EPJ Web of Conferences **307**, 04019 (2024) https://doi.org/10.1051/epjconf/202430704019
EUROPHOTON 2024

1 mJ 20 kHz efficient and robust end-pumped Yb:YAG femtosecond laser for nonlinear frequency conversion

Julius Lukošiūnas[1,2], Raimundas Burokas[1,2], Aivaras Kazakevičius[1,2], Rokas Danilevičius[2], Andrejus Michailovas[1,2]

1. *National Center for Physical Sciences and Technology, Savanorių pr. 231, LT-02300, Vilnius, Lithuania*
2. *Ekspla ltd., Savanorių pr. 237, LT-02300 Vilnius, Lithuania*

Reliable and robust high energy femtosecond laser systems are desirable in a variety of nonlinear frequency conversion applications such as harmonic generation, parametric amplification, and ultrafast pulse shaping, enabling the generation of new wavelengths and tailored pulse characteristics. These lasers are often used as pump sources in high intensity optical parametric amplifiers due to lower amplified parametric fluorescence background in the ps to ns temporal window. End pumped Yb:YAG laser systems exhibit good parameters for high energy and average power lasers with major problems being nonlinear temporal and thermally induced spatial distortions. However, Yb doped femtosecond pump lasers are evolving and replacing traditional Ti:Sapphire lasers used in broadband mid-IR OPCPA systems for ultrafast vibrational spectroscopy [1, 2].

Our goal is to develop efficient, robust and cost effective 1 mJ-level with high repetition rate laser system based on a hybrid laser approach utilizing all-fiber seeder and free-space amplification. A simple laser design allows us achieve excellent stability, high energy and good temporal contrast, which are critical for efficient nonlinear optics application; high repetition rate allows to speed up application process. Many spectroscopy fields use mid-infrared tunable lasers pumped by femtosecond lasers and higher repetition rate allows achieving faster measurements. As compared to previous work, we increased repetition rate and average power of our pump laser intended to use in sum frequency generation spectrometer while keeping the same pump pulse energy [3]. In this work we demonstrate 420 fs laser system operating at 20 kHz pulse repetition rate delivering 1 mJ energy pulses.

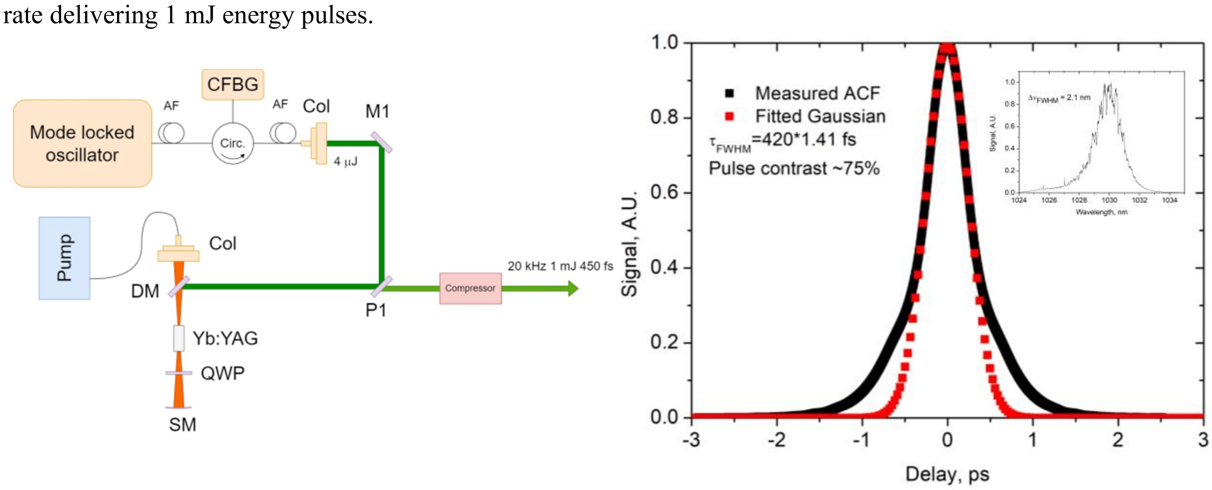

Fig 1. Schematic representation of laser setup (left). AF – fiber amplifier, CFBG – chirped fiber Bragg grating, Circ. – circulator, Col – beam collimator, P1 – thin film polarizer, DM – dichroic mirror, SM – spherical mirror, QWP – quarter-wave plate, M1 – high reflectivity mirror. On the right – intensity autocorrelation function of the output pulse; the inset shows pulse spectrum with FWHM of ~2.1 nm.

The laser system is shown in Fig. 1 (left). SESAM mode-locked fiber oscillator was utilized for femtosecond pulse generation, then stretched in fiber Bragg grating (CFBG) and amplified in several fiber amplifier stages. The 4 µJ output pulses were further used as a seed for a free-space end-pumped Yb:YAG amplifier. The output pulse spectrum was ~2.1 nm at FWHM which corresponded to 420 fs Fourier transform-limited pulse duration (Fig 1. right). Measured beam quality was close to diffraction limited (M2 ≤1.2) and second harmonic generation experiment yielded maximum ~68% efficiency indicating insignificant output pulse phase distortion (Fig. 2 right, red curve). Additionally added B integral of ~1 radian by passing our laser output pulse through 6 mm thickness UVFS window lowered maximum second harmonic generation efficiency by approximately 10% (Fig 2 right, black curve) - this indicates the need to carefully design femtosecond optical systems. Long term (40 h) average power stability was less than 0.5% RMS (Fig. 2 left). These results show that such femtosecond laser design is suitable for nonlinear frequency conversion application – excellent laser stability, beam quality and efficient nonlinear effects are the key factors for a reliable OPA system.

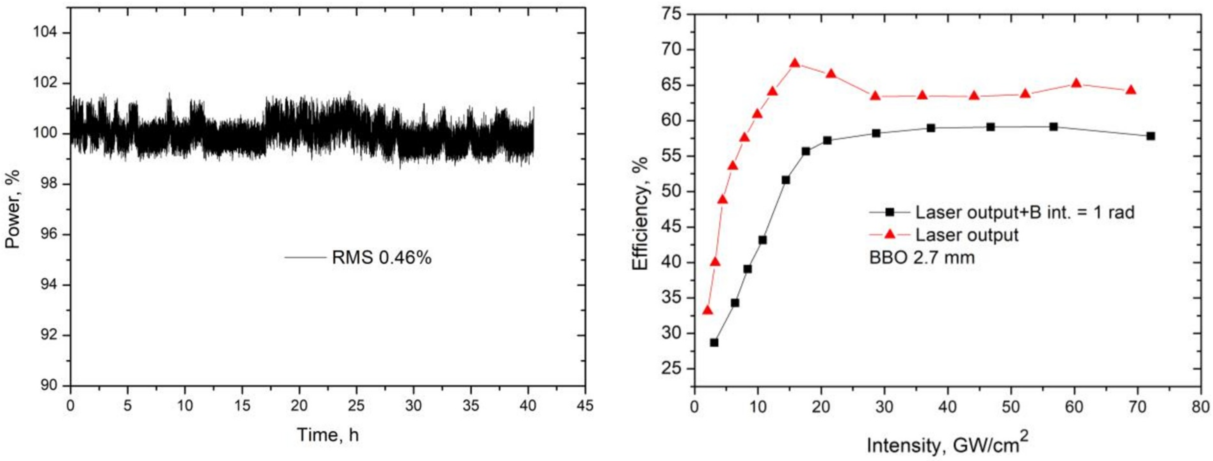

Fig. 2. On the left: long term power stability over 40 hours. On the right: second harmonic generation efficiency in 2.7 mm thickness BBO crystal from the laser output (red curve) and with added additional B integral of 1 rad (black curve).

References

[1] Rimantas Budriūnas, Karolis Jurkus, Mikas Vengris, and Arūnas Varanavičius, "Long seed, short pump: converting Yb-doped laser radiation to multi-μJ few-cycle pulses tunable through 2.5–15 μm," Opt. Express 30, 13009-13023 (2022)

[2] Andrea Villa, Aaron M. Ross, Riccardo Gotti, Marco Lamperti, Francesco Scotognella, Giulio Cerullo, and Marco Marangoni, "Broadly tunable mid-infrared femtosecond pulses directly generated by an optical parametric amplifier," OSA Continuum 4, 2837-2844 (2021)

[3] J. Lukošiūnas, R. Kananavičius, R. Danilevičius, R. Januškevičius, P. G. Schunemann, and A. Michailovas, "Efficient high resolution broadband SFG spectrometer utilizing BGSe nonlinear crystal covering 2.5-10 μm spectral range," in Laser Congress 2023 (ASSL, LAC), Technical Digest Series (Optica Publishing Group, 2023), paper ATh2A.4.