

the particularly high concentration of the chromophore. There's a limit to how dense you can pack the chromophores before they start to crystallize and the material becomes opaque. At a concentration of 50% DMNPAA, the Arizona group is pushing the limit. Few other research groups have been able to make optically clear composite mixtures with such high fractions of chromophores. Perhaps his group succeeded, Peyghambarian said, because they had such a uniform compound, largely free of impurities that could cause crystallization.

To read and write holograms into their polymer device, Peyghambarian and his colleagues used small diode lasers, operating at a power of just 1–2 milliwatts. The cover of this issue is a photograph of a three-dimensional image of a penny that was retrieved from holographic storage in the new material; the red color reflects the 675-nm wavelength used to read and write the image.

Photorefractive materials can be used for other types of optical processing besides storing holograms. For example, if you send two beams through a sample, the weaker beam can exchange energy with the stronger one, growing in intensity. The Arizona researchers measured a net optical gain coefficient of about 210 cm^{-1} in their compound. For a sample with a thickness of about 100 microns, this coefficient enables the image to be amplified by a factor of 10 or so. A typical value for the gain coefficient in an inorganic crystal is $20\text{--}50 \text{ cm}^{-1}$, although the smaller gain coefficient is offset by the larger thicknesses available in crystals.

Limitations and hurdles

Diffraction efficiency is only one of many properties required of a photorefractive material to be used in a practical optical storage device. Another is the lifetime of the image—both during storage in the dark and, more critically, during multiple read operations. The image in a photorefractive device tends to fade a bit each time one shines a light on it to retrieve information. For the inorganic crystals, procedures have been developed to “fix” the image, by either thermal or electrical means, but the procedures are by no means perfect. So far there are no techniques for fixing the refractive grating in the newer, polymeric materials, although IBM researchers have been able to decrease the erasure rate by lowering the reading-beam intensity.⁴ Peyghambarian told us that the data storage time for his group's new material is now limited to a matter of

hours, because the charges do not remain trapped for long.

Yet another property of an optical storage device is its thickness. One would like to be able to store many images at once within a volume of photorefractive material. To retrieve each image one would rotate the storage medium (or the readout beam) to a particular angle. This technique works fine for inorganic crystals, which can be a few centimeters thick. By contrast, a typical photorefractive polymer is only about 100 microns thick. The Almaden group has demonstrated, however, that one can still make a large volume of the photorefractive polymeric materials by stacking many thin layers, each with its own electrodes.⁵

One possible disadvantage of polymers compared with crystals is that the former require the application of an applied field, on the order of tens of volts per micron.

The development of suitable photorefractives is not the only thing standing in the way of a complete system for holographic storage. There are significant hurdles to overcome with the other components as well. In the complete system envisioned, information starts as digital data stored in a computer. These data are impressed upon an array of liquid crystals known as a spatial light modulator such that the information gets coded as a pattern of light and dark spots on a light beam passing through the modulator. The image beam is then combined with a reference beam to form a hologram in a photorefractive medium. The retrieved image can then be recaptured with an array of photodetectors, which convert the optical signal back to digital data for deposition once more into a computer.

Moving the Mona Lisa

Until last spring no one had put all the components together in this way. So the field got a boost, if only psychological, when John F. Heanue, Matthew C. Bashaw and Lambertus Hesselink of Stanford University successfully implemented a fully digitized system: They took the Mona Lisa from her resting spot as digitized data in a computer, beamed her up

through a spatial light modulator, stored her in a lithium niobate crystal and reconstituted her holographically.⁶ (See the photo on page 17 of a flock of birds treated in the same manner.) The lady was very little the worse for the wear (or had her smile faded?).

The experiment was an important feasibility demonstration, showing that there are no fundamental limitations to the technology. To deal with problems that had plagued earlier attempts at a digital system—the cross talk between adjacent pixels in the spatial light modulator and the variations in the intensity of the recalled data “pages”—the Stanford researchers adopted a differential encoding technique. The experiment also demonstrated the need for further improvements to the materials and components. For example, the spatial light modulator used by the Stanford experimenters was less than optimal for their application, so they had to use an array of 8 by 8 pixels for every transmitted bit. As a result, the image transfer time was long—about one hour—and the amount of data stored was small—163 kilobytes. The group also incurred an error rate of one per million, unacceptably high for commercial purposes. Hesselink points out, however, that the raw bit error rate is comparable to that for existing optical storage devices and that proper signal processing can improve this error rate.

—BARBARA GOSS LEVI

References

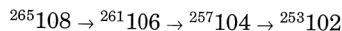
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CONVINCING EVIDENCE SEEN FOR ISOTOPES OF ELEMENT 110

On 9 November a group of researchers led by Peter Armbruster and Sigurd Hofmann at the Gesellschaft für Schwerionenforschung (GSI) in Darmstadt, Germany, observed a sequence of four alpha par-

ticles emitted from selected reaction products of a thin piece of ^{208}Pb under bombardment from a beam of 311-MeV ^{62}Ni ions. The alphas clearly represented a decay chain, being essentially coincident in position and

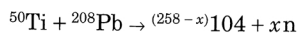
following one another at intervals ranging from a few hundred microseconds to a few hundred milliseconds. Indeed, the last three alphas had energies and delay times that clearly matched the decay chain



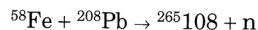
Equally clearly, the first alpha was from the reaction $^{269}_{110} \rightarrow ^{265}_{108}$. Over the following two weeks in November the researchers observed three more such decay chains.¹ In December they announced² the observation of seven decay chains corresponding to isotope $^{271}_{110}$, obtained by bombarding $^{208}_{82}\text{Pb}$ with $^{64}_{28}\text{Ni}$. The Darmstadt group includes collaborators from GSI; the Joint Institute for Nuclear Research in Dubna, Russia; Comenius University, Slovakia; and the University of Jyväskylä, Finland.

Evidence for the observation of a single atom of another isotope, $^{267}_{110}$, had been reported six months earlier by Albert Ghiorso at a conference in Taormina, Italy.³ His group at Lawrence Berkeley Laboratory performed the experiment in fall 1991 using LBL's now-shut-down Super-HILAC accelerator to bombard $^{209}_{83}\text{Bi}$ with $^{59}_{27}\text{Co}$ and using the now-dismantled SASSY2 separator to analyze the products. Many characteristics of the event match those expected for a $^{267}_{110}$ nucleus, but instead of seeing a clean sequence of fully observed alpha decays, the LBL group apparently missed an alpha decay by $^{263}_{108}$ because of known equipment problems, and a previously unobserved electron-capture decay of $^{259}_{106}$ must also be assumed. With the Super-HILAC and SASSY2 no longer in operation the experiment has not been repeated, leaving the lone event highly suggestive of $^{267}_{110}$ but open to question.

The GSI researchers performed several preliminary experiments to enhance their ability to see $^{269}_{110}$. First they studied the excitation functions of the reactions



for $(x = 1, 2, 3)$ and



During their studies of the alpha-decay chain of $^{265}_{108}$ they observed seventy-five 108 decays, substantially more than the three seen in their 1984 observations of the element. The 104 and 108 results allowed them to predict the narrow beam-energy window that would optimize the cross section for the desired one-neutron evaporation channel in their Ni-Pb reaction. Because of the Ni-Pb reaction's low cross section weeks of beam

time would have been needed to directly find the correct energy window for the production of 110 nuclei. When they set their Ni-beam energy to the predicted optimum for producing element 110 they saw one such nucleus produced about every three days.

Ronald Loughheed (Lawrence Livermore National Laboratory), part of a Livermore-Dubna collaboration competing with the GSI group at the end of the periodic table, calls the Darmstadt results "very solid" and lauds the experiment as being well done. Aaldert H. Wapstra of NIKHEF (the National Institute for Nuclear and High-Energy Physics) in Amsterdam, who was secretary of IUPAC-IUPAP's Transfermium Working Group, says the GSI group's observations are as convincing, if not more so, as their earlier work on the discovery of elements 108 and 109, for which the TWG assigned GSI "major credit" and sole credit, respectively. (See the news story in PHYSICS TODAY, November 1993, page 20.)

The Livermore-Dubna collaborators also are looking for element 110, but two neutrons higher, at isotope $^{273}_{110}$. They are bombarding $^{244}_{94}\text{Pu}$ with $^{34}_{16}\text{S}$ and hope to have definitive results in the near future. Like isotope $^{271}_{110}$, isotope $^{273}_{110}$ would be

close to a "rock of stability" that theories incorporating deformed nuclear shapes predict will occur near neutron number $N = 162$. (See the news story in PHYSICS TODAY, November 1993, page 22.) One sign of this stability can be seen in the $(1.4^{+1.0}_{-0.4})$ -msec half-life of $^{271}_{110}$, which is about 8 times as long as the (170^{+160}_{-60}) - μ sec half-life of $^{269}_{110}$. Meanwhile the group at GSI is hot on the trail of element 111, bombarding $^{209}_{83}\text{Bi}$ with $^{64}_{28}\text{Ni}$.

—GRAHAM P. COLLINS

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"The centrifuge is still broken?"