THE NEW POSSIBILITY TO PRODUCE HOLOGRAPHIC OPTICAL ELEMENTS USING THE LOWEST COST LASER DIODES

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1. INTRODUCTION

The history of semiconductor heterolasers and microoptics for them started in 1968 with continuous wave double heterojunction semiconductor lasers operating at room temperature. The lasers were developed by Prof. Zh.I. Alferov and his research team at A.F. Ioffe Physico-Technical Institute.¹

Effective coupling of semiconductor lasers to the other elements of integrated and fibre optics, and the use of laser diodes for pumping solid state lasers, are important for laser diode applications. Single mode semiconductor lasers without astigmatism, with near diffraction limited modes and asymmetry factor (Q) equal to 1 would be ideal for all applications. However, even laser diodes with a single narrow stripe and the only the lowest single transverse mode, are operating on two, three or more longitudinal modes.²

A single stripe laser diode operating in zero transverse mode close to the diffraction limit can be easily focused to a point. It is more difficult to provide high efficiency coupling of the radiation of a multimode laser into a waveguide or active crystal. The technique of beam division from a laser array with emitting area about 10 mm allows us to achieve a Q factor around 1 and to obtain total efficiency up to 90 %.³ However, adjustment of such multielement coupling devices is rather complicated.

Special devices with improved far field and near field patterns, such as a device consisting of a master laser and tapered amplifier, allow one to obtain zero hyper mode operation and simpler adjustment.⁴ However, these are very expensive and rather complicated devices, as are also DFB and DBR laser diodes.

One of the solutions for the problem of effective coupling would be for example a beam-correcting holographic doublet recorded at 488 nm, which could successfully correct the astigmatism of a multimode laser diode at 820 nm.⁵ However only such holographic
optical elements (HOE) that could be recorded by laser diode itself, that is, self aligned HOEs, allow coupling close to ideal, and recording such holograms with a multimode laser diode is a problem.

2. THE CRITERIA FOR APPLICABILITY OF MULTIMODE SEMICONDUCTOR LASERS IN HOLOGRAPHY

The ideal source for recording is a single longitudinal mode, single transverse mode laser diode. Using this laser is not difficult, because the width of lasing spectrum is in the range of 20-500 MHz and the worst case - 500 MHz - gives us a coherence length of about 60 cm. However, to the best of our knowledge, using standard commercial laser diodes, especially high power single mode lasers or high power multimode lasers, was never considered except in Ref. 6,7.

Of course, if the longitudinal modes are equidistant and their widths are narrow, it is possible to record the hologram with an efficiency depending only on the width of longitudinal mode, by fine tuning of the photoplate position. This is the case of mode locked operation of the laser diode (LD). This type of operation can be achieved with the LD with a saturable absorber and an operating current to threshold current ratio of 3 to 10. This is the standard amplitude-modulation mode locking case, which corresponds to the phases of all modes being fixed and approximately equal.

Mode locking operation may be understood more broadly as a regime where the modes are equidistant with fixed phases but the difference between the phases of two adjacent modes is not small. Mode locking can be obtained with no saturable absorber, using a fast optical nonlinearity in the active layer of a semiconductor laser. Possibly this type of mode locking can be realised for laser diodes with both narrow and broad stripes.

3. EXPERIMENTS

We investigated the possibility of recording holograms using a multimode laser diode. We used (AlGa)InP quantum-well LDs with 5-8 μm wide stripe and with a maximum intensity of lasing around 690 nm (Fig. 1). The operating current to threshold current ratio was in the range 1.2-1.6. The spectral width at half power was 40 - 60 nm.

![Fig. 1 Typical Spectrum of LDs.](image-url)