Nd:LuLF, A New Nd Laser Material

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Abstract

Nd:LuLF, a novel laser material isomorphic to YLF, has been grown and evaluated on both polarizations in a simple, wavelength selective resonator.

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Nd:LuLF, Nd:$LuLiF_4$, has been grown and characterized both spectroscopically and as a Nd laser operating at 1.047 and 1.053 μm. Nd:LuLF possesses the advantage of polarized emission spectra, as does its isomorph, Nd:YLF. Using its birefringence, a simple, wavelength selective resonator was constructed consisting only of the laser rod, a highly reflective curved mirror, and a flat output mirror. Using this resonator, laser operation was characterized at both 1.047 or 1.053 μm through small alignment changes.

Prior to the growth of the LuLF laser material, high quality, low oxygen fluoride starting materials were prepared to minimize contamination. Lutetium oxide was converted to 0.99999 pure LuF_3. This material was combined with as purchased LiF and the lanthanide series dopant fluoride powders. Lanthanide series compounds, such as LuF_3, tend to be quite susceptible to oxygen and moisture contamination. Thus manufacture of the high purity crystallized LuF_3 at the point of use insures a superior starting material, compared to that which can be purchased from standard commercial vendors. One of the chemistry related benefits of LuLF is that unlike YLF, $YLiF_4$, it can be grown from a stoichiometric melt. This implies that more of the melt could be used to grow the boule, and fewer inclusions should result due to imbalances in the chemical ratios. Fewer inclusions should improve the resistance to laser induced damage.

The growth of the Nd:LuLF was performed in a research growth furnace similar to the production furnaces used for the growth of the production line of Nd:YLF. A Czochralski furnace purged with inert gas was used for the growth of this boule. Diameter control was maintained by a weight based feedback temperature control system.

After the boule was grown, flats were polished along the sides and the boule was inspected. The cone and interface were then removed and the ends of the boule section were polished for the determination of the wavefront distortion. The Nd:LuLF laser rod was fabricated using techniques similar to those developed for the fabrication and polishing of Nd:YLF

Spectroscopic quantities including the absorption spectra, the emission cross section, the lifetime, and the refractive indices were measured. Absorption spectra for the a and c axes of Nd:LuLF are quite similar to the absorption spectra of Nd:YLF, however, some of the absorption features tend to be shifted to slightly longer wavelengths. Emission spectra were also taken for both the a and c axes of Nd:LuLF in the region between 0.85 and 1.45 μm. By normalizing using the measured lifetime, the stimulated emission cross section was determined. Results are shown in Figure 1 where the π polarized emission peak can be observed at 1.047 μm while the σ polarized emission peak can be observed at 1.053 μm.

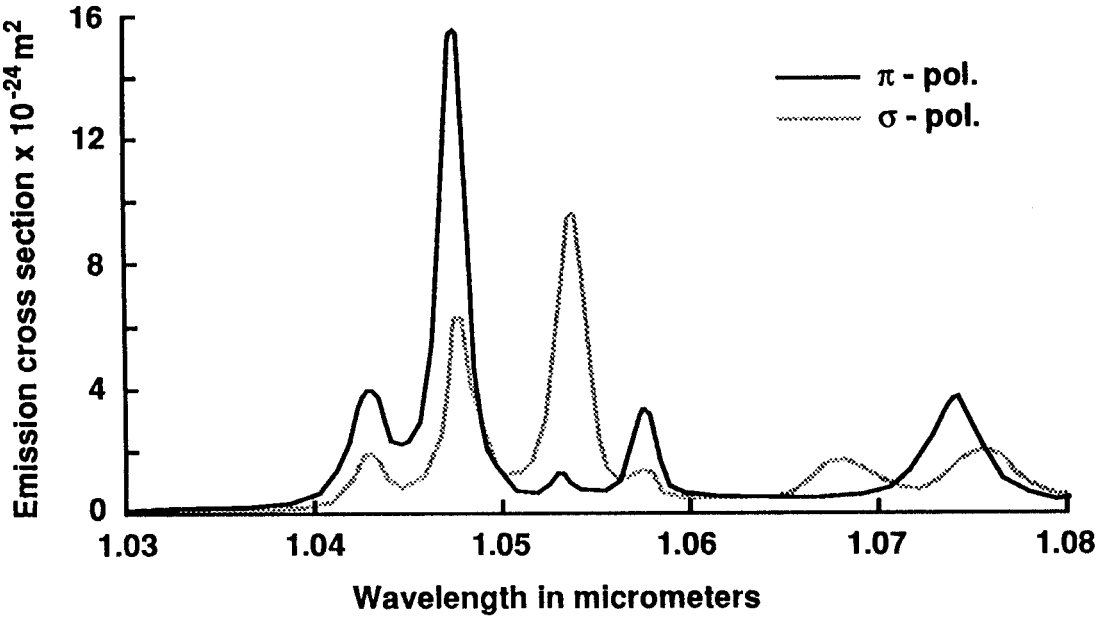
Absorption measurements indicate that the concentration of Nd in the Nd:LuLF lasers material is lower than anticipated, which implies a lower efficiency for this boule of laser material. Line strengths of the absorption features for both the a and c axes in Nd:LuLF were compared with the corresponding features in a sample of Nd:YLF with a 0.01 Nd concentration. Line strengths ratios indicate that the Nd concentration in the LuLF sample is 0.64 that of the Nd concentration in YLF sample. If the Nd concentration in the Nd:LuLF laser rod is 0.0064, then the absorption efficiency will be approximately two thirds that of Nd:YLF with a concomitant decrease in the laser efficiency.

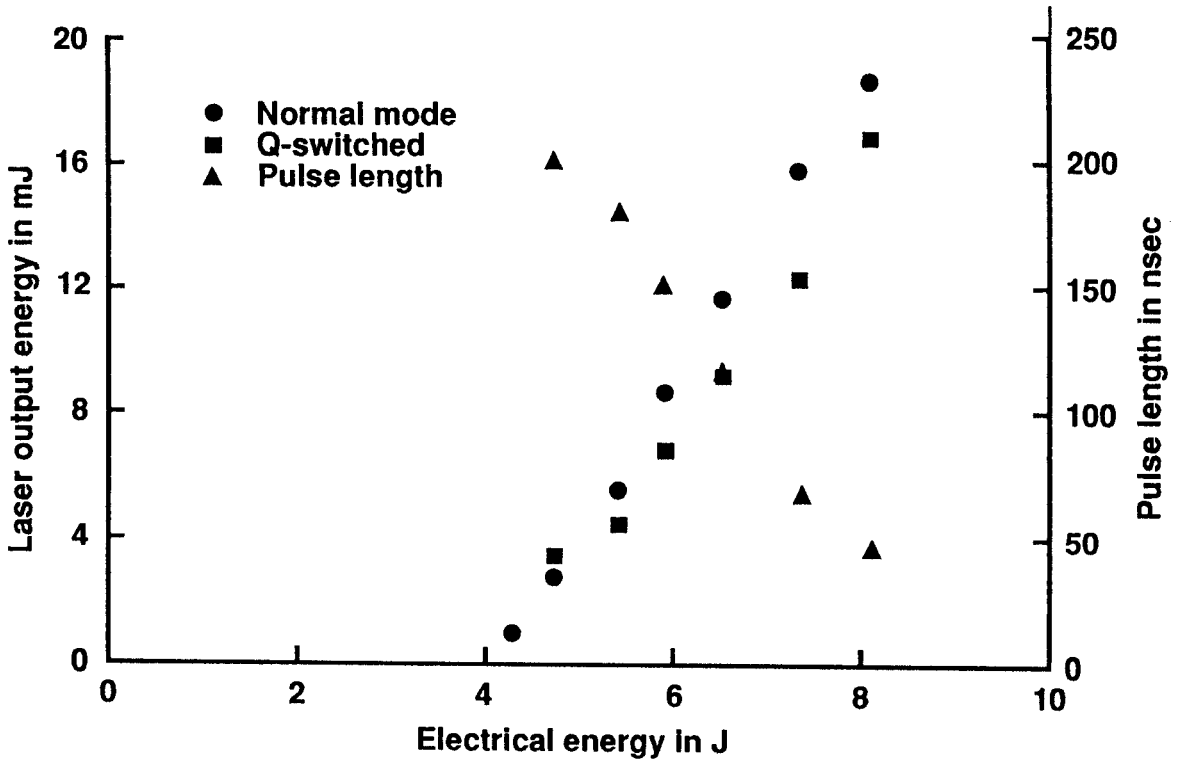
Lifetime of the Nd:LuLF is 504 μsec, slightly longer than that of Nd:YLF. Lifetime was measured by exciting the Nd:LuLF sample in the laser cavity and observing the fluorescence at 1.064 μm after the flashlamp pulse had disappeared. Lifetime appeared to be a single exponential decay with no evidence of lifetime shortening caused by amplified spontaneous emission. Refractive indices of LuLF were measured at 0.633 μm and found to be 1.464 and 1.488 for the ordinary and extraordinary waves, respectively.

Lasing in an a axis Nd:LuLF laser rod was characterized using flashlamp pumping. A 5.0 by 55.0 mm laser rod with a 1° wedge was fabricated from the available laser material. It was pumped in a specularly reflecting cavity by a 4.0 mm bore by 50 mm arclength Xe flashlamp. Cooling was achieved using flowing water in a flooded cavity configuration. An approximately square pulse with duration of 120 μsec was used. A resonator consisting of a 5.0 m radius of curvature highly reflecting mirror and a flat output mirror was employed. The resonator could be aligned for operation at either 1.047 or 1.053 μm. Various reflectivity output mirrors were used to determine the losses and optimize the performance.

Plots of the threshold and slope efficiency as a function of mirror reflectivity indicate that a slope efficiency of 0.01 can be approached even with this boule of laser material. If the Nd concentration is only 0.0064, it is reasonable to expect that for a Nd concentration of 0.01, the threshold of a Nd:LuLF laser would decrease while the slope efficiency would increase proportionally. Curve fitting this data indicates that the losses are reasonably low, approximately 0.1 for a round trip. Losses of this size are typical of normal mode lasers and indicate that the optical quality of the Nd:LuLF is good even though the growth process is in the nascent stage. In a resonator consisting of a 2.0 m radius of curvature mirror and a 0.70 reflecting output mirror, a threshold and slope efficiency of 3.5 J and 0.0078 were observed.

Q-switched operation of Nd:LuLF is similar to normal mode with no obvious limitation, to the level of excitation used in these experiments, caused by a finite lower laser level lifetime. Normal mode and Q-switched performance as well as Q-switched pulse length appear in Figure 2. As commonly observed, the normal mode energy increases somewhat faster than the Q-switched energy due to storage efficiency effects.



Performance of Nd:LuLF Normal Mode and Q-Switched

5.0 x 50 mm laser rod, 0.0064 Nd