Photonics Research | July 2006

Microcavity Is Sensitive Detector for Heavy Water

Sensitivity boosted by factor of 30 over other techniques.

Researchers at California Institute of Technology in Pasadena have demonstrated a technique for detecting heavy water (D_2O) that is 30 times more sensitive than the best competing approach. They fashioned a tiny optical microresonator from silica and immersed it in varying concentrations of D_2O in H_2O. Because H_2O has greater optical absorption than D_2O, the cavity had a lower Q in solutions with a higher concentration of H_2O. Using the method, the scientists have detected D_2O concentrations as low as 10^{-4} percent.

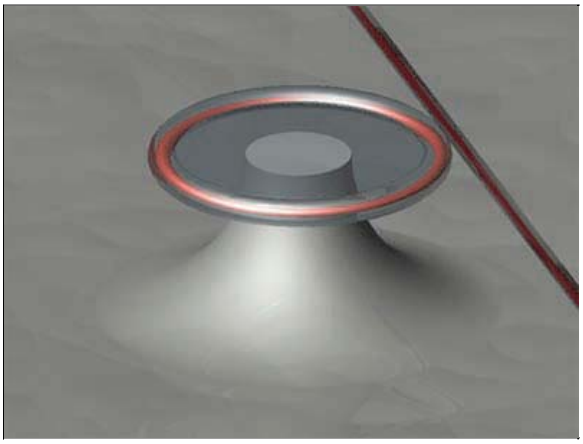

Figure 1. *The toroidal optical microcavity is on resonance whenever the light coupled into it from the adjacent waveguide has a wavelength that fits an integral number of times around the ring's circumference. The sharpness of a resonance (i.e., the cavity's Q) depends on the optical absorption of the fluid in which the cavity is immersed. Because heavy water has lower absorption than normal water, the microcavity is a sensitive detector of heavy water. Images ©OSA.*

The microcavity is a silica toroid approximately 150 µm in diameter (Figure 1). A tapered waveguide, fabricated by softening a SMF-28 fiber and pulling it to an 1-µm-diameter waist, coupled light from a tunable, single-mode diode laser at ~1320 nm into and out of the microcavity. To determine the microcavity's Q, the researchers tuned the laser across a microcavity resonance and measured its bandwidth.

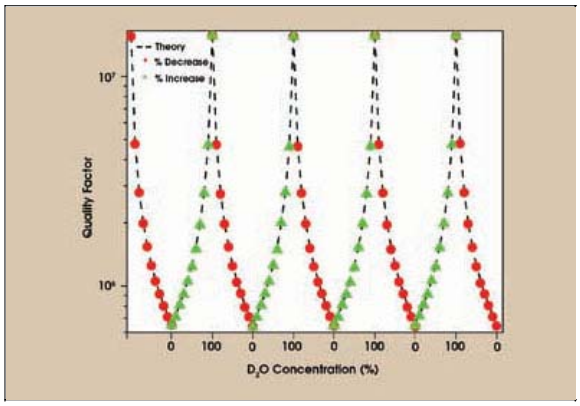

Figure 2. *The microcavity Q changed by more than an order of magnitude as the fluid in which it was immersed changed from pure heavy water to pure normal water.*

In their initial experiment, they immersed the microcavity in varying concentrations of D_2O in H_2O, starting with pure D_2O and winding up with pure H_2O. They decreased the D_2O concentration by 10 percent each time, recorded the spectrum at each stop and flushed their apparatus carefully between steps. They observed that the

microcavity Q decreased from more than 10^7 to less than 10^6. They then stepped their way back to pure D_2O, demonstrating that the method is reversible, and performed this measurement cycle several times, demonstrating that it is repeatable (Figure 2).

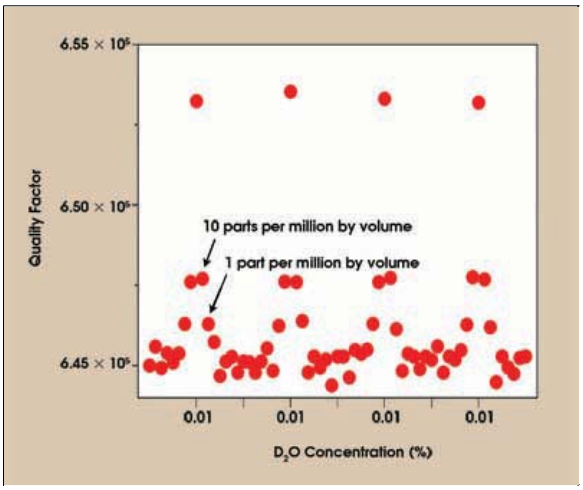

Figure 3. *The researchers recorded a strong signal from the heavy water when its concentration was 10^{-3} percent (10 parts per million by volume) and a weak but identifiable signal when its concentration was 10^{-4} percent (1 part per million by volume).*

To quantify the sensitivity of the technique, the Caltech scientists repeated the experiments with much lower D_2O concentrations. This time, they varied the D_2O from 10^{-2} to 10^{-9} percent. They noted a strong D_2O signal at a concentration of 10^{-3} percent and a weak but identifiable signal at 10^{-4} percent (Figure 3). They believe that even greater sensitivities are possible with the technique because they made no serious attempts to reduce operational sources of noise in their experiments.

Optics Letters, June 15, 2006, pp. 1896-1898.

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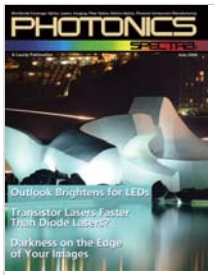

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