Focused-ion-beam nano-structured rib waveguides in $KY(WO_4)_2$ for laser applications

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Bulk $KY(WO_4)_2$ (hereafter KYW) laser crystals doped with rare-earth ions are recognized to be among the most promising host materials for obtaining novel solid-state lasers. The rare-earth ions RE^{3+} are easily incorporated in the KYW structure by replacing the Y^{3+} ions, resulting in a stoichiometric active material with high absorption and emission cross-sections [1].

The realization of waveguiding structures with such materials is of great interest for future active integrated optics devices. In order to achieve highly confined single-mode propagation and low optical losses, we have developed a new KYW:Yb layer co-doped with Lu^{3+} and Gd^{3+} ions. A special composition of $KLu_{0.253}Gd_{0.13}Yb_{0.017}Y_{0.6}W$ has provided reproducible crack-free layers with a refractive-index contrast as high as 7.5×10^{-3}, which is the highest value reported for KYW:Yb / KYW composite structures. Rib waveguides obtained by reactive ion etching (RIE) are characterized by propagation losses below 1 dB/cm at the Yb^{3+}-fluorescence wavelength ($\lambda \approx 1020$ nm) and by a high optical confinement. As a consequence, they offer a great potential for the realization of efficient nano-structured waveguides such as Bragg grating filters or even DBR/DFB (Distributed Bragg Reflection/ Distributed FeedBack) micro-lasers.

Here, the first promising results concerning the realization of Bragg filters on KYW by focused ion beam (FIB) etching are reported. This tool is very powerful for producing nano-structures in a large variety of materials [2]. In this work, different thin conductive layers have been tested and a 20-nm-thick aluminum layer has been chosen to reduce charging effects. Then, FIB parameters have been optimised to etch periodical nano-scale patterns with a high aspect ratio at a high speed. The dimensions and the shape of the grating have been fixed by numerical simulations to obtain efficient rib-based Bragg filters at $\lambda \approx 1020$ nm. Such gratings, with a periodicity as low as 250 nm and a high aspect ratio, have been milled on the KYW:Gd,Lu,Yb / KYW ribs (Figs. 1 & 2). Current work concentrates on the optical characterization and optimization of these first Bragg filters produced in a double tungstate material.

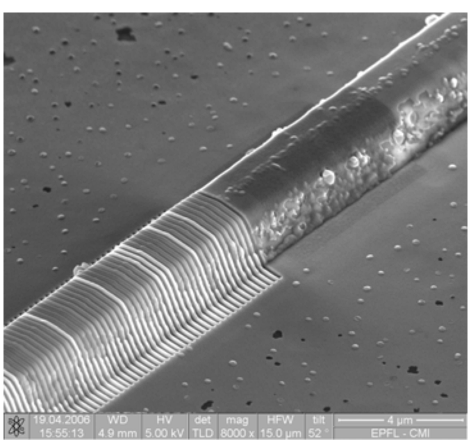

Fig 1 : Tilted SEM image of a 250-nm-period Bragg grating corrugated on a 5-μm-wide, 1.8-μm-high rib waveguide produced in a 3.5-μm-thick $KLu_{0.253}Gd_{0.13}Yb_{0.017}Y_{0.6}W$ layer.

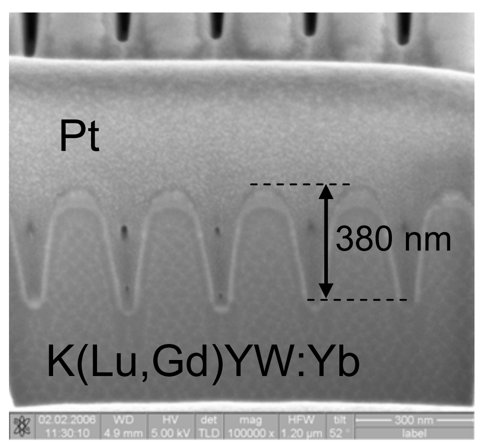

Fig 2 : SEM image of the cross-section of a Bragg grating pattern.

[1] Y.E. Romanyuk, C.N. Borca, M. Pollnau, S. Rivier, V. Petrov, and U. Griebner, Opt. Lett. **31** (1), 2006, p. 53.
[2] M.J. Vasile, Z. Niu, R. Nassar, W. Zhang, and S. Liu, J. Vac. Sci. Technol. B **15** (6), 1997, p. 2350.