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Recent advances in SWIR and MWIR solid-state and fiber sources

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Laser sources in the short-wave infrared (SWIR) around 2 µm wavelength and non-linear converters covering the mid-wave infrared (MWIR) spectral range are important for a large variety of applications like in environmental sensing, detection and ranging, optical free-space communication, optical countermeasures, medical treatments and surgery, and fundamental physics research. Especially recent developments in two-micron pulsed thulium and thulium-holmium doped solid-state and fiber lasers allow for significant average-power and pulse-energy scaling of mid-IR OPOs based on conversion crystals like ZnGeP2, CdSiP2 and OP-GaAs, thereby broadening the scope of various applications. Continuous-wave (cw) sources in the 2 µm range are important for materials processing and communication. Therein, a focus is put on all-fiber designs and robust, if possible self-aligning, laser resonators, which allow for stable and ruggedized designs for industrial applications under harsh environments. The presentation gives an overview of fundamental concepts, recent achievements as well as novel results in the field.

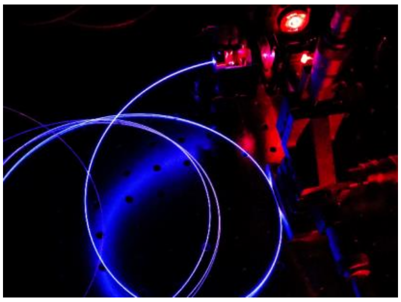

Fig. 1 Thulium-doped fiber laser operating in the 2 µm wavelength range.

Fiber lasers: In the field of SWIR fiber lasers significant achievements have been obtained in all-fiber cw thulium-doped and thulium-holmium co-doped fiber lasers, see fig. 1. By employing a single amplifier stage with a thulium-doped fiber laser, up to 0.94 kW of output power at 58 % slope efficiency and a linewidth less than 0.2 nm have been realized at around 2036 nm. In order to shift the output wavelength further, thulium-holmium co-doped fibers were used to realize a single-oscillator fiber laser with 145 W of cw output power at 2.2 µm, thereby significantly shifting the power limits in this wavelength range. In pulsed operation, record values in pulse energy of 0.96 mJ in Gaussian pulses with a pulse width of 44 ns and a peak power of 20.5 kW were obtained with thulium-doped step-index fibers. The output spectrum shows a narrow FWHM linewidth of < 1 nm.

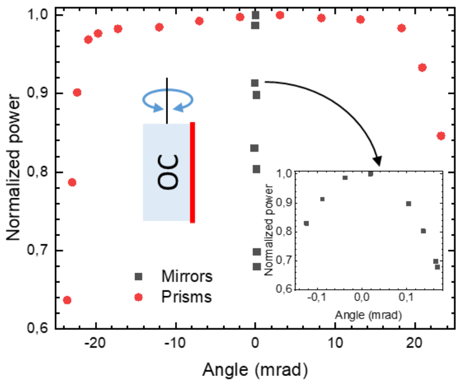

Fig. 2 Alignment sensitivity of a mirror and a Porro-prism resonator of a Ho^{3+}:YAG laser.

Solid-state lasers: A first continuous-wave crossed-Porro-prism laser was recently demonstrated based on a quasi-three-level Ho^{3+}:YAG crystal with output powers > 30 W – an important step to guide future quasi-three-level laser designs which were so far not considered efficiently compatible with Porro-resonators as a result of the reabsorption loss in these materials. As can be seen in fig. 2, an alignment sensitivity up to a factor of 200 lower than the corresponding mirror resonator can be achieved. By using ZGP non-linear crystals, record conversion slope efficiencies of 60 % at 8.2 W average output power could be realized using 2 µm temporally rectangular pulses from a fiber MOPA. This marks a new power scaling of this topology and will allow for further power increase in the near future.