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1 kHz Yb:YAG thin-disk high-energy picosecond regenerative amplifier

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1J-1kW-1ps is a real scientific and technological challenge involving thermal, energy and short pulse management. Yb:YAG is nowadays the best-suited amplifier material to address these challenges. Recently, 1.1 J at 1 kHz has been reported with cryogenic-cooled thick Yb:YAG disks but at a longer pulse duration of 4.5 ps [1]. On the other hand, shorter pulses of 920 fs have been obtained by the solely thin-disk technology with an energy of 720 mJ at 1 kHz [2]. In the frame of laser development (HORIZON) for new high energy secondary sources and plasma physics, CELIA has chosen an alternative way combining thin-disk technology to provide a high energy front-end and rotating water-cooled disk technology for the final power amplifier. Although the best performances of Yb:YAG thin-disk regenerative amplifiers reach 200 mJ at 1-5 kHz [2,3], most of the published schemes are rather complex and may leave key issues unreported. Here, we report on the development of the Yb:YAG thin-disk front-end based on a simple scheme with the experimental results and the faced issues.

The regenerative cavity is based on a 220-µm 7%-doped Yb:YAG thin-disk CW diode-pumped at 969 nm. The 12 mm disk is mounted on a diamond heat-sink and it has a 4 m radius of curvature when not pumped. The thin-disk is placed at one end of a 4.8 m long linear cavity. A magnification telescope is inserted in such a way that the fundamental mode has a 4.8 mm diameter on the disk matching 86% of the flat-top pump diameter. The regenerative operation is insured by a thin-film polarizer combined with a large aperture BBO single crystal ($12x12x40\ mm^3$) operating at 1 kHz. The cavity is seeded by 1.2 mJ-1.4 ns stretched pulses with a 2.5 nm spectral bandwidth (FWHM).

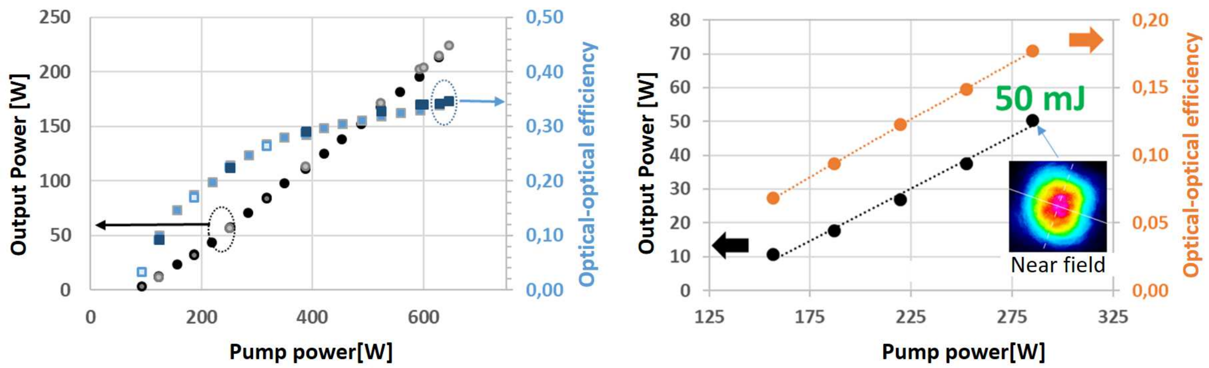

Fig. 1 Output power and efficiency as a function of the pump power in (a) fundamental mode CW operation and (b) seeded regenerative operation at 1 kHz.

In CW and fundamental mode operation, the cavity delivers more than 220 W of output power with 35% optical-optical efficiency with a beam quality factor M^2=1.08. In regenerative operation, an amplified pulse energy up to 50 mJ has been obtained with a non- saturated optical-optical efficiency of 18% which is, to the best of our knowledge, the best performance ever reported for a CW-pumped regenerative cavity with a single Yb:YAG thin-disk head. The amplified pulses have been then recompressed down to 900 fs. Finally, we will show also how the thermal issues occurring in the Pockels-cell limit the output power of the regenerative amplifier. Despite an extremely low single-pass absorption of the BBO crystal, its temperature increases beyond 40 °C at 50 W output power degrading the long-term voltage contrast ratio of the Pockel's cell, the beam quality and the output power stability. To the best of our knowledge, such behaviour in regenerative amplifiers has never been reported and we will discuss how to address this issue to further increase the output energy.

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