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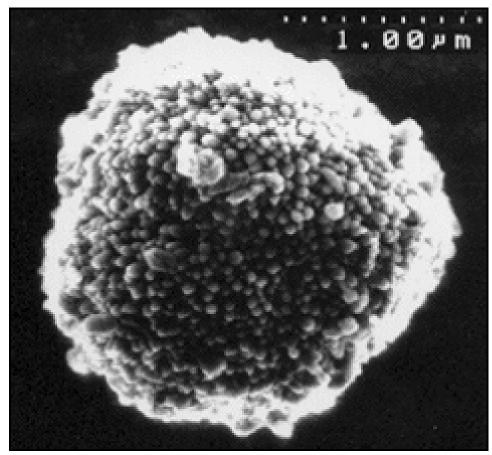
Disorderly Crystals Produce Laser Light

Richard Gaughan

EVANSTON, Ill. – Lasers are models of meticulous manufacturing processes and precision alignment. An agglomeration of randomly ordered nanocrystals is about as far from precision manufacturing as can be imagined, but researchers have observed lasing in just such a cluster of zinc oxide nanocrystals. The disorder not only does not interfere with the lasing, but is responsible for it. If development efforts live up to the promise of the early measurements, the microlasers could find applications as sources for optical computers or photonic crystals.



The disordered structure of zinc oxide clusters (left) would seem to preclude their use as a laser material, but the random scattering and interference phenomena in the clusters yield coherent 382-nm light (above). Courtesy of Hui Cao.

Hui Cao and her team at Northwestern University had postulated that strong scattering in a highly disordered structure would result in a mean free path of about half a wavelength. In such a situation, multiple scattering and wave interference phenomena can trap light, a condition called Anderson localization. Cao reasoned that confinement by Anderson localization would produce a laser cavity in these structures, so the team precipitated 1.7-µm-diameter ZnO clusters of roughly 20,000 randomly ordered nanocrystals to test the hypothesis.

When the researchers pumped the clusters with 15-ps pulses of 266-nm, fourth-harmonic light from a mode-locked Nd:YAG laser, the crystals exhibited lasing behavior. Above a threshold of about 0.3 nJ of pump power, the wideband output spectrum narrowed to one with a 0.22-nm-wide peak at 382 nm.

As the pump energy increased, additional confinement regions within the cluster also began to lase, and additional narrow peaks appeared in the output spectrum. The output energy curve, as measured over one-third of the spherical cluster, also exhibited a slope change indicative of reaching lasing threshold. The results of photon statistics measurements confirmed that the zinc oxide generates coherent light.

Future Lasers

Cao would like to lower the lasing threshold for the disordered-media laser, but the options may be limited. "Anderson localization predicts three-dimensional light confinement in a region of the dimension on the order of optical wavelength," she said. "It is very hard to achieve such 3-D confinement with ordinary mirrors. We are now trying to increase the scattering strength to improve the confinement and lower the lasing threshold."

For the present, she is intrigued by the paradoxical lasing from a random medium. "A disordered medium is usually regarded to be something messy and useless," she said. "It is amazing to see [that] coherent light, which is something ordered and good, is generated from the disordered medium."

Cao isn't taking all the credit, however. "It's exciting to see the self-formation of microcavities in a disordered medium. It seems that nature makes the microcavities for us."

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