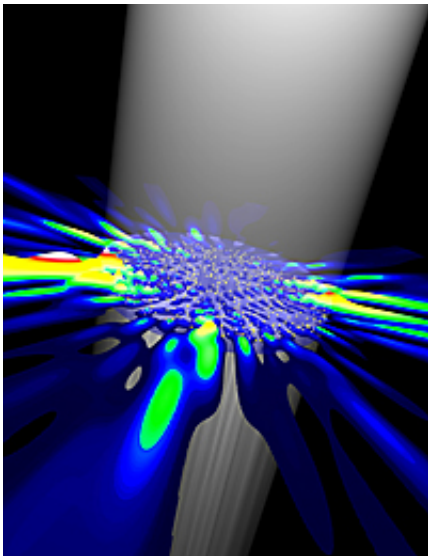


# New unifying theory of lasers advanced by physicists

May 27 2008

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The image shows an artists rendering of a random laser that is pumped with incoherent light from the top and emits coherent light in random directions. (Courtesy of Robert Tandy & Science Magazine).

Researchers at Yale and the Institute of Quantum Electronics at ETH Zurich have formulated a theory that, allows scientists to better understand and predict the properties of both conventional and non-conventional lasers, according to a recent article in *Science*.

“The lasers that most people are familiar with emit a narrow beam of light in a fixed direction that has a well-defined wavelength and a

predictable power output — like those in laser pointers, bar-code readers, surgical instruments and CD players,” said senior author A. Douglas Stone, the Carl A. Morse Professor of Applied Physics at Yale.

In these conventional lasers, the light is trapped and amplified between parallel mirrors or interfaces and bounces back and forth along one dimension. Scientists can determine what the light output will be based on the “leakiness” of the mirrors, which is usually quite small.

But, a new breed of lasers — diffusive random lasers (DRLs) — made possible by modern nanofabrication capabilities, consist of a simple aggregate of nanoparticles and have no mirrors to trap light. These lasers were pioneered by Hui Cao, now a professor of applied physics at Yale, and have been proposed for applications in environmental lighting (“laser paint”), medical imaging and displays. Until now, there has been no simple way for scientists to predict the wavelengths and intensities of the light emitted by DRLs.

Although, superficially, conventional lasers and DRLs appear to operate very differently, experimental results indicated many basic similarities, and scientists have searched for a unifying description that would apply to all lasers.

The properties of a laser are determined by measuring the lasing modes, including the pattern of light intensity within the laser, and the wavelengths of light it puts out. With conventional lasers, these modes can easily be obtained through simulations.

“For random lasers, time-dependent simulations are difficult to do, hard to interpret, and don't answer the question: ‘What is the nature of the lasing modes in a random laser,’” according to Stone. “Researchers really wanted a description similar to that for conventional lasers, but no one knew how to develop such a description.”

To create their unifying theory, the researchers derived a wholly new set of non-linear equations that fit both conventional and non-conventional lasers — such as the DRL or other nanostructured lasers. Based on these equations Stone, his former PhD student Hakan Tureci, now at ETH Zurich, and two other members of Stone’s research group, Li Ge and Stefan Rotter, created a detailed computer code that can predict all the important properties of any kind of laser from simple inputs.

“The state of laser theory after forty years was an embarrassment; it was essentially qualitative, but not predictive or quantitative,” says Stone. “We went back to the basics — and we think we have now solved that problem.”

A “Perspective” review of the theory in the same issue of Science noted, “By developing a new theory in which the main properties of a laser can be physically understood . . . they have provided a substantially broader perspective of laser physics that unifies the physical description of many possible laser structures.”

“Ultimately, we hope that our code can be used as a design tool for new classes of micro- and nano-lasers with important applications” says Stone, who also believes that eventually their theory will become part of the answer to the question: “How does a laser work?”

Citation: Science 320: 643-646. (May 2, 2008) [DOI: 10.1126/science.1155311]

Source: Yale University

Citation: New unifying theory of lasers advanced by physicists (2008, May 27) retrieved 25 April 2024 from <https://phys.org/news/2008-05-theory-lasers-advanced-physicists.html>

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