Novel rib structures in Yb-doped $KY(WO_4)_2$ for laser applications

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Channel waveguides structures are the building blocks of the future integrated optics devices. In order to allow for high functionality in optical routing and processing, such devices have to be compact and highly efficient. On the one hand, increased integration density and light bending capability require the use of waveguides with high refractive-index-contrast. On the other hand, the waveguides with low refractive-index-contrast usually present lower diffraction losses required in lasers or amplifiers. Therefore, there is a need of fabricating active epilayers with flexible refractive-index-contrast. Here we report, for the first time, on the fabrication of flexible refractive-index-contrast rib waveguides based on Yb-doped $KY(WO_4)_2$ epilayers (hereafter KYW).

We use liquid-phase epitaxy to grow 1.7 at.% Yb-doped KYW layers on undoped (010) KYW substrates. The corresponding refractive index contrast is as low as $\Delta n=6 \times 10^{-4}$, which is suitable for demonstrating highly-efficient planar waveguide laser action [1]. The planar layers were structured using reactive ion etching (RIE) and standard photolithography processes for producing high quality µm-size ribs with low roughness. Rib-channels of 15-µm width and 5-µm height have been dry-etched in a 10-µm layer, creating single-mode waveguides with mode-beam diameters of 17x12 µm. Fig. 1(a) and (b) present the polished end-face cross section and the mode intensity profile at 965 nm.

Single-mode waveguide structures, with improved light confinement and coupling efficiency with standard optical fibers require higher refractive-index-contrast while keeping the Yb doping level fixed. To achieve this goal, we use co-doping of the KYW layer with optically inert rare-earth Gd^{3+} and Lu^{3+} ions. The refractive index contrast obtained was $\Delta n=7.5 \times 10^{-3}$, ten times higher than in the KYW:Yb layers, while keeping the Yb-doping constant at 1.7 at.%. The cut-off thickness for supporting the fundamental-mode propagation at 1µm dropped from 4 µm in Yb:KYW epilayers to 1.5 µm in Yb:K(Lu,Gd)YW layers. By use of similar photolithography and dry-etching processes we have obtained highly confined single-mode rib waveguides of 5-µm width and 1.8-µm height in a 3.5-µm thick epilayer. The mode-beam diameters at 965 nm were measured to be 5.7x3.9 µm. Fig. 1 (c) and (d) show the end-face cross section and the mode intensity profile for the co-doped Yb:K(Lu,Gd)YW layers. The propagation loss measurements of all fabricated ribs has been performed at 670 nm, to avoid the optical absorption of Yb^{3+} ions. By assuming a perfect fiber/rib coupling and losses mainly due to Rayleigh scattering, we estimated an upper limit of 1.5 dB/cm for the propagation losses at the fluorescence wavelength (near 1µm).

These novel rib-structures offer great potential for applications towards integrated optics based on KYW, including miniaturized lasers with structured mirror gratings. Current work focuses on the realization of more complex passive and active optical functions at the nano-size level.

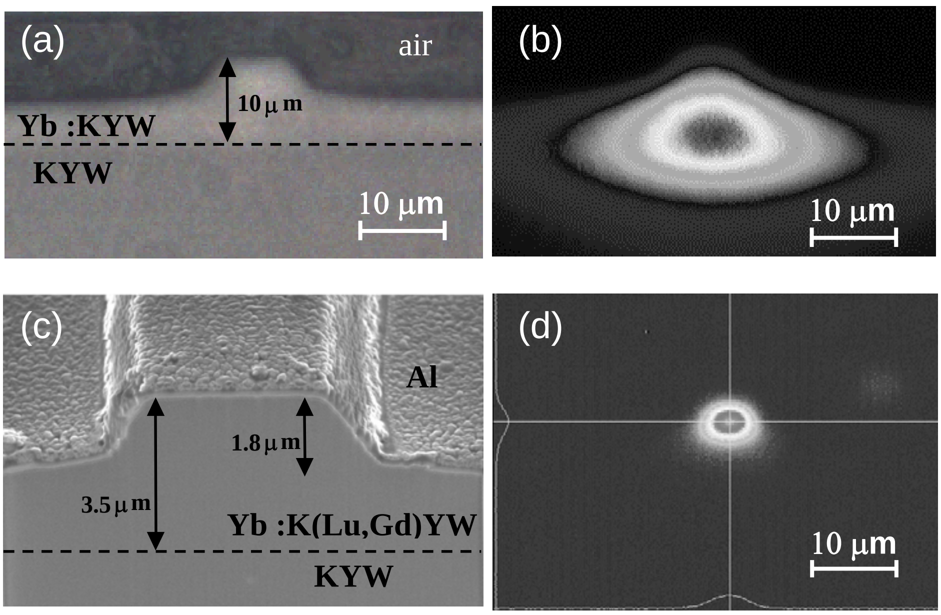

Fig. 1. *Coupling end-face cross-section as seen with an optical microscope for (a) Yb:KYW layer and with an SEM for (c) co-doped Yb:KYW layer. An Al-layer was used to reduce charging effects; corresponding mode intensity profiles for (b) the low index and (d) the high-index contrast layers.*

[1] Y.E. Romanyuk, C.N. Borca, M. Pollnau, S. Rivier, V. Petrov, and U. Griebner, Opt. Lett., 31, (2006), 53.