0.5 - 1.3 GHz tunable pulse repetition rate solid state laser generating 230 fs pulses with 200 mW average power

Roger Wüst[1], Daniel Hug[1], Benjamin Rudin[2], Florian Emaury[2], Bojan Resan [1,3*]

1. Institute of Product and Production Engineering, University of Applied Sciences and Arts Northwestern Switzerland (FHNW), Klosterzelgstrasse 2, Windisch, CH-5210, Switzerland

2. Menhir Photonics, Industriestrasse 42, Glattbrugg, CH-8152, Switzerland

3. Faculty of Medicine, Josip Juraj Strossmayer University, Josipa Huttlera 4, Osijek, 31000, Croatia

**bojan.resan@fhnw.ch*

In the recent years the demand for ultrafast laser systems with various parameters in terms of wavelength, power, and pulse repetition rate has risen continuously, as one can remarkably improve the minimal processed feature size and throughput with different laser parameters for different materials and different processes [1].

In the field of laser micromachining, the concept of ablation-cooling was introduced by Fatih Ömer Ilday's team [2,3]. Using femtosecond pulses and very high pulse repetition rates in GHz range, which enables the ablation-cooling process, it was demonstrated micromachining with an extremely low heat-affected zone. This principle reduces the single pulse energy required for the process and has a broad range of possible scientific, medical and industrial applications.

Single and multimode diode pumped solid state ultrafast lasers in the GHz pulse repetition rate regime have been demonstrated previously, but each of them with very different laser cavity and not tunable in repetition rate [4–7]. In our work, we demonstrate a novel concept for a fundamentally modelocked laser cavity, which allows to continuously tune the pulse repetition rate from 0.5 to 1.3 GHz with the same optical components on a simple mechanical platform. Furthermore, we demonstrate that our femtosecond laser has a very low noise level, considering that the laser was an open breadboard setup.

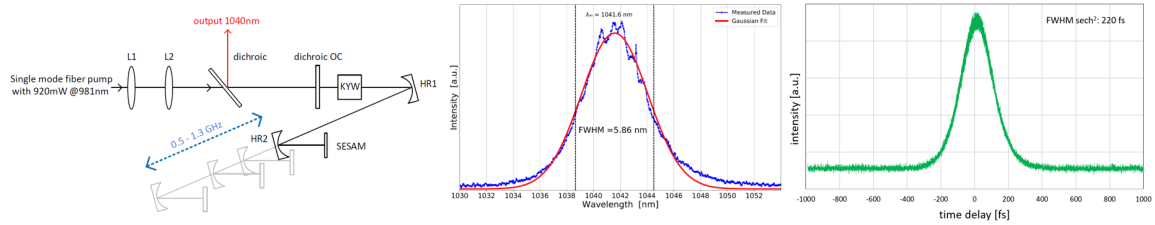

Fig. 1 Laser cavity setup (left), optical spectrum (middle) and SHG intensity autocorrelation trace (right) of a 1.23 GHz pulse repetition rate cavity

The Yb:KYW crystal based cavity emits 230 femtosecond pulses at a central wavelength around 1040 nm, with a self-starting SESAM modelocking. In a robust modelocked operation mode, an average power up to 200 mW is achieved using a stabilized single mode pump diode at a wavelength of 981 nm, emitting 920 mW average power, while the laser in continuous wave (CW) mode delivers up to 400 mW with the pump power of 920 mw. Atmospheric air cooling was sufficient for both CW and modelocked laser operation.

The developed laser will be used for investigation of the performance of 100 W-level amplifiers [8] and GHz fast modulators to achieve 100 W, GHz repetition rate, fs laser with single pulse switching capability. Moreover, this laser will be used as a widely tunable pulse repetition rate seed source for in-depth studies of micro machining in the regime of ablation-cooling, and other application where continuous tunability of the pulse repetition rate is beneficial. Furthermore, the low noise laser seems promising as a clocking signal for synchronization of other signal sources in various applications.

References

[1] R. Stoian and J.-P. Colombier, "Advances in ultrafast laser structuring of materials at the nanoscale," Nanophotonics **9**, 4665–4688 (2020).
[2] H. Kalaycioglu, P. Elahi, O. Akcaalan, and F. Ilday, "High-repetition-rate ultrafast fiber lasers for material processing (Invited paper)," IEEE Journal of Selected Topics in Quantum Electronics **24**, (2018).
[3] C. Kerse, H. Kalaycıoğlu, P. Elahi, B. Çetin, D. K. Kesim, Ö. Akçaalan, S. Yavaş, M. D. Aşık, B. Öktem, H. Hoogland, R. Holzwarth, and F. Ö. Ilday, "Ablation-cooled material removal with ultrafast bursts of pulses," Nature **537**, 84–88 (2016).
[4] P. Wasylczyk, P. Wnuk, and C. Radzewicz, "Passively modelocked, diode-pumped Yb:KYW femtosecond oscillator with 1 GHz repetition rate," Opt. Express, OE **17**, 5630–5636 (2009).
[5] A. Agnesi, A. Greborio, F. Pirzio, G. Reali, J. A. der Au, and A. Guandalini, "40-fs Yb^{3+}:$CaGdAlO_4$ laser pumped by a single-mode 350-mW laser diode," Opt. Express, OE **20**, 10077–10082 (2012).
[6] S. Pekarek, A. Klenner, T. Südmeyer, C. Fiebig, K. Paschke, G. Erbert, and U. Keller, "Femtosecond diode-pumped solid-state laser with a repetition rate of 4.8 GHz," Opt. Express, OE **20**, 4248–4253 (2012).
[7] Z. Y. Zhang, A. E. H. Oehler, B. Resan, S. Kurmulis, K. J. Zhou, Q. Wang, M. Mangold, T. Süedmeyer, U. Keller, K. J. Weingarten, and R. A. Hogg, "1.55 µm InAs/GaAs Quantum Dots and High Repetition Rate Quantum Dot SESAM Mode-locked Laser," Sci Rep **2**, 477 (2012).
[8] V. Markovic, A. Rohrbacher, P. Hofmann, W. Pallmann, S. Pierrot, and B. Resan, "160 W 800 fs Yb:YAG single crystal fiber amplifier without CPA," Opt Express **23**, 25883–25888 (2015).