Pulse energy enhancement by means of fiber Bragg gratings in actively Q-switched Tm^{3+}-doped fiber lasers operating at 2050 nm and 2090 nm

Julian Schneider[1,2], Patrick Forster[1,2], Dieter Panitzek[1], Dominik Lorenz[1,2], Clément Romano[1], Marc Eichhorn[1,2], and Christelle Kieleck[1]

[1] *Fraunhofer IOSB (Institute of Optronics, System Technologies and Image Exploitation) Gutleuthausstraße 1, 76275 Ettlingen, Germany*
[2]*Institute of Control Systems, Karlsruhe Institute of Technology, Fritz-Haber-Weg 1, 76131 Karlsruhe, Germany*

Corresponding author: julian.schneider@iosb.fraunhofer.de

Q-switched Tm^{3+}-doped fiber lasers enable the efficient generation of nanosecond pulses at wavelengths around 2 µm in a compact single-oscillator configuration. Their capability of reaching high average output power makes them attractive pump sources for nonlinear frequency conversion into the mid-wave infrared (MWIR), which in turn is ideally suited for spectroscopy, optical countermeasures, and minimally invasive surgery. Methods for frequency conversion into the MWIR include the use of optical-parametric oscillators (OPOs) based on nonlinear crystals such as $ZnGeP_2$ (ZGP) and the generation of a supercontinuum (SC) in fluoride fibers featuring low guiding losses in this spectral range [1,2]. In order to achieve high MWIR output power efficiently, it is necessary to improve the 2 µm pump lasers in terms of pulse energy, peak power, and average output power.

We present a diode-pumped Tm^{3+}-doped actively Q-switched fiber laser optimized for generating high pulse energies by using a fiber Bragg grating (FBG) as an output coupler (OC). Using an FBG OC with a tailored reflectivity at the operating wavelength instead of a straight cleaved fiber end prevents broadband feedback seeding ASE and parasitic lasing, which eventually limit the maximum achievable pulse energy.

Figure 1 shows the pulse energy at constant pump power versus the pulse repetition rate (PRR) of the fiber laser with and without using an FBG at an operating wavelength of 2050 nm. Splicing the FBG on the OC side allows further scaling of the pulse energy by 20 % before parasitic lasing occurs. At the maximum pulse energy of 960 µJ, Gaussian pulses with a pulse width of 44 ns and a peak power of 20.5 kW were obained. The output spectrum shows a narrow FWHM linewidth of < 1 nm and exhibits a SC tail extending beyond 2.4 µm, which contains more than 40 % of the total output power. This highlights the potential of the Q-switched fiber laser to generate a broad high power MWIR SC that may be further extended by pumping a fluoride fiber.

By using another FBG, it was even possible to Q-switch the fiber laser at a wavelength of 2090 nm where ZGP features low absorption losses. The results are shown in Figure 2. The laser reaches a maximum pulse energy of 720 µJ with a pulse width of 105 ns, a peak power of 6.5 kW, and a narrow linewidth < 1 nm.

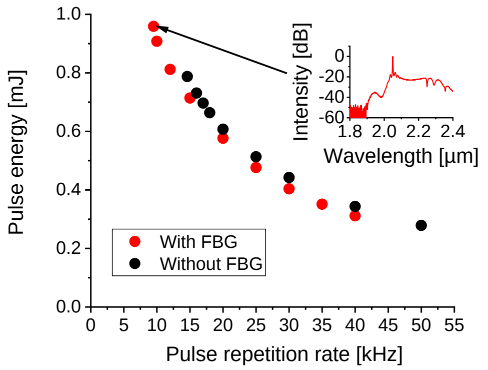

Figure 1: Pulse energy versus PRR of the fiber laser with and without FBG. For the highest pulse energy of 960 µJ a SC appears in the output spectrum.

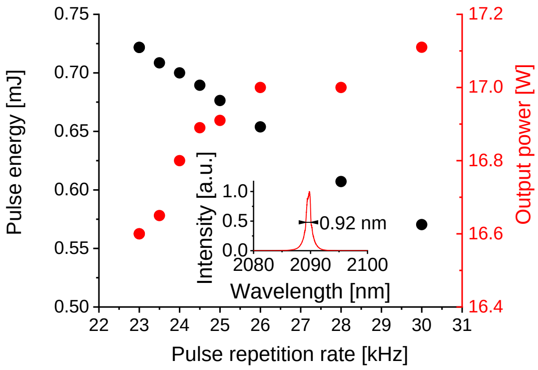

Figure 2: Pulse energy and average output power versus PRR at an operating wavelength of 2090 nm. The inset shows the output spectrum at the highest pulse energy of 720 µJ.

The demonstrated pulse energies and peak powers are unique values for a Q-switched fiber laser operating at wavelengths of 2050 nm and 2090 nm. However, the average output power was < 20 W, limited by pump power. For future work, we plan to significantly increase the average output power by applying two high power pump diodes at 793 nm.

References

[1] J. Schneider, P. Forster, C. Romano, M. Eichhorn, and C. Kieleck, "High pulse energy $ZnGeP_2$ OPO directly pumped by a Q-switched Tm^{3+}-doped single-oscillator fiber laser," Opt. Lett. 46, 2139-2142 (2021).
[2] G. Scurria, I. Manek-Hönninger, J. Carré, A. Hildenbrand-Dhollande, and S. Bigotta, "7 W mid-infrared supercontinuum generation up to 4.7 µm in an indium-fluoride optical fiber pumped by a high-peak power thulium-doped fiber single-oscillator," Opt. Express 28, 7672-7677 (2020).