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Disordered Films, Powders Exhibit Lasing Capabilities

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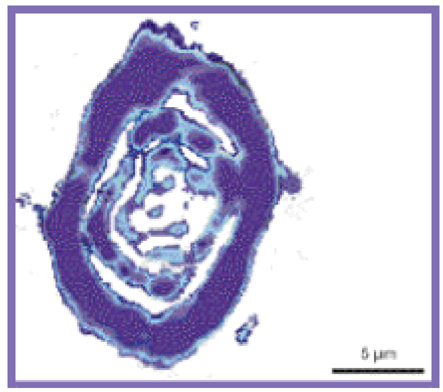
Semiconductor lasers may be brighter than light-emitting diodes (LEDs), but that advantage certainly comes at a premium. Now researchers at Northwestern University have demonstrated lasing in highly disordered films and powders, a development that should enable the manufacture of brighter displays at a lower cost than that of LEDs.



This amplified image shows how lasing occurs in closed loops when pump power crosses a particular threshold. The excitation spot is ~35 µm in diameter.

The interdisciplinary team recently reported in *Applied Physics Letters* the laser action in zinc oxide polycrystalline thin films grown directly on an amorphous fused silica substrate. Unlike conventional semiconductor lasers -- which have well-aligned hexagonal grains in films that must be epitaxially grown on templates -- the Northwestern group has demonstrated 380-nm lasing that requires neither epitaxial growth nor templates.

Researchers have since demonstrated the lasing ability in ZnO and gallium nitride powders as well, which can be spread easily on glass, plastic or any other substrate. ZnO, in particular, is inexpensive, readily available and easy to work with, said Robert P.H. Chang, who led the research. He is a professor of materials science and engineering and director of the university's Materials Research Center. The team also includes Hui Cao, an assistant professor of physics and astronomy, and Seng-Tiong Ho, an associate professor of electrical and computer engineering.

"We did the polycrystalline films first," Chang said. "It's pretty poor quality, and yet it works like a charm. So then I said, 'Gee whiz, I don't need it. Zinc powder works, too.' "

Using transmission electron microscopy, the researchers have seen that the ZnO films are highly disordered, with grain sizes ranging from 50 to 150 nm. In the powder experiments, grain sizes averaged 100 nm. Although grain size is important, Chang said, he did not want to go into further detail for proprietary reasons.

The experimental setup uses a frequency-tripled mode-locked 355-nm Nd:YAG laser to pump the powder or film. The pump beam is focused on the surface with a spot or stripe of 40 to 100 µm. The powder or film begins to lase as the excitation intensity reaches 400 kW/cm^2, although oscillation stops if the excitation area is too small.

Rather than forming well-defined cavities with mirrors, the cavities are self-formed by strong optical scattering in the ZnO material. This is typically considered detrimental to lasing, but the researchers found that particularly strong optical scattering induces lasing by forming closed loop paths for the light.

Unlike other semiconductor lasers, the emission from this laser can be seen from all directions. The powder, in fact, emits three-dimensionally, Chang said. This makes the laser particularly suited for display applications, offering much better viewing angles than typical flat panel displays and emission that is 1000 times brighter than LEDs. With the potential to manufacture the devices so inexpensively, Chang hopes to exploit their capabilities in the toy market. Although an Nd:YAG has been used in research to pump the material, that will have to be changed for practical uses, he said.

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