Nano Focus

Liquid gain provides real-time tuning of plasmonic lasing

The advent of the plasmon laser has revolutionized how nanoscopic features can overcome the diffraction limit of light. A recent collaboration between groups at Northwestern University and Duke University has achieved real-time dynamic tuning of the plasmon laser's wavelength. Their groundbreaking research produced devices in which the emission wavelength was controlled using the surrounding dielectric environment of a liquid gain medium rather than through physical doping of a solid-state medium or using a different dye molecule.

According to corresponding author Teri Odom (Northwestern), the design of this tunable plasmon laser "breaks the mold of conventional architectures" by using solutions of dye molecules as the gain medium rather than solid-state materials. "Liquid gain provides a simple and robust approach to achieve tunable lasing emission," she says. "We have discovered a way to tune the lasing wavelength simply by changing the gain medium—by changing the refractive index [of the liquid] the dye is dissolved in."

This work is described in the April 20 issue of *Nature Communications* (DOI: 10.1038/ncomms7939), where Odom, along with colleagues G.C. Schatz of Northwestern University, M. Mikkelsen of Duke University, and their colleagues created these dynamically tunable plasmon lasers from two-dimensional (2D) Au nanoparticle arrays surrounded by a liquid gain medium. The devices were fabricated according to a design strategy that arranged plasmonic resonators in a fixed 2D array so as to harness the band-edge plasmons of the Au nanoparticles (NPs), and produce lasing emission perpendicular to the substrate. The lasing emission was controlled based on interactions of the Au NPs with the surrounding dielectric environment, which included a range of substrates (polymers, glass, silica) and IR-140 dye molecules dissolved in an organic liquid as the gain medium.

By matching the refractive index of the liquid gain medium with that of the substrate, the lasing wavelength could be tuned over the entire dye bandwidth by changing the dielectric environment. To demonstrate this tunability, the group constructed a microfluidic channel containing a Au NP array and measured the lasing emission as they flowed organic liquids with different refractive indices through the channel while pumping with a femtosecond laser. By systematically changing the refractive index of the liquid gain medium, they realized reversible dynamic tuning of the lasing wavelength over a bandwidth of 50 nm.

"I think this work is a very clever and creative approach to achieve tunable plasmonic lasing in a fluidic environment," said Jennifer Dionne, an expert in plasmonic materials at Stanford University. She notes, "Among several exciting applications, this work could enable miniature coherent light sources for microfluidic arrays, and also significantly increase the sensitivity of lab-on-a-chip sensors. I commend the authors for some very nice experimental and theoretical work."

Although revolutionary, the concept of using a liquid as a gain medium has room for development. In order for this technology to be integrated into current devices, researchers will need to consider both temperature control of the liquid as well as methods to excite the gain medium that do not involve use of a femtosecond laser. If these challenges are met, lasing devices based on liquid gain materials will pave the way for studies of fundamental light/matter interactions and the realization of novel lasing technology.

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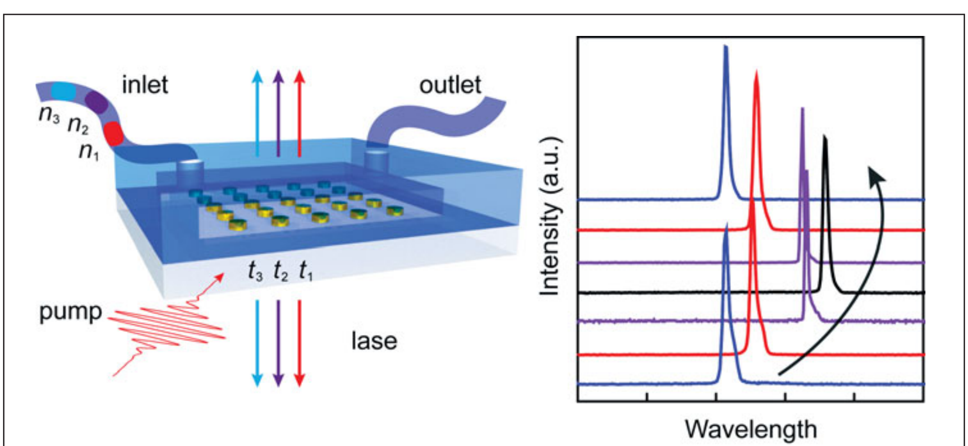

Schematic of a microfluidic device containing an Au nanoparticle array and the emission spectra showing a reversible shift in lasing wavelength with changing refractive index (*n*); *t* stands for time. Teri Odom, Northwestern University.