Broadband enhancement relies on precise tilt

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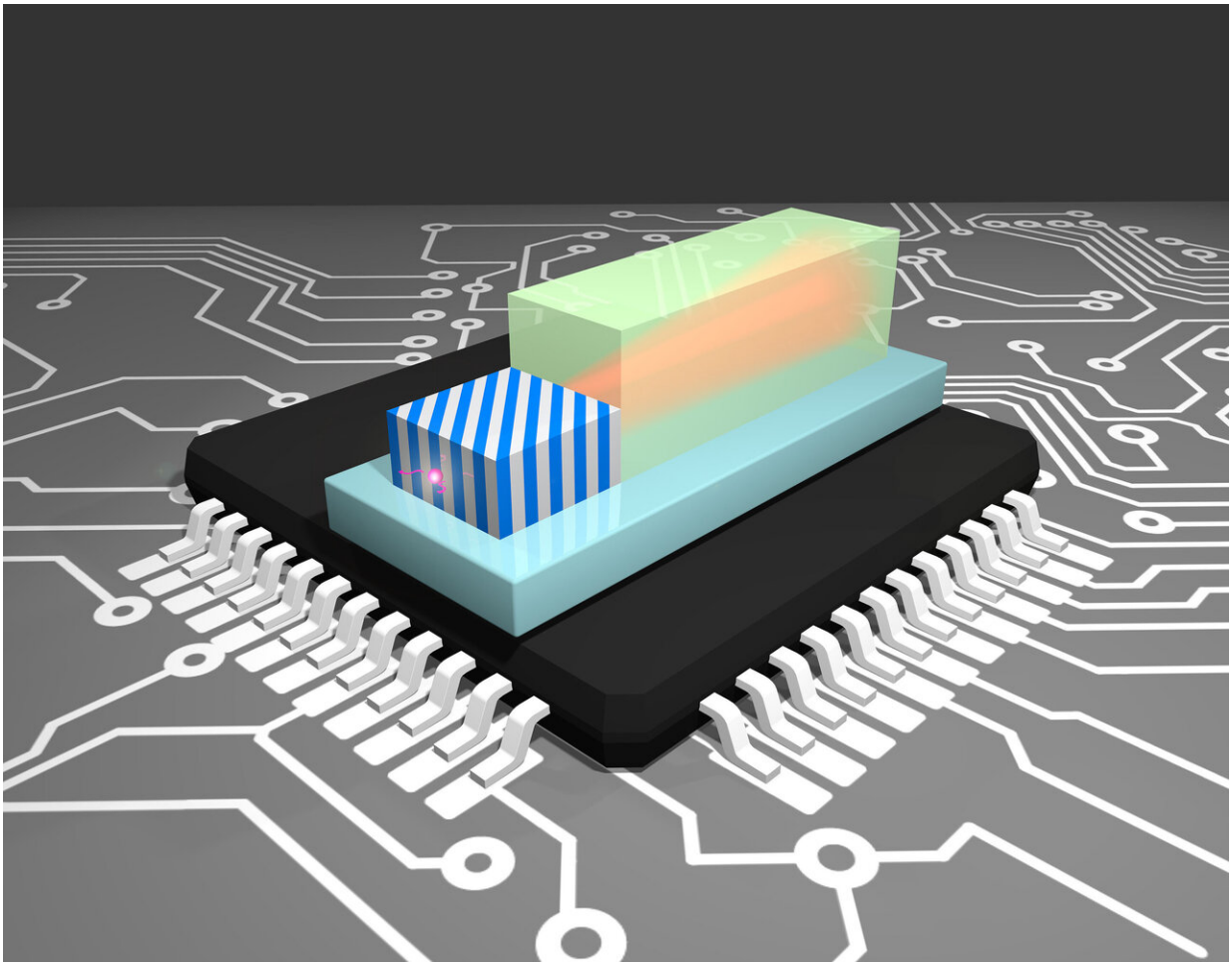

Broadband enhancement of the on-chip single photon extraction via tilted hyperbolic metamaterials. A quantum emitter is positioned very close to a hyperbolic metamaterial, whose optical axis is tilted with respect to the end facet of nanofiber. Credit: Lian Shen

Quantum photonics involves a new type of technology that relies on photons, the elementary particle of light. These photons can potentially carry quantum bits of information over large distances. If the photon source could be placed on a single chip and made to produce photons at a high rate, this could enable high-speed quantum communication or information processing, which would be a major advance in information technologies.

In this week's issue of *Applied Physics Reviews*, a simple on-chip photon source using a type of material known as a hyperbolic metamaterial is proposed. The investigators carried out calculations to show that a prototype using the hyperbolic metamaterial arranged in a precise way can overcome problems of low efficiency and allow for high repetition rates for on-chip photon sources.

Until recently, single-photon sources have usually been made from self-assembled quantum dots in semiconductors or from materials, like diamonds, with structural defects. It is difficult, however, to produce single photons at high rates from such materials. Some approaches to remedy this problem have been tried, but so far, the results suffer from a narrow bandwidth and low efficiency.

Another way to approach these problems is to use special materials, such as metamaterials, for the photon source. Metamaterials are stacks of metallic and dielectric layers, structured at a level much smaller than the wavelength of light in use. They exhibit unusual optical properties when formed into shapes, such as nanowires. Electrons flowing through the material set up a collective oscillation known as a surface plasmon, generating localized electromagnetic fields.

Hyperbolic metamaterials are highly anisotropic versions of these metamaterials. They manipulate light in a variety of ways. For example, they can shrink the wavelength of light and allow it to travel freely in

one direction while stopping it in another.

The investigators propose a geometry for their on-chip photon source where a hyperbolic metamaterial is tilted at a precise angle with respect to the end facet of the nearby nanofiber used to transmit the emitted photons. By choosing the tilt angle carefully, light reflections are suppressed at the interface with the fiber.

Calculations by the group showed that this simple geometrical arrangement should overcome previous limitations with these materials.

Co-author Lian Shen said, "Our work represents a vital step toward the implementation of spectrally broad single photon sources with high repetition rates for on-chip quantum networks."

More information: "Broadband enhancement of on-chip single photon extraction via tilted hyperbolic metamaterials," *Applied Physics Reviews*, aip.scitation.org/doi/10.1063/1.5141275

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