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50-W, >2-µJ SESAM-modelocked Ho:YAG thin-disk oscillator at 2.1 µm

Sergei Tomilov,[1,*] Yicheng Wang,[1] Martin Hoffmann,[1] Jonas Heidrich,[2] Matthias Golling,[2] Ursula Keller[2] And Clara J. Saraceno[1]

1. Photonics and Ultrafast Laser Science, Ruhr Universität Bochum, Universitätsstraße 150, 44801 Bochum, Germany

2. Department of Physics, Institute for Quantum Electronics, ETH Zürich, Auguste-Piccard-Hof 1, 8093 Zürich, Switzerland

**E-mail: sergei.tomilov@ruhr-uni-bochum.de*

Average power scaling of ultrafast laser systems operating in the short-wave infrared region (SWIR) from 1.4 µm to 3 µm continues to attract significant interest for a variety of scientific and industrial applications. In this spectral range, laser systems based on Ho-doped gain materials directly emitting at 2.1 µm are particularly attractive and have made significant progress, however so far only very few results were demonstrated in power-scalable laser geometries. In particular, the thin-disk geometry is promising for energy scaling of ultrafast amplifiers and for directly modelocked oscillators with high repetition rate and average power [1]. Previously, only one ultrafast TDL was demonstrated in this wavelength region based on Ho:YAG using Kerr-lens modelocking [2] where 25 W of average power and 0.325 µJ of pulse energy were achieved. More recently we showed record-high power single-mode CW operation up to 112 W [3]. Here, we demonstrate a SEmiconductor Saturable Absorber Mirror (SESAM) modelocked Ho:YAG thin-disk laser (TDL) emitting at 2.1-µm wavelength that achieves twice the average power and more than six time the pulse energy of previous demonstration, reaching 50 W of average power, with 1.13-ps pulses, 2.11 µJ of pulse energy and ~1.9 MW of peak power. To the best of our knowledge these are both the highest average power and pulse energy of any modelocked oscillator in this wavelength region to date.

The laser resonator used for modelocking is depicted in Fig. 1. It is based on a 2-at.%-doped and 190-µm-thick Ho:YAG disk pumped by a Tm-fiber laser with a maximum power of 209 W and emitting at 1908 nm. The laser beam passes the active medium twice in order to increase the available gain. For precise SPM control, we introduced a 2-mm thick undoped YAG plate on a translation stage and at Brewster's angle between the mirrors of a telescope, formed by two curved concave mirrors with a radius of curvature (RoC) of 0.3 m. All the flat folding intracavity mirrors are dispersive, introducing -21000 fs^2 of group delay dispersion per roundtrip. The high-power GaSb-based SESAM for this laser system was designed and grown using molecular beam epitaxy (MBE) at ETH Zurich [4].

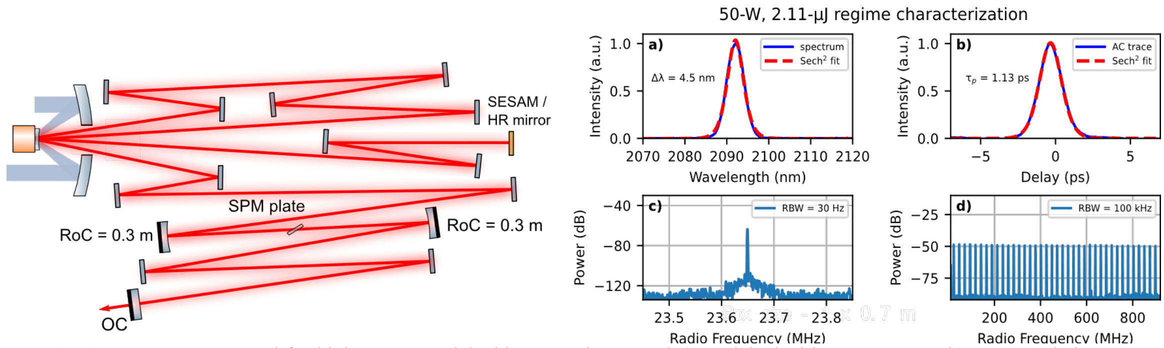

Fig. 1 Laser resonator used for high power modelocking experiment and a) modelocked laser spectrum, b) autocorrelation trace, radio-frequency spectra of the regime depicting c) the first beatnote, d) the harmonics in a 900 MHz span. RBW stands for resolution bandwidth.

At the full pump power using the 2% output coupler we achieved stable soliton modelocking at an average power of 50 W at a repetition rate of ~23.7 MHz. At this power level, the pulses had a duration of 1.13 ps assuming sech^2 pulse shape, with 4.5-nm spectral bandwidth, corresponding to a time-bandwidth product of 0.348. The radio-frequency spectrum confirms stable modelocking with no modulations within the measurement range. Single-pulse operation was verified using a fast photo-detector and sampling oscilloscope.

We are confident that reducing the pulse duration to the few hundred femtoseconds and increasing the available pulse energy of this system towards the 10-µJ level in future should be straightforward with tailored SESAM designs. In its current implementation, external pulse compression can already bring this system to scientific applications.

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