

Evidencing the resonant and non-resonant contributions to the index of refraction of a Nd:YAG rod amplifier

Martin Maillard,^{1,2} Gabriel Amiard-Hudebine,¹ Marc Tondusson,¹ Mikaël Orain,² Eric Freysz¹

1. Univ. Bordeaux, CNRS, LOMA UMR 5798, Talence 33400, France
2. ONERA/DMPE, Université de Toulouse, 31055 Toulouse, France

Abstract: Measuring at both 532 nm and 1064.5 nm the temporal evolution of the lens induced in a Nd:YAG rod amplifier, we reveal the resonant and non-resonant contribution of the Nd³⁺ ions to the refractive index.

An index gradient is generally induced in an amplifier medium (AM) upon its longitudinal or transverse optical pumping. This index gradient acts as lens that needs to be properly compensated to avoid the degradation of the beam shape quality at the exit of the AM. Two contributions are responsible for this index gradient. One is mainly assigned to the heating of the AM amplifier [1]. However, besides this thermal lens effect, another phenomenon often overlooked, is linked to the change of the AM complex refractive index $n(\lambda) = n'(\lambda) + in''(\lambda)$ upon the population of the different electronic states of the doping ions [2]. It was found to be comparable with the thermal effect in Nd-doped materials [3]. Hereafter, using a wavefront analysis method, we show that excited state population and thermal lenses can be easily revealed in Nd:YAG rod amplifier under quasi-continuous side pumping by laser diode bars centered around 808 nm. This contribution resonant around 1064 nm for Nd³⁺ ions is evidenced in Nd:YAG rod amplifier upon its optical pumping.

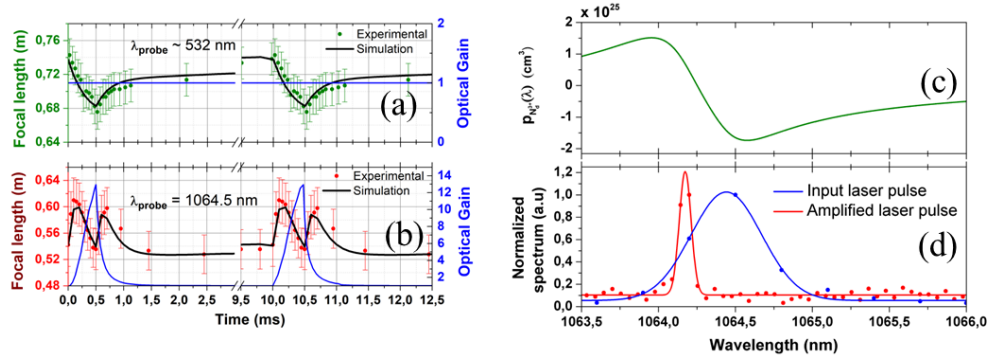


Fig. 1: Evolution of the focal length (green and red dots) and gain (blue lines) of a Nd:YAG rod amplifier side pumped at 100 Hz by 500 μ s and 808 nm pulses and measured at (a) 532 nm and (b) 1064.5 nm. (c) Polarizability of the Nd³⁺ ions as a function of the wavelength. (d) Spectrum of the laser probe with (red curve) and without (blue curve) amplification in the Nd:YAG rod.

Figures 1a-b display the temporal evolution of gain (blue lines) and the focal length (green and red dots) of our AM, Nd:YAG rod (Northrop Grumman RBAT34-1C2) side pumped by 808 nm diode bars at 100 Hz repetition rate. These measurements were performed by a Schack-Hartmann wavefront sensor using the pulse delivered by Nd:YAG micro-laser (Standa STA-01-7-OEM) centered 1064.5 nm. The micro-laser pulses are temporally synchronized and delayed in time with respect to the 500 μ s long pump pulses. At 532 nm (Fig. 1a), f_{AM} the focal length induced in the AM steadily decreases when the pump pulse is on. It relaxes back towards its quasi-static value f_{qs} when the pump is off. At $\lambda=1064.5$ nm the evolution of f_{AM} is very different. During the excitation of the AM, while the gain g increases up to $g \sim 13$, f_{AM} increases and decreases (Fig. 1b). Besides the probe wavelength is shifted by ~ 0.3 nm (Fig. 1d). When the pump is off, g steadily relaxes back to 1 while f_{AM} increases before relaxes back towards f_{qs} . To account for the evolution of f_{AM} at 532 nm and 1064.5 nm, we have developed a model which accounts well for our experimental results (Fig 1a-b black curves) [4]. It shows that f_{qs} is solely due to the heating of the Nd:YAG rod. The evolution f_{AM} result from both the quasi-continuous wave modulation of the AM index of refraction Δn by both the heating of the AM and the population of the excited state of Nd³⁺ ions. At 1064.5 nm, the pulse propagating in the AM is amplified and it experiences a shift of its central frequency λ_l which results in a resonant shift of the polarizability $P(\lambda_l)$ of the Nd³⁺ ions (Fig. 1c). This modulates the index of the AM $\Delta n(\lambda_l) \sim P(\lambda_l) \cdot N(Nd^{3+})$ where $N(Nd^{3+})$ is the population of the excited Nd³⁺. As shown in Fig. 1b (black curves) at $\lambda=1064.5$ nm, the shift of λ_l and change in $N(Nd^{3+})$ induce an increase followed by a decrease (decrease followed by and increase) of f_{AM} when the pump pulse is on (off). This is at variance with the behavior recorded at $\lambda \sim 532$ nm (Fig. 1a), where f_{AM} steadily decreases (increases) when the pump pulse is on (off).

References

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