Presented at Photonics West, LASER'97, High-Power Lasers and Applications, Solid-State Lasers VI, Conf.#2986

Characteristics of Diode-Pumping Erbium Ytterbium-Doped Glass Laser

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Abstract:

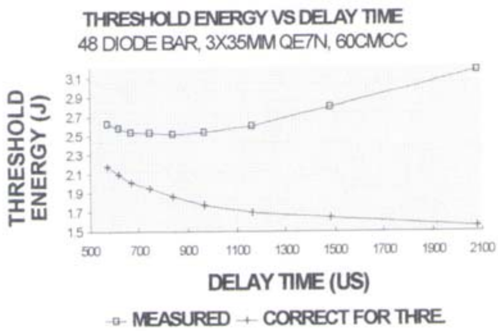
The various aspects of erbium glass laser characteristics were carefully examined, including the influences of pumping pulsewidth, dopant concentration, output wavelength, relaxation oscillation and energy transfer processing between Yb^{3+} and Er^{3+}.

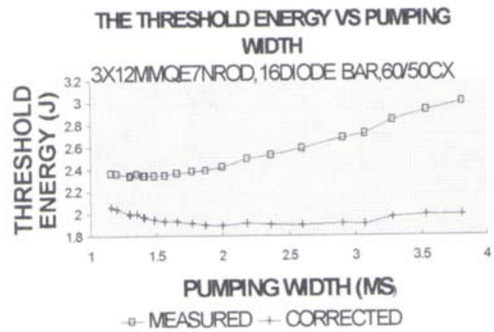
Keywords: Erbium glass, relaxation oscillation, energy transfer

Kigre has been under contract with the United States Army Night Vision & Electronic Sensors Directorate (NVESD) to investigate laser diode pumped, passively Q-switched Er:Glass lasers. Under this project we have studied various aspects which influence the passive Q-switching of Er:Glass lasers. Some of the parameters studied include resonator geometry, configuration, and losses, in addition to gain media geometry, and dopant concentration.[1] In comparison with the traditional flashlamp pumping technology, laser diode pumping is inherently more efficient.

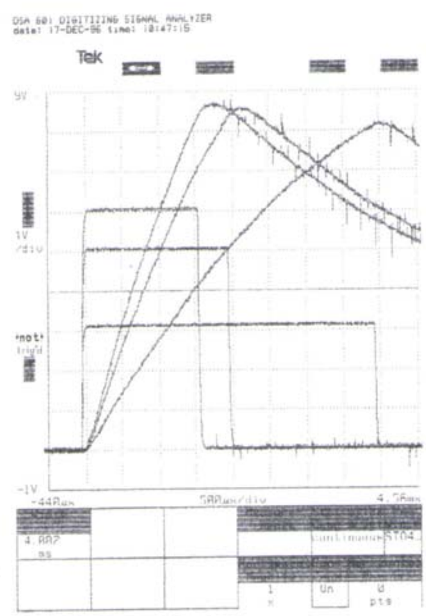
Diode pumping induces lower thermal loading which in turn results in a more stable output. Evidence of this is observed in the stable spike free output produced during our study of diode pumped Er:Glass lasers. This phenomenon is not readily observed under flashlamp pumping. Diode pumped Er:Glass laser studies have revealed many new possibilities for the development and production of high peak and avarage power eye-safe laser transmitters.

The experimental pumping geometry utilized a total of 48 laser diode bars. The pumping array consisted of 11mm, 60watt quasi-CW bars arranged in three 16 bar radial segments. A 3mm diameter, 35mm long Er:Glass rod was centered in the 6mm diameter array. The maximum tested pumping pulsewidth duration of the array was 4ms, yielding a maximum pump energy of 11.5J.





The threshold energy was measured for different pumping pulsewidth durations. The measured data are shown in FIG.1 and Fig.2 for different size rods. The measured data shows the threshold energy increasing with increased pulsewidth. The 10A threshold current of the pumping diode array does not directly contribute to pumping the Erbium ions. This diode threshold current contributes a linear increase in diode threshold energy with increased pumping duration. After correcting for this factor, the threshold vs pulsewidth curves become rather flat. This shows that the threshold energy basically does not change with pumping pulsewidth duration. This result contradicts flashlamp pumping data[2], but makes sense because of 8ms fluorescent lifetime exhibited by the $4I_{13/2}$ manifold of the Erbium.



Fluorescent measurements confirm the above threshold testing results. A photo-diode was placed on axis with the Er:Glass rod at a distance of 40 cm. Measurements of the 1535nm fluorescence were performed with a 1535nm narrow band filter. Fig.3 shows three different pumping durations along with their corresponding fluorescence intensity. The pumping pulses are adjusted so as to provide equal amounts of pumping energy above diode array threshold. At the end of each pumping pulse the fluorescence intensity nearly reached the same high point. This indicates to us that the same population inversion is being achieved in the rod for each pump pulse of different duration.

The laser's output wavelength was measured and the results were found to be similar to that of previous studies[3]. In long pulse operation the output wavelength is basically dictated by the reflectivity of output coupler or the gain in the rod or the inversion of population. Erbium exhibits an overlapping between absorption and fluorescence in the 1.5 micron region. Even at lower population inversion levels, for example 30-35% inversion, there is the possibility to lase at longer wavelengths, say 1556-1564nm, in which area there is little or no absorption. The lasing wavelength shifts to shorter wavelengths gradually as the inversion level is increased to the peak gain region 1535nm. In our measurements 1556nm corresponds to a 90% output coupler. When the output coupler reflectivity is lower than 80% or when the laser is operating in a Q-Switched mode the output wavelength is confined to 1535nm.

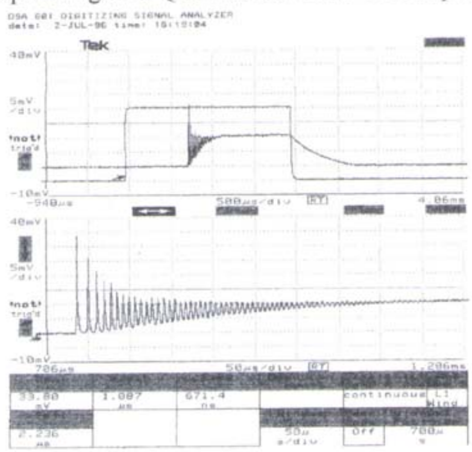


Fig.4 Relaxation oscillation

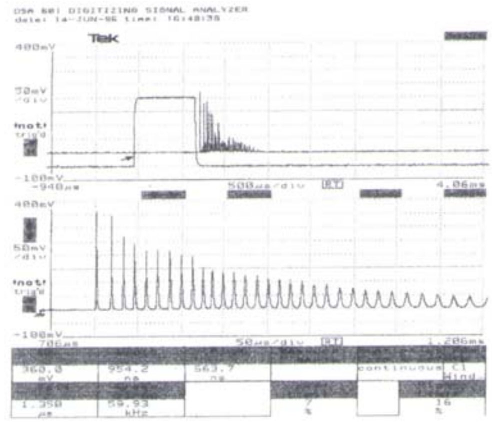


Fig.5 Relaxation oscillation

The laser's relaxation oscillation behavior were observed under various conditions. The diode pump output is much more stable and less noisy than lamp pumping. Perfect relaxation oscillations were observed in the TEMoo output as shown in fig.4,5. The pulse begins with a perfectly dumped relaxation oscillation then is then followed by a noise free steady state laser pulse output. It was found to be easier to obtain perfect relaxation oscillations and a steady state output by using lower doping concentration rods. The narrow pulse train observed near threshold was attributed to saturable absorption of Er^{3+}ions. The first pulse is narrowest and then the pulses gradually get wider. The pulses widths were found to be in the range of 500-1500ns. The stable, low noise diode pumping allow more than 1ms relaxation oscillation free laser output with total output energies of up to 400mj.

In Fig.5, the laser output is shown to begin to drop immediately after the pumping pulse has ended. This shows that at least a portion of pumping energy is transfer to Erbium ions faster than the average energy transfer time between Yb^{3+} and Er^{3+}. According the oscilloscope trace the transfer time for some of the energy is less than 0.1ms.

[1] Wu, Hamlin, Hutchinson, and Marshall, to be presented at the 1997 Advanced Solid State Laser Conference.

[2] Shibin Jiang, Scott J.Hamlin, J.D.Myers, D.L.Rhonehouse, M.J.Myers, "High Average Power 1.54um Er^{3+}:Yb^{3+}-Doped Phosphate Glass Laser" CLEO 1996

[3] Shibin Jiang, J.D.Myers, D. Rhonehouse, G. Bishop, M.J. Myers, S.J. Hamlin, "Further Investigation of 1.5um Er^{3+} Doped Novel Phosphate Glasses and Lasers", CLEO, 1995.