NONLINEAR OPTICS

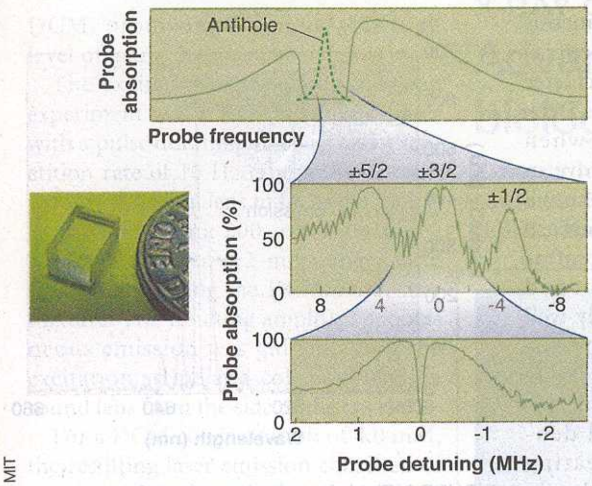
Crystal slows and stops light

When properly manipulated by laser pulses, Bose-Einstein condensates (BECs) made of magnetically trapped clouds of atoms cooled to near absolute zero can slow and even stop light (see *Laser Focus World*, April 1999, p. 16). Such atomic clouds, however, are difficult to create and maintain. Scientists at the Massachusetts Institute of Technology (MIT; Cambridge, MA), Texas A&M University (College Station, TX), the Electronics and Telecommunications Research Institute (Daejon, South Korea), and the Air Force Research Laboratory (Hanscom AFB, MA) are now slowing light in the same manner with a crystalline solid cooled to 5 K. The crystal is easy to mount and work with.

As with a BEC, the crystal slows light by a phenomenon known as electromagnetically induced transparency (EIT), in which two laser beams—a coupling beam and a probe beam—intersect within the material, causing quantum interference and thus optical transparency within a narrow passband. Most solids have broad optical linewidths that limit this effect, but one crystal—praseodymium-doped yttrium silicate—exhibits spectral hole burning, enabling EIT to occur. The researchers chose a commercially available crystal containing 0.05 atomic percent praseodymium. The crystal is 3 mm thick with polished, antireflection-coated entrance and exit faces.

A single dye laser produces 606-nm light that is shifted in frequency by acousto-optic devices to generate the required frequencies. Because the coupling and probe beams cause spectral hole burning in the crystal and thus reduced optical absorption, a third auxiliary beam creates an absorbing "antihole," providing a high optical density for EIT—which then produces a very narrow passband within the antihole (see figure).

The narrower the antihole width is, the less work the coupling beam has to do to achieve EIT. Laser jitter causes the antihole width to be on the order of 2 MHz; a more stable laser would reduce the width to less than 100 kHz. But because even 2 MHz is much narrower than the



A schematic of electromagnetically induced transparency (EIT) in a praseodymium-doped yttrium silicate crystal shows the inhomogeneous optical absorption line (top), an antihole created by an auxiliary laser beam (center), and the narrow EIT passband (bottom). The scan of EIT shows an efficiency of close to 100%. The crystal itself is smaller than a dime (inset).

4.4-GHz intrinsic inhomogeneous width of the optical transition, a low coupling intensity is sufficient to establish EIT. In one example, the intensities are 470 W/cm^2 for the coupling beam, 1.1 W/cm^2 for the probe beam, and 47 W/cm^2 for the auxiliary beam.

The group velocity of the light to be slowed is measured with a chopper and a lock-in amplifier. A group delay of 65 μs was observed, which corresponds to a light speed of 45 m/s within the crystal. The researchers also slowed individual light pulses. Because EIT-induced slowing of pulses depends mostly on the intensity of the coupling beam rather than the probe (pulse) beam, the crystal can slow pulses with complex shapes without altering them.

By reducing the intensity of the coupling beam to zero, the researchers brought light pulses to a halt, trapping them in the crystal. Restoring the coupling beam got the pulses moving again. Such a scheme will be important for quantum computing, in which single photons will be stored and then read out, says Selim Shahriar, one of the MIT researchers. In another application, light slowed to under the speed of sound within the crystal will enable novel Brillouin scattering effects, notes Shahriar.

John Wallace

DYE LASERS

High-gain media leads to potent dendrimer laser

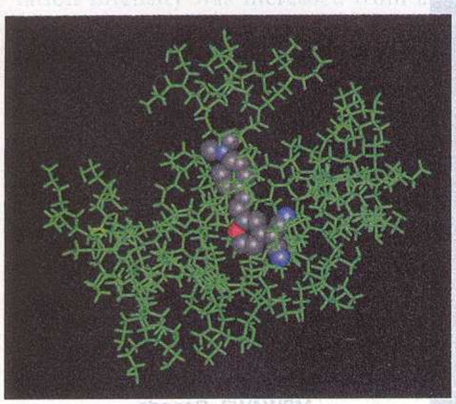


FIGURE 1. The DCM dye nestles in the branches of a large polymer dendrimer molecule.

Researchers at the Communications Research Laboratory (Kobe, Japan) have reportedly demonstrated dye lasers with mirrorless cavities and spectral linewidths of less than 0.1 nm using hyper-structured material called dendritic macromolecules, or dendrimers, as the active laser medium.[1] Such dendrimer lasers, combined with the flexibility and tunability of organic lasers, could soon enable lasers as small as 100 nm in size.

Conventional organic laser dyes produce a large fluorescence yield, but typically are limited to low dye concentrations of less than 1 mM/l