# Dependence of particle size and applied pressure on the random laser emission of $Nd^{3+}$:$YVO_4$ powders

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**Abstract:** The aim of this work is to find the optimal parameters of particle size and applied pressure to obtain the highest amplified spontaneous emission (ASE) for nanocrystalline $Nd^{3+}$:$YVO_4$ powder prepared as pressed pellets.
**OCIS codes:** (290.5850) Scattering, particles; (140.3380) Laser materials

## 1. Introduction

The theoretical possibility of generating stimulated emission in scattering media with gain (random laser) was historically proposed by Letokhov in 1960s [1, 2] and experimentally demonstrated in 1993 by Gouedard et al. [3].

A major advantage of random lasers over regular lasers is that their production is cheap and the required technology relatively simple [4] and it is possible to produce random lasers with several different materials like semiconductor nanoparticles, ceramic powders, polymers, organic materials and biological tissues. Potential applications require optimization of random laser performance [5].

M. A. Noginov et al. [5] have studied the dependence of random laser emission in $NdSc_3(BO_3)_4$ powder on the particle size.

The aim of this work is to find optimal parameters of particle size and applied pressure to obtain the best random laser amplification (i.e., higher percentage of amplified spontaneous emission (ASE)) for nanocrystalline $Nd^{3+}$:$YVO_4$ powder prepared as pressed pellets.

## 2. Sample preparation and experimental setup

The powder of the $Nd^{3+}$:$YVO_4$ crystal was obtained by grinding the crystal and subsequently sieving the powder in different particle sizes. Then pressures of 1, 3, 5, 7, and 10 kN were applied with a mechanical press. A set of pressed pellets was fabricated having a variety of particle sizes with a variety of applied pressure (See Table 1).

Table 1. Particle sizes and applied pressures for preparation of $Nd^{3+}$ (1.33 mol%):$YVO_4$ powder pressed pellets.

| **Particle size** | **Applied pressure** |
|---|---|
| $10 \le x \le 20$ µm | 1, 3, 5, 7, and 10 kN |
| $20 \le x \le 45$ µm | 3 kN |
| $45 \le x \le 75$ µm | 3 kN |
| $75 \le x \le 106$ µm | 3 kN |
| $106 \le x \le 180$ µm | 3 kN |

The pellets were pumped using a laser diode in quasi-continuous regime operating at 808 nm with 5 Hz repetition rate and 150 µs pulse width.

The pump beam size was made as small as possible to increase the laser pump intensity in order to achieve a low threshold for laser action [6, 7].

For the setup, two cylindrical lenses with f = -13 and f = -25 mm, a spherical lens with f = 20 mm, a dichroic beam splitter, neutral density filters, and an Ocean Optics spectrometer (Model HR 2000 with 0.11 nm resolution) were used. The setup is shown in Fig. 1.

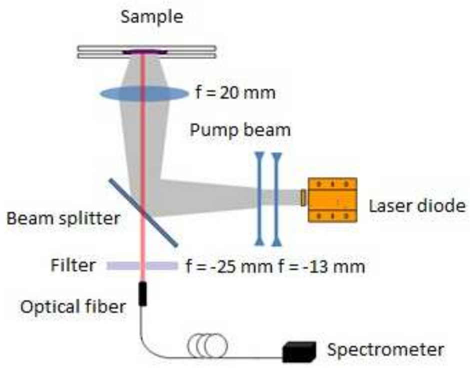


Fig. 1. Experimental setup: The diode beam is first collimated by two cylindrical lenses with focal lengths of – 13 mm and – 25 mm, respectively, and then focused onto the sample with a spherical lens f = 20 mm [6]. A neutral density filter was placed in front of the optical fiber to attenuate the ASE measured in the backscattered direction.

## 3. Results and discussions

Different from a previously published work by our group [6] where the pressure was not varied in the pellet fabrication, we now observed ASE independent of the position of the sample (i.e., at the center of edge of the sample) for lower pressures. This means that we now have a better control on the sample preparation.

Increasing the pump energy gradually, a threshold pump intensity was observed, at which a sharp ASE line at the $^4F_{3/2} \rightarrow {}^4I_{11/2}$ transition (1064, 32 nm) appears [6] (See Fig. 2). The following results refer to the $^4F_{3/2} \rightarrow {}^4I_{11/2}$ transition.

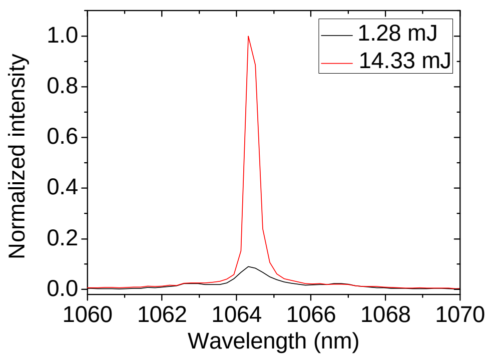


Fig. 2. Normalized ASE spectra for the sample with particle size between $75 \leq x \leq 106$ µm, with an applied pressure of 3 kN. The figure shows the sample's ASE for two different laser pump energies; 1.28 mJ (low peak depicted by the black line) and 14.33 mJ (high peak depicted by the red line).

In Fig. 3 the normalized intensity of the ASE is shown versus incident laser pump energy for the sample with particle size $10 \leq x \leq 20$ µm and varying applied pressure. One can observe that up to a pressure of 5 kN, there is an increase in ASE and after these pressures the ASE started to decrease again.

In Fig. 4, five different particle sizes, as described in Table 1, were pressed with 3 kN. Analyzing the results from Fig. 4, the particle sizes $45 \leq x \leq 75$ µm and $75 \leq x \leq 106$ µm show the highest increase signal amplitude. The sample with particle sizes $106 \leq x \leq 180$ µm wasn't stable for pressures lower than 3 kN. Therefore, for larger particle sizes, it is necessary to apply a higher pressure in order to fabricate stable pellets.

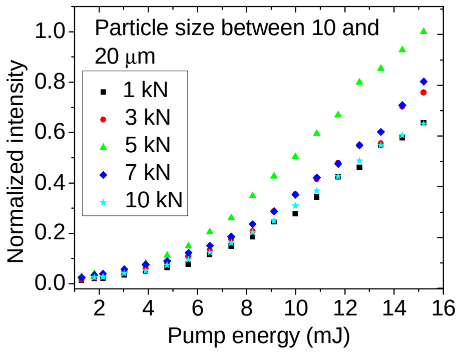


Fig. 3. Normalized intensity of the ASE versus the incident laser pump energy for the five samples with particle size of $10 \leq x \leq 20$ µm with varying applied pressure. The results in the graph are obtained by measuring the stimulated emission peak located at 1064 nm corresponding to the $^4F_{3/2} \rightarrow {}^4I_{11/2}$ transition.

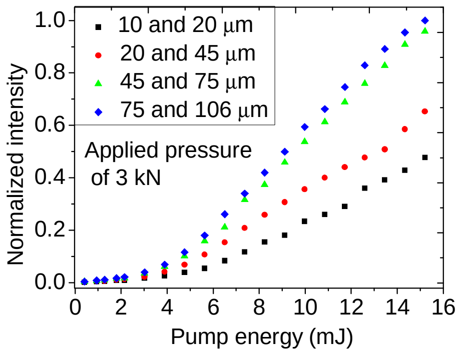


Fig. 4. Normalized intensity of the ASE versus the incident laser pump energy for the sample with varying particle sizes and a constant applied pressure of 3 kN. The results in the graph are obtained by measuring the stimulated emission peak located at 1064 nm.

## 4. Conclusion

Pressed pellets of $Nd^{3+}$:$YVO_4$ powder have been prepared using various different pressures and grain sizes; their optical at 1064 nm has been analyzed under high-power diode-pumping at 808 nm. A 30% increase in amplified spontaneous emission was found when optimizing the preparation pressure to 5 kN. Under constant applied preparation pressure, the samples with the largest particle size provided the largest amplified spontaneous emission. Our next step is to repeat the measurements for all particle size described in table 1 and larger particle sizes applying 5 kN pressure. In addition we will measure the coherent backscattering in order to determinate the transport mean free path.

## 5. Acknowledgments

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