Nano Focus

Laser design emits multicolor light

The possibility of a single device that outputs multicolor laser light has long intrigued the laser research community. Most devices available today feature a highly stable, single-color output; multicolor output is only possible by combining many individual lasers. Now, scientists have developed the capability to generate multiwavelength lasing in a single device, with precise control over the different colors. They report their findings in a recent issue of *Nature Nanotechnology* (doi:10.1038/NNANO.201).

Lasers are traditionally composed of two mirrors that sandwich a "gain" material, in which light is amplified by bouncing between the two mirrors and is then partially transmitted through one of the mirrors. To ensure a stable output of a single color, the industry exploits stringent mode selection rules.

Several years ago, Teri W. Odom, professor of chemistry at Northwestern University, developed a new way to design laser cavities. Instead of mirrors, she based the cavity on periodic arrays of metal nanoparticles, which resulted in a lasing signal at the same wavelength as the single band-edge mode. Now she has expanded this work to an "array of arrays" of gold nanoparticles. These nanoparticle superlattices result in multiple band-edge modes and, therefore, when combined with optically pumped gain, can emit multiple colors.

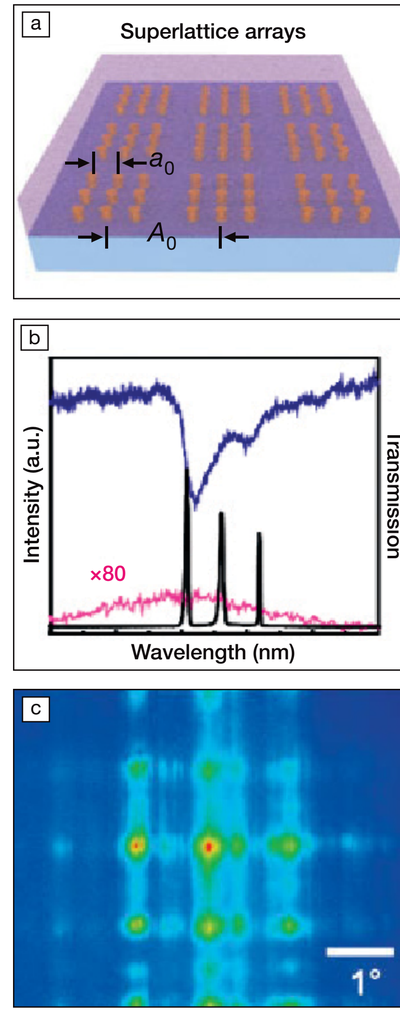
The multiple length scales in this architecture—hundreds of nanometers between particles, micron-sized patches of particles, and microscale separation between patches—were responsible for producing the multiple band-edge modes. If these modes overlapped with the gain bandwidth, simultaneous lasing at different wavelengths became possible. Odom controlled the specific lasing wavelengths and their intensities by changing the particle and patch size and spacing of the nanoparticle arrays.

"Our new work provides a strategy to eliminate costly fabrication processes and can directly produce multiple stable lasing peaks from a single device," Odom says. "More than that, we achieved active control of the wavelength and intensity of these multiple lasing beams by simply varying cavity architecture."

Shangjr Gwo, professor of physics at National Tsing Hua University in Taiwan, who was not involved in the study, observes that it would be interesting to see if this approach can also be applied to other gain media, such as two-dimensional semiconductor monolayers, and introducing multiple gain media for a wider lasing spectral range. "Their work opens the door to engineering slow light at multiple band edges, which is useful to manipulate strong light–matter interactions for lasing, nonlinear optics, and quantum optics," he says.

Odom's plasmonic nanolasers offer a step forward in chip-based laser designs and miniaturization. The nanoparticle superlattice arrays can easily be scaled and integrated with commercially available optoelectronic devices because they use similar top-down nanofabrication tools, and the substrates are patterned over large (>1 square inch) areas.

Compared to incandescent light bulbs, lasers are efficient light sources with many applications. Multiple-color nanolasers can be integrated as individual pixels in compact optical displays. Odom intends to design white nanolasers by simultaneously generating blue, green, and red wavelengths. "We should be able to change the 'whiteness' by controlling the relative intensity of the blue, green, and red channels, just as we can in our smaller wavelength range now," Odom says.



Multimodal nanolasing in (a) gold nanoparticle superlattices surrounded by liquid dye solutions; (b) lasing modes emerge from multiple band edges at both zero and nonzero wave vectors in the optical band structure; and (c) multiple lasing spots were detected in the far field from the superlattice arrays. Credit: Danqing Wang, Odom Group, Northwestern University.

Additionally, the work offers possibilities for ultrasensitive sensing in chemical processes and for live-cell imaging using multiple colors, since different dye-labeled cellular components would be excited by different colors.

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