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Tungstate Laser Operates in Waveguide Mode

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Optically pumped waveguide lasers have an inherent advantage over conventional lasers in that the overlap between the pump light and the laser mode is necessarily quite high because both are constrained to propagate together in the narrow waveguide. Among optically pumped lasers, rare-earth-doped $KY(WO_4)_2$ (KYW) lasers show great promise because of their unusually high absorption and emission cross sections. Recently, scientists in Europe produced the best of both worlds by demonstrating what they believe is the first KYW waveguide laser.

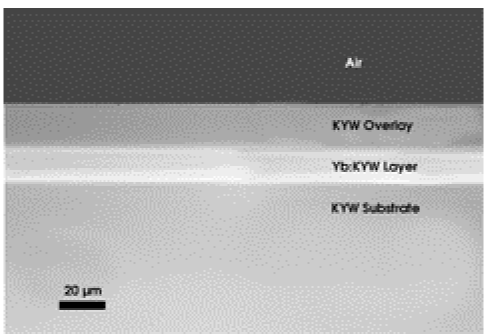

Figure 1. The active Yb-doped layer of KYW was sandwiched between two layers of undoped KYW in this buried-waveguide structure. ©OSA.

The scientists, from Ecole Polytechnique Fédérale de Lausanne in Switzerland and from Max Born Institut für Nichtlineare Optik und Kurzzeitspektroskopie in Berlin, fabricated the lasers by liquid-phase epitaxy. They produced single-crystal layers of Yb-doped KYW on substrates of undoped KYW. The thickness of the doped lasers ranged from 10 to 100 µm, and the Yb concentration was from 1.2 to 2.4 atomic percent. In several cases, they added a 20-µm layer of undoped KYW to the top of the structure to produce a buried Yb-doped waveguide (Figure 1). In other cases, the Yb-doped layer acted as a surface waveguide.

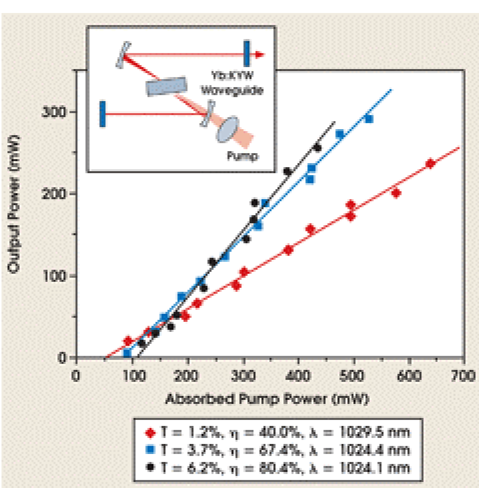

Figure 2. Housed in a Z-resonator (inset), the Yb:KYW laser generated up to 290 mW. ©OSA.

For their laser experiments, the investigators set up a Z-resonator with 2 W of 980.5-nm pump light from a homemade Ti:sapphire laser entering through one of the folding mirrors (Figure 2, inset). They used two Yb:KYW samples in this configuration: one a buried waveguide with 2.4 percent atomic doping and the other, a surface waveguide with 1.2 percent atomic doping.

In both cases, the waveguide layer was 17 μm thick with polished but uncoated end faces. The scientists obtained the best result — 290 mW of output power from 510 mW of absorbed pump power — with a 3.7 percent output coupler on the surface waveguide laser (Figure 2). With a 6.2 percent output coupler, the slope efficiency of the Yb:KYW waveguide laser was as high as 80.4 percent, which the scientists believe to be the highest value yet reported for a dielectric oxide waveguide laser and one of the highest for an Yb-doped laser.

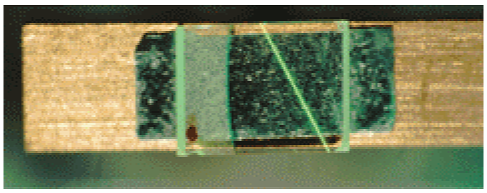

Figure 3. The Yb:KYW waveguide was mounted on an uncooled copper plate. The green fluorescence, from the minute presence of Tm and Er ions, indicates the laser channel.

The investigators saw slightly inferior output with the buried-waveguide laser, although its losses should have been lower. They attribute the poorer performance from the device to its higher doping, which led to higher reabsorption losses. (Yb:KYW is a three-level system, so a laser photon can be absorbed to excite an Yb ion from the ground level to the excited laser level.) Because the Yb:KYW samples were mounted on an uncooled copper plate (Figure 3), the researchers were concerned that the laser's power might be limited by thermal effects. To ensure that that was not the case, they chopped the pump beam with a 10 percent duty cycle and observed that the power fell to 10 percent of its unchopped level.

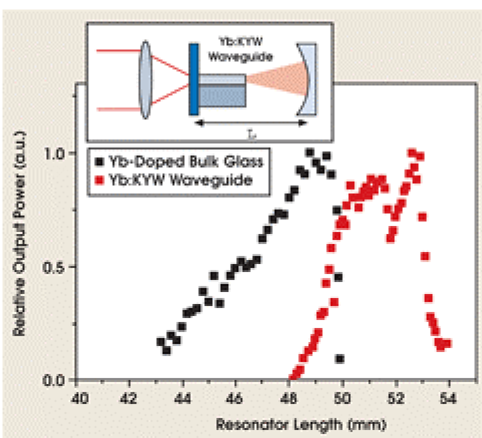

Figure 4. To demonstrate that the layered Yb:KYW structure was guiding light, the scientists stretched a hemispheric resonator beyond its normal instability region. ©OSA.

To demonstrate beyond doubt that the layered KYW structure was functioning as a waveguide, they conducted a second set of laser experiments using a resonator with one flat and one concave mirror (Figure 4, inset). Such a resonator is stable so long as the separation between the mirrors is equal to or less than the mirror's radius of curvature, and it will not support oscillation if the mirror separation exceeds the curvature. With a 50-mm-curvature mirror, the scientists first used bulk glass as the lasing medium. As they pulled the mirrors apart, the laser was extinguished, as expected, when the optical distance between the mirrors exceeded 50 mm (Figure 4).

But when they replaced the bulk glass with the Yb:KYW waveguide, they obtained laser oscillation in the resonator with a mirror separation as great as 54 mm. The waveguide, in effect, was imaging the flat mirror at a position closer to the concave mirror. The image was not at the end of the waveguide — that is, the mirror separation could not be increased by the full length of the waveguide — because the waveguide confined light in only one transverse dimension.

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