Diode array-pumped mid-infrared cw Cr\textsuperscript{2+}:CdSe laser

V A Lazarev\textsuperscript{1}, M K Tarabrin\textsuperscript{1,2}, S O Leonov\textsuperscript{1}, V E Karasik\textsuperscript{1}, A N Kireev\textsuperscript{2}, V I Kozlovsky\textsuperscript{2,4}, Yu V Korostelin\textsuperscript{2}, Yu P Podmar’kov\textsuperscript{2,3}, M P Frolov\textsuperscript{2,3} and M A Gubin\textsuperscript{2,4}

\textsuperscript{1}Bauman Moscow State Technical University, Moscow, 105005 Russia
\textsuperscript{2}P. N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, 119991 Russia
\textsuperscript{3}Moscow Institute of Physics and Technology, Moscow, 117303 Russia
\textsuperscript{4}National Research Nuclear University MEPhI, Moscow, 115409 Russia

E-mail: vladimir.al.lazarev@gmail.com

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 µm produced a broadband output of 200 mW at 2.6 µm 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\textsuperscript{2+}:CdSe to be a promising candidate as a mid-IR source. The first operation of a crystalline Cr\textsuperscript{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\textsuperscript{2+}:CdSe laser operating at 2.6 µm. A tunable single-frequency cw Cr\textsuperscript{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\textsuperscript{2+}:CdSe laser pumped by a 1.94-µm 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\textsuperscript{2+}:CdSe laser. The Cr\textsuperscript{2+}:CdSe crystal, with a Cr\textsuperscript{2+} concentration of 1.1·10\textsuperscript{18} cm\textsuperscript{-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].
The Cr$^{2+}$:CdSe crystal was grown by physical vapor transport [12]. The optical axis of the crystal was directed at 3$^\circ$ 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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