As the relentless demand for storage continues, Adele Dyer looks at advances in the field.

Crystal vision

Remember when a 40Mb hard disk seemed huge? Now we have enormous amounts of storage available and still need more. With current technology, bulk storage often means just that; and with the need for more storage space for even larger files in the future, new technologies have to be developed. For some time we have thought of storage in two-dimensional terms, as data recorded on to a flat surface like a hard disk or CD-ROM. But research is under way that would enable 3D data to be created in the form of holograms and stored in crystals.

The idea of using holograms was originally mooted in the seventies. The basic theory is fairly simple: two laser beams are used simultaneously to alter the state of particles in crystal, creating electronic patterns. These patterns can then be read by another laser beam and interpreted as data. Within the crystal there are many thousands of layers, each of which can store a "page" of data. As the crystal can be seen from many different views, with each view storing a separate set of data, you can squeeze an enormous amount of information on to a tiny area. You could store two MPEG2 feature films – around 12Gb – on a crystal the size of a sugar lump. Researchers have managed to squeeze up to 10,000 pages, each with one megabit of information, on to a crystal around a centimetre square. More importantly, the data can be accessed extremely fast. These speeds can be achieved because there are no mechanical moving parts; an entire page can be retrieved at once, rather than each bit of data in a series being fetched individually from a rotating disk.

Researchers are aiming for a data throughput rate of at least one billion bits per second – more than ten times the speed possible today. This high-speed throughput and capacity would mean fast file access and faster download times, making it ideal for recording high-quality video. It would be invaluable for almost instantaneous searches on huge data libraries. Data integrity would be enhanced, as data information is spread throughout the crystal by laser. As there is no specific point at which the data is stored absolutely, the crystal can be damaged and still retain data: if you break the crystal in half, you will still be able to read the data, but at only half the signal strength.

If you think this all sounds too good to be true, you would be right. There are several problems inherent in the technology. Firstly, holograms are volatile. Creating the hologram is relatively easy, but getting it to remain unchanged within the crystal is not. Secondly, if you can store the hologram, the problem then lies in how to read the data without corrupting it. In other words, if you create a hologram by shining a light at a crystal, how do you prevent the data from being corrupted when you shine another light at it to read it.

The California Institute of Technology is trying a new approach, using crystals doped with small amounts of iron and manganese atoms.

▲Two-dimensional recording may be around for a few years yet, but with the development of crystal storage, its days are numbered

You can squeeze an enormous amount of information on to a tiny area. You could store TWO MPEG2 FEATURE FILMS on a crystal the size of a sugar lump

The atoms are excited by illuminating them with ultraviolet light at the same time as recording the hologram using red light beams. When the data is read using a red light beam only, the manganese atoms can be read; but in the absence of ultraviolet light they are not excited and so retain the data without loss. Even with this advance, however, it will be some time before we see holographic storage replacing hard disks.

Reports of the death of paper have been exaggerated. Paul Trueman finds it has an unexpected future.

Pulp fiction

There are numerous competing technologies heading our way in the next few years, all united in their attempts to replace the common paper book. The technologies being developed by rivals at MIT (Massachussets Institute of Technology) and Xerox PARC are not only using the concept of a paper book as a physical and theoretical shell for their ideas, but are going on from that to redefine the whole idea of reading.

The MIT Media Lab is developing an electrophoretic alternative to the paper solution, codenamed "The Last Book". The theory is that the Last Book will be made up of real paper substrates that contain thousands of individual electrically addressable particles of electronic ink — "e-ink", that can reconfigure itself over and over again on the same page *ad infinitum*. The e-ink developed by Joseph Jacobson and his team consists of electrically susceptible two-colour micro-particles, suspended in a clear outer shell. The charge across the electrodes defines the position of the particle, flipping it over to display one or the other colour. The spine of the Last Book will contain a small display, from which the reader can select the tome of their choice. At the touch of a button, the book will effectively re-draw itself to whichever work the user requests, transforming it from Hamlet to Trainspotting and back. While far cheaper than producing a liquid-crystal TFT display, the paper will be considerably more expensive than treated pulp, with a 21.59x27.94cm page costing between $1-10 per page (MIT's approximation), rather than a few cents per page. Jacobson and his team reckon on an eventual paper thickness of 200 microns.

The book will re-draw itself to whichever work the user requests, transforming it from HAMLET TO TRAINSPOTTING AND BACK AGAIN

▼A VERSION OF THE ELECTRONIC BOOK FROM A COMPANY CALLED EVERYBOOK: ARE WE FACING A FUTURE WITHOUT LIBRARIANS?

Each page has a common set of address electrodes linked to a single controlling chip in the spine of the book. The display driver contained within the chip will be robust enough to sense and work around a damaged page, printing out on the remaining pages. Also under development is a plan to design the display to be touch-sensitive to a stylus, allowing the user to indicate when they wish the type to be enlarged, or to add their own annotations.

MIT's "rival", Nicolas K. Sheridon, came up with the idea for the Gyricon twenty years ago, but nothing came of it at Xerox PARC where he worked. Sheridon returned to his idea five years ago, and now it is only a few years from being brought to market. The "digital ink" theory behind the Gyricon is rather more tangible than that of the Last Book's micro-particles. The display has the texture of rubber crossed with thick cardboard, and is made up of thousands of minute rubber beads, each varying from 0.01-0.03mm in diameter. The balls are mixed into molten transparent silicone rubber, then cooled and cut into sheets. When the sheets are soaked in oil, they expand and the balls are left free to rotate. When a charge crosses the screen, the beads flip one way or another (it's a Xerox trade secret how they actually do this), and because they have a different colour each side, the display can reconfigure itself upon each charge. The models in development are powered by small solar cells, and the integrity of the displays remains even after two years and three million erasures.

Sheridon believes that eventually the display could be used in laptops and handhelds. "It would probably allow you to run a laptop for six months on a few AA batteries," he says, because the display doesn't need to be refreshed or be backlit.

Ben Elton posited the idea of one-book-shows-all in his thriller *Another Eden*. Elton raised the problem that people like the feel of paper when reading. After the invention of the LCD and the proliferation of the wall-size flatpanel, it seems a triumph for the Gutenberg press that the books of the future will seek success by recreating the feel of dried pulp.