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JOURNAL DE PHYSIQUE IV
Colloque C4, supplément au Journal de Physique III, Volume 4, avril 1994

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In this paper, we report the influence of proton exchange waveguide parameters on the fluorescence characteristic of Nd:$LiTaO_3$. This information permitted the realization of a stable, C.W. Nd doped lithium tantalate waveguide laser. It presents a threshold of 24 mW and a slope efficiency of 15%. Operating at about 60°C, it was possible to observe up to 8 mW output power at 1.0816 µm for 75 mW absorbed pump power without any instabilities due to photorefractive effects, which are the best results observed to date.

Following the recent success in fabricating waveguide lasers and laser devices in rare-earth doped lithium niobate [1,2,3], it appeared interesting to develop similar elements in rare-earth doped lithium tantalate in view of this latter material's reputation for having a considerably higher optical damage threshold. Unfortunately, first attempts, using Proton Exchanged (PE) waveguides on Nd:$LiTaO_3$ were not very successful[4]. In order to improve these performances we decided to use an annealed PE waveguide, which was realized on a X-cut lithium tantalate substrate[5] doped with 0.1 mole % of Nd^{3+}. A titanium mask consisting of 13 groups of 7 guides with opening widths ranging from 1 to 7 µm was used to fabricate the guides. Proton exchange was carried out for 3.5 hours, in a benzoic acid bath melted at 330°C and diluted with 0.5 mole % lithium benzoate. This results in a high proton density step index profile guide[6], with protons having replaced approximately 80% of the lithium atoms. We then proceeded with a 1h annealing at 350°C, in an oxygen rich atmosphere, which, as previously reported[7], increases both the depth and the index increase of the waveguide (Fig.1).

During this fabrication process we monitored the fluorescence properties of the waveguides and especially the $^4F_{3/2}$ excited state lifetime of the Nd^{3+} ions. In the substrate we used, the Nd^{3+} $^4F_{3/2}$ level shows a lifetime of 100 µs and the fluorescence spectrum presented in figure 2. In the as exchanged waveguide, the room temperature fluorescence spectrum was not strongly modified, but the fluorescence decay was then governed by two much shorter lifetimes, 60% of the signal decaying with a 3 µs lifetime and 40% of it, decaying with a 33 µs lifetime. Obviously, only the last 40% of Nd^{3+} ions can efficiently contribute to laser action, which allows predicting a rather high threshold that we indeed observed with our first laser.

But the fluorescence behaviour of the waveguide was dramatically improved by the annealing. If as expected the room temperature fluorescence spectrum is once again not modified, the fluorescence lifetimes increased by a factor of two, compared to the as-exchanged waveguide (Table 1) and furthermore, the proportion of Nd ions presenting the short lifetime is reduced to 21% of the total population.

We think that these changes induced by the annealing, to the index profile as well as to the variation in the proportion of Nd ions showing a very short lifetime, are correlated to the reduction of "interstitial" protons introduced in the crystal by the initial exchange[6]. Some experiments are underway to establish that more firmly.

To take advantage of these improvements, we realized a cavity, butting to the sample, two multilayer dielectric mirrors with reflectances of 99% at 1.08 µm for the input and 70% for the output. No index matching liquid was used. Pumping with a Ti:sapphire laser tuned to 0.810 µm, two laser lines[8] were observed at 1.0816 µm and 1.0971 µm. The characteristics of a 4 µm wide waveguide laser operating at 1.0816 µm and 1.0971 µm are shown in figure 3. Operating at about 60°C, we observed a stable, C.W. output power for both wavelengths. At 1.0816 µm, the threshold is of 24 mW and the slope efficiency 15%, figures which should be improved by the use of dielectric mirrors deposited on the end faces. At 1.0816 µm, up to 8 mW stable output power was observed for 75 mW absorbed pump power without evidence of dramatic effects due to optical damage. Changing the coupling conditions[8] allows to obtain the 1.0971 line, which exhibits a slightly higher threshold of about 40 mW and a lower slope efficiency of 5%.

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	1st Lifetime / proportion	2nd Lifetime / proportion
Bulk	100 µs / 100 %	
Waveguide	33 µs / 40 %	3 µs / 60 %
Annealed waveguide	68 µs / 79 %	7 µs / 21 %

Table 1. Fluorescence lifetimes of the different Nd:$LiTaO_3$ PE waveguides

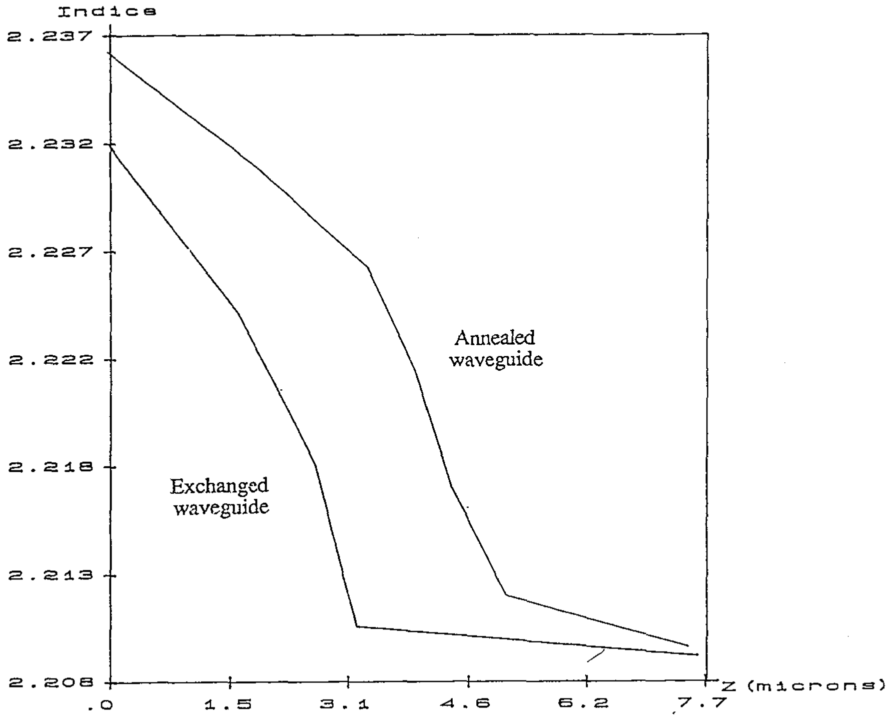

Figure 1. Index profiles of the waveguides

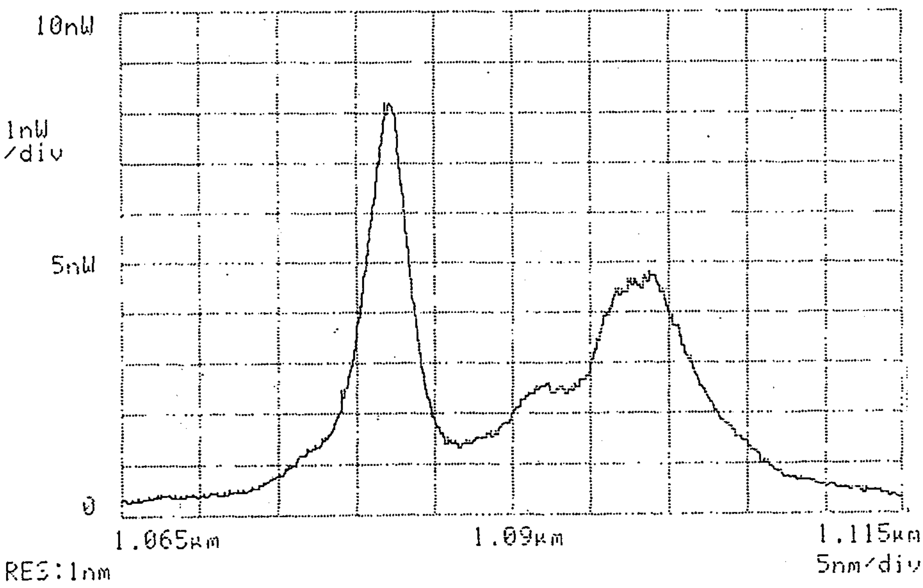

Figure 2. Fluorescence spectrum of Nd:$LiTaO_3$

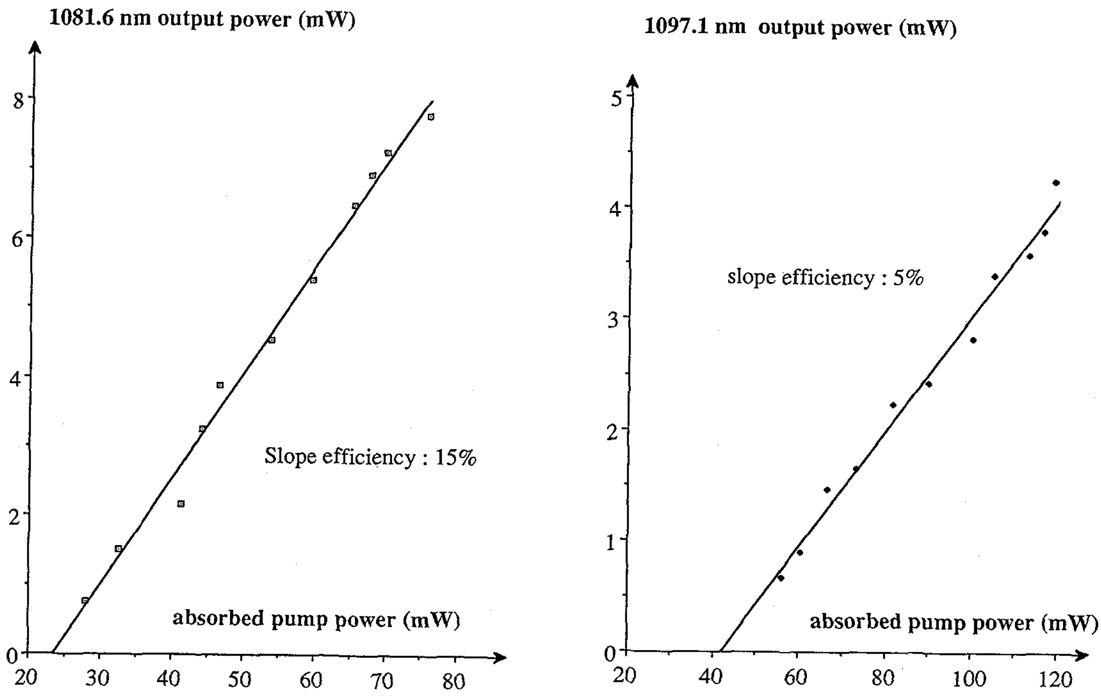

Figure 3. Characteristics of 4 μm wide waveguide laser.