Breakthrough in nano-optics: Researchers develop plasmonic amplifier

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Researchers at the University of Iceland, University of Cologne and the Fraunhofer Institute Jena have demonstrated net optical amplification in a plasmonic waveguide.

The results of the team, which were published in the journal Nature Photonics this week, represent an important breakthrough in the field of plasmonics. Optical amplification is the only feasible strategy to make light travel over sizable distances when it is bound in a plasmonic mode. Achieving such a macroscopic propagation of surface plasma waves is critical for many applications of the emerging plasmonics technology, which range from compact communication devices and optical computing to the detection and characterization of cells, virus particles or even single molecules.

Research on plasmonics, a relatively new branch of optics, has received an increasing level of international attention over the last decade. This interest is mainly driven by the fact that surface plasmons, travelling along the interface between a metal and a dielectric, allow confining optical energy to volumes that are significantly smaller than those accessible with conventional dielectric waveguiding structures such as optical fibers.

Apart from being of fundamental interest on its own, tightly focused optical energy can be used as a 'nano-probe' which provides valuable measurements in fields like solid-state physics, chemistry and the life sciences. In addition, the tight confinement of the optical field is an interesting feature as it promises optical devices with reduced dimensions. This is of particular relevance for the field of optical communications, optical computing and hybrid microelectronic/optical circuits. However, under normal circumstances, optical energy travels over very short distances in plasmonic waveguides, before it is absorbed due to Ohmic loss in the metal.

Although clever design can somewhat increase the useful length of plasmonic waveguides, it is widely accepted that the only way to completely overcome this problem is to add a mechanism that continuously amplifies the light as it travels along the plasmonic waveguide. However, integrating such plasmonic amplification has turned out to be a challenging task. The team consisting of researchers from the University of Iceland, from Harvard University, and from the University of Cologne and the Fraunhofer Institute in Germany, developed a structure that provides sufficient amplification to overcome the intrinsic absorption of a plasmonic waveguide.

In fact, the optical amplification is sufficient to provide a net gain of the plasmon-bound light as it travels along the waveguide. The researchers used a structure consisting of an ultra-thin gold film that was embedded in a highly fluorescent polymer, optically pumped by an ultrafast laser source. The structure was designed to channel the light generated by the fluorescent polymer to the plasmonic waveguide. As the plasmonic wave travels along the waveguide, its intensity is increased by stimulated emission of the optical energy stored in the fluorescent polymer.

“For many years the propagation loss issue in plasmonic waveguides has been a major hurdle for the development of devices that make use of surface plasmon effects,” says Klaus Meerholz. “The key to the success of our work was that we found a way to embed the plasmonic waveguides into an amplifying fluorescent polymer without affecting the properties of the waveguide too much,” explains Malte Gather.

More information: Malte C. Gather, Klaus Meerholz, Norbert Danz, Kristjan Leosson, Net optical gain in a plasmonic waveguide embedded in a fluorescent polymer, in: *Nature Photonics* (30 May 2010), doi:10.1038/nphoton.2010.121

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