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# Diode array-pumped mid-infrared cw $Cr^{2+}$:CdSe laser

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**Abstract.** The operation of a room-temperature, solid-state, Cr-doped CdSe continuous-wave laser is demonstrated. Longitudinal pumping with a continuous-wave diode laser array at 1.94 $\mu$m produced a broadband output of 200 mW at 2.6 $\mu$m with an incident power slope efficiency of 6.4%.

## 1. Introduction

Mid-infrared lasers are of interest for various scientific and industrial research [1–3]. A potential application of mid-infrared lasers is in master oscillators with a short-term frequency stability, which are based on lasers stabilized by Doppler-free saturated absorption and saturated dispersion resonances in low-pressure gas cells [4, 5].

Spectroscopic studies [6] and preliminary laser experiments [7] have shown $Cr^{2+}$:CdSe to be a promising candidate as a mid-IR source. The first operation of a crystalline $Cr^{2+}$:CdSe tunable laser was demonstrated in [8, 9]. Further improvements in the output characteristics of Cd chalcogenide lasers were demonstrated in [10], which produced an efficient Tm-fiber pumped $Cr^{2+}$:CdSe laser operating at 2.6 $\mu$m. A tunable single-frequency cw $Cr^{2+}$:CdSe laser was demonstrated in [11]. Recent progress in scientific and industrial research has increased the need for compact, low-cost, robust laser sources. For this reason, diode lasers appear to be highly promising for use as pump sources.

In this letter, we report the efficient cw operation of a room-temperature $Cr^{2+}$:CdSe laser pumped by a 1.94-$\mu$m diode laser array. We obtained a maximum cw output power of 200 mW at 2630 nm with an incident pump power of 2.8 W at 1940 nm, corresponding to an input power slope efficiency of 6.4%.

## 2. Experimental setup

Figure 1 shows the experimental setup of the $Cr^{2+}$:CdSe laser. The $Cr^{2+}$:CdSe crystal, with a $Cr^{2+}$ concentration of $1.1 \cdot 10^{18}$ $cm^{-3}$, had a cross-section of 1.5 mm × 5 mm and a length of 4.9 mm. The temperature of the water-cooled copper block, which contains the laser crystal, was about 8 °C. This allows for a decrease in the threshold pump power and an increase in the upper laser level lifetime [6].

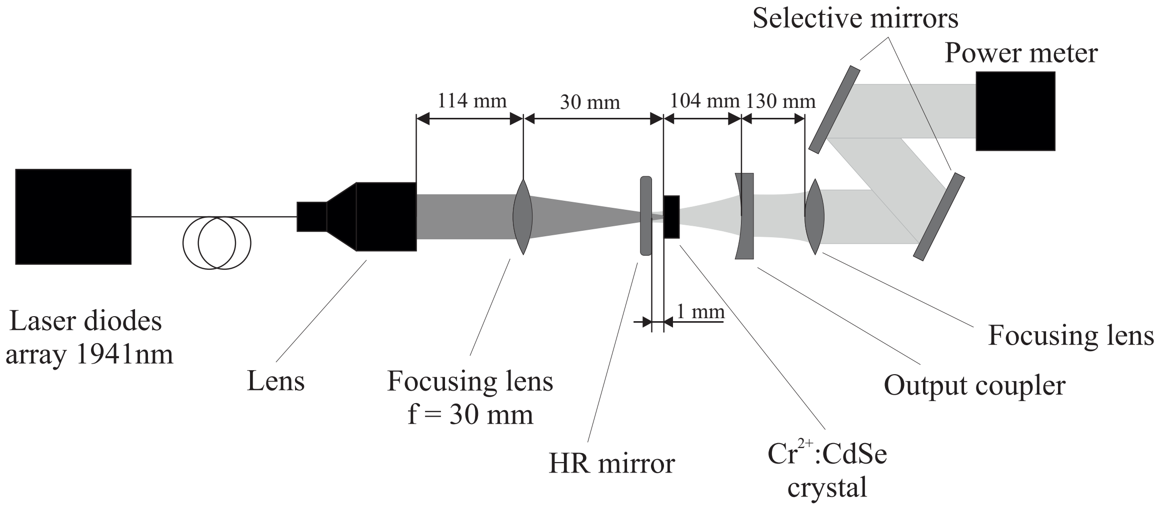


**Figure 1.** Schematic of the cw Cr:CdSe crystal laser (Setup I).

The $Cr^{2+}$:CdSe crystal was grown by physical vapor transport [12]. The optical axis of the crystal was directed at 3° from the normal to the polished surfaces of the active element. Based on the absorption spectrum of the $Cr^{2+}$:CdSe crystal, a room-temperature diode laser array with an emission wavelength of about 1940 nm was used as the pump source. The diode laser array had a fiber output with a diameter of 400 $\mu$m. The absorption coefficient of the $Cr^{2+}$:CdSe crystal at 1940 nm was 2.143 $cm^{-1}$.

The cavity of the $Cr^{2+}$:CdSe laser consisted of a planar dichroic input mirror (high transmission at 1940 nm of nearly $\tau = 90\%$ , low transmission at 2400–3100 nm of $\tau = 0.15\%$) and a spherical dichroic output coupler with a low transmission $\tau = 2.75\%$ at 2630 nm. We used a set of output couplers with radii of 50, 75 and 100 mm to match a waist size to a focal spot of a pump source. The best matching was achieved by $R_{OC} = 100$ mm,

To focus the beam of the pump diode laser array, we used a set of lenses with focal lengths of 20, 25, 30, 35 and 40 mm to match a focal spot size with a waist size. The best matching was achieved by a lens with a focal length of f = 30 mm, which focused the beam of the pump diode laser array, propagated through the fiber, to a waist size of about 500 $\mu$m within the $Cr^{2+}$:CdSe crystal. The laser beam then was collimated by a lens and was filtered from the pump radiation by two dichroic mirrors.

## 3. Slope efficiency of cw output

The transmission of the $Cr^{2+}$:CdSe crystal was 35% for a 1940 nm diode laser array pump. The output power was measured by a power meter, as shown in Figure 1. The $Cr^{2+}$:CdSe crystal laser cw output power as a function of incident pump power is shown in Figure 2. The maximum output power was 200 mW at 2630 nm, corresponding to an incident pump power of 2.8 W on the $Cr^{2+}$:CdSe crystal surface, and the input power slope efficiency was 6.4%. The threshold input pump power was 0.76 W.

## 4. Conclusions and Discussion

We demonstrated a $Cr^{2+}$:CdSe cw laser, pumped by a diode laser array. The maximum output power was 200 mW, achieved by a simple plano-concave resonant cavity, corresponding to an input power slope efficiency of 6.4%.

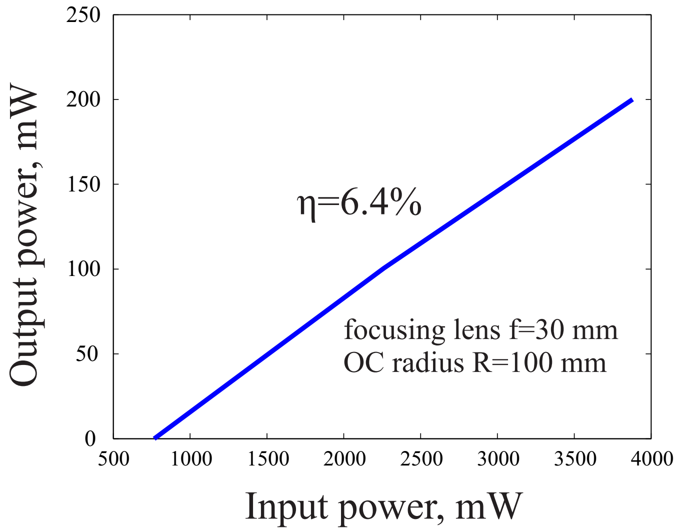


**Figure 2.** Output power of the cw $Cr^{2+}$:CdSe laser.

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