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Optical Pick-up for Blue Optical Recording at NA = 0.85

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Sony and Philips have recently developed the basic technology for a 22.5 GB optical recording system, based on a blue laser ($\lambda = 405$ nm) and high numerical aperture (NA = 0.85) objective lens. This system is referred to by the acronym DVR (for Digital Video Recording). In this paper we describe the relization of a compact optical pickup unit capable of writing and reading data on disc according to the DVR format.

Key words: optical recording, blue laser diode, high numerical aperture, NA = 0.85, optical pickup unit, beam shaper, laser driver IC

1. Introduction

Sony and Philips have recently developed the basic technology for a 22.5 GB optical recording system, based on a blue laser ($\lambda = 405$ nm) and high numerical aperture (NA = 0.85) objective lens.[1] This system is referred to by the acronym DVR (for Digital Video Recording), as the recording of high definition digital video is expected to be the leading application. In the DVR system, sufficient tilt margin is ensured by addressing the information layer through a 0.1 mm thin cover layer. Tight margins (± 3 micron) are imposed on the thickness of this cover layer, so that dynamic spherical aberration correction is not needed.

The OPU concept is depicted schematically in Fig. 1. The blue laser diode (Nichia Corporation) is driven by a new programmable laser driver IC, with a closed loop laser output control (using a forward sense diode). This IC is mounted directly on the OPU. The far-field pattern of the laser beam is made approximately circular using a plastic cylindrical/toroidal surface beam shaper (see Fig. 2), mounted onto the laser.[2] This beam shaper has a beam shape factor of 2 and its position with respect to the laser diode can be adjusted to eliminate any residual astigmatism. Next, the beam passes through a PBS, a quarter wave plate, and a collimator lens. A small NA lens (NA = 0.08) is used for collimation in order to ensure a high rim intensity of the laser beam at the objective pupil. Using commercial laser diodes from Nichia Corporation, typical radial and tangential rim intensities of over 70, respectively 90% are obtained. This results in an excellent spot quality guaranteeing good writing performance. The price to pay is a reduced optical throughput efficiency from laser to disc of only 15%. In Fig. 3 the effect of reduced rim intensity on the drive performance is illustrated. The figure shows that under DVR format conditions (bit length bl = 86 nm) the readout performance decreases considerably for tangential rim intensities less than 50%.

The collimator lens is mounted into a low bandwidth one-dimensional electromechanical actuator.[3] By shifting the position of the collimator, the conjugate of the beam is varied, inducing spherical aberration of the focused spot that can be used for compensation of spherical aberration due to variations in cover layer thickness. In Fig. 4 the effect of this cover layer thickness variation on the overall OPD and its compensation by adjusting the conjugate, is shown. The adjustable collimator allows for future dual layer extensions of the DVR format. Alternatively, the collimator position can be adjusted once and for all during drive assembly.

The objective is a rigid two-element NA = 0.85 lens, with entrance pupil diameter of 3 mm ($F = 1.765$ mm), free working distance to the disc of FWD = 0.15 mm and wavelength $\lambda = 405$ nm[4] (see Fig. 5). Each element is a plano-aspheric lens, made at Philips Optical Pickup Lens facility using a standard Philips manufacturing process. A spherical glass body is used as a starting point. A plastic aspherical correction layer is added to the spherical surface of the glass body by a photo polymer replication technology. Using only two aspherical surfaces in the design results in a limited decenter tolerance of the two lens elements. Although at first sight this seems to complicate the assembly of the two lens elements, this is not the case: we can make use of the well defined outer diameter of the plano-spherical glass bodies used in the manufacturing process of the aspheric elements. Furthermore, when we consider designs in which both bodies have a thickness which is larger than their radii, the outer diameter remains well defined even when the lenses are tilted. Using a rigid lens mount with two cylindrical holes that are accurate in diameter and co-axial, the centring of the two elements can be easily accomplished within a few micron. What remains left is the alignment in tilt and distance between the two lens elements. For our research prototypes, this is done manually, under interferometric control. In this way, we have reproducibly made lenses with an RMS wavefront aberration at 405 nm below 30 mλ (best result: 20 mλ).

The objective is mounted in a standard high bandwidth two-dimensional actuator developed for DVD. The objective is provided with a "bumper" made out of a soft material to avoid disc damage during an accidental contact. The wavelength shift of the blue laser diodes when switching from read (typically 4 mW output of the laser) to write powers (typically 40 mW laser output) is in the 0.5–0.6 nm range typically at constant environmental temperature. This shift occurs almost instantaneously and can therefore not be compensated

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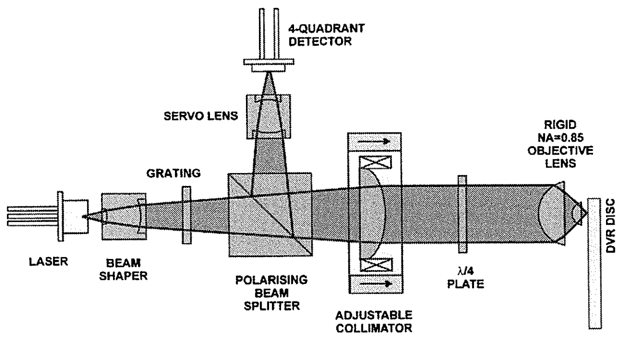

Fig. 1. Schematic drawing of DVR OPU.

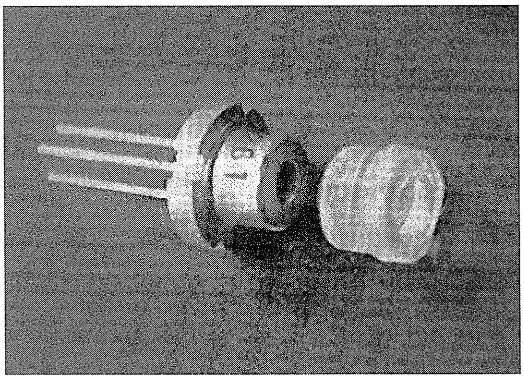

Fig. 2. Laser diode and plastic beam shaper.

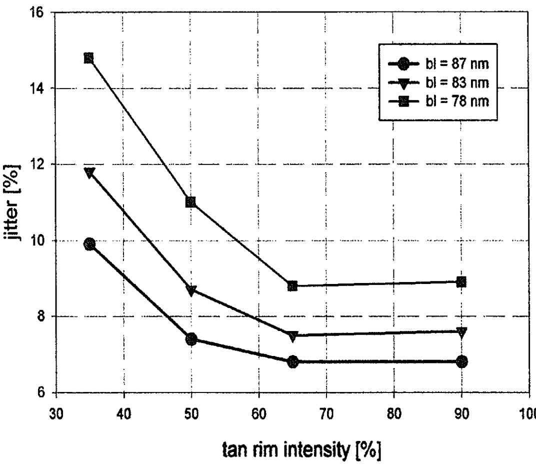

Fig. 3. Readout jitter as function of tangential rim intensity (data are written with 90% tan rim intensity), for various bit lengths bl.

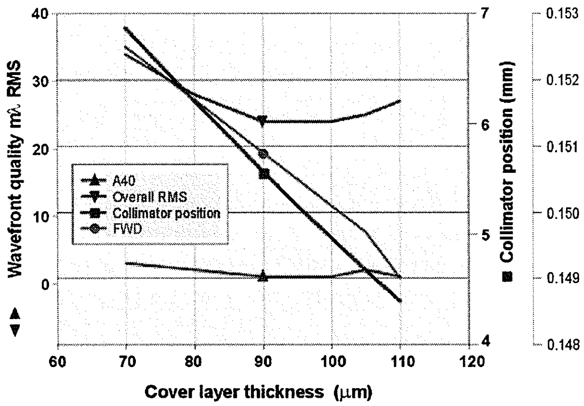

Fig. 4. The spherical aberration A40 term can be reduced to almost zero for cover layer thickness between 70 and 110 μm, by adjusting the collimator position over a distance of about 2 mm.

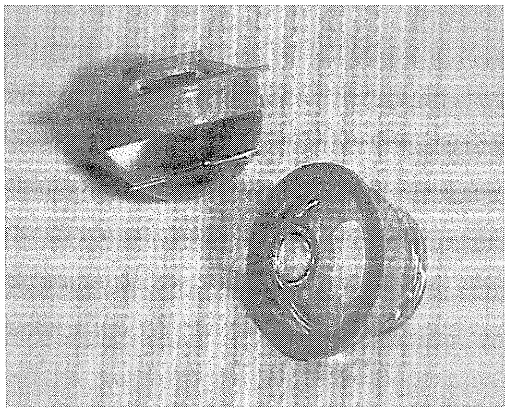

Fig. 5. NA = 0.85 objective lens.

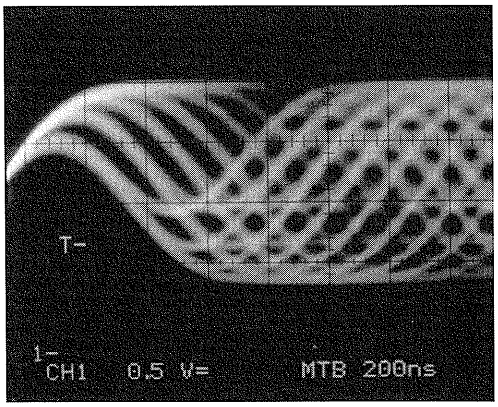

Fig. 6. Data eye pattern of high density DVR ROM disc readout.

directly by the actuator. A wavelength shift of $\Delta\lambda = 0.5$ nm results in a RMS defocus wavefront aberration of 30 mλ, showing that the lens set can deal with the above mentioned wavelength shift.

The objective has been tested using a special high density DVR ROM disc (track pitch 260 nm) that has been provided by Pioneer Corporation and was made via e-beam mastering.[5] Figure 6 shows the eye pattern of the data read from this high density DVR disc. A data-to-clock bottom jitter of 7.1% has been obtained using our NA = 0.85 objective lens, as is shown in Fig. 7. The figure illustrates the sufficient radial and tangential tilt margin for readout of this high density ROM disc. For the DVR format (capacity 22.5 GB, track pitch 300 nm) these tilt margins have been specified as 0.6° for radial and 0.3° for tangential direction.

A p-i-n type photodiode optimized for 405 nm light is used

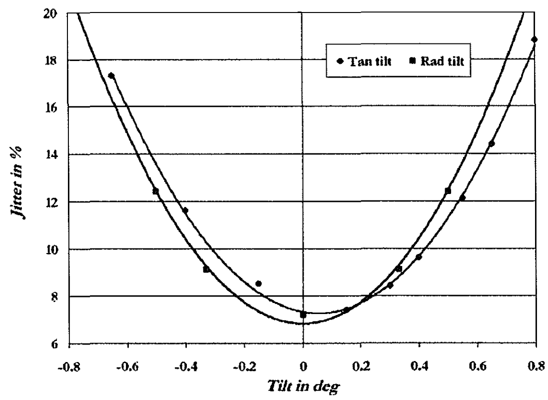

Fig. 7. Radial and tangential tilt margens for DVR system, reading high density 25 GB ROM disc.

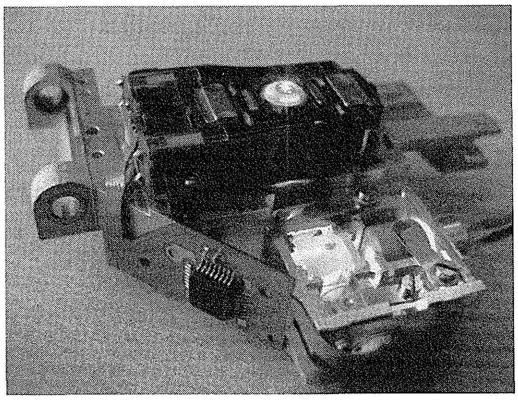

Fig. 8. Photograph of assembled DVR OPU.

to detect the focusing and tracking error signals, as well as the hf signals. The preamplifier IC is mounted on the flexfoil close to the detector. Using this detector-preamp combination user bit rates of 35 Mbit/s can be realized. Standard astigmatic focusing and 3-spot push pull tracking is used. The pregrooved substrate has a wobbled land-groove structure with headers. The wobble is detected as a high frequency push-pull signal, and used to generate the system clock during recording. The headers contain embossed addresses, and mirror marks for focus offset correction.[1] The complete DVR channel and servo electronics has been implemented using

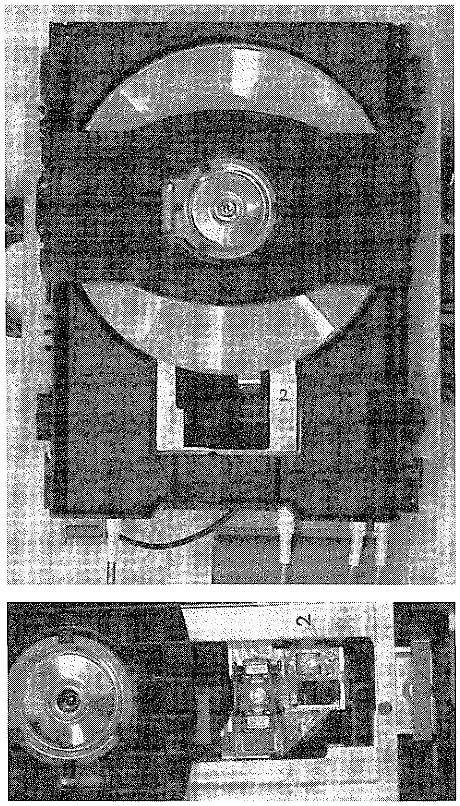

Fig. 9. Photograph of DVR drive.

field programmable gate arrays (FPGAs).

Figure 8 shows a photograph of an assembled OPU. An optical drive has been constructed comprising this DVR optical pick-up and electronics (see Fig. 9). The correct functioning of the DVR drive has been proven in a demonstrator video recorder for recording and playback of a HDTV video stream.

References

1) K. Schep, B. Stek, R. v. Woudenberg, M. Blüm, S. Kobayashi, T. Narahara, T. Yamagami and H. Ogawa: *Technical Digest ISOM 2000* (2000) p. 210.
2) J. J. M. Braat: App. Opt. **34** (1995) 2665.
3) J. P. Baartman, J. Aarts and B. H. W. Hendriks: *Conference Digest ODS 2000* (2000) p. 210.
4) B. H. W. Hendriks and P. G. J. M. Nuyens: Proc. SPIE **3749** (1999) 413.
5) M. Katsumura, H. Kitahara, M. Ogasawara, Y. Kojima, Y. Wada, T. Iida and F. Yokogawa: Technical Digest ISOM 2000 p. 18.