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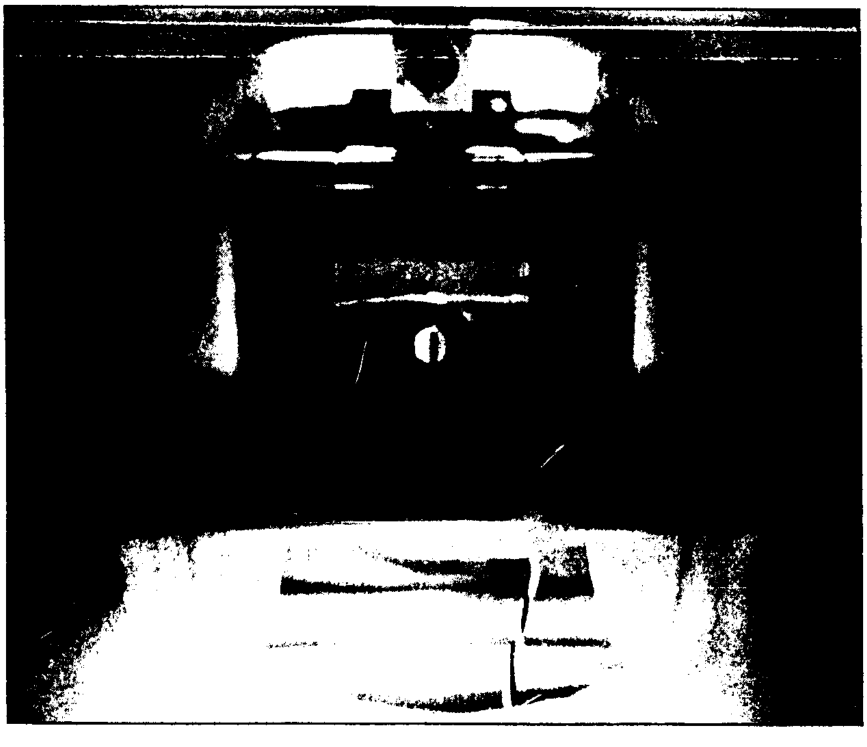
Single-Atom Laser Glows in MIT Lab

CAMBRIDGE, Mass. — Massachusetts Institute of Technology researchers have successfully obtained laser oscillation and emission from a single atom, a long-sought advance in laser physics.

The single-atom laser, which the researchers call a microlaser, was the product of PhD thesis research by Kyungwon An, a student from Seoul, Korea, under the direction of Michael S. Feld, a physics professor who directs MIT's George R. Harrison Spectroscopy Laboratory. A report on the achievement appeared in the Nov. 21 issue of *Physical Review Letters*.

"This development has been long sought, and it is expected to lead to further fundamental advances in our knowledge of light and its interaction with atoms," Feld said.

Today's lasers use many billions of atoms or molecules to achieve the photon multiplication required to generate coherent light. These lasers are inefficient in terms of emissions per atom in the gain medium and resonator losses.



A close-up of the microlaser. The supercavity mirrors, separated by 1 mm, are seen in the white circle in the center. The vertical black bar cutting the circle is the gap, and the white "halves" of the circle are the mirrors. Photo by Kyungwon An.

The MIT researchers realized that the key to developing a single-atom laser was to use a strong atomic transition in an extremely efficient resonator. Use of a single atom is then actually helpful because it is not affected by perturbations of neighboring atoms.

In their microlaser, the researchers flow excited barium atoms through a 1-mm-wide supercavity at a rate of about 4 million atoms per second so that one atom or less is inside the resonator at any moment. Laser operation begins when an atom emits a photon into the empty resonator. Each successive atom may then emit more photons, leading to an equilibrium state in which the energy loss due to the cavity decay is exactly canceled by the energy injected by the excited atoms.

Unlike an ordinary laser, however, the microlaser never reaches a steady state because atoms continue to undergo atom-photon Rabi oscillations, so the mean photon number changes during an atom's 270-ns passage.

With an average of one atom inside the resonator, the researchers measured an emission rate of more than 10 million laser photons per second, with about 11 photons stored in the resonator. (Emission was at 791 nm.)

The researchers overcame several technical obstacles on the way to their laser. They developed an ultrastable resonator and a pump laser that would stay in tune with the barium's atomic transition. They also created a high-efficiency detection scheme, using an avalanche photodiode to achieve a 36 percent counting efficiency — far superior to conventional photomultiplier tubes at this wavelength.

The microlaser is of great theoretical interest to the field of cavity quantum electrodynamics, which studies the interaction between atoms and the electromagnetic field mode of a resonant cavity.

The researchers have already discovered some surprising features of microlaser operation. For example, when the average