Laser diode wavefronts and waveguide parameters: interferometric measurements

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ABSTRACT

Interferometric measurements of wavefront phase distributions for laser diodes applied in optical disk memory units were carried out. The influence of laser diode wavefront astigmatism on the focused light spot dimensions was investigated.

1. INTRODUCTION

Laser diodes have wide applications as light sources in precise optical systems, such as optical disk memory units. One of the main parameters of such devices is a diameter of the light spot focused by an output objective since this value defines primarily the information density of an optical disk. Evidently that laser diode wavefront aberrations have a great influence on light spot dimentions. An increase of an input aperture of an optical focusing unit which is necessary for more complete usage of the laser power leads to enhancement of wavefront distortions and hence to enhancement of the focused spot diameter relative to that of the diffraction limited spot. As known, in the first approximation aberrations of laser diode wavefronts manifest themself as astigmatism which is caused by difference of the cofinement conditions for the light field energy in the p-n junction plane and in the perpendicular plane[1,2]. So in a common case the wavefront exiting from the laser diode is cylindrical. The beam waist perpendicular to the junction plane is located at the output faset of the laser diode and the waist parallel to the junction plane (imaginary waist) is located behind the output faset at the distance Δz called astigmatic distance or longitudinal astigmatism. The astigmatic distance is a generalized parameter of the laser diode wavefront. For more exact wavefront characterization it is need to have quantative data for the phase distribution.

In this report we present the results of the interferometric wavefront phase distribution measurements for the laser diodes (type ILPN-212) applied in optical disk memory units. We also investigated the influence of the laser diode wavefront aberrations on the diameter of the light spot focused in these optical units.

2. EXPERIMENTS AND RESULTS

The investigations of the wavefront phase distribution were carried out with a help of the twobeam selfreference interferometer. Fig.1 shows the optical scheme of the interferometer. Radiation of the laser diode LD was collected by the microobjective MO_1 with a numerical aperture NA=0.65 matching to the laser beam divergence and then focused at the focal plane F of the lens L_1. Lens L_1 transformed laser diode beam with large divergence to the collimated beam which then devided into

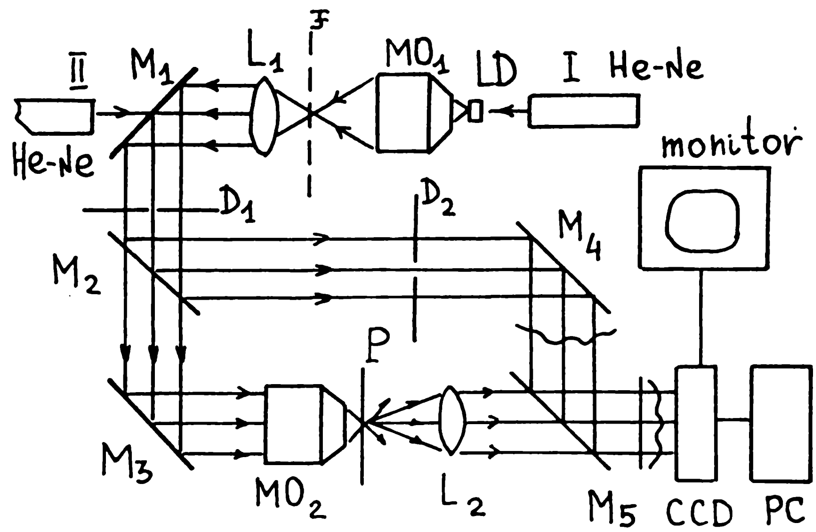

Fig. 1 Experimental setup for laser diode wavefront interferometric measurements

two arms by the semitransparent mirror M_2 ($R_{\lambda=800nm,45^0}$ =20%). For the formation of the reference beam free of aberrations the optical filtering device was positioned in one of the interferometer arms. It consisted of co-focal microobjective MO_2 and lens L_2 with the focal lenth ratio 1:10. The pinhole P with the diameter 15μm was located in their common focus. Laser diode wavefront under investigation and formed reference wavefront were brought together by dielectric mirrors M_4 and M_5. The resaltant interferogram was observed and analysed by means of CCD unit connected with a personal computer. Owing to the investigated laser diodes generated in the near IR spectral range and had a low output power the adjustment of the interferometer was carried out with the help of He-Ne laser I. In addition the front focal plane of the lens L_1 was finded by the use of He-Ne laser II . Subsequently the laser diode wavefront was being focused by the microobjective MO_1 just at this plane. Laser beam waist was observed by means of a night vision device. After laser diode having mounted in a holder in front of MO_1 it was adjusted relative to the microobjective position so that to achieve unobstructed passage of the laser diode radiation through the pinhole P. For more precise adjustment of the interferometer with a laser diode as a ligth source two diaphragms D_1 an D_2 were located in the interferometer scheme. During the measurements these diaphragms were removed.

As shown by K.Tatsono and A.Arimoto[3], the interference pattern at the plane of the detector depends on the position of the laser diode wavefront waists relative to the focus of the lens L_1. The form of the interferometric lines changes from elliptical to straight, to hyperbolic, to straight and back to elliptical, in so doing the straight lines are observed when one of the beam waists coincides with the lens focus and the hiperbolic lines are observed when lens focus is located between the beam waists. In this connection during the investigations of the laser diode wavefronts the beam waist locations relative to the lens focus were chosen the same (the waist parallel to the p-n junction plane coincided with the lens focus).

Using this interferometer the wavefront phase distributions of the GaAs-AlGaAs laser diodes applied in the optical disk memory units have been measured. The laser diodes with the astigmatic distances varied between 5 μm and 60 μm were chosen for our experiments. Each laser was a single mode device operating in the spectral range 780-800 nm. Laser diode output power was supported at the same level of 4 mW. The wavefront phase distributions for two laser diodes with astigmatic distances Δz = 26 μm and Δz= =44μm are shown in Fig.2 as an example. As may be seen from Fig.2 the most significant phase distinctions are appeared at the peripheral parts of the wavefronts. At the central part of the wavefronts the phase variations are no more than 1.5 - 2 rad. The boundaries of the input apertures of optical focusing systems, in which the investigated laser diodes were used as a light sources, are depicted by arrows A'B' and A"B".

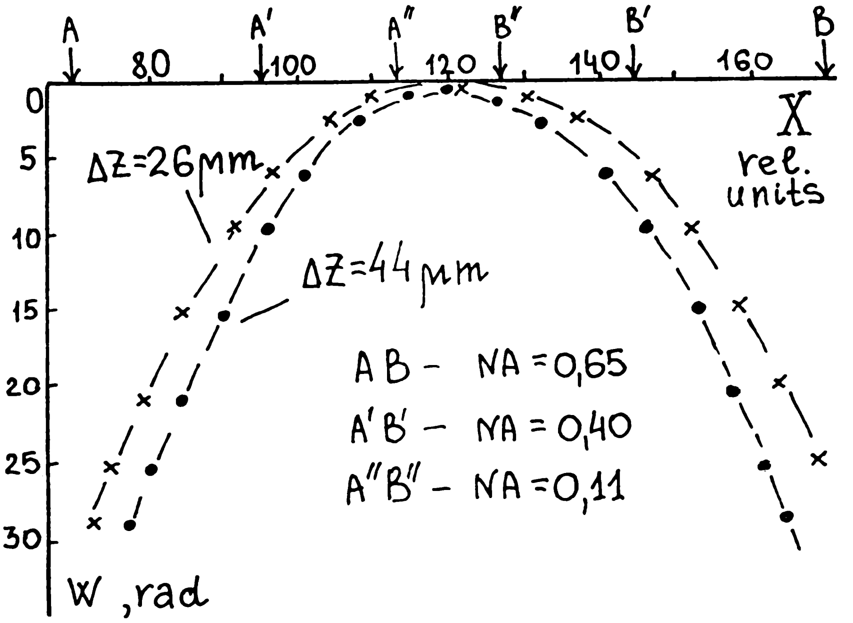

Fig.2 Wavefront phase distributions at the plane of CCD unit for two laser diode

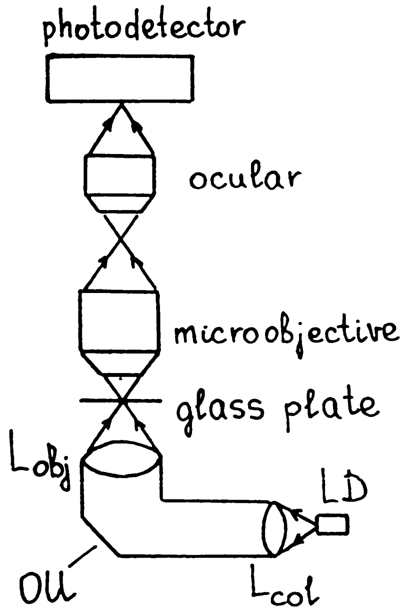

Fig.3 Simplified scheme used for measurements of the laser beam spot diameter. Here OU is the optical disk memory unit

Influence of the astigmatic character of the laser diode wavefronts on the focused light spot dimenions was studied for two optical disk devices: 1) reading optical unit with an input collimator aperture NA = 0.11 and with an output aperture of the focusing objective NA = 0.47, and 2) the WORM (write once, read many) type optical unit with an input collimator aperture NA = 0.40 and an output focusing objective aperture NA = 0.55. Dimensions of the laser beam spot focused by the optical disk memory unit were measured accoding to the scheme shown in Fig.3. Relative positions of all optical unit elements were unchanged during the experiments. When laser diode having changed the precise adjustment of its position relative to the collimator focal plane was fulfilled and the measuring microscope objective was removed to find the plane of the shaply focused light spot. The diameter d of the spot was defined by measuring of the first diffraction minimum size.

Experimental dependence of the relative diameter d/d_{th} of the focused light spot on the astigmatic distance of the laser diodes for the reading and writing optical units is shown in Fig 4. Here d_{th} is the diameter of the focused spot in a diffraction limited optical system connected with the output aperture NA of a system by the relation $d_{th}=1.22\ \lambda\ /NA$, λ is the radiation wavelength. From the comparison of Fig.2 and Fig.4 it follows that in an optical system with a small input aperture cutting off the

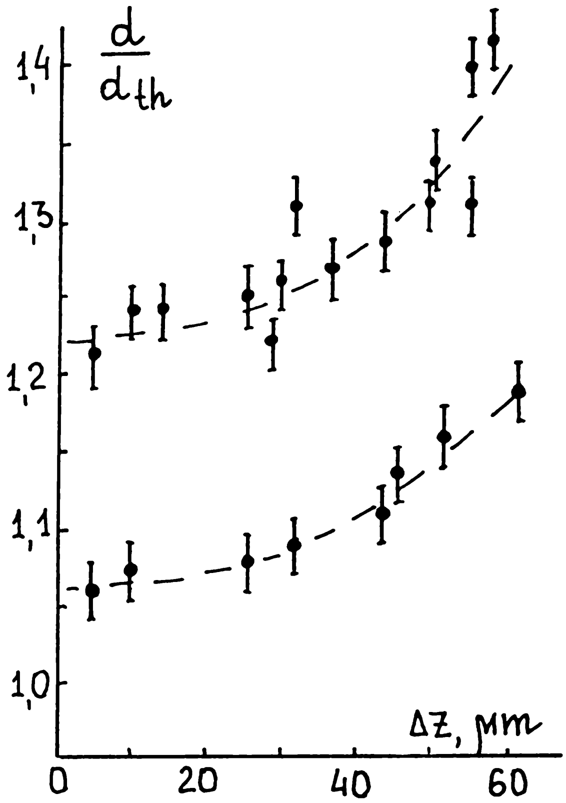

Fig.4. Experimental dependence of the relative diameter of the focuced laser beam spot on the laser diode astigmatic distance

central part of the laser diode wavefront where aberrations do not exeed 1,5-2 rad, the dimention of the focused spot is greater than that of the diffraction limited spot by no more than 20% in a wide range (Δz is from 0 to 60 μm) of the laser diode astigmatic distances. For the laser diodes with astigmatic distance about 5 μm this spot exeeding is about 6%. In the case of the optical system with more wide input aperture (in our case it is of 0.40) in which wavefront aberrations rise up to 10 rad and more the focused spot dimension exeeds sufficiently the diffraction limited spot (21- 24% for laser diodes with Δz being in the range of 0 to 20 μm, and about 40% for laser diodes with Δz being about 60 μm). Besides, since phase differences at the wavefront edges for laser diodes with different astigmatic distances are greater then the differences at the central part, the dependence of d/d_{th} shows the stronger rise for an optical system with exeeding input aperture. For Δz being in the range of 0 to 60 μm the rise of d/d_{th} is about 20% for NA=0.40 and is about 13% for NA=0.11.

It's necessary to note specially that the results received in this work for given optical systems are qualitativly true in the common case for another focusing optical systems.

3. CONCLUSIONS

Interferometric methods were used to obtain information concerning the phase distribution of the laser diode wavefronts. The influence of laser diode wavefront astigmatism on the dimensions of the focused light spot was investigated. A knowledge of phase aberrations of laser diode wavefronts makes possible to predict the output parameters of the precise focusing optical systems where these laser diodes applied and also may be used for the design of the correcting optics.

4. ACKNOWLEDGEMENTS

The authors wish to thank V.P.Konyaev and M.V.Zverkov for help in laser diode sampling.

This work was supported by Meyer Foundation and the American Physical Society.

The authors acknowledge the financial support of the Batory Foundation due to which the author's participation in the conference was possible.

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