Growth and characterization of highly Yb^{3+}-doped $KY(WO_4)_2$ thin layers

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Crystals of the monoclinic double tungstates $KY(WO_4)_2$ (= KYW), $KGd(WO_4)_2$, and $KLu(WO_4)_2$ are excellent laser host materials due to their high refractive indices on the order of 2, good thermal conductivity, and large transition cross-sections of rare-earth ions, in particular Yb^{3+}, doped into these crystals. Yb^{3+}-doped double tungstate thin layers enable lasing with a small quantum defect [1] and high slope efficiency [2], making them well suited for high-power lasers [3] and waveguide lasers [4]. Co-doping KYW:Yb^{3+} layers with appropriate amounts of Lu^{3+} and Gd^{3+} increases the refractive index contrast with respect to the undoped KYW substrate, thus reducing the required layer thickness for waveguiding, while simultaneously providing lattice matching between layer and substrate [5]. On the other hand, for thin-disk laser applications highly Yb^{3+}-doped KYW layers are needed. This can be achieved by either growing $KLu(WO_4)_2:Yb^{3+}$ layers on undoped $KLu(WO_4)_2$ substrates because of the similar ion radii of Yb^{3+} and Lu^{3+} [3] or co-doping a KYW:Yb^{3+} layer with Gd^{3+} for compensating the induced lattice mismatch with respect to the undoped KYW substrate.

Here we report the liquid phase epitaxial growth and characterization of highly Yb^{3+}-doped (15, 20, and 47.5at%) layers on (010)-oriented, pure KYW substrates. Lattice matching was achieved by adjusting the amount of Gd^{3+} and Lu^{3+} in the KYW:Yb layer (Fig. 1), with optimized compositions of $KYb_{0.15}Gd_{0.10}Y_{0.75}(WO_4)_2$, $KYb_{0.20}Gd_{0.13}Y_{0.67}(WO_4)_2$, and $KYb_{0.475}Gd_{0.447}Lu_{0.078}(WO_4)_2$. At elevated growth temperatures of 920-925ºC a low level of supersaturation was achieved, leading to slower growth rates (15-18 µm / h). This approach resulted in lattice-matched, crack-free layers of thickness ranging from 10 to 50 µm.

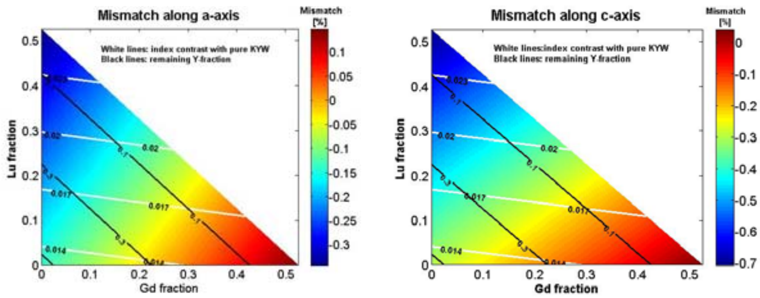

Fig. 1. Lattice mismatch in *a* and *c* axis and refractive index increase for $KGd_xLu_yYb_{1-x-y}(WO_4)_2$ versus the fractions of Gd^{3+} and Lu^{3+} ions

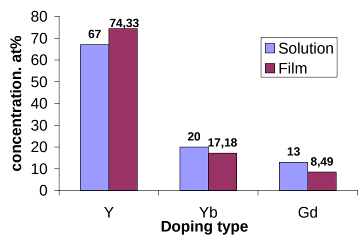

Fig. 2. ICP-LA-MS results

The Y^{3+}, Yb^{3+}, and Gd^{3+} concentrations in a grown layer were determined by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). The concentrations determined by LA-ICP-MS in the grown layer differ slightly from those in the solution (Fig. 2). X-ray investigations confirmed the high crystallinity of the layers.

These results on the growth and characterization of high-quality, highly Yb^{3+}-doped KYW layers form the basis for applications of these layers as high-gain amplifiers and thin-disk lasers. With perpendicular pumping, in a nominally 20at.% Yb^{3+}-doped, 34-µm-thick layer an output power of 279 mW at 533 mW of absorbed pump power with a slope efficiency of 64% was achieved, leading to more than 52% optical-to-optical efficiency [6].

The authors acknowledge financial support by The Netherlands Organization for Scientific Research (NWO) through the VICI Grant no. 07207 "Photonic integrated structures".

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