Optical rib waveguides in Yb-doped $KY(WO_4)_2$ epilayers

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Channel waveguide structures are the building blocks of 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 in both passive and active operation modes. 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, operation as a waveguide laser or amplifier is more efficient in low refractive-index-contrast waveguides with low diffraction losses. 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 channel waveguides based on Yb-doped $KY(WO_4)_2$ epilayers (hereafter KYW).

We used 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 $\Delta n = 6x10^{-4}$, which is suitable for demonstrating highly efficient planar waveguide laser action [1]. These planar layers were structured using reactive ion etching (RIE) and standard photolithography processes for producing high-quality ribs with low surface roughness. Channels of 15-μm width and 5-μm heigth were etched in a 10-μm thick layer, creating single-mode waveguides with mode-beam diameters of 17x12 μm^2. Figures 1(a) and (b) present the 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 used co-doping of the KYW epilayer with optically inert Gd^{3+} and Lu^{3+} ions. The refractive-index contrast obtained was $\Delta n = 7.5x10^{-3}$, ten times higher than with the KYW:Yb layers, while keeping the Yb-doping constant at 1.7 at.%. The cut-off thickness for supporting fundamental-mode propagation dropped from 5 μm in KYW:Yb epilayers to 1.5 μm in KYW:Lu,Gd,Yb epilayers. By use of similar photolithography and dry-etching processes we obtained highly confined single-mode channel waveguides of 5-μm width and 1.8-μm heigth in a 3.5-μm thick epilayer. The mode-beam diameters at 965 nm were measured to be 5.7x3.9 μm^2. Figures 1 (c) and (d) show the end-face cross-section and the mode intensity profile for the co-doped KYW:Lu,Gd,Yb layers. The propagation losses of the fabricated ribs were measured at 670 nm to avoid the optical absorption of Yb^{3+} ions. 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 1 μm).

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

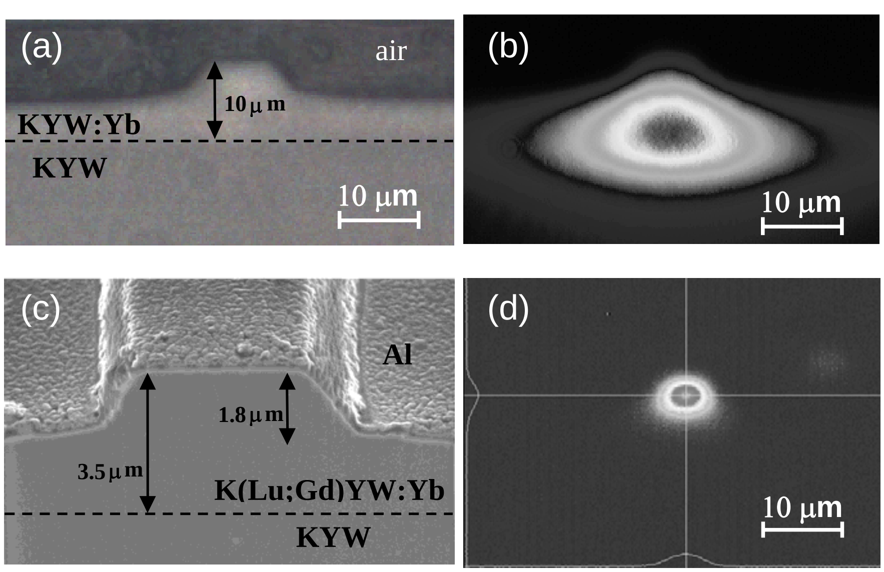

Fig. 1. *Coupling end-face cross-section of (a) a KYW:Yb layer seen with an optical microscope and (c) a co-doped KYW:Yb layer seen with a SEM. An aluminum layer was used to reduce charging effects; corresponding mode intensity profiles for the low-index (b) and high-index (d) contrast layers.*

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