Diode-pumped, stimulated random emission using a powder of Nd:YVO_4

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In random lasers, which refer to lasing in disordered media, strong multiple scattering plays a constructive role instead of being only a loss factor [1]. Random lasers have received considerable attention for several years due to its unique properties and its potential applications. Being demonstrated in a wide variety of media, including powders of rare-earth crystals, pulsed and continuous-wave lasing emission has been reported [2].

In this work, emission intensity and linewidth narrowing is experimentally analyzed in an optical pumped random media, observing a sharp threshold and pulsed emission on only one transition, namely, the $^4F_{3/2}\rightarrow{}^4I_{11/2}$.

The powder was obtained by grinding a 1.4mol% Nd^{3+}:YVO_4 laser crystal using an agate mortar and a pestle. The mean diameter of the particles was 390 nm (determined by laser diffraction technique). A sample with flat surfaces and dimension of Φ5x1 mm^3 was obtained by compressing ~33.7 mg of powder with a manual punch tablet.

For the experiment, a QCW laser diode bar was used as the pump source, tuned to the maximum of the Nd^{3+} absorption for this sample (809 nm) with 100 µs pulse width and 3 Hz of repetition rate. The excitation beam was focused to a square shape with area of 5.33 mm^2. The samples' backscattered luminescence, caused by the normal incidence beam from the diode bar, was separated from the pump excitation by a beam splitter, then collected and analyzed using a fast oscilloscope and a spectrometer.

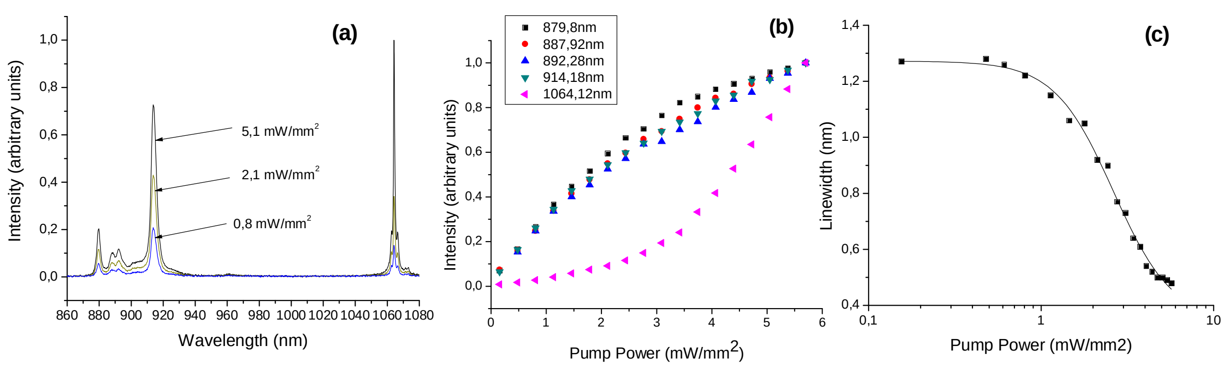

Figure – (a) Sample emission spectra irradiated with powers of 0.8, 2.1 and 5.1 mW/mm^2 of average intensity. (b) Normalized peak emission intensity from optically excited Nd^{3+}:YVO_4 powder at five wavelengths versus incident laser power. Observe that only the 1064 nm emission has an exponential increase. (c) Linewidth narrowing from the $^4F_{3/2}\rightarrow{}^4I_{11/2}$ emission transition.

At low pump intensity (0.81 mW/mm^2), several fluorescent emissions from $^4G_{7/2}\rightarrow{}^4I_{9/2}$, $^4G_{5/2}\rightarrow{}^4I_{9/2}$, $^4F_{3/2}\rightarrow{}^4I_{9/2}$, and $^4F_{3/2}\rightarrow{}^4I_{11/2}$ Nd^{3+} transitions were visible, as seen in **Figure a**. However, by increasing the pump intensity gradually, a threshold value is observed, accompanied by a sharp emission line at the $^4F_{3/2}\rightarrow{}^4I_{11/2}$ transition (1064.12 nm). **Figure b** shows the exponential growth for this transition, demonstrating that stimulated random emission for this sample has been obtained. Other fluorescent emissions suffered a spectral quenching. The spectral width of this transition decreased as a function of pump power, from 1.30 nm to 0.48 nm (**Figure c**).

At higher duty cycles or longer pulses (400 µs pulse width and 30 Hz of repetition rate), a spectral broadening of the $^4F_{3/2}\rightarrow{}^4I_{11/2}$ transition with increased pump power is observed. This broadening is related to thermal effects that are more significant in a powder than in bulk crystal, on account of the poor thermal conductivity of the inhomogeneous structure. This temperature dependence is relatively strong for samples with a narrow gain spectrum, like the Nd^{3+}:YVO_4 and much smaller in systems with broad gain spectra, such as ZnO powder [3].

[1] D. S. Wiersma, "The physics and applications of random lasers", *Nature Physics* **4**, 359-367 (2008).

[2] B. Li and Stephen C. Rand, "Continuous-wave amplification and light storage in optically and electrically pumped random laser media", *Opt. Soc. Am. B* **24**, 799-807 (2007).

[3] Y. Feng *et al*, "Thermal effects in quasi-continuous-wave Nd^{3+}:$Y_3Al_5O_{12}$ nanocrystalline-powder random laser", *Appl. Phys. Lett.* **84**, 1040-1042 (2004).