power of 430 mW. Slope efficiency was 25%. The maximum output power of the crystal was found to be 139 mW at approximately 747 nm with the pump laser diode operating at maximum capacity.

The researchers said that their previous work with the material showed that most of the power was absorbed in the material. The conclusion of the study was that the microchip laser system they designed can operate near wavelengths that produce visible/near-infrared radiation. And with further optimization the technology can be directly applicable to a variety of industries requiring infrared lasers.

**Tara Washington**

## Plasma conditions measured in bubbles imploded by extreme sonoluminescence

High-intensity ultrasound waves traveling through liquid leave bubbles in their wake. Under the right conditions, these bubbles implode spectacularly, emitting light and reaching very high temperatures, a phenomenon called sonoluminescence. Researchers have observed imploding bubble conditions so hot that the gas inside the bubbles ionizes into plasma, but quantifying the temperature and pressure properties has been elusive.

Now University of Illinois professor Kenneth S. Suslick and former student David Flannigan, now at the California Institute of Technology, have experimentally determined the plasma electron density, temperature, and extent of ionization.

Suslick and Flannigan first observed super-bright sonoluminescence in 2005 by sending ultrasound waves through sulfuric acid solutions to create bubbles.

“The energies of the populated atomic levels suggested a plasma, but at that time there was no estimate of the density of the plasma, a crucial parameter to understanding the conditions created at the core of the collapsing bubble,” said Suslick, the Marvin T. Schmidt Professor of Chemistry and a professor of materials science and engineering.

The new work, published in the June 27th online edition of *Nature Physics* (DOI: 10.1038/NPHYS1701), uses the same setup, with a solution of concentrated sulphuric acid (85 wt%) containing Ar at 5% of saturation. The new work contains a detailed analysis of the shape of the observed Ar emission spectrum, which provides information on the conditions of the region around the atoms inside the bubble as it collapses.

Plasma emission from collapsing bubbles: The imploding bubbles move around after each collapse, tracing out a lit path, like a person flinging their arm around while holding a flashlight. Photo courtesy Hangxun Xu and Ken Suslick.

“The temperature can be several times that of the surface of the sun and the pressure greater than that at the bottom of the deepest ocean trench,” Suslick said.

“What’s more,” he said, “we were able to determine how these properties are affected by the ferocity with which the bubble collapses, and we found that the plasma conditions generated may indeed be extreme.”

The researchers observed temperatures greater than 16,000 K—three times the temperature on the surface of the sun. They also measured electron densities during bubble collapse similar to those generated by laser fusion experiments. However, Suslick said that his group has not observed evidence that fusion takes place during sonoluminescence, as some have theorized possible.

In addition, the researchers found that plasma properties show a strong dependence on the violence of bubble implosion, and that the degree of ionization, or how much of the gas is converted to plasma, increases as the acoustic pressure increases.

“It is evident from these results that the upper bounds of the conditions generated during bubble implosion have yet to be established,” Suslick said. “The observable physical conditions suggest the limits of energy focusing during the bubble-forming and imploding process may approach conditions achievable only by much more expensive means.”