Improved thermal performances of resonant reflection waveguide grating structure

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We present the intra-cavity characterization (within an Yb:YAG thin-disk oscillator) of a single-layer resonant waveguide grating (RWG) using a crystalline material (namely Sapphire) as substrate. The operating principle of the present device is the same as in [1]. It offers high reflectivity > 99% with a narrow spectral bandwidth of typically <1 nm FWHM for a given polarization and angle of incidence. Commonly single-layer dielectric waveguide gratings are based on sub-wavelength grating integrated with a high-index waveguide (such as Ta_2O_5 or Nb_2O_5) coated on a fused silica substrate. Often, they suffer from heating caused by the absorption in the waveguide layer, in addition to the relatively low thermal conductivity of the substrate, thus limiting their applications in high average power lasers. In the present contribution, we report on a RWG composed of a Ta_2O_5 waveguide layer coated on a structured sapphire substrate with better thermal performance at high average laser power (i.e., at high-power densities on the grating surface). The designed device consists of a single Ta_2O_5 layer of 200 – 235 nm thickness deposited upon a binary grating with a period of 515 nm and a groove depth of 120 nm etched into a sapphire (Al_2O_3) substrate [2]. The RWG was designed to operate for TE polarization at 1030 nm and an angle of incidence of ~ 10°.The suitable choice of substrate material offers a thermal conductivity that is an order of magnitude higher than fused silica. Before its implementation in the laser cavity, the fabricated sample was first characterized in a spectroscopic setup to measure its reflectivity for both TE and TM polarizations. At the central wavelength of our laser i.e. 1030 nm, the reflectivity for TE and TM polarizations were measured to be R_{TE} = 99.2 ± 0.2% a R_{TM} = 8 ± 0.2%, respectively.

(Fig. 1-left) shows the measured output power and efficiency of the emitted beam using our RWG as folding mirror in a multimode (M^2~ 6) Yb:YAG thin-disk laser cavity. Up to 191 W of output power at an optical efficiency of 39% is achieved, corresponding to ~ 15% efficiency drop compared to an HR folding mirror. This is consistent when considering the lower reflectivity of the RWG and its use in a double-pass configuration inside the resonator. Furthermore, the grating surface temperature was measured to be below 32°C (see Fig. 1(right) at the maximum output power of 191 W (corresponding to 52 kW/cm² of power density on the grating). The linear fit function reveals a slope of 0.257 K/(kW/cm²). This shows a significant reduction, by a factor of 6, in the temperature rise in comparison to the performance of an RWG on silica presented in [1]. The spectral bandwidth of the emitted beam was measured to be 0.5 nm (FWHM), equivalent to a reduction by a factor of 4 compared to the resonator with the HR folding mirror. Based on this promising result, further experiments are in progress to implement the RWG in a fundamental-mode laser cavity. The obtained results will be presented in the talk.

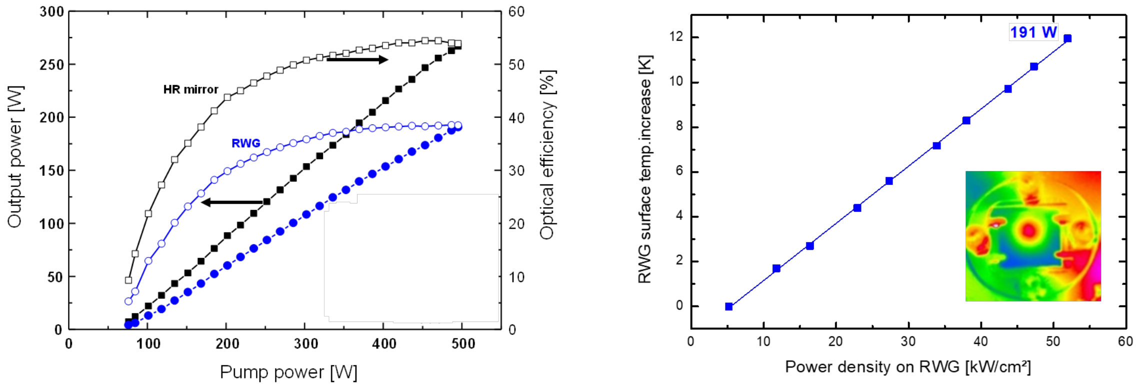

Fig. 1 Left side: Output power (solid circles) and optical-optical efficiency (empty circles) in multi-mode operation, with a HR folding mirror or RWG. Right side: RWG surface temperature increase versus pump power density on RWG.

Acknowledgments: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No.813159

References

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