Pr:$YAlO_3$ microchip lasers operating at crystal temperatures close to liquid helium temperature

M.Fibrich[1,2], J. Šulc[1], H. Jelínková[1]

1. Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering
Břehová 7, 115 19 Prague 1, Czech Republic
2. Institute of Physics ASCR, ELI-Beamlines, Na Slovance 1999/2, 182 21 Prague, Czech Republic

In this contribution, Pr:YAP laser performance enhancement by operating the laser close to liquid helium temperature is reported; watt-levels of the laser output in the near-infrared, orange, green, and cyan-blue spectral region are presented under the 4-W InGaN LD pumping.

To realize Pr:YAP laser systems, the microchip resonator geometry formed by a cavity mirrors directly deposited on the crystal faces was proposed. This geometry allows to minimize resonator losses and it is also very attractive due to its compact and rugged design. Four microchip crystals of the same active ion concentrations (c = 0.6 at. %), dimensions (ϕ5× 5 mm), cuts (along the b-axis according to Pbnm notation), and the output facet reflectivities of R = 98% at the respective wavelengths of interest (around 747 nm, 622 nm, 547 nm, and 493 nm) were used. The microchip pump sides (pump mirror) were highly transmissive for the LD pump radiation, and highly reflective (R > 99.8%) for the generated radiations. Besides, special attention was paid to a suppression of the laser oscillations at the orange laser transition (except the microchip crystal designed for the orange emission) because the emission cross section in the orange (622 nm) is e. g. two times higher than that in the red (747 nm), and ten times higher than that in the green (547 nm) at the very low crystal temperatures. All Pr:YAP crystals were grown by the Czochralski method. The microchip crystal was mounted on the cold-finger of the He-cryostat (OptistatDry BLV cryostat; Oxford Instruments) with uncoated CaF2 windows. The crystal temperature could be set at any value within the 4 – 300 K range. Blue InGaN LD (Nichia Corporation) with the maximum available output power of 4 W at 447 nm wavelength in a linearly polarized beam was used as a pump source. The pump LD radiation collimated by an aspherical lens (f = 4.5 mm, 0.55 NA, ARC = 400–600 nm) was focused into the microchip crystal by a lens with the 60 mm focal length, resulting in a spot size of about 60 μm in radius. A half-wave plate designed for the 400–800 nm wavelengths (Thorlabs Inc.) was employed to set the LD beam polarization parallel with the “c”-crystallographic axis of the Pr:YAP crystal, which provides the higher absorption efficiency if compared with E⊥a crystal orientation. Laser output radiation was detected behind the cut-off filter.

The Pr:YAP input-output characteristics at 5 K crystal temperature for the 747 nm, 622 nm, 547 nm, and 493 nm emission are displayed in Fig. 1. The highest output power amounting to 1.5 W was reached at 747 nm laser transition. The corresponding oscillation threshold and slope efficiency with respect to the absorbed pump power were 300 mW and 46%, respectively. The Pr:YAP lasers behaviors in terms of the maximal output power as a function of the crystal temperature within the 5–300 K range are seen in Fig. 2.

It is obvious, the crystal temperature has a strong impact on the Pr:YAP output properties. The laser performance enhancement is driven not only by the increase of the emission cross section while the crystal temperature is going down, but also by the involved temperature dependent energy transfer processes, such as cross-relaxation (orange laser transition) or reabsorption processes (blue laser transition).

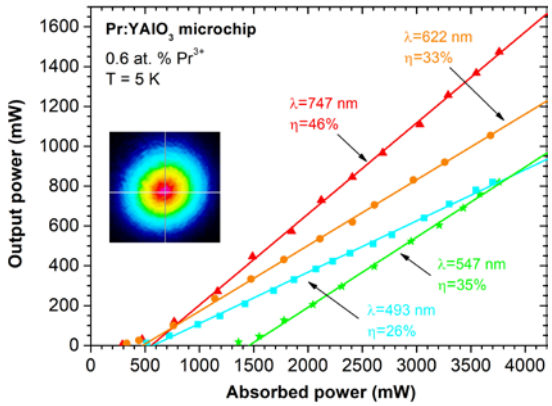

Fig. 1. Output characteristics of Pr:YAP microchip lasers designed for generation in near-infrared, orange, green, and cyan-blue laser transitions at 5 K crystal temperature; inset − spatial beam profile at maximal output power for illustrative purposes.

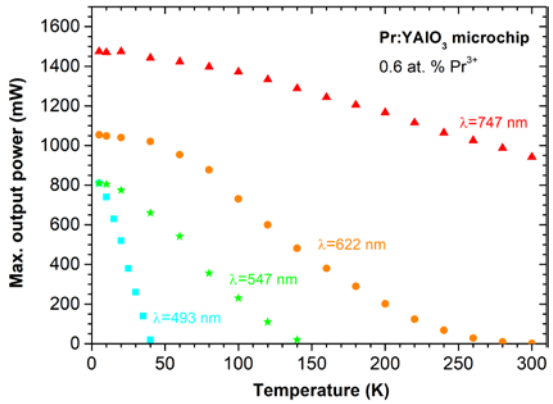

Fig. 2. Maximal output powers of Pr:YAP microchip lasers designed for generation in near-infrared, orange, green, and cyan-blue laser transitions as a function of crystal temperature.