

Laser Operation of Bulk Crystals and Epitaxially Grown Composites of Yb:KLu(WO₄)₂



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MOTIVATION

Efficient laser operation based on thin Yb-doped double tungstate layers

- Introduction of the monoclinic double tungstate laser crystal Yb:KLu(WO₄)₂ (Yb:KLuW)
- Growth of KLu(WO₄)₂ and Yb:KLu(WO₄)₂ single crystals by the Top-Seeded-Solution Growth (TSSG) slow-cooling method
- Growth of thin Yb:KLuW layers on KLuW crystal substrates by Liquid Phase Epitaxy (LPE)
- KLuW can incorporate high Yb-concentrations approaching the stoichiometric KYb(WO₄)₂

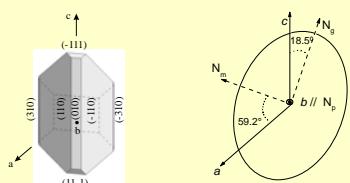
Yb:KLuW and epitaxial Yb:KLuW layers hold great promise as new laser materials for diode-pumped high-power lasers, thin disk and waveguide designs as well as for ultrashort (ps/fs) pulse laser systems.

CHARACTERIZATION OF BULK AND EPITAXIAL Yb:KLuW

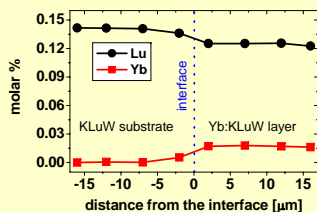
KLuW crystal grown by TSSG



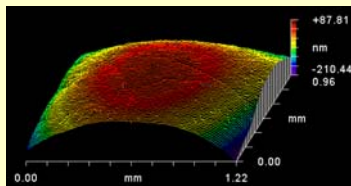
Morphological sketch and optical ellipsoid of KLuW



Evolution of Lu and Yb concentration at the Yb:KLuW/KLuW epitaxial interface

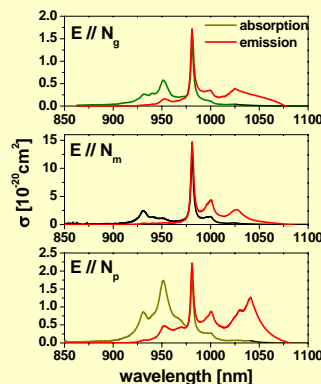


Surface profile plot – (010) epitaxial layer



LPE growth: homogeneous layers on all natural crystal faces
Layer thickness (010) face: 100 μm (substrate thickness: 1.1 mm)
Layer surface: ROC = 0.71 m, rms < 0.8 nm
Yb-doping – epitaxial layer: 7.8x10²⁰ Yb³⁺ ions/cm³

SPECTROSCOPIC CHARACTERIZATION



Absorption cross section E||m

- σ_{abs} exceeds 15 times that of Yb:YAG
- can be Yb-doped up to the stoichiometric KYbW
- \Rightarrow 13 μm absorption length at 981 nm

Emission cross section E||m

- larger than Yb:YAG @ 1030 nm
- broad amplification bandwidth supports sub-100 fs pulses

Fluorescence lifetime

- 375 μs (0.5 mol% Yb)

similar to Yb:KdW and Yb:KYW

LATTICE MISMATCH FOR EPITAXIAL COMPOSITES

Unit cell parameters of KLuW and KYW in comparison to KYbW - KYbW: ideal epitaxial layer -

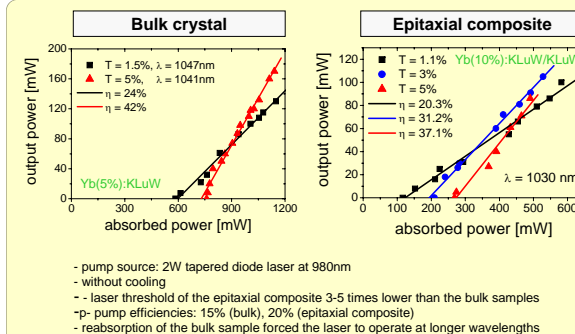
Space group:	C2/c	Point group:	2/m	room temperature
cell parameters	a [Å]	b [Å]	c [Å]	<Δg>
KLuW	10.576(7)	10.214(7)	7.487(2)	
KYbW	10.590(4)	10.290(6)	7.478(2)	
difference Δg	0.13%	0.74%	0.12%	0.33%
YAG	12.0116(3)			
YbAG	11.9380(5)			
difference Δg	0.61%			0.61%
KYW	10.6313(4)	10.3452(6)	7.5547(3)	
KYbW	10.590(4)	10.290(6)	7.478(2)	
difference Δg	0.39%	0.53%	1.01%	0.64%

\Rightarrow KLuW substrates – less strain at the epitaxial interface

REFERENCES Yb:KLuW

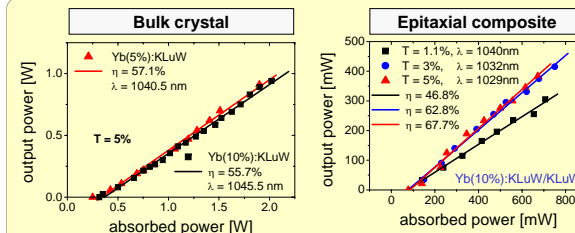
- Crystal growth** X. Mateos et al. *Opt. Mat. in press*
Bulk laser X. Mateos et al. *IEEE JQE* **40**, 1056 (2004)
Epitaxial laser U. Griebner et al. *IEEE JQE* **41**, in press (2005)

CW LASER OPERATION – Diode-pumped



- pump source: 2W tapered diode laser at 980 nm
- without cooling
- laser threshold of the epitaxial composite 3-5 times lower than the bulk samples
- p- pump efficiencies: 15% (bulk), 20% (epitaxial composite)
- reabsorption of the bulk sample forced the laser to operate at longer wavelengths

CW LASER OPERATION – Ti:sapphire-pumped



- pump wavelength: 980 nm
 - thickness bulk crystals: 2.8 mm Yb(5%):KLuW; 2.2 mm Yb(10%):KLuW
 - no crystal damage (intracavity intensity > 1 MW/cm²)
 - pump efficiencies: 50% (bulk), 55% (epitaxial composite)
- Higher efficiencies of the epitaxial composite structure than the bulk crystals because of the strongly reduced reabsorption

SUMMARY

- Inclusion-free Yb:KLuW single crystals have been grown.
- High-quality epitaxial growth of Yb:KLuW layers on KLuW substrates
- First lasing of Yb³⁺ in the double tungstate host KLuW (P = 1W, η_c = 50%)
- First epitaxially grown laser based on Yb:KLuW (P = 0.42W, η_c = 55%)
- Improvement by one order of magnitude in comparison to our initial results obtained with Yb:KYW/KYW epitaxial structures