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**4.2 W Cr<sup>2+</sup>:ZnSe FACE COOLED DISK  
LASER**

**Jason B. McKay, Won B. Roh, and Kenneth L. Schepler**



**2002**

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# 4.2 W Cr<sup>2+</sup>:ZnSe Face Cooled Disk Laser

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**Abstract:** We report a 10-kHz Cr<sup>2+</sup>:ZnSe laser using the face-cooled disk approach which produced 4.27 W at 2.5  $\mu\text{m}$  with 47% optical efficiency when pumped by a Q-switched Tm,Ho:YLF laser.

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## 1. Introduction

The Cr<sup>2+</sup> laser is a promising candidate for tunable mid-IR applications. However, thermal effects have prevented the typical end-pumped, side-cooled rod laser design from producing more than 2 watts in output power[1, 2]. A resonator designed for maximum suppression of thermal effects is required for further power scaling. An attractive approach for power scaling the Cr<sup>2+</sup> laser is the face-cooled disk laser design used to demonstrate high-power (>100 W) Yb lasers[3, 4]. Although intended for high-power lasers, this approach easily lends itself to power scaling the Cr<sup>2+</sup> laser at more modest power levels. This paper reports demonstration of 4.27 W output from a face-cooled Cr<sup>2+</sup>:ZnSe disk laser.

## 2. Face Cooled Disk Laser

The face cooled disk is essentially a longitudinally pumped active medium, which is also cooled longitudinally through its polished faces. By using a pumped spot larger in diameter than the disk thickness, the pump-induced heat is primarily extracted longitudinally. This design therefore reduces radial thermal gradients in the active medium, thus reducing thermal lensing effects.

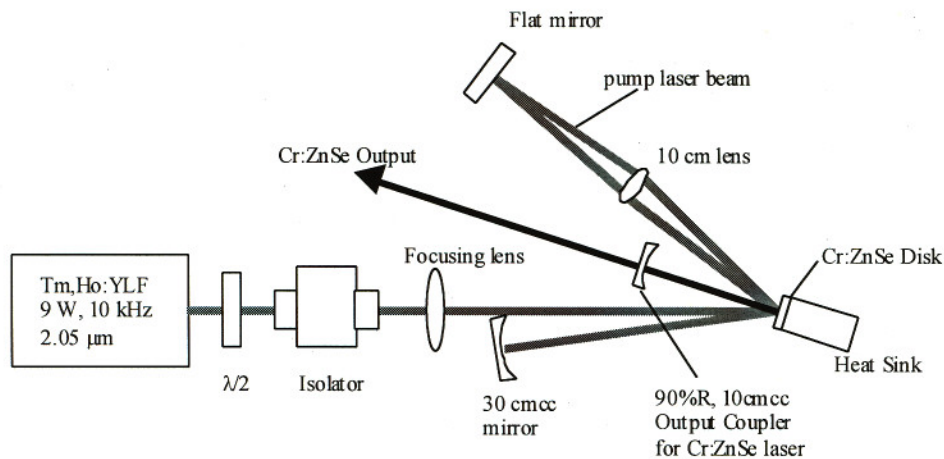


Figure 1. Cr<sup>2+</sup>:ZnSe Disk Laser Setup

The  $\text{Cr}^{2+}:\text{ZnSe}$  disk laser, shown in Fig. 1, consisted of a pump laser, the  $\text{Cr}^{2+}:\text{ZnSe}$  disk, an output coupler, and multi-pass pumping optics. The pump laser, which was a Q-switched  $\text{Tm,Ho}:\text{YLF}$  laser with 9 W average power at 2.05  $\mu\text{m}$ , 10-kHz pulse repetition rate, was focused to a radius of 0.5 mm at the disk. The  $\text{Cr}^{2+}:\text{ZnSe}$  disk was 1 mm thick and doped to  $2.3 \times 10^{19} \text{ cm}^{-3}$   $\text{Cr}^{2+}$  concentration. The disk was AR coated on one face and HR coated on the other face for both pump and  $\text{Cr}^{2+}$  laser wavelengths. The HR coated face was soldered to a water-cooled heat sink. The output coupler was a 90% reflecting, 10-cm concave radius of curvature mirror placed 8 cm from the surface of the disk. Multi-pass pumping optics consisted of a 10-cm focal length lens, a flat mirror, and a 30-cm concave radius of curvature mirror that were used to image the pump laser back onto the disk with unity magnification four times to yield eight one-way passes. Eight-pass pumping provided 95% pump light absorption. The pump beam was aligned off axis to eliminate the need for dichroic mirrors in the resonator and produced an elliptical [2 mm x 1 mm] gain region.

The  $\text{Cr}^{2+}:\text{ZnSe}$  laser produced up to 4.27 W of output with 9 W input (see Fig. 2). Threshold was 610 mW (61  $\mu\text{J}/\text{pulse}$ ), and slope efficiency was 50% with respect to incident pump power. Overall optical efficiency at full power was 47%. This  $\text{Cr}^{2+}$  laser was stable and ran for over six hours with less than 2% variation in average output power. This configuration showed no sign of efficiency rolloff at higher pump power, the typical effect of thermal lensing. A smaller pump beam diameter led to increased radial thermal gradients and thus thermal instability. Thus the ~1-mm diameter incident pump spot size represents the smallest useful pump spot size with respect to the 1-mm thick disk for this system.

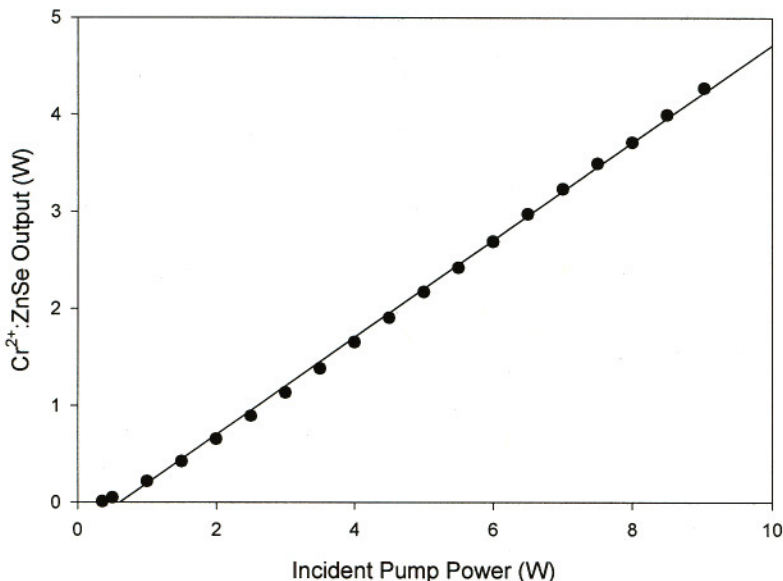


Figure 2.  $\text{Cr}^{2+}:\text{ZnSe}$  Laser Performance

The  $\text{Cr}^{2+}$  output beam was elliptical in shape with divergence that was 3 and 6 times diffraction limited along the minor and major beam axes, respectively. Output beam quality did not significantly change as a function of pump power. Laser bandwidth at full power was 56 nm FWHM – typical for a free-running pulsed  $\text{Cr}^{2+}$  laser with broadband mirrors. Output pulse width was 220 ns, consisting of several short gain-switched pulses followed by a longer pulse which lasted for the duration of the remainder of the 290-ns FWHM pump pulse.

This resonator configuration did not allow for CW  $\text{Cr}^{2+}$  laser operation.  $\text{Cr}^{2+}$  laser threshold for CW pumping is expected to be on the order of 16 W for a 1-mm beam diameter. This is more power than is available from our  $\text{Tm,Ho}:\text{YLF}$  pump laser. Continuous wave operation with 9 W pump power would require a smaller beam diameter and thus thinner disks.

### 3. Summary

We have shown that the face-cooled disk laser can effectively reduce thermal effects in  $\text{Cr}^{2+}$  lasers by demonstrating a 4.2-W,  $\text{Cr}^{2+}:\text{ZnSe}$ , face-cooled disk laser with output power limited only by the available pump power. The difficulty of compensating for thermal lensing inside a resonator is traded for the less difficult task of efficiently absorbing the pump laser in a thin laser crystal. For this demonstration, efficient absorption of the 2.05- $\mu\text{m}$  pump power required a 1-mm thick disk, which required pulsed operation and resulted in multi-mode output given the available optics. We intend to achieve better performance in the future by using thinner disks, which should allow a smaller pump beam diameter to be used, improving beam quality and enabling CW operation. To maximize pump absorption in the thinner disks, higher  $\text{Cr}^{2+}$  doping density, additional pumping passes, and pumping at wavelengths closer to the  $\text{Cr}^{2+}$  absorption peak will be used.

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