

K^+K^-n events. The peak, centered at 1.54 ± 0.01 GeV, rose 4.6 standard deviations (σ) above the nonresonant background. The invariant masses were subjected to a rough correction for the nonzero momenta of the target neutrons inside the nuclei. Given the experiment's resolution, the SPRing-8 group could only say that the peak's intrinsic width was less than 25 MeV.

If this is indeed the predicted Θ^+ , it must be an isospin singlet. That is, it must appear only in the charge state $+1$. That seems to be confirmed by the absence of a 1.54 GeV peak in the K^+p invariant-mass distribution for events created in an alternative liquid-hydrogen target.

So provocative a result, overturning four decades of conventional wisdom, cries out for confirmation. The next reported sighting of the Θ^+ , appearing on the Web in April, was almost archaeological.² On dusty shelves at the Institute of Theoretical and Experimental Physics (ITEP) in Moscow lay long-abandoned bubble chamber film from a 1986 experiment in which Anatoli Dolgolenko and colleagues had exposed a liquid-xenon bubble chamber to an 850-MeV-momentum K^+ beam from ITEP's small proton synchrotron.

The bubble chamber is long gone. But in 1999, having learned of the Θ^+ prediction, Dolgolenko and a handful of intrepid colleagues undertook to rescan the old film for events in which the K^+ produced a K^0 (that decayed to $\pi^+\pi^-$) together with a proton and an unseen recoil nucleus. Protons and pions were identified by the bubble densities of their tracks, and their momenta were determined from stopping ranges in the xenon.

All this took three years, there being no money to hire scanners. In the final sample of 541 events, the K^0p mass peak, centered at 1539 ± 2 MeV, rose 4.4 σ above background. Its measured width yielded an upper limit of only 9 MeV on the intrinsic width of the resonance, a tribute to the excellent resolution of old-fashioned bubble chambers.

The unusually narrow width of the Θ^+ is an issue that theorists are grappling with. And it's getting more difficult every day. In August, Richard Arndt and colleagues at George Washington University reported a reanalysis⁶ of the world's low-energy K^+ -nucleon scattering data, mostly from the 1960s and 70s. From the fact that these old data show no clear evidence of the Θ^+ , they conclude that its intrinsic width cannot be larger than about 1 MeV!

The most statistically significant Θ^+ peak thus far was reported in July

Composite Molecules Store Rewritable Digital Data

In today's world of DVDs and gigabyte hard drives, storing data on magnetic tapes seems rather quaint. But tape remains a choice medium for archiving very large volumes. Unlike a magnetic disk, a tape can be wound up to create a capacious, three-dimensional data store. Of course, rewinding the tape to reach the bytes you want takes time. An ideal storage medium would combine tape's compact three-dimensionality with a disk drive's speedy access.

Fourteen years ago, Peter Rentzepis and Dimitri Parthenopoulos of the University of California, Irvine, developed a prototype aimed toward realizing that ideal. They embedded a transparent matrix with photochromes—molecules that flip between two stable structures in response to light of the right frequency. Subvolumes of the matrix, each containing several thousand photochromes, served as the data bits.

To write a bit, Rentzepis and Parthenopoulos pointed two perpendicular laser beams at the corresponding subvolume. Ordinarily, the light would pass right through without absorption. But the combined frequency of two beams was set at just the right value to trigger the molecular shape shift. Provided the beams were intense enough, a nonlinear two-photon absorption process would kick in, and where the beams converged, the bit would flip from zero to one.

For their original prototype, the researchers used a single molecular species, spiropyrans, which fluoresces in one of two structural states and thereby provides the means, in principle, to read the bits. Unfortunately, spiropyrans' shape-shift band overlaps with its fluorescence band. In a practical device, reading would cause writing.

Now, Rentzepis and his Irvine colleagues Alexandr Dvornikov and Yongchao Liang have found a way to solve the overlap problem.¹ Instead of trying to find a single molecule for the job, the group made a new molecule by grafting together a photochrome and a dye molecule.

Although the concept sounds simple, creating a composite molecule proved tough. To work, the composite not only has to have separated bands, but it should also retain the photochromicity and fluorescence of its components. Moreover, it should fluoresce in only one of its two photochromic states.

After two years of painstaking lab work, the group found the right pair of molecules. The photochrome, a fulgimide, has a polar, open form and a nonpolar, closed form. Violet light of 400 nm in wavelength converts the polar form to the nonpolar form. Green, 530-nm light reverses the change. For the dye, Rentzepis chose oxazine, whose red 650-nm fluorescence appears only in nonpolar environments.

Rentzepis hoped the fulgimide's polarity would control the combined molecule's fluorescence. That turns out to be the case—provided the chemical link between fulgimide and oxazine is close. Both species have terminal pentene groups. Liang, a synthetic chemist, found that the best linkage occurs when one molecule—fulgimide, say—gives up its terminal pentene ring and shares oxazine's.

How does the composite perform? When embedded in transparent plastic, the molecules switch state in picoseconds and do so reliably over 10 000 cycles. The accompanying figure shows a 90-mm-diameter, 6-mm-thick test disk, illuminated with red light to generate fluorescence. Green light wrote the letter A. Violet light erased the disk. Green light rewrote the letter B.

Inevitably, creating a practical device will involve surmounting a host of obstacles, among them the inefficiency of two-photon absorption. But the potential is clear. With its storage density limited ultimately by the wavelength of laser light, photochromic storage could pack 100 terabytes of data into a volume the size of a matchbox.

Charles Day

Reference

1. Y. C. Liang, A. S. Dvornikov, P. M. Rentzepis, *Proc. Natl. Acad. Sci. USA* **100**, 8109 (2003).

