press information

Philips Data Systems

PHILIPS

Issued: November 1978

Release date: Nov. 7th 1978

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DIODE LASER RECORDER GIVES 10^{10} USER BITS PER 12" DISK

Philips Data Systems recently introduced the world's first diode laser optical recording system. Using similar techniques to those developed for VLP (Video Long Play), it allows high-density recording and retrieval of data on an ultra-compact system that employs a pre-grooved, double-sided 12" disk. The high information capacity of 10^{10} bits, which is equivalent to some 500.000 type-written pages, represents a ten times improvement in capacity over the most advanced magnetic disk pack systems currently available. The system features a direct read after write facility plus fast, random access. Any address can be reached in a mean time of 250 ms, thereby providing virtually instant access to 5×10^9 bits (the capacity of one side).

Multi disciplines make it possible

While the basic potential of lasers for optical data recording has been known for several years, a number of problems have prevented the development of a practical read/write system. Such a system would have to use a miniature diode laser and a compact optical system, combined with a sensitive recording medium having archival storage quality, and would need a high-accuracy servo system in order to provide a fast random access facility. In other words, state-of-the-art breakthroughs would need to be made on several fronts.

We were in a unique position to make these breakthroughs, says Dr. Bulthuis of the Research Laboratories, because of parallel developments in Video Long Play. "We already had the basic know-how for all the disciplines in house. All that we at Philips really needed was a single breakthrough in diode lasers, which came from the Corporation's semiconductor operations, plus a matching recording material."

The diode laser used in the new recording system is of the AlGaAs DH type and employs a 0,1 mm square semiconductor chip, housed in a transistor-sized encapsulation. Despite its small size, the power of the pulsed light output is adequate for it to replace a big gas laser and its associated modulator. It is mounted in the ultracompact 40 gram optical system shown in fig. 1, which also contains the electro-optics for radial tracking and focussing.

Reading and writing

A diode laser system of this type can read optical data in the same way as a Video Long Play system. With an increase in power the laser can also write or "burn" data into a suitable recording medium. In the Philips system this is done by melting micron sized holes into a tellurium-based recording material (see appendix for full details). Data written in this way can be read afterwards in reflection. The system detects the difference between a high light level, coming from the reflective surface and the low light level coming from the hole, where the majority of light escapes. These high and low light levels are converted into electronic binary signals and thus represent data bits.

Data written in this manner must naturally be accompanied by an address, otherwise it cannot be found and has no value. Moreover the system must enable the data and address to be written anywhere on the useful recording area if the necessary random access facility is to be provided. This would appear to demand absolute positioning accuracy down to the micro-sized data holes, but in fact once again Philips found the solution by an adaptation of their established VLP know-how.

High-speed random access

In the VLP system video data is normally read sequentially from pressed, plastic disks. Information is made by forming a relief pattern in the substrate of the disk having a depth of one quarter of the laser light wavelength. When data is read, interference occurs between the areas of relief and non-relief, which results in low and high reflected light levels.

In the new diode laser recording system there is a pre-grooved track having a depth of one eight of a wavelength together with the address headings as shown in fig. 2. A detailed photograph of the pre-grooved track in which data has been written is shown in fig. 3. The optical system can therefore track along the pre-groove, whether it contains written data or not and at the same time it can find and read headings (for details see optical appendix). Thus, data can be posted virtually anywhere on the useful recording area, thereby providing a random access facility for both writing and reading.

Using VLP mastering and replicating techniques, relief headings are produced in plastic substrates. There are 128 sectors per track and 45.000 spiral tracks, as illustrated in fig. 4. Between headings there is the shallower pre-groove. The recording material is then evaporated on the surface of the disk and two such disks placed back-to-back in the sealed, air-sandwich constructrion of fig. 5.

As illustrated, the laser light is focussed through the 1 mm thick plastic substrate in order to provide optimum protection against dust, fingerprints and scratches. This does not result in any degradation of recording sensitivity. The optics read address headings, can optically track along the pre-groove and write data into the pre-groove by burning holes in the recording layer, as previously described. The objective lens is positioned 2 mm away from the surface of the plastic substrate, thereby eliminating the low clearance problem of magnetic systems.

In this way the system can be used to write up to 1 k user bits of data into each of 45.000 x 128 sectors, each of which can be individually addressed. With a disk rotation speed of 2,5 revolutions per second, this gives a mean access time of 250 ms for a storage capacity of 5 x 10^9 user bits.

From these figures one can quickly calculate that the writing speed is 300 k user bits/sec, but as Dr. Bulthuis points out "... there are no problems in running the system at much higher speeds and we have written and read data at a rate of 6 M user bits/sec".

Precise positioning

While the use of a pre-groove eliminates the need for absolute positioning accuracy, the recording system still demands very precise and quick positioning. This is achieved by mounting the optical system on the arm shown in fig. 6, which is driven by a linear motor. An optical grating on the arm is used to bring the optics very quickly to within 10 tracks (16 um) and track reading, followed by sector reading then takes over. With this technique the maximum time to go from outer to inner track is only 100 ms, so that at 2,5 revolutions per second the maximum access time to reach the equivalent of five magnetic disk packs is only 500 ms.

Having found the required address, the optical system must be maintained in focus and on track. For focussing, the position of the objective lens, relative to the recording layer, is controlled by a voice coil and is held to within 1 µm. For tracking, the same linear motor is used as for the random access loop and eccentricities of up to 100 um are reduced to a track error of 0,1 µm.

A recording system that's error-free

Error-free retrieval of data is achieved by a combination of data modulation, interleaving of code words throughout a sector and a high 20% redundancy. In this way 99,9% of all errors are detected and are automatically corrected by the electronic error correction system (see disk/format appendix for details). The remaining 0.1% are detected by the system and all data in that sector is then rewritten in a new sector. In practical terms this effectively means that the recording system is error-free.

Future applications

Two different application areas are foreseen by Philips: one being the storage of alphanumeric information and the other that of images. This latter facility demands high bit volume storage, which now becomes practical due to the system's high 10^{10} bit storage capacity. Therefore since both words and images can be recorded and retrieved, with fast random access, this new medium may well become the electronic equivalent of paper and microfilm.

High density is combined with archival storage, which will allow this optical system to replace magnetic tape and disk for a wide range of applications, including infrequently updated large data bases, for example in (business) 'Viewdata'. The current data density is already higher than magnetic material by an order of magnitude and this is a figure that is likely to improve still further in future. Therefore as the technique develops, the storage cost/bit will be so significantly different from anything available today, that fundamental storage concepts will change.

With the electronic equivalent of the printed page, for both words and illustrations/photos, there is virtually no limit to the kind and quantity of information that can be recorded, retrieved and also transmitted, over existing and future communication networks such as fiber optic data highways. For example in the office of the future, optical systems will certainly be integrated into word processing systems to provide an electronic filing cabinet for all documents including the images received through facsimile devices. This is a logical step in the development of electronicmail. And in hospitals, patient records will be able to cover the complete life history, with comprehensive data including X-ray images, graphs and other visual material, as well as written and even spoken words.

The possibilities of the new recording medium, with its high 10^{10} bit storage capacity available on a low-cost, compact, reliable peripheral having archival storage quality are therefore enormous. Today's system can be regarded as a gigantic PROM, but by extrapolating current technology one can foresee higher bit rates and densities plus erasable materials. Such systems would lead to the creation of gigantic RAMs, making this new medium the candidate for many future storage applications.

Optical appendix

The purpose of the optical system is to concentrate sufficient laser light power into a very small spot size on the recording layer. It must also generate suitable signals for the focusing and tracking errors of the spot. Such an optical system is shown in fig. 7.

The light source is a Gallium Aluminium Arsenide diode laser, emitting radiation at a wavelength of 820 nm. About 40% of the diverging output beam is collected by the first lens. The second optical element is a weak cylindrical lens that corrects for the astigmatism of the output beam. The collimated beam is reflected by a polarising beam splitter and is focused by an objective lens (NA = 0.6) onto a 300 Å thin recording layer which partly reflects and partly absorbs the incident light. The diameter of the spot on the disk is one micron.

The reflected light re-enters the optical system and the light is then transmitted by the beam splitter due to the quarter wave plate. In this way the reflected light is separated from the incoming light beam. About 50% of the light passes through a semi-transparent mirror and strikes a split photodiode. The unbalance between the signals from the two halves of the diode is used as the tracking error signal. The other 50% is reflected at the mirror and is focused via a prism onto another split photodiode. The differential signal from this photodiode yields the focusing error. The error signals are then used for the tracking and focusing servo systems, both of which have a bandwidth of 1 kHz.

Writing is performed by modulation of the laser drive current. Light pulses with a power of 12 mW during 50 ns are sufficient to burn holes of one micron in the recording layer.

Reading is performed with a light source having a lower power. The data, which is stored as non-reflecting holes in the recording material, is detected by the same photodiode as used for the focusing signal.

Disk format appendix

On the disk there is a spiral groove 0,6 micron wide and 0.06 micron deep, which, when read through the substrate, is optically around one eight of the laser wavelength. This groove is used for radial tracking and the distance between tracks (grooves) is 1,67 microns.

Each track is divided into 128 sectors and each sector has a heading address, as shown in fig. 2, followed by the continuous groove for the data field. Data is written by burning micron sized holes in the 300 Å thick, tellurium-based recording layer. Up to 1 k user bits/sector are specified, even though outer sectors have double this storage capacity. Optically this is an amplitude modulation, superimposed on the phase structure of the continuous groove.

The pre-grooved heading contains information on the synchronization of the sector, the words and the bits, as well as the track and sector number. The recording data field is written synchronously with the heading and comprises 22 codewords per sector. These codewords consist of 16 data symbols, each of which is 4 bits. Three out of 16 symbols are used for error correction.

On the disk the codewords are written with an interleaving procedure, so that any long error bursts are divided over several codewords. In this way it is possible to correct any one wrong symbol per codeword and to detect two or more wrong symbols in codewords in a sector. In the latter case a rewrite of the whole sector is done. Normally only 0,1 % of the sectors need a rewrite.

Captions

Fig. 1
The diode laser optical read/write head.

Fig. 2
Cross-section shows pre-grooved track on which data can be written, together with the quarter wavelength headings.

Fig. 3
Electron microscope photo of pre-grooved track.

Fig. 4
Plan view of disk illustrates how over 5 million sectors can be individually addressed for both writing and reading, thereby providing easy data management.

Fig. 5
Philips system uses air-sandwich construction to protect data without any loss of recording sensitivity.

Fig. 6
Optical read/write head (right) mounted on arm. A linear motor is used for fast random access and radial tracking.

Fig. 7
Schematic of the ultra-compact diode laser optical read/write head and servo signals.

Fig. 8
Philips diode laser recorder uses double-sided 12" disk to store the equivalent of 500.000 typewritten pages. Access to any line on any page can be gained in less than half a second.

Fig. 9
Philips ultra-compact diode laser optical recorder uses a pre-grooved, double-sided 12" disk.

Fig. 10
The Philips team responsible for the world's first diode laser optical recorder.

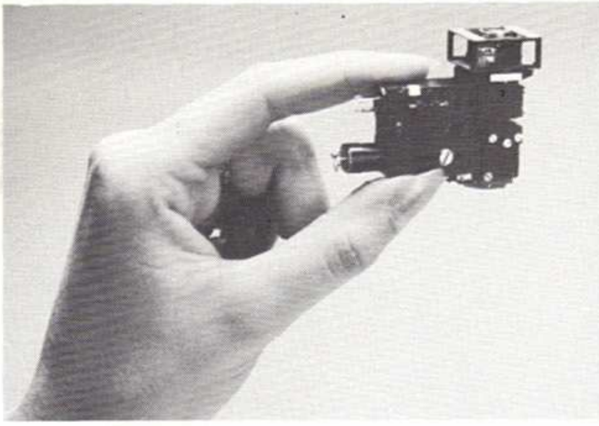

Fig. 1

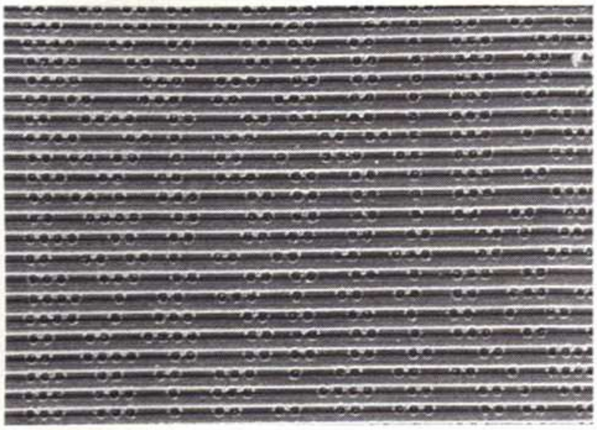

Fig. 3

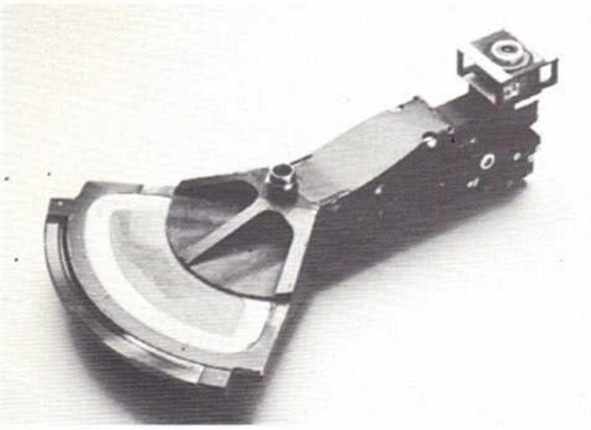

Fig. 6

Fig. 10

Fig. 9

Fig. 8

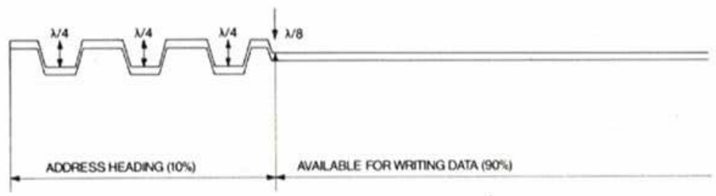

Fig. 2

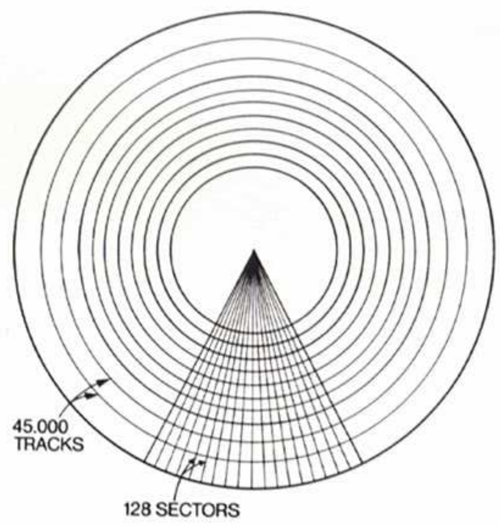

Fig. 4

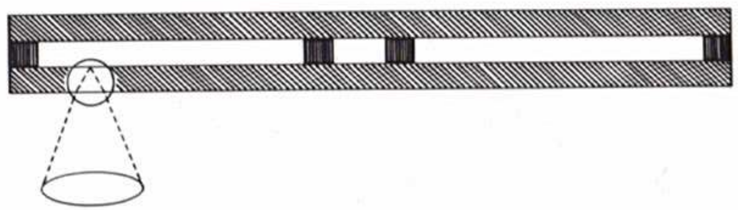

Fig. 5

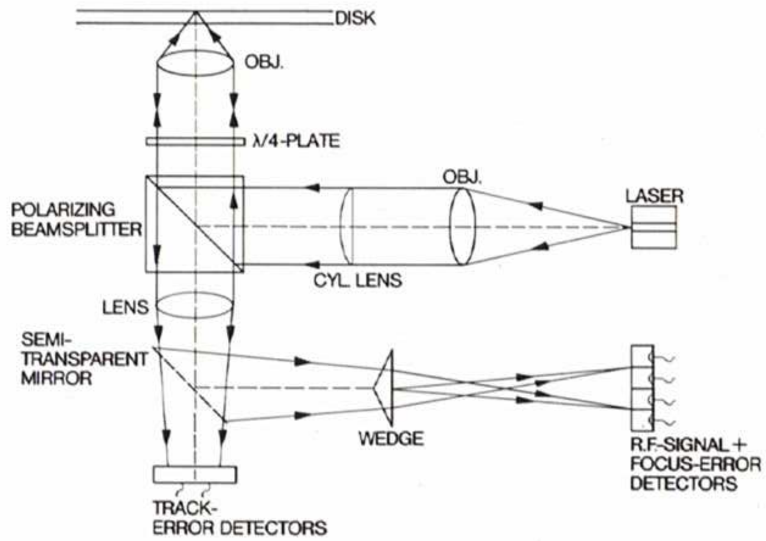

Fig. 7