# Impact of diffractive optics on the design of optical pick up

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## 1. INTRODUCTION

With over 100 millions units per year, the optical pick up is probably the most widely produced electro optic assembly on these days. It is also the driving force of semiconductor laser production with development of higher power for high data rate recording and shorter wavelength for high density. The production of CD pick up is of course highly cost driven; over 20 years of optical storage history and ten years of CD, the reduction in size, power consumption and cost can be compared to the evolution of integrated circuit. Diffractive optics plays a significant role in this roadmap, although as will be seen not all functions can be expected to be played by diffractive optics. Refractive lens will remain the leading technology for all functions that involves strong bending of the rays.

In the near future the production od CD and CD-ROM player is expected to reach a plateau at twice today's production but MO drives and soon DVD are taking off.

## 2. STRUCTURE AND FUNCTIONS OF OPTICAL PICK UP

Whereas magnetic storage and audio disc rely on the proximity of media and sensing device to localize information, optical storage consists in focusing of a beam on the information elements. Although the density is strongly limited by the diffraction limit, optical storage is definitely advantageous in terms of spacing between media and head and therefore provides immunity to dust; it will remain the leading technology for removable media.

The role of optical head is triple:

-focus the beam on the spot to be read,

-detect information as encoded by phase, amplitude or polarization,

-sense the tracking errors and react toward optimal position.

Simple considerations on data rate and sensor sensitivity show that single spot readout requires a high intensity light source that only coherent laser source can achieve; the semiconductor laser was a key element to the development of cheap and compact optical head. This component has a lot of wonderful peculiarities but two major drawbacks:





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-its emission pattern is not axio-symetric: vertical diffraction angle is up to three times the horizontal one,

-its wavelength is not well defined during the production process and may further vary with the temperature at a rate of .3nm/°C.

The design of optical pick up will have to cope with these problems.

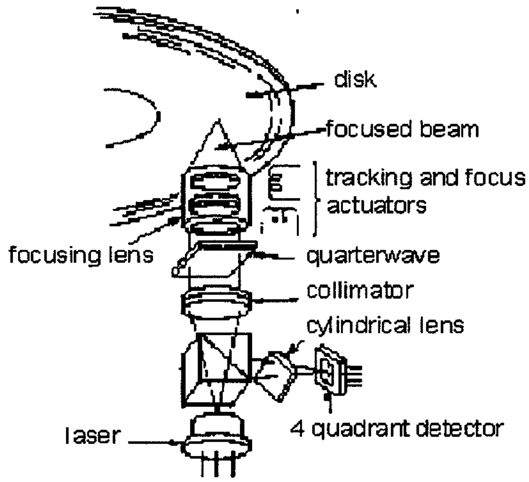


Figure 1: structure of a pick up

When a high numerical aperture beam is focused on the disk, its reflection is focused back right into the laser source; therefore a beam splitter or a circulator is needed in order to deflect the beam towards the detectors.

Many types of sensors have been deviced in order to sense the focus and radial tracking errors.

The most widely used focus sensors are:

-astigmatic sensor: some cylindrical focusing effect is added on the return path in order to elongate the focused spot in one of the two directions 45° away from the track according to the focusing error. A four quadrant detector assembly senses the shape of the returning spot,

-asymetric sensor: a part of the far field of the returning beam is blocked or deviated in order to generate a disymetry of the returning spot; this disymetry is cancelled when the beam is well focused.

The most widely used tracking sensors are:

-three spots: two sidebeams are focused slightly left and right to the track; the balance of reflected power ot these two beams provides the error signal,

-push pull sensor: the tracking error generally introduces a disymetry of the far field pattern; the sign and amplitude of this disymetry is related to the pit depth and is specified in the disc standard.

As can be seen, error sensing requires an action in the far field (splitting, masking, wavefront deformation) and detection in the near field. A diffractive element is useful in order to separate the reflected beam from the incident one while introducing such action in the far field (wave front shaping or beam division).

## 3. ADVANTAGES OF DIFFRACTIVE COMPONENTS

In a conventional CD pick up, the separation of the incident and the reflected beam is performed by a half reflective mirror and as the returning beam is exactly focused on the laser source, the detectors must be positioned precisely on the conjugate of the laser source through the half mirror. The stability of the return spot is so stringent that up to recently, the housing that holds together the laser, detectors and half mirror could not be made of injected polymer. A diffractive beam splitter, on the other hand is only slightly deflecting the beam and its positioning is far more tolerant. In other words, whereas a mirror must be adjusted within a fraction of half wavelength at the edge of the beam, the positioning of a grating is tolerant up to a fraction of its pitch. This is more than an order of magnitude more tolerant and may accomodate plastic housing.

Another advantage of the diffractive beam splitter is that any type of optical function can be added at nearly no cost on the diffracted beam. This allows to implement the "three beam method" by acting on the incident beam or to introduce astigmatism on the returning spot. It is also possible to split the far field of the beam and focus it on different detectors as is necessary in the "asymetric focus sensor".

All these functions can be implemented at very low cost; it is possible not only to replicate the diffracting function by photolithography but to realize very cheap elements by simple injection molding. The photopolymerization process ("2P") also allows the very precise replication of a nickel master in a UV-curable resist; since the substate may be glass, long term dimensional stability can be reached at low cost.

## 4. PROBLEMS ASSOCIATED WITH DIFFRACTIVE OPTICS

If so much versatility can be expected from diffractive optics, one may wonder why all the functions of optical pick up are not done that way. One of the strong limitations is the instability of the source wavelength. Thermal variations generate a shift that may reach 1% of nominal wavelength; even if refocusing corrects the first order of the effect, stigmatism is also a question since for the high numerical aperture needed to focus on a disk, the pitch does not vary linearly with the radius of the lens.

Even in such a function as beam splitting, the chromatism of the grating affects the position of the returning spot and precludes sensors which need a 2-dimensional positioning of the spot with respect to the detectors like astigmatism.

Another problem encountered with diffractive optics is the existence of many orders of diffraction. This is taken as an advantage to generate the two lateral beams of the "three beam sensor" but it is disadvantage when using grating as a beamsplitter since the -1 diffracted order of the incident beam may overlap with the +1 diffracted order of the returning beam; this is generally solved by using diffraction angle larger than the optics field, but at the cost of higher chromatism and more stringent positioning. We are developing beamsplitters with no -1 diffracted order for use in a self adjusting pick up; some profiles are characterized by a perfect phase compensation of the different zones of the grating in one or another order: we choose a three level profile that provides respectively 0%, 25% and 41% on the -1, 0 and +1 orders.

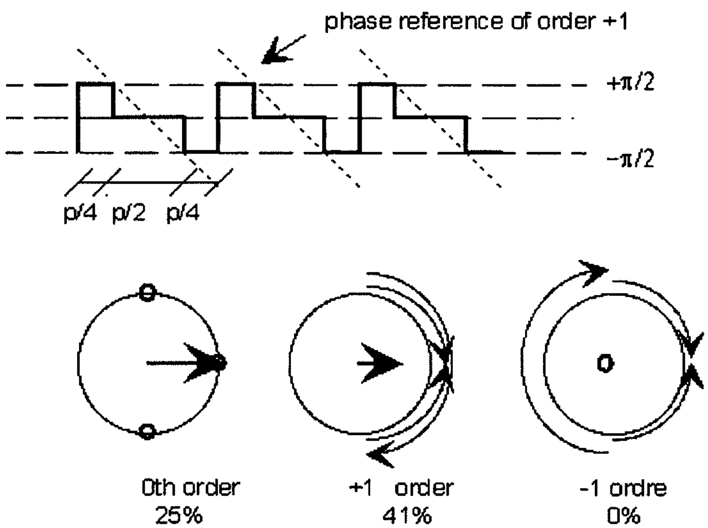


Figure 2: holographic profile for optical pick up

Even if duplication of diffractive optics can be done at very low cost, the realization of the master is often a problem. As soon as more than two levels are required to define the profile of the grating simple photolithograhic process can not be used. Oblique ion etching has been used but it offers low versatility and requires long experimentation to get proper results. Fortunately, recent developments of multilevel binary optics allow to realize complex profiles provided the spatial frequency is not too high.

## 5. SOME ACHIEVEMENTS OF PICK UP USING DIFFRACTIVE OPTICS

The most important achievement today is the mass production of a laser assembly by Sharp. This assembly integrates all the function of a CD pick up except the moving lens; this includes laser, laser power sensor, RF and tracking sensor assembly, three beam grating and beamsplitter grating. The sequence of mounting and adjustements is of uttermost importance for the industrial process:

-the three chips (laser,power sensor, detector assembly) are mounted and wired in the socket,

-the double faced holographic plate is positioned in front of the case and rotated until the asymetric sensor is well balanced,

-a reference index is made with respect to the three beam sensor for positioning the laser assembly into the final pick up.

Such a laser assembly is also used for magnetooptic pick up for MD application; however, the magnetooptic readout function has not been integrated yet.

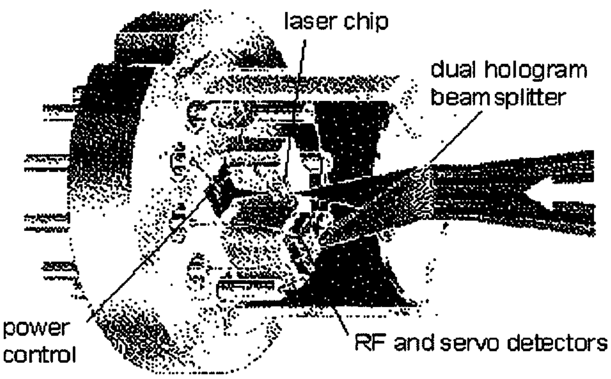


Figure 3: holographic laser assembly

## 6. FUTURE CHALLENGES FOR DIFFRACTING OPTICS

### 6.1 Magnetooptic pick up

Both the rapid growth of MO drives (3.5") and the emergence of cheap magnetooptic drive in the audio field (MD) creates the need for simpler magnetooptic pick up. Polarization effects appear when the diffraction angles are important; this raises once again the problem of wavelength dependance. An elegant solution was proposed by Maeda et al where two polarizing holograms are superimposed on the same plate and result in a small deflection of the beam.

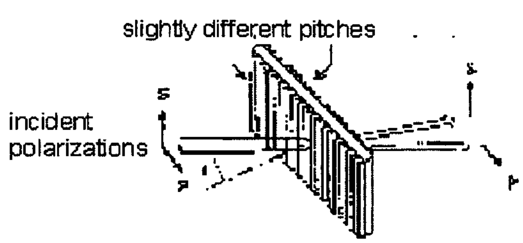


Figure 4: compensated polarizing gratings

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