Demonstration of a Hybrid Ho:YLF Ho:LuLF Slab Laser

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Abstract: We present a continuous-wave slab laser utilising both Ho:YLF and Ho:LuLF as laser gain media. 30 W of output power at 2 µm was demonstrated in a stable concave-plane resonator while 13 W was achieved in a hybrid stable-unstable configuration when pumped with a high-power Tm:YLF slab laser.

There are a number of applications that require solid-state lasers operating in the 2 µm wavelength region. This need has driven the development of high power Ho^{3+} doped lasers pumped by Tm^{3+} doped lasers operating near 1.9 µm [1]. The fluoride host materials YLF and LuLF for Tm^{3+} and Ho^{3+} are attractive due to their favourable properties, including a weak negative thermal lens, which is preferred when scaling to high power levels.

In this paper we present for the first time a 2 µm oscillator consisting of both a Ho:YLF and a Ho:LuLF slab crystal in one laser cavity, end-pumped by a 180 W Tm:YLF slab laser. This was implemented in a stable concave-plane resonator as well as in a hybrid stable-unstable resonator configuration.

Our high power Tm:YLF slab laser [2] was modified to operate at 1.890 µm by forcing it on to the π-polarisation with an intra-cavity Brewster plate and choosing an appropriate resonator. This pump laser produced up to 180 W incident on the Ho:YLF and Ho:LuLF oscillator crystals which were placed in series to increase the absorption of the pump light. A total of 95 to 108 W was absorbed by the crystals in a single pump-pass configuration. The Ho:LuLF crystal had dimensions 2 x 10 x 20 mm^3 of which the 2 x 10 mm^2 faces were AR coated at 2 µm. The Ho:YLF crystal was cut at Brewster's angle with dimensions 2 x 10 x 43 mm^3. Both crystals were a-cut with the c-axes horizontal, which together with the Ho:YLF's Brewster faces forced the laser to oscillate on the π-polarisation. The incident pump beam radii were w_y = 0.5 mm and w_x = 2.8 mm in the two planes. The slab geometry was preferred for the 0.5% doped Ho:YLF and Ho:LuLF crystals to facilitate easy coupling of the elliptical pump beam into the oscillator crystals, and to reduce the likelihood of thermal fracture when scaling to multi-hundred watt power levels.

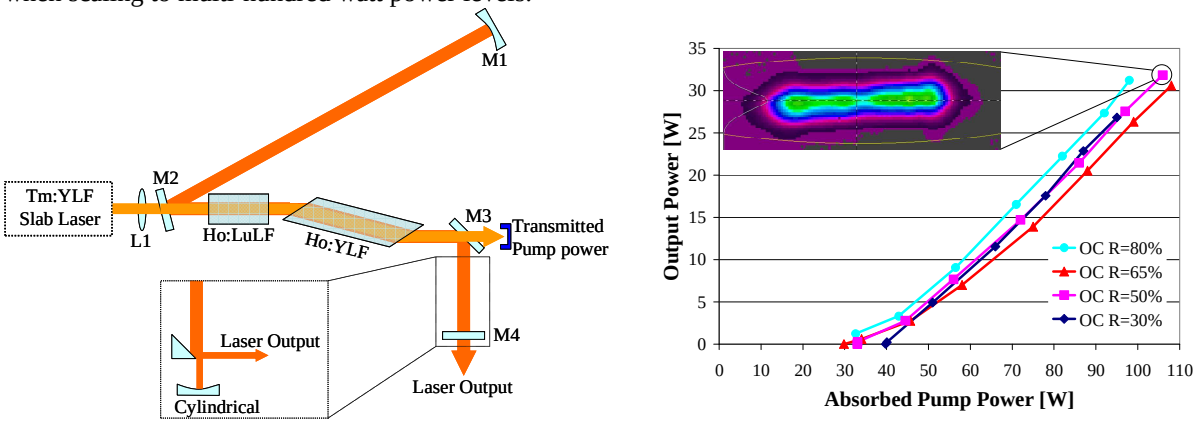

Fig. 1 (a) Optical layout of the two Ho:YLF & Ho:LuLF laser resonators. (b) Output power of the stable Ho:YLF & Ho:LuLF laser.

The stable concave-plane resonator, as shown in Fig 1(a), consisted of a high-reflective end-mirror (M1) with radius of curvature r = 600 mm, flat dichroic pump mirrors (M2, M3) and a flat output coupler mirror (M4). Mirrors with reflectivity R = 80%, R = 65%, R = 50% and R = 30% at 2 µm were selected as output couplers. The hybrid stable-unstable resonator configuration utilised a cylindrical mirror of curvature r = 449 mm in position M4 and a knife-edge mirror to couple out the laser beam. In both configurations the total resonator length was 650 mm which became stable for a weak negative thermal lens inside the Ho^{3+} crystals.

The maximum output power of the Ho:YLF and Ho:LuLF laser, as shown in Fig 1(b), was 32 W with the R = 50% output coupler which corresponded well to our initial numerical simulations of the system. The output of the laser showed some temporal spiking and the wavelength ranged from 2.040 to 2.079 µm for the different output coupler mirrors. The elongated output beam was a consequence of the slab geometry of the laser. The output of the hybrid stable-unstable resonator was an improved beam quality but the output power was reduced to 13 W at maximum pump power. It was concluded that multi-pass pumping will increase the efficiency of the laser.

[1] W. Koen, H.J. Strauss, C. Bollig, M.J.D. Esser, C. Jacobs, O.J.P. Collett, K. Nyangaza and D. Preussler, "200 mJ Single Frequency Ho:YLF & Ho:LuLF Slab Amplifier System at 2064 nm" *submitted to* 4th EPS-QEOD Europhoton Conference, Hamburg, Germany 2010.
[2] M. Schellhorn, S. Ngcobo, C. Bollig, M. J. D. Esser, D. Preussler, K. Nyangaza, "High-power diode-pumped Tm:YLF slab laser," CLEO Europe, Munich, Germany, 14-19 June 2009, CA1.3 (2009).