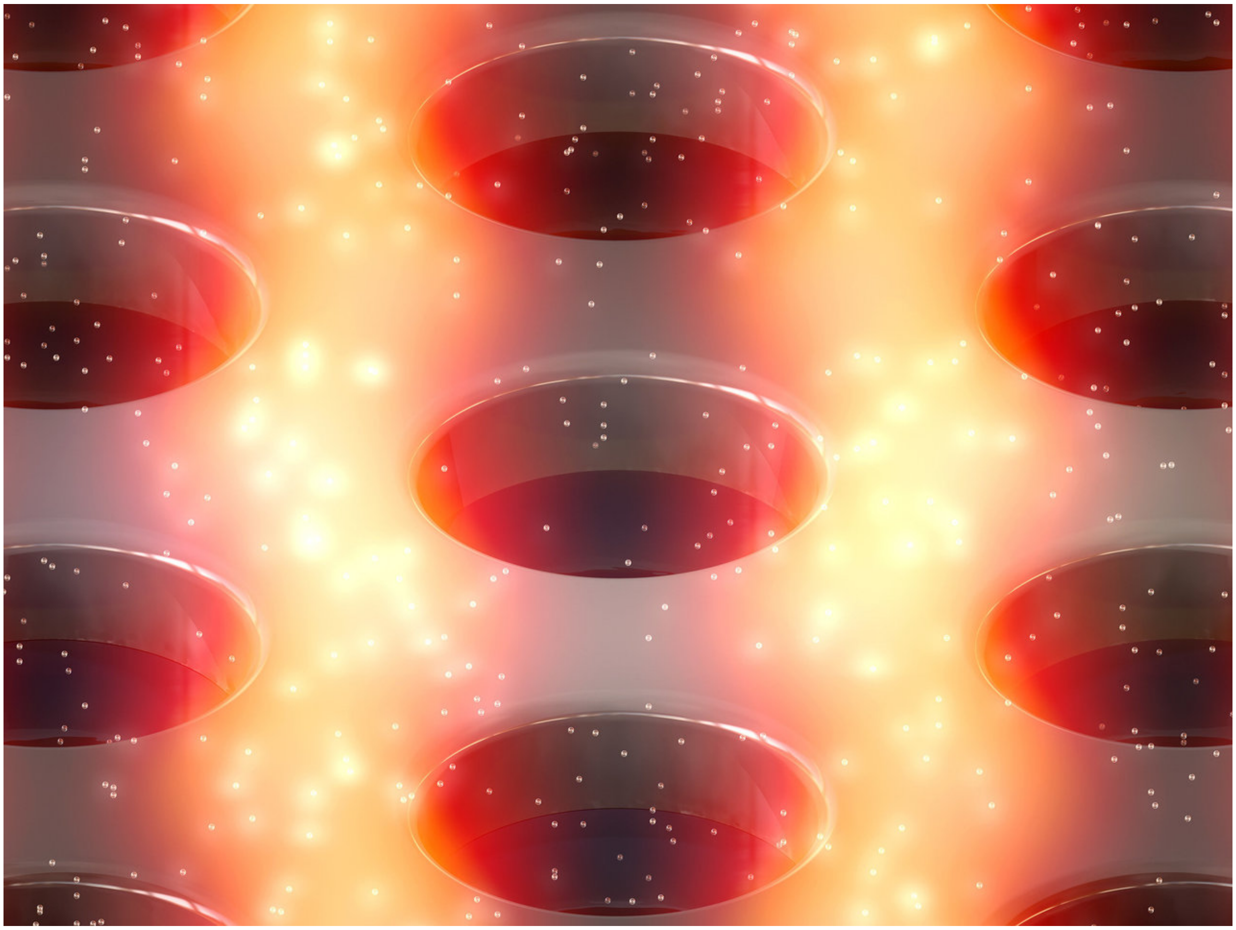

The computer simulation shows how the electromagnetic field is distributed in the silicon layer with hole pattern after excitation with a laser. Here, stripes with local field maxima are formed, so that quantum dots shine particularly strongly. Credit: Carlo Barth/HZB

Photonic nanostructures can be used for many applications besides solar cells—for example, optical sensors for cancer markers or other biomolecules. A team at HZB using computer simulations and machine learning has now shown that the design of such nanostructures can be selectively optimised. The results are published in *Communications Physics*.

Nanostructures can increase the sensitivity of optical sensors enormously—provided that the geometry meets certain conditions and matches the wavelength of the incident light. This is because the electromagnetic field of light can be greatly amplified or reduced by the local nanostructure. The HZB Young Investigator Group "Nano-SIPPE" headed by Prof. Christiane Becker is working to develop these kinds of nanostructures. Computer simulations are an important tool for this. Dr. Carlo Barth from the Nano-SIPPE team has now identified the most important patterns of field distribution in a nanostructure using machine learning, and explained the experimental findings.

The photonic nanostructures examined in the paper consist of a silicon layer with a regular hole pattern coated with quantum dots made of lead sulphide. Excited with a laser, the quantum dots close to local field amplifications emit much more light than on an unordered surface. This empirically demonstrates how the laser light interacts with the nanostructure.

In order to record what happens when individual parameters of the nanostructure change, Barth calculates the three-dimensional electric field distribution for each parameter set using software developed at the Zuse Institute Berlin. Barth analyzed these enormous amounts of data with other computer programs based on machine learning. "The computer searched through the approximately 45,000 data records and grouped them into about 10 different patterns," he explains. Finally, Barth and Becker identified three basic patterns in which the fields are amplified in specific areas of the nanoholes.

This allows the optimization of photonic crystal membranes based on excitation amplification for virtually any application. Some biomolecules accumulate preferentially along the hole edges, for example, while others prefer the plateaus between the holes, depending on the application. With the correct geometry and the right excitation by light, the maximum electric field amplification can be generated exactly at the attachment sites of the desired molecules. This would increase the sensitivity of optical sensors for cancer markers to the level of individual molecules, for example.

More information: Carlo Barth et al, Machine learning classification for field distributions of photonic modes, *Communications Physics* (2018). DOI: 10.1038/s42005-018-0060-1

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