Waveguide lasers in Tm^{3+}-doped $KY_{1-x-y}Gd_xLu_y(WO_4)_2$

G. Lifante[1], W. Bolaños[2], J.J. Carvajal[2], X. Mateos[2], G.S. Murugan[3], A. Subramanian[3], J.S. Wilkinson[3], E. Cantelar[1], M. Aguiló[2], F. Díaz[2]

[1]Advanced Materials for Integrated Guided Optics (AMIGO), Departamento de Física de Materiales, Universidad Autónoma de Madrid, Madrid, Spain
[2]Física i Cristal·lografía de Materials i Nanomaterials (FiCMA-FiCNA). Department de Química Física i Inorgànica, Universitat Rovira i Virgili, Tarragona, Spain
[3]Optoelectronics Research Centre, University of Southampton, Southampton, United Kingdom

Summary

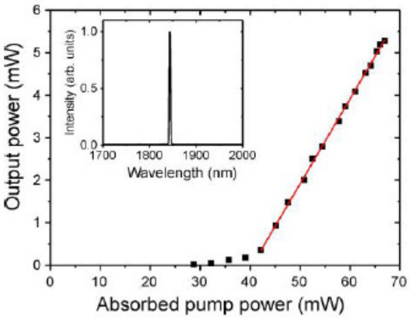
Recent results on the fabrication and characterization of waveguide lasers on monoclinic potassium double tungstates are presented. Using as guiding material a Tm-doped $KY_{1-x-y}Gd_xLu_y(WO_4)_2$ lattice matched layer grown on a $KY(WO_4)_2$ substrate by Liquid Phase Epitaxy (LPE), laser oscillation in CW and in Q-switching regimes at ~1.84 μm, in slab and channel waveguides, is demonstrated.

Introduction

The family of laser crystals known as monoclinic double tungstates $KRE(WO_4)_2$ (RE = Y, Gd, Lu) were obtained for the first time in the 70s, and they were soon recognized as excellent host for active lanthanide ions for the fabrication of solid state lasers [1]. However, their potential applications as promising materials for integrated optics were recognized only seven years ago [2]. The inherent advantage of waveguide lasers over conventional bulk lasers is the good overlap between the pump light and the laser mode, because both are constrained to propagate together in the narrow waveguide, leading to high intensities for relatively low power. Laser emission in the 2 μm spectral range is of particular interest for applications in atmospheric monitoring, laser radar and medicine. Among the lanthanide ions exhibiting laser transitions around 2 μm, the trivalent thulium (Tm^{3+}) with the emission based on the $^3F_4 \rightarrow {}^3H_6$ transition is one of the most attractive, since it can be pumped directly around 800 nm with AlGaAs diode lasers. Moreover, waveguide lasers with their simple monolithic structure are attractive for integrated optical devices with the potential for on-chip integration. Here, waveguide laser geometry is in particular advantageous for three-level lasers in which the final level is thermally populated, such as Tm^{3+}.

Results and discussion

Tm^{3+}-doped lattice matched epitaxial layers, with a concentration of 3 mol%, were obtained by LPE over **b** oriented $KY(WO_4)_2$ substrates. Buried planar waveguides were then fabricated by growing a $KY(WO_4)_2$ cladding layer, by LPE, on top of the already polished active epitaxial layer. Buried channel waveguides have also been fabricated according to the following procedure [3]: (i) Microstructuring of a $KY(WO_4)_2$ substrate by UV photolithography and Ar-ion milling. (ii) Epitaxial Lateral Overgrowth (ELO) of the Tm-doped $KY_{1-x-y}Gd_xLu_y(WO_4)_2$ lattice matched layer over the surface of the microstructured $KY(WO_4)_2$ substrate. (iii) LPE growth of a $KY(WO_4)_2$ cladding layer. Based on such Tm-doped waveguides, we have demonstrated three types of waveguide lasers [3,4]. First, planar waveguide lasing was demonstrated in a monolithic cavity at 1843.6 nm operating in the CW regime. The laser cavity was formed by butting two dielectric mirrors against the ends of the sample. This planar waveguide laser had a slope efficiency of 23% with respect to the absorbed pump power, Figure 1 (left). The second guided laser we demonstrated consisted on the passively Q-switched operation of the planar waveguide by introducing a Cr:ZnSe plate as saturable absorber (SA). The SA crystal was butt-coupled between the output coupler and the end face of the waveguide, as can be seen in Figure 1 (right). The passive Q-switch laser was reached at an absorbed pump power of 41 mW. The output spectrum consisted of a single peak centred at 1844. 7 nm



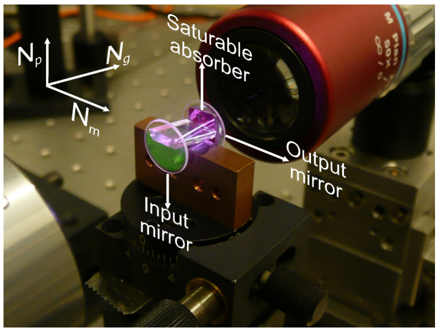


Fig. 1: Left: CW laser operation for TE pump polarization using dielectric mirrors. Right: passive Q-switch laser using a saturable absorber.

Finally, the third waveguide laser we demonstrated consisted on the CW lasing using $KY_{0.58}Gd_{0.22}Lu_{0.17}Tm_{0.03}(WO_4)_2$ buried channel waveguides fabricated as explained above. The feedback provided by the 11% Fresnel reflections at the end faces alone was sufficient to enable mirrorless laser oscillation for both TE and TM pump polarizations, with efficiencies of up to 13% with respect to the launched pump power.

Conclusions

Planar and channel waveguide lasers emitting in the 1.8 μm spectral range using $KY_{0.58}Gd_{0.22}Lu_{0.17}Tm_{0.03}(WO_4)_2$ epitaxial layers grown on $KY(WO_4)_2$ substrates have been developed. CW laser oscillation with slope efficiency of 26% was obtained, and passive Q-switching was demonstrated using a slab waveguide. Also, based on buried channel waveguides fabricated by a novel combination of Ar ion milling and LPE, mirrorless Tm^{3+}-doped waveguide laser was demonstrated.

Acknowledgements

Work supported by the Spanish Government (projects MAT 2008-06729-C02-02/NAN, MAT 2009-14102, PI09/90527 and TEC2010-21574-C02-01-02), Catalan Government (project 2009SGR235) and Comunidad Autónoma de Madrid (Spain) (project S2009/TIC-1476).

References

[1] V. Petrov, M. C. Pujol, X. Mateos, O. Silvestre, S. Rivier, M. Aguiló, R. Solé, J. Liu, U. Griebner, F. Díaz, Laser & Photon. Rev. **1**, 179, 2007.
[2] Y. E. Romanyuk, I. Utke, D. Ehrentraut, V. Apostolopoulus, M. Pollnau, S. García-Revilla, R. Valiente, J. Cryst. Growth **269**, 377, 2004.
[3] W. Bolaños, J.J. Carvajal, X. Mateos, G.S. Murugan, A.Z. Subramanian, J.S. Wilkinson, E. Cantelar, D. Jaque, G. Lifante, M. Aguiló, F. Díaz, Opt. Express **18**, 26937, 2010.
[4] W. Bolaños, J.J. Carvajal, X. Mateos, E. Cantelar, G. Lifante, U. Griebner, V. Petrov, V.L. Panyutin, G.S. Murugan, J.S. Wilkinson, M. Aguiló, F. Díaz, Opt. Express **19**, 1449, 2011.