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Laser action in chromium-activated forsterite for near infrared excitation

V. Petricevic, S. K. Gayen, and R. R. Alfano

CUNY-City College, Institute for Ultrafast Spectroscopy & Lasers, New York, New York 10031.
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Recently, we reported[1-3] room-temperature pulsed laser action in chromium-activated forsterite ($Cr:Mg_2SiO_4$). The free-running laser output was centered at 1235 nm with a spectral bandwidth (full width at half-maximum, FWHM) of 22 nm. The laser emission was stimulated by the 532-nm excitation of the green-red absorption band of the system. The crystal is characterized by a shallow absorption band spanning the 850–1200-nm wavelength range, which overlaps a significant portion of the emission spectrum and was previously thought to inhibit laser action in that region. In this communication, laser action in chromium-doped forsterite for 1064-nm excitation of this band is reported. The near infrared absorption thus turns out to be effective in populating the initial level of the lasing transition.

The absorption and fluorescence characteristics of Cr:forsterite in the near infrared spectral region are shown in Fig. 1. The room-temperature absorption spectrum is a double-humped band covering the 850–1200-nm wavelength range. The room-temperature fluorescence spectrum extends from 1000 to 1400 nm and peaks at 1140 nm. At liquid nitrogen temperature both the spectra show a sharp zero-phonon line at 1093 nm followed by elaborately structured vibrational sidebands. A detailed analysis of the vibrational sidebands is out of the scope of the present paper and will be presented in a future publication. The fluorescence lifetime is 15 μs at room temperature and 20 μs at liquid nitrogen temperature.

The cavity arrangement used for obtaining laser action in $Cr:Mg_2SiO_4$ has been described elsewhere.[1] An identical arrangement was used in this measurement, except that the separation between the front and the back mirrors was 40 cm, and the pump beam was focused 5 cm in front of the sample by a 50-cm focal-length lens. The fundamental and second harmonic emissions from a Q-switched Nd:YAG laser (Quanta Ray DCR-1) operating at a 10-Hz repetition rate were used for excitation of the near infrared and visible bands, respectively. Pulsed laser action was readily observed for both the 1064- and 532-nm pumping at or above the respective thresholds. To switch from one pump wavelength to the other, one merely had to change a filter in the beam path to transmit the desired wavelength and block the other. The amplitude and duration of the $Cr:Mg_2SiO_4$ laser

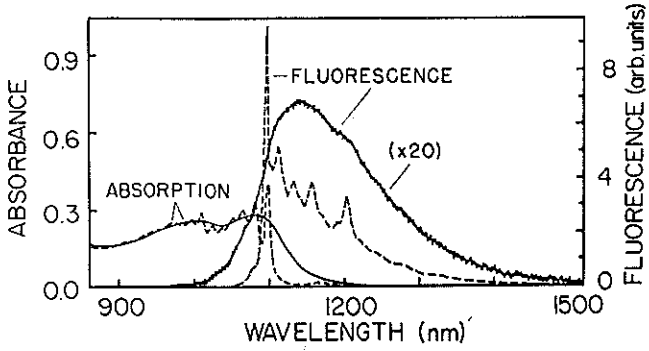

Fig. 1. Near infrared absorption spectrum and fluorescence spectrum for 1064-nm excitation of $Cr:Mg_2SiO_4$ at room temperature (solid line) and liquid-nitrogen temperature (broken line) for $E \| b$ axis. The crystal contains 0.04 at.% of Cr ions and has a thickness of 4.5 mm along the excitation direction.

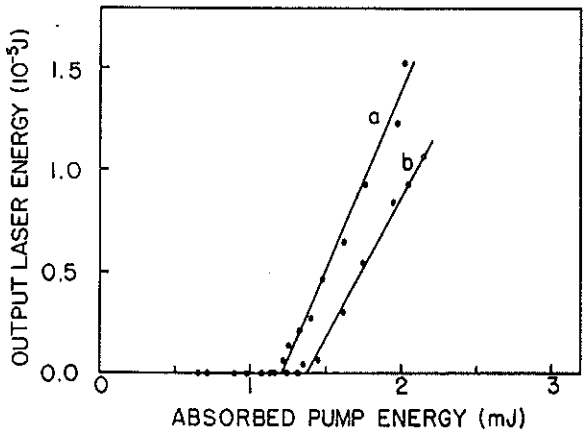

Fig. 2. Output energy of $Cr:Mg_2SiO_4$ laser as a function of input energy for (a) 1064-nm pumping, and (b) 532-nm pumping.

Table I. Properties of Laser Emission for the Two Excitation Wavelengths

Property	Value at the excitation wavelength	
	1064 nm	532 nm
Lasing threshold (absorbed energy)	1.25 mJ	1.37 mJ
Slope efficiency	1.8%	1.4%
Spectral bandwidth (FWHM)	25 nm	22 nm
Center wavelength	1235 nm	1235 nm

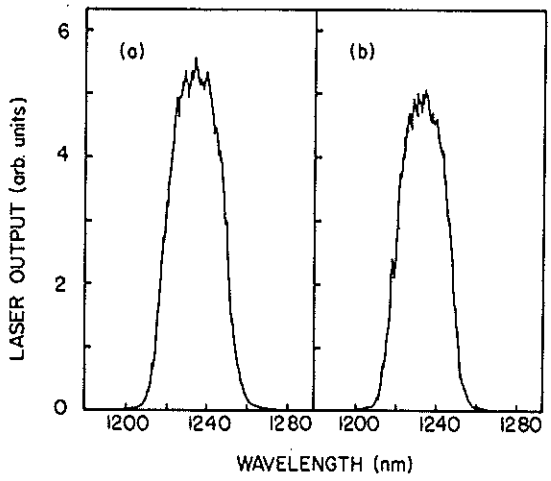

Fig. 3. Spectra of free running $Cr:Mg_2SiO_4$ laser for (a) 1064-nm pumping and (b) 532-nm pumping.

pulse, as well as its delay with respect to the pump pulse, varied as expected with the pulse-to-pulse energy fluctuation of the pump pulses. However, for a similar level of excitation and within the time resolution of the experiment, there was no appreciable difference in the delay between the pump pulse and the output laser pulse for the two pump wavelengths. The laser thresholds and slope efficiencies for the two excitation wavelengths, 1064 and 532 nm, are shown in Fig. 2. The spectra of the free-running laser for pumping at 1064 and 532 nm are displayed in Figs. 3(a) and (b), respectively. Table I summarizes and compares the characteristics of laser emission for the two excitation wavelengths.

The close similarity of laser parameters clearly indicates that the infrared band is responsible for laser action for both the 532- and 1064-nm excitations. For 532-nm pumping there is a fast transfer of excitation from the levels directly pumped to the lasing level. Chromium-activated forsterite thus has the useful property that it can be pumped by the fundamental of Nd:YAG or Nd:glass lasers, and no frequency doubling is necessary. A detailed understanding of the spectroscopic properties that lead to this behavior of this system is an interesting problem and will be presented in an upcoming publication.

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Note added in proof: We obtained cw laser action in chromium-activated forsterite pumping with 1064-nm cw radiation from a Nd:YAG laser. Using a single plate birefringent filter in pulsed mode, tuning over 1167–1270 nm range has also been demonstrated.

References

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