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Light-Shrinking Device Enables Detection of Ultra-Tiny Substances

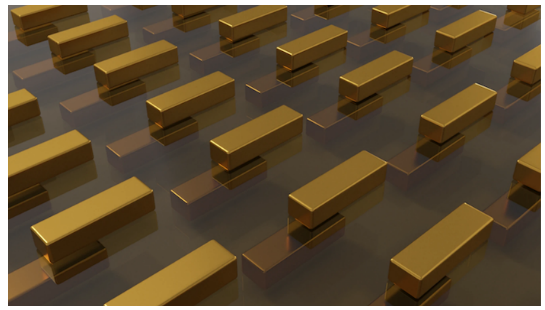

Illustration of the multilayered periodic plasmonic structure supporting exceptional points (EPs). Image courtesy of Kanté lab/Nature Physics

Engineers at the University of California San Diego and the University of California Berkeley have created light-based technology that can detect biological substances with a molecular mass more than two orders of magnitude smaller than previously possible. The advance was made possible by building a device that shrinks light while exploiting mathematical singularities known as exceptional points (EPs).

The research, published in *Nature Physics*, could lead to the development of ultra-sensitive devices that can quickly detect pathogens in human blood and considerably reduce the time needed for patients to get results from blood tests.

“Our goal is to overcome the fundamental limitations of optical devices and uncover new physical principles that can enable what was previously thought impossible or very challenging,” said Boubacar Kanté, associate professor of electrical engineering and computer sciences and faculty scientist at Lawrence Berkeley National Laboratory, who led the work while a professor of electrical and computer engineering at UC San Diego. “What I’m really excited about is the ability to implement such singularities at such a small scale. The results are both fundamentally exciting and practically important.”

The wavelength of light is much larger than the size of most biologically relevant substances. For light to strongly interact with these small substances, its wavelength must be reduced.

The researchers used plasmons, which are small fluids of electronic waves that can move back and forth in metallic nanostructures.

The group placed two plasmonic nano-antenna arrays on top of each other with each array producing plasmon resonances that control light waves of a certain frequency. The researchers then “coupled” the nano-antenna arrays, pushing the two waves to come together until they finally resonated at the same frequency and, most critically, lost energy at the same rate—a moment known as the exceptional point. This marked the first time researchers have used EPs for plasmons.

When an external substance comes into contact with the EP and disturbs the synchronized rates of lost energy, the device detects the substance with higher sensitivity.

"While many methods have been explored to make biosensors more sensitive, using the EP of coupled plasmonic nano-antenna arrays to raise sensitivity is a unique approach. It alters the basic relation between the signal and the target concentration (or copy number) from a simple linear relation to a square-root equation, which is key to the superb sensitivity of the design," said Yu-Hwa Lo, electrical and computer engineering professor at the UC San Diego Jacobs School of Engineering and co-author on the study.

The device detected anti-Immunoglobulin G in blood, the most common antibody in human blood to fight infection, at a molecular weight 267 times lighter than in previous reports using plasmonic arrays.

Adding additional plasmonic arrays to the original device could also further boost the sensitivity at the EP, Kanté said.

Paper title: "Symmetry-breaking-induced plasmonic exceptional points and nanoscale sensing." Co-authors include Jun-Hee Park, Abdoulaye Ndao, Wei Cai, Liyi Hsu, Ashok Kodigala and Thomas Lepetit.

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