Fabrication of sub-wavelength circular diffraction gratings for high-power laser applications

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We present design, fabrication process and optical characterization (reflectivity measurements) of a polarization selective circular output grating coupler. It is to be used in a thin-disk laser cavity for the generation of a laser beam with radial polarization at λ=1030 nm.

1 Introduction

Radial and azimuthal polarization states are found to be interesting for various applications ranging from particle trapping and acceleration to material processing [1]. In the latter case laser beams with radial and azimuthal polarizations have allowed to increase cutting and drilling rates between 20% and 50% respectively [2, 3].

Grating waveguide structures (GWS), which result from the combination of a sub-wavelength grating and a planar waveguide, have been reported to be an efficient approach to generate polarized laser beams [4]. These optical components provide a powerful tool for tailoring polarization as well as spectral and spatial properties of the laser beam [5]. Generation of laser beams with axially-symmetric (radial or azimuthal) polarization directly out of a laser cavity is possible with the help of circular GWS used either an end mirror (Grating waveguide mirror GWM) or an output coupler (Grating waveguide output coupler GWOC). Their working principle is described in details in reference [6].

In this contribution we present design, fabrication and optical characterization (reflectivity measurements) of a GWOC for thin-disk laser operating at $\lambda = 1030$ nm.

2 Design

The GWOC design consists of fused silica substrate with a shallow grating (groove depth σ=35 nm, period Λ=840 nm) in it, on top of which a stack of standard partial reflector composed of alternating Nb_2O_5 and SiO_2 layers (see schematic in Fig. 1).

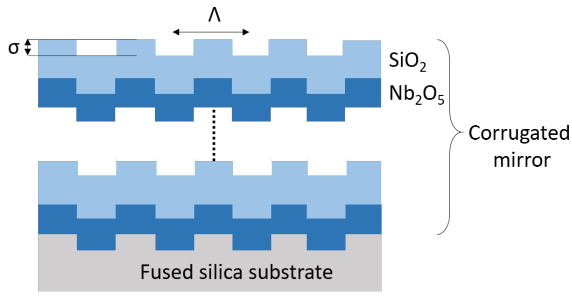

Fig. 1 *Cross-section of GWOC structure.*

This design allows to achieve 95% reflectivity for TM (radial) polarization whereas the reflectivity of the TE polarization is drastically reduced to approx. 20% (see Fig. 2).

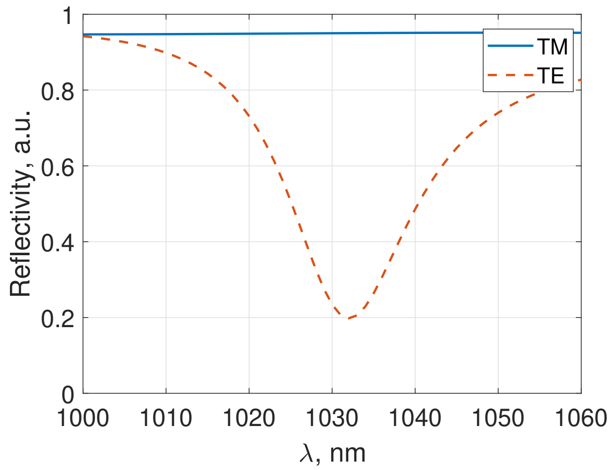

Fig. 2 *Calculated TE and TM reflectivities of GWOC versus wavelength.*

3 Fabrication

Circular diffraction gratings were fabricated by means of scanning beam interference lithography

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(SBIL) that is operated in radial coordinates. In this method two incident beams are focused on the rotating substrate and form a small (10...100 µm) interference pattern with a period $\Lambda = \lambda/2\sin\theta$, where λ is the wavelength of the incident light and θ is the angle of incidence. The interference pattern is scanned across the rotating substrate producing uniform, continuous rings. The position of the beam is interferometrically controlled assuring a low positioning error [7]. Produced by SBIL, pattern is then transferred into the substrate by reactive ion etching with CHF_3 and Ar gas combination (PlasmaLab 80 Plus, Oxford). After that, the Nb_2O_5/SiO_2 sequence was applied by magnetron sputtering (HELIOS, Bühler Leybold Optics) by the Institute of Fresnel, France. The image of the fabricated sample and the AFM scan are shown in Fig. 3

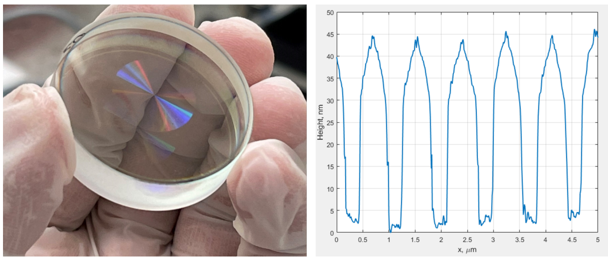

Fig. 3 *Picture of the GWOC (left) and the AFM scan (right).*

As can be seen from the AFM scan, final structures have a groove depth of approx. 40 nm with the top of the grating having a triangular shape.

4 Results and discussion

The reflectivity of the fabricated GWOC was measured with a spectroscopic setup according to DIN EN ISO 13697 under normal angle of incidence [6]. The simulation and measurement results are presented in Fig. 4. As can be seen, at 1030 nm the reflectivity for TM polarization shows a good agreement with simulations (94.8% $\pm$ 0.2%). On the other hand, the slight difference in the reflectivity for TE polarization cab be attributed to the over-etching of the diffraction grating. Nevertheless, the reflectivity for TE polarization (34.9% $\pm$ 0.2%) is low enough to filter out TE polarization within the laser cavity. Future experiments will be dedicated to the implementation the GWOC in a thin-disk laser cavity.

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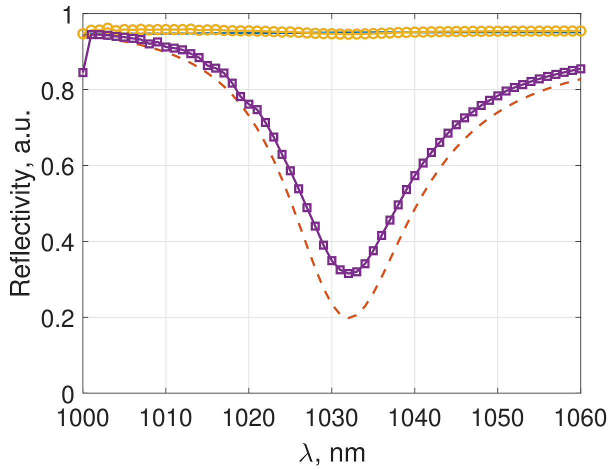

Fig. 4 *Reflectivity measurements of GWOC. Lines with circles and squares are measurement results for TM and TE polarizations respectively. Solid and dashed lines are simulation results for TM and TE polarization respectively.*

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