Multi-Watt, mJ nanosecond pulses amplification in a Yb:$LuLiF_4$ single crystal fiber grown by micro-pulling-down

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Single crystal fibers (SCFs) grown by the micro-pulling-down (μ-PD) method represent a very attractive solution for power scaling of solid-state lasers owing to a long absorption length and a favorable surface-to-volume ratio that enhances thermal dissipation. μ-PD technique was successfully employed mainly in growing cubic crystals, most impressive results being obtained with Yb:YAG [1]. We recently demonstrated successful growth of a birefringent Yb-doped $LuLiF_4$ (LLF) SCF and cw-regime high-power amplification with excellent beam quality preservation even at very high (~ 90 W) absorbed pump power [2]. Birefringent SCFs are particularly attractive, as they provide a quite straightforward means of avoiding beam quality degradation at high thermal load due to depolarization. In this work we present what is, to the best of our knowledge, the first demonstration of pulse amplification in the nanosecond regime in a Yb-doped birefringent SCF amplifier.

The seeder for the experiment was a house-made, diode-pumped Yb:YLF passively Q-Switched laser emitting at 1020 nm and providing 110-ns, 180-μJ pulses at 5.2 kHz repetition rate (≈ 1-W average power), in an almost diffraction limited beam quality ($M^2 \approx 1.1$). The setup of the multi-pass amplifier is shown in Fig. 1(a). In this configuration, the seed beam polarization is rotated by the Quarter-Wave Plate (QWP) so that 1st and 4th pass exploit the amplifier gain for polarization parallel to Yb:LLF *c*-axis, whereas the 2nd and 3rd pass produce amplification along the *a*-axis. The seed beam was focused to $w_s \approx 140$ μm by the lens f_2, and spherical mirror R_1 re-imaged the seed in the amplifier.

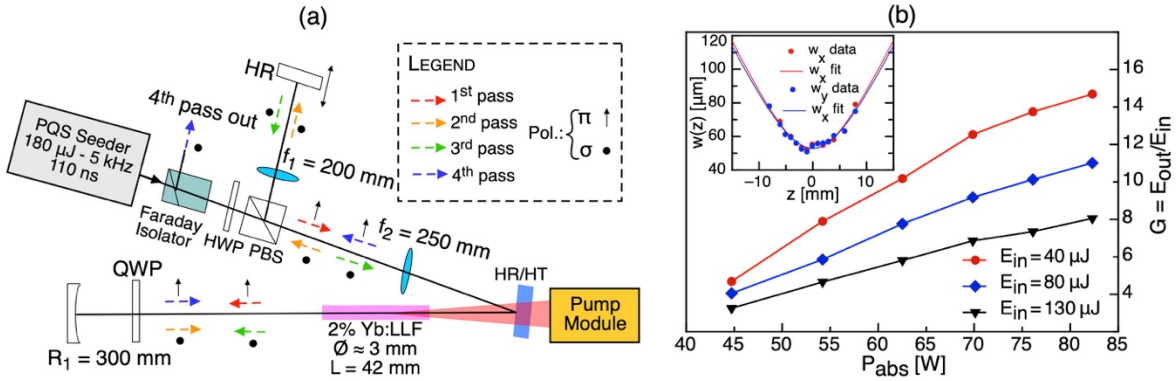

Fig. 1 (a) Experimental setup. HR: High-Reflectivity mirror at 1020 nm; HWP: Half-Wave Plate at 1020 nm; PBS: Polarizing Beam Splitter; HR/HT: flat dichroic highly reflective at 1020 nm and with High Transmittivity at 976 nm; QWP: Quarter-Wave Plate at 1020 nm. (b) Four passes amplification gain as a function of the absorbed pump power for different seeder energy. In the inset we show the result beam quality measurement carried out after amplification.

The Yb:LLF SCF was pumped by a 100-W maximum power, multimode fiber coupled (NA = 0.22, Ø = 105 μm) laser diode emitting at 976 nm. The pump beam was focused in the amplifier to a $w_p \approx 200$ μm, in order to match the pump beam confocal parameter to the 42-mm SCF length. The amplifier crystal was mounted in a water-cooled copper holder kept at 4 °C. A maximum pulse energy/average output power of 1.05 mJ/5.5 W was obtained at the maximum incident seeder energy/average power of 130 μJ/670 mW, corresponding to a four-passes gain $G \approx 8$ (see Fig. 1(b)) and resulting in a maximum amplified pulse peak power of 10 kW. By fitting the experimental data, we estimate a saturation power of the amplifier of about 10 W and a four-passes small signal gain $G_0 \sim 40$. Seeder beam quality was very well preserved during amplification, even at the maximum absorbed pump power > 80 W. In the inset of Fig. 1(b) we show the beam quality measurement results after amplification and after we corrected the slight astigmatism of the amplified beam (already present in the seeder) with a telescope using cylindrical lenses, obtaining an almost perfectly circular beam with $M^2 = 1.1$.

References

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