

Optical Disc Technology for Permanent and Erasable Memory Applications

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INTRODUCTIONS

Use of a rotating disc as a means of storing analog or digital information offers one an indisputable advantage over a roll of tape. The advantage is, of course, the rapid accessibility to any part of the memory and the readily available means for indexing the information in storage.

One disadvantage of using a disc is the smaller amount of memory capacity in comparison to tape for a given physical volume. Unlike a roll of tape, the total memory surface of a disc must be protected by a jacket or a shroud, making it physically thick and thus less efficient as a vehicle for memory.

The recording density of magnetic memory has increased 1000 fold over the past two decades. In early 1960's the track pitch of a practical recording system was 20 mils. and the recording wavelength, or a flux reversal rate was about 2500 reversals per inch.

Today, the track pitch of 1 mil is not uncommon and flux reversal rate for a longitudinal recording is approaching 100,000 per inch. Experiments on vertical flux recording indicate that a flux reversal rate in excess of 200,000 per inch is now possible.

1 mil track pitch and 100,000 reversal per inch means a recording density of 100 mega bits per square inch. This very impressive density is a result of 20 years of relentless pursuit in the refinement of head material and fabrication technology, and magnetic media material.

Because of the head to media interface conditions, the best magnetic disc memory still operates at a recording density substantially lower than the tape memory.

During the course of pursuit for recording density improvements, alternative formats of recording, especially for disc recording applications, were examined extensively. Results of the search for an alternate medium for high density recordings, led to the development of the optical disc.

The area required for one bit of data on a optical disc, from the outset of optical recording development, was assumed to be only limited by the defraction limited laser beam spot size. A very high recording density in an order of 100 mega bits per square inch, thus, was believed to be achievable.

OPTICAL MEMORY DISC

Mass reproduced, read-only optical memory disc systems are currently operating at a recording density at or about 100 mega bits per square inch. Examples are "CD" Compact Audio Disc Players and Video Disc Players such as "VHD", "Laser Disc", and "Selectavision".

For broadcast and/or teleproduction applications, recording and playback capabilities are essential for the optical video storage system.

Early attempts for optical recorder/player systems were based upon a form of material transfer or removal.

Each recorded bit is a hole or a depression formed on a thin layer of inorganic or organic material coated on a glass or plexiglass platter.

Use of a high power laser for the formation of a hole or a depression on the platter makes this type of recording less energy efficient. Another basic limitation of this form of recording is that the process is irreversible.

DESIRED CHARACTERISTICS FOR AN OPTICAL MEMORY

The magnetic memory continues to be one of the most desirable forms of information storage devices. What we are looking for in an optical memory is, therefore, the characteristics of magnetic memory, combined with the inherent high density capability of optical storage means, as listed below:

1. In field record and playback.
2. Use of the same device or head for both recording and playback operations.
3. High energy efficiency
4. Environmental immunity of recorded and archived material
5. In addition, the ability to re-record over a perviously recorded surface is highly desirable.

METAL-METAL OXIDE THIN FILM

To meet the aforementioned characteristics the form of recording must not entail physical alteration of the surface, but rather, alteration of its optical characteristics, i.e. the rate of optical transmission or reflection coefficients.

The laser beam should not evaporate and/or melt the material. It should be used as a means to heat the material and alter only optical characteristics.

For the best possible playback efficiency, the material should generate a high degree of optical property transfer before and after recording. The material should be a good infrared absorbant for high energy efficiency. For the long term integrity of the recorded information, the material should also be thermally stable and chemically inert. Of those organic and inorganic materials tested, metal-metal oxide of certain rare metals, i.e. Tellurium, Antimony, Germanium and Molybdenum are found to possess desirable properties. Figure 1 shows the change of light transmission property measured at a wavelength of 633 nanometers.

All test materials show an abrupt change in the transmission coefficient when heated to a certain temperature. Average level of oxygen content, shown by X, is always smaller than the stoichiometric value for the respective substance.

TELLURIUM-TELLURIUM OXIDE THIN FILM MEMORY

Because of a high degree of optical property transition with smaller amounts of infrared radiation, and overall superior thermal and chemical stability, Tellurium-Tellurium Oxide was determined to be the best material for both permanent and re-recordable optical memory.

Since the optical property of the material depends greatly upon the average level of oxygen content, X, selection of the proper level and accurate control during the manufacturing of the disc are both important.

The material has a greater depth of modulation (change of optical property) with a lower degree of infrared radiation when the X value is less than unity. Environmental stability of the material, however, is not optimum. At the X value of 1.1, modulation depth is somewhat decreased, but the stability of the recorded information is completely immune to environmental effects, a highly desirable characteristic. This is the selected value for both permanent and re-recordable memory material.

The memory layer is produced by a multi-source evaporation method as shown in Figure 2. By controlling the disc exposure time for pure tellurium and tellurium oxide, the desired value of X can be obtained.

IMPURITY ADDITIONS

Addition of small amounts of impurities such as Tin (Sn), and Germanium (Ge), further improve the properties of Tellurium-Tellurium Oxide as a re-recordable memory.

Effects of Germanium impurity additive are shown in Figure 3. While maintaining essentially the same depth of modulation, the transition temperatures were shifted upward with the addition of impurities. Upward shift of transition temperature improves the thermal stability of recording.

The effect of adding a small amount of tin to the basic material are shown in Figure 4. Unlike Germanium, addition of tin up shifts the transition temperature only by a moderate degree.

RECORDING, PLAYBACK AND ERASURE PROCESSES

The same solid state laser operating at a 830 nanometer wavelength is used for recording and readout (playback) operations with changes in power density.

The spot size for record/readout process is 0.8 micrometers in diameter and the applied power is 8mw and 1mw respectively for recording and readout.

A separate laser operating at a 780 nanometer wavelength is used for erasure with the erasing laser beam foot print optically elongated to cover an elliptical area of 1×10 micrometers. Power output of the erasing laser is 10mw. The reversible process of recording and erasing is shown in Figure 5.

A high power density laser beam is applied to the material for a short period of time, quickly raising the temperature of the area and shifting its light reflectivity from a high zone to a low zone.

To erase the spot and bring the reflectivity value to the former level, the material must be brought up to a temperature, which is substantially lower than in the record process, at a slower rate.

By elongating the erase beam foot print in the direction of disc rotation and reducing the power density of the laser spot, the beam foot print makes a larger exposure over the previously recorded spot and the power density to make the degree of temperature elevation smaller.

The change of light reflectivity from the unrecorded, blank condition to recorded condition and then to the erased, ready for rerecord state is shown in Figure 6.

The change of reflectivity is approximately 2:1 and the low reflectivity state is the recorded condition.

STRUCTURE OF THE DISC AND SYSTEM

The same basic structure apply for both non-erasable and erasable disc.

As shown in Figure 7 the recording material, Tellurium-Tellurium Oxide with a controlled amount of impurity for an erasable disc, is evaporated on the surface of the 1.1mm thick acrylic resin platter. The substrate has a pre-grooved laser guiding track of 700 angstroms deep and 0.8 micrometers wide with a track pitch of 1.65 micrometers. The recording material has a thickness of approximately 1200 angstroms, and it is over-coated by a transparent protective layer. Two discs are then glued together to form a double layer disc of 2.5mm thick.

The width of the guiding track is equal to the diameter of the recorded bit, and the depth is 1/8th of the laser wavelength.

Major components of a total recorder/reproducer system are shown in Figure 8.

Specifications for the standard 20cm non-erasable disc are shown in Figure 9. Total capacity of this 23,000 track disc is 700 kilo bytes.

The disc is also capable of analog FM signal recording for conventional video recording. At the recording wavelength of 1 micron, i.e. 5MHz FM carrier recorded on the inner most track at 5 meters per second writing speed, a C/N ratio of 55dB at 30KHz sampling bandwidth is obtainable.

SUMMARY

The first practical and popular application of an optical memory system, is for permanent document storage and retrieval purposes.

With 700 mega bytes of memory, 10,000 pages of 8" X 11" documents may be stored on a single 20cm disc.

A Single Disc Optical Memory System can now be complemented by a 50 disc capacity automatic disc handling system shown in Figure 10.

Light Transmission Characteristics

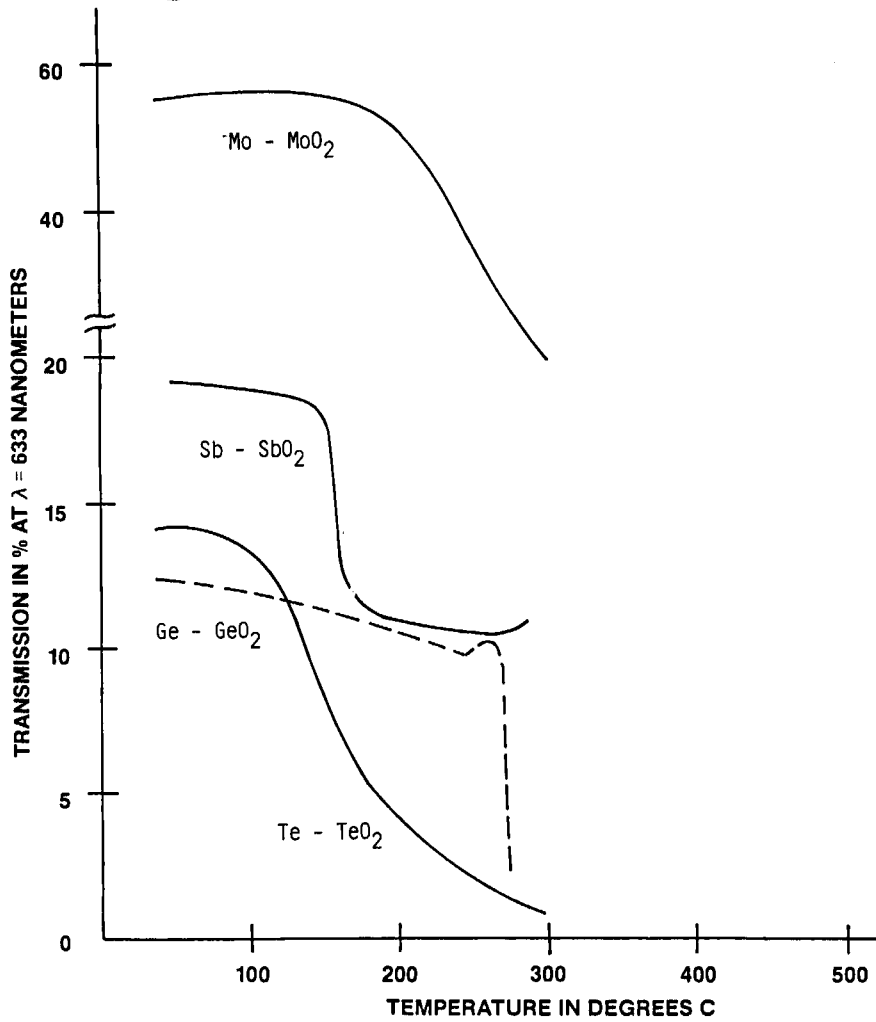
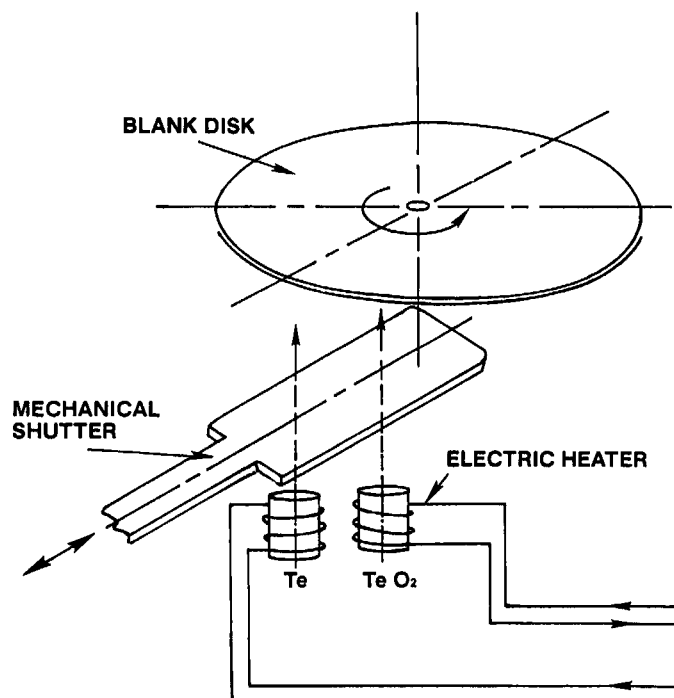


Fig. 1. Light Transmission Characteristics.

Multi Element Evaporation System

Fig. 2. Multi Element Evaporation System.



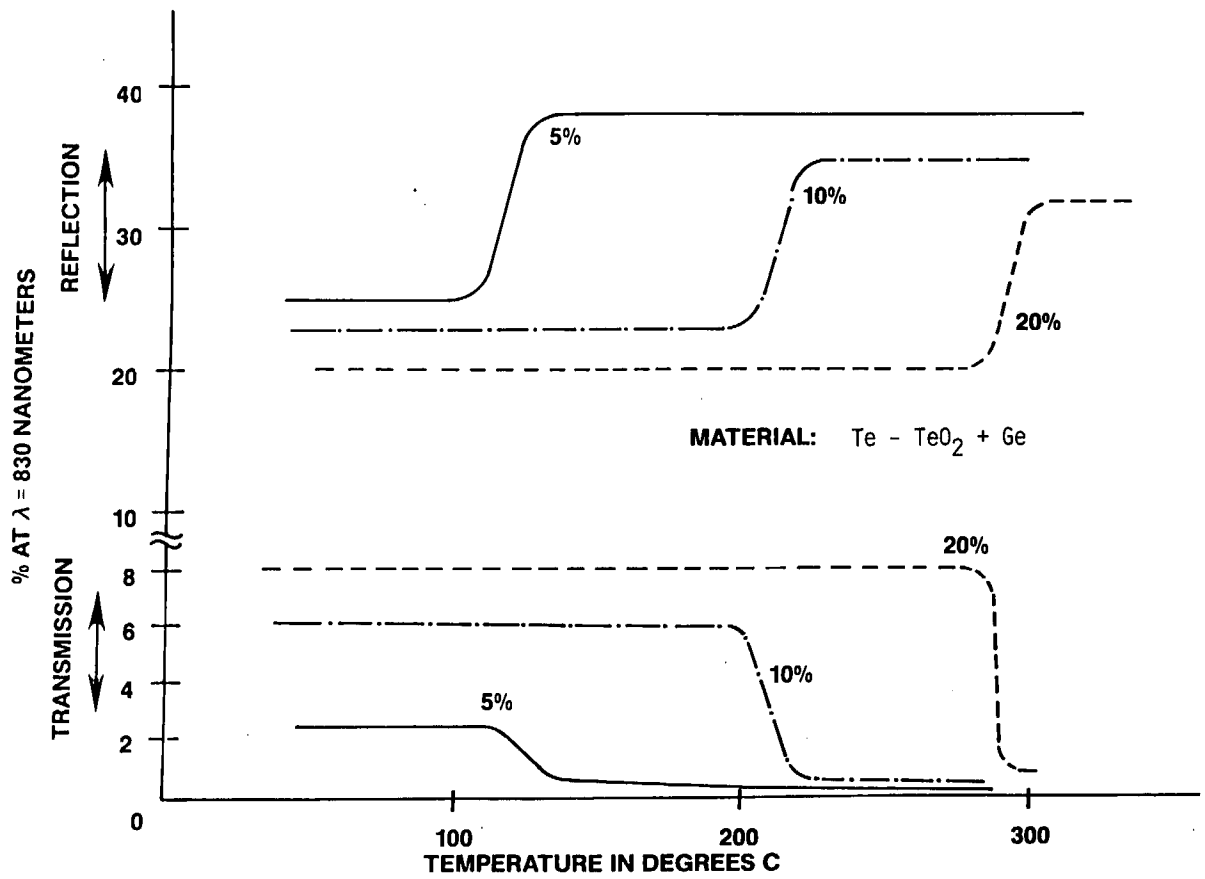


Fig. 3.

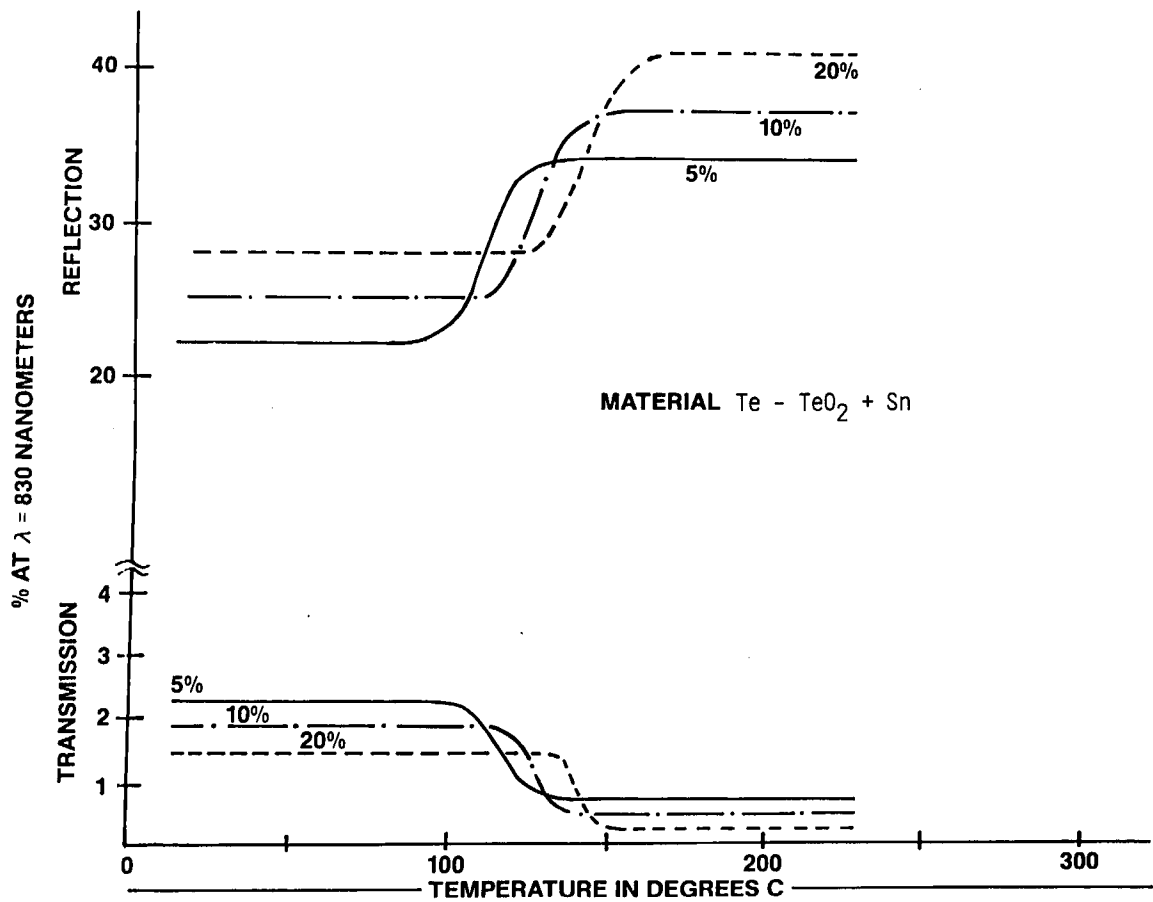


Fig. 4.

Record Layer Temperature

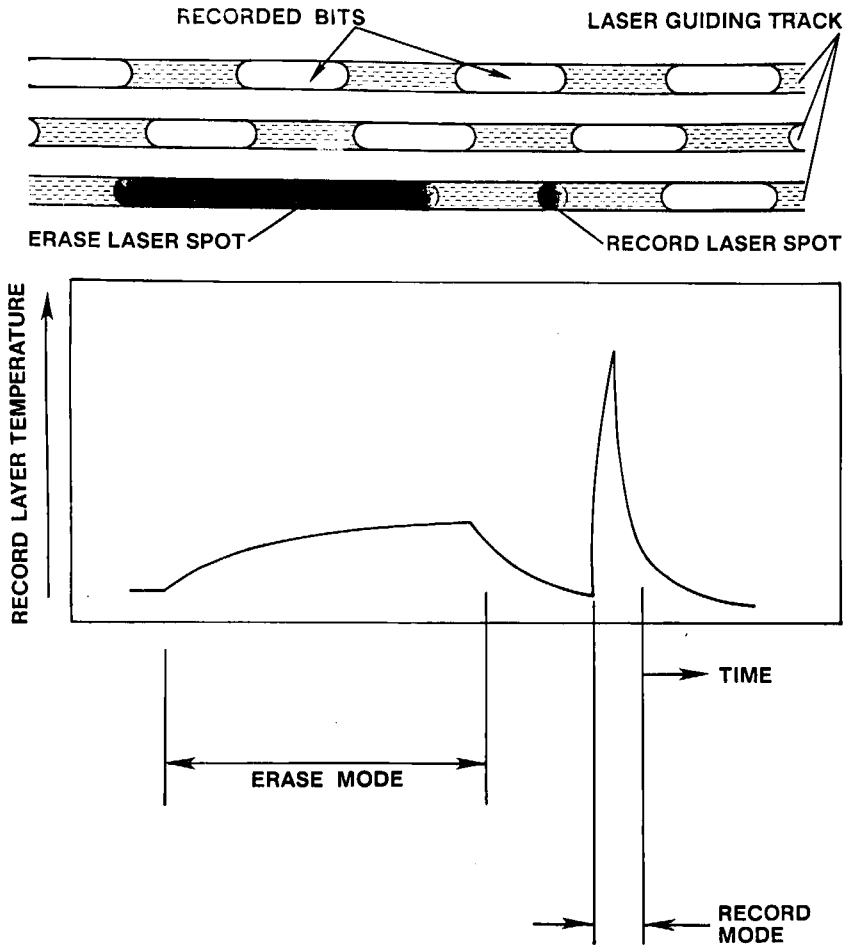


Fig. 5. Record Layer Temperature.

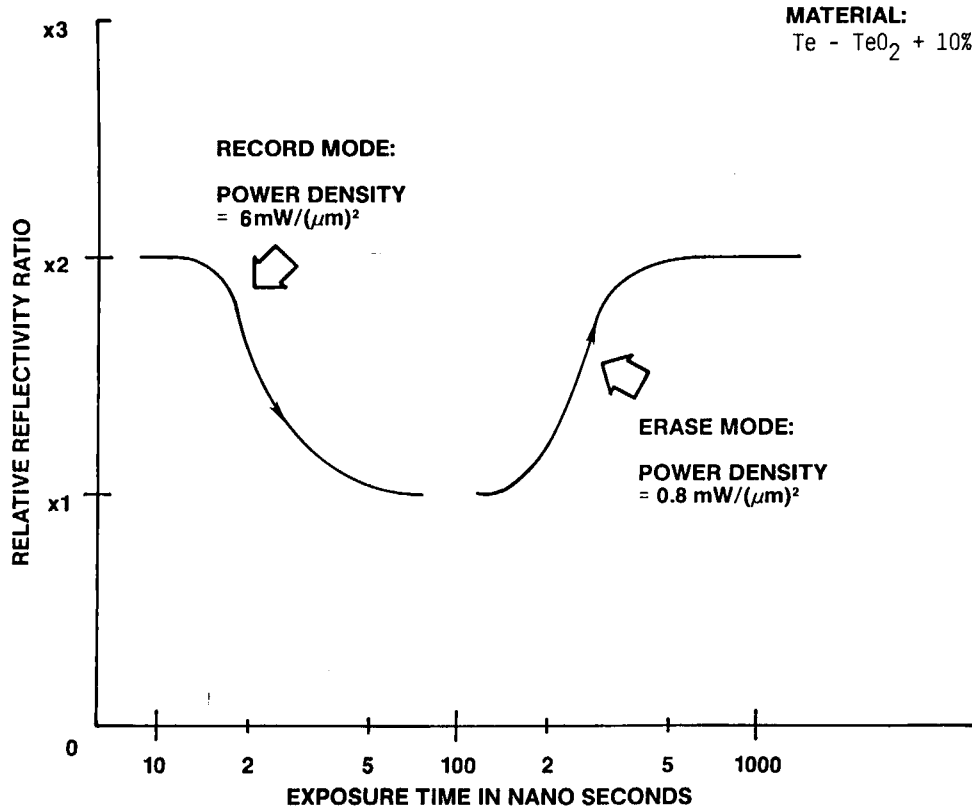


Fig. 6.

Optical Disc Structure

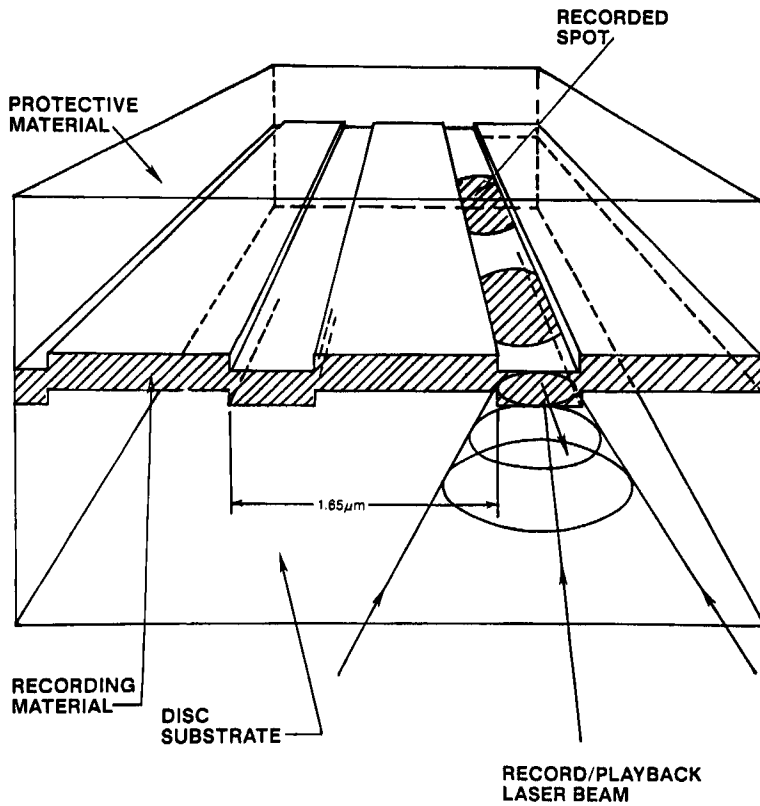


Fig. 7. Optical Disc Structure.

Basic Components, Erasable Optical Disc Recorder/Reproducer

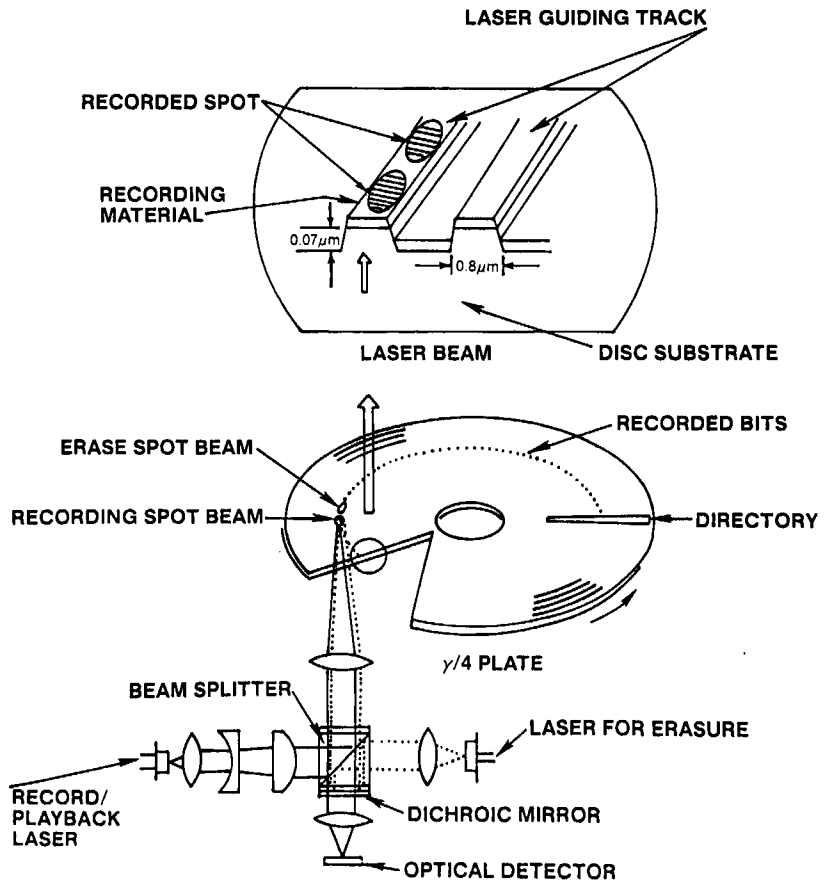


Fig. 8. Basic Components, Erasable Optical Disc Recorder/Reproducer.

Specifications, Optical Memory Disc

DIAMETER	200 mm
THICKNESS	2.5 mm
RECORD LAYER MATERIAL	Te - TeO ₂
DISC CONSTRUCTION	WITH PROTECTIVE COATING
TOTAL DATA CAPACITY	700 MB
TRACK STRUCTURE	SPIRAL TRACK WITH GUIDING GROOVE
NO. OF TRACKS	23,000
TRACK PITCH	1.65 mm
DATA CAPACITY PER TRACK	32 kB
RECORD/PLAYBACK LASER	DIODE $\lambda = 830$ nm
RECORD POWER	5 m μ
PLAYBACK POWER	1 m μ
DISC ROTATION	900 rpm
AVERAGE ACCESS TIME FOR A TRACK	0.3 sec
DATA TRANSFER RATE	5 MB/sec.

Fig. 9. Specifications, Optical Memory Disc.

Multiple Disc Automatic Handling System

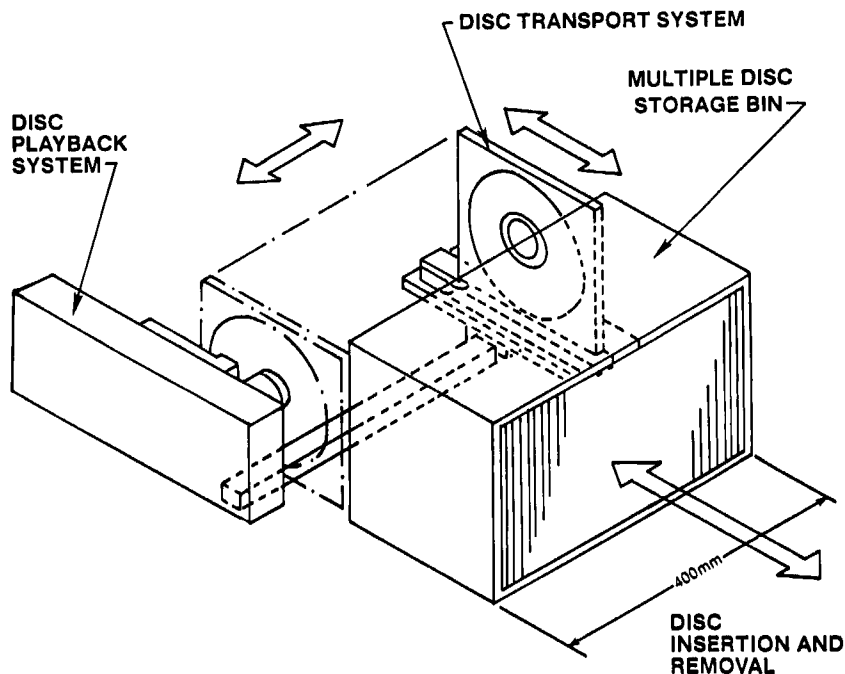


Fig. 10. Multiple Disc Automatic Handling System.