Rapid Time to Fire Nd:Cr:GSGG Lasers

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Motivation—It is well known that laser rods made of gadolinium scandium gallium garnet (GSGG) doped with neodymium and chromium are radiation hard, which is important for laser applications in high radiation environments. One open question surrounding Nd:Cr:GSGG Q-switched lasers is how quickly the laser can be fired after it is triggered. If this firing time is too long, this laser technology will be inadequate for some weapons applications.

Accomplishment—It has been demonstrated that the discharge time of the flashlamps, which pump the Nd:Cr:GSGG laser into the excited state, can be decreased by multi-channel plasma formation in the flashlamps. In contrast to other methods, which also speed up the flashlamp discharge, multi-channel plasma formation should not increase the chance of catastrophic failure because it does not increase the peak current flowing through the flashlamp. By quickly discharging the flashlamp the laser medium becomes inverted more quickly, decreasing the time to fire.

A typical flashlamp will have a straight trigger wire running along the outside of the quartz tube to initiate the plasma formation, and the plasma will develop from a single channel which forms on the inside of the quartz tube right next to the trigger wire. As the plasma channel expands to fill the tube, the current increases until it peaks and the power in the capacitors drops. Using a spiral configuration, the trigger wire (see Fig. 1) initiates the plasma formation along multiple channels allowing the plasma to expand and fill the tube more quickly. We found that the flashlamp optical emission reached its peak value 25% faster for a spiral trigger wire than for a straight trigger wire under fast firing conditions. We have also developed models for the inversion dynamics in Nd:Cr:GSGG in order to predict gain power as a function of time given different flashlamp dynamics and spectral characteristics. The inversion dynamics of Nd:Cr:GSGG are more complicated than more common lasers such as Nd:YAG. In Nd:YAG when a flashlamp photon is absorbed by a neodymium ion, the ion almost instantaneously decays into the lasing excited state where it has a lifetime of about 250 µs. Nd:Cr:GSGG lasers are more efficient than Nd:YAG because the chromium ions, which have different absorption resonances than the neodymium ions, absorb flashlamp photons and nonradiatively transfer their excitation to the neodymium ions with an average transfer time of 17 µs. Figure 2 compares fluorescence at 1064 nm from Nd:YAG and Nd:Cr:GSGG laser rods which are pumped by a flashlamp that has been frequency filtered. It is evident that Nd:Cr:GSGG is better at converting flashlamp light of all wavelengths to inversion and fluorescence, but at those wavelengths where the chromium ions contribute significantly to the inversion process the inversion rise time is much longer. By curve fitting similar measurements with 50 nm spectral filters for the flashlamp light we have developed models for the inversion dynamics of Nd:Cr:GSGG as a function of pumping wavelength

Significance—By decreasing the flashlamp firing time without sacrificing flashlamp lifetime, and by modeling the dynamics of the inversion processes in Nd:Cr:GSGG, we can improve the ability of radiation hard lasers to operate in rapid time to fire applications.

Sponsors for various phases of this work include: Nuclear Weapons Program

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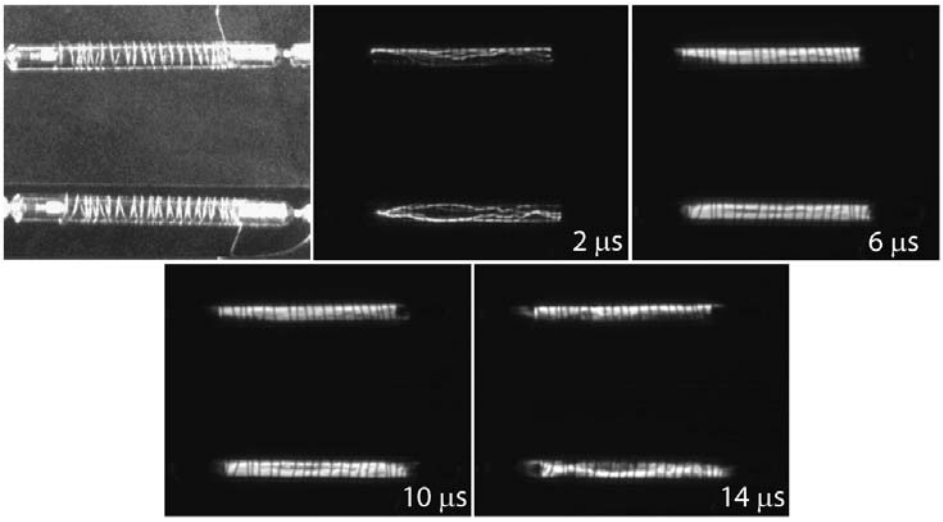

Figure 1. Framing-camera images of the plasma formation in a 1000-Torr flashlamp with a spiral trigger wire. The first image shows a long exposure time of the flashlamp before it is discharged. The remaining images show the plasma formation at times 2 µs, 6 µs, 10 µs, and 14 µs after the discharge is triggered. Different exposure times and amplifier gains were used to avoid saturating the individual images.

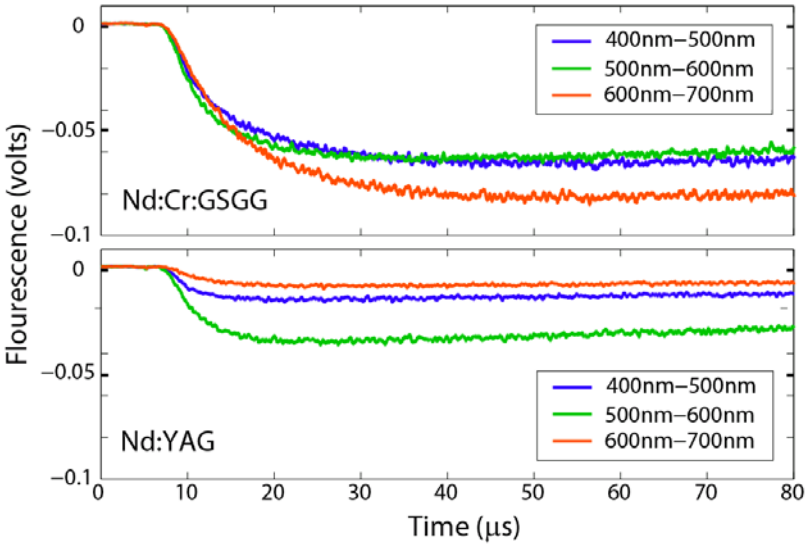

Figure 2. Measurements of 1064 nm fluorescence from Nd:Cr:GSGG and Nd:YAG laser rods. The same flashlamp light was used to pump both rods, and the pump light was wavelength filtered before the rods to select wavelength bands of 400nm to 500nm, 500nm to 600nm, and 600nm to 700nm.