Information Storage in Three Dimensions

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For the first time, researchers have successfully turned a glass material into three-dimensional information storage using a light-based technique. This achievement may be a big step forward for the real-life implementation of such materials, which have the potential to store terabits of data (1,000 gigabits, or about 125 gigabytes) in just a single cubic centimeter.

The research was performed by scientists from the University of Bordeaux 1, one of the four universities in Bordeaux, France. The work is described in a paper published in the February 13, 2008, online edition of *Optics Letters*.

“The necessity for increasing data storage capacity of memory devices, along with the growth of high-density technologies, requires the use of three-dimensional optically based systems,” said physicist Lionel Canioni, one of the paper's authors, to *PhysOrg.com*.

There are a few methods being explored for optical-based three-dimensional information storage. One method is based on the phenomenon of “photochromism,” which, simply put, is when a material can reversibly change color -- i.e. undergo a chemical change -- when exposed to electromagnetic radiation (light). An everyday example are “transition”-type sunglass lenses.

Photochromism is an example of “single-photon” excitation, meaning that each photon in the light source (such as a laser beam) excites a single electron in the material. When those electrons quickly become deexcited, they each emit a single photon with almost the same energy as the absorbed photon.

Another promising method, explored by Canioni and his colleagues, involves multi-photon excitation—the excited electrons each absorb multiple photons—and is therefore a bit more sophisticated. Because each electron that is excited absorbs more than one photon, the laser interacts with a smaller volume of material. This allows the storage material to be activated with a higher spatial resolution in three dimensions, which allows for a larger information storage density.

The material the group used is a specific type of zinc phosphate glass that contains silver ions. The samples are one millimeter thick, colorless, and highly polished. The researchers irradiated the samples with very short, intense pulses of a laser beam, which were focused 200 micrometers (µm, or millionths of a meter) into the sample. The group varied the laser power and the number of pulses the sample received, and measured how the irradiated area of the material absorbed and re-emitted the light.

They noticed that the irradiation caused the silver atoms to form closely packed clusters with a nanoscale size comparable to that of molecules. At certain values of laser power and number of pulses, the silver clusters re-emitted the laser light at a key frequency—specifically, a frequency three times as high as the laser light, known as the third-harmonic. The researchers used the beam from an intense laser to “write” information into the material. The same beam, but with a lower intensity, induces the third-harmonic from the clusters, which is used to read the information out.

At about the 200 µm depth, the group wrote three layers of information, each layer containing a 12-by-12 grid of bits with a bit spacing of 3 µm and a layer spacing of 10µm (which corresponds to a gigabit per square centimeter). In the first, second, and third layers, respectively, Canioni and his colleagues wrote the letter “U,” the letter “B,” and the number “1” (for University of Bordeaux 1), using the bits to form the characters.

They tested the permanence of the images by subjecting the samples to heat treatments. Only when subjected to a temperature of 400 °C for 20 minutes did the written information vanish as the glass reorganized itself. After re-polishing the samples, the information could be rewritten.

Said Canioni, “We can state that the recording is very stable in standard conditions (up to 85 °C). The third-harmonic signal is not modified, even after several hours of unstopped exposure.”

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