Comparison of crossed-Porro prism resonator design with conventional mirror resonator design in a Ho^{3+}:YAG laser

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Ho^{3+}:YAG lasers that emit light at a wavelength of 2.09 µm have a variety of technological applications. For instance, they can be used in medicine, for atmospheric measurements, for material processing, and for the pumping of optical-parametric oscillators. Crossed Porro prisms as cavity end mirrors yield high stability against misalignments but were so far used only in four-level lasers [1]. Due to their retro-reflective property in the axis perpendicular to their apex, each of the prisms stabilizes the laser in one direction.

In this work, we present the first continuous-wave crossed-Porro-prism laser (Porro resonator) involving a Ho^{3+}:YAG crystal and compare it to a conventional resonator that uses mirrors as cavity end reflectors (mirror resonator). The crystal is pumped by a commercial 1.908 µm Tm^{3+}-doped fiber laser. Since the reflection in the Porro prisms is based on two consecutive total internal reflections and, thus, 100 % of the incident light is reflected back from the prisms, for output coupling a combination of a wave plate and a polarizer is used. Furthermore, the linear cavity contains an intra-cavity telescope, which enlarges the mode on one of the prisms, in order to reduce the intra-cavity losses.

Fig. 1(a) shows the power-power curves of the mirror and Porro resonator. While the mirror resonator shows a high slope efficiency of 74.8 % with respect to the absorbed pump power, the slope efficiency of the Porro resonator is slightly lower with a value of 67.4 %. This is attributed to losses at the apex of the prisms [2]. The maximum output power of the mirror and the Porro resonator is 37.8 W and 30.7 W, respectively. In the Porro resonator, the output power is limited by temporal instabilities that occur above an absorbed pump power of 42 W. These instabilities are eventually ascribed to instabilities in the thermal lens [3].

Fig. 1(b) shows a comparison of the beam quality of the mirror and the Porro resonator depending on the absorbed pump power. To measure the beam quality, the output beam is focused by a plano-convex lens and the $1/e^2$ beam diameter of the focused beam is measured along the propagation direction. For both resonator designs, a very good M^2 of smaller than 1.2 (with one exception) is shown. In combination with the high slope efficiency, this shows that a good mode matching between pump and laser mode is established. In the Porro resonator, the M^2 even surpasses that of the mirror resonator which is attributed to the retro-reflective property of the prisms.

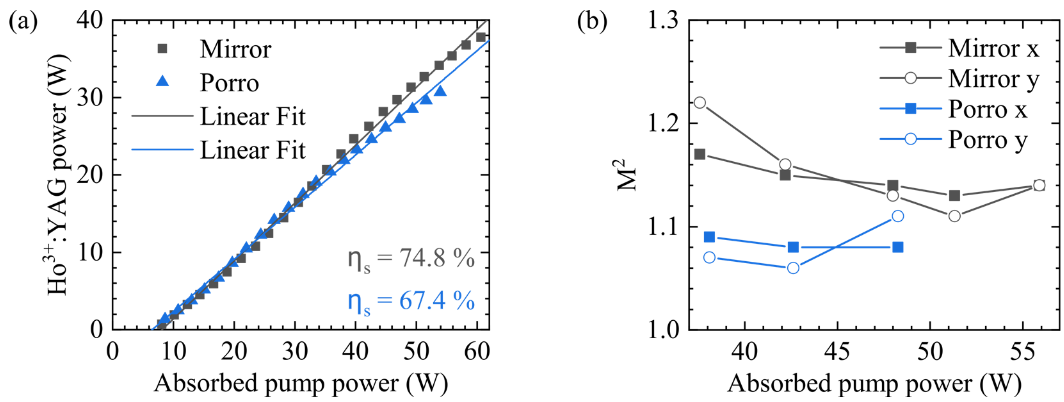

Figure 1 (a) Comparison of power-power curve of the mirror and the Porro resonator. (b) Comparison of the beam quality of the investigated resonators.

In conclusion, we presented a quasi-three-level Ho^{3+}:YAG laser involving two crossed-Porro prisms as cavity end reflectors and compared it to a conventional mirror resonator. While the Porro resonator suffered from losses at the apex of the prisms and, thus, had a reduced but still high slope efficiency in comparison to the mirror resonator, it clearly surpassed the mirror resonator in terms of beam quality while enhancing the resonator stability by a factor of up to 200 [3].

References

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