Degradation of passively Q-switched microlaser performance due to pump-light induced bleaching of the saturable absorber

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Abstract: We present experimental evidence and theoretical modeling for pump-light-induced bleaching of the saturable absorber in Cr:YAG passively Q-switched Nd:YAG microlasers. This effect leads to significantly increased pulse durations and reduced pulse energies compared to expectations.

OCIS Codes: (140.3540) and (140.3430)

Introduction

In passively Q-switched microlasers the compact nature of these structures can lead to sub-optimal pulse generation due to unabsorbed pump light contributing to the bleaching of the saturable absorber. This mechanism is significant because it effectively raises the unsaturated transmission value of the absorber which leads to a change in the system dynamics that increases pulse duration and decreases pulse energy [1,2]. For example, we present experimental confirmation of pump induced bleaching increasing pulse durations from 640 ps to 880 ps.

Experimental results

We assembled and characterized a cw, Ti:Al_2O_3-laser-pumped Nd:YAG/Cr:YAG microlaser, as shown in Fig.1. The total cavity length was 1.5 mm of which 1.25 mm was 1.3% Nd-doped YAG. The Cr:YAG unsaturated absorption coefficient was 7.5 cm^{-1} and the output coupler reflectivity was 85%. The microlaser was pumped with a 25-μm diameter beam via a single-element focusing lens.

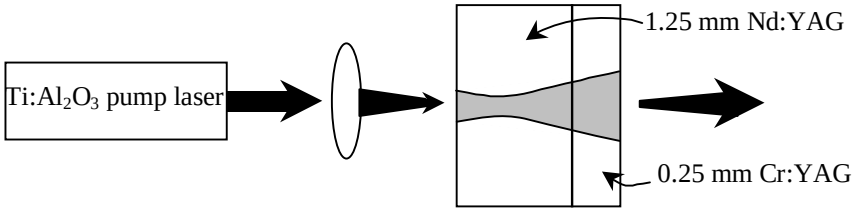

Fig. 1. Experimental arrangement for a Cr:YAG passively Q-switched Nd:YAG laser pumped by a cw Ti:Al_2O_3 laser.

Unlike a diode laser pumping source, the Ti:Al_2O_3 laser bandwidth was much narrower than the individual absorption features in the Nd:YAG. This enabled us to tune the Ti:Al_2O_3 laser to several different absorption features as a means to carefully control the ratio of pump light absorption in the Nd:YAG to that absorbed in the Cr:YAG. This allowed us to control the amount of pump-light induced bleaching in the Cr:YAG. The incident pump power at the microlaser was approximately 700 mW.

Referring to Fig. 2 it can be seen that the measured pulse duration is not invariant in relation to absorbed pump power as earlier work [1,2] would suggest. In Fig. 2 increasing Nd:YAG transmission corresponds to increasing pump-light absorption by the Cr:YAG. Data is given for pump wavelengths of 794.5 nm, 795.7 nm, 799.2 nm, and 809.0 nm. This range of wavelengths covers a factor of three change in both Nd:YAG and Cr:YAG absorbed pump power.

Theoretical analysis

We believe unabsorbed pump light is absorbed by and partially bleaches the Cr:YAG. This results in the microlaser photon flux effectively seeing an absorber with a higher small-signal transmission and results in the generation of longer, lower-energy pulses than predicted theoretically [1,2]. We have modified the analysis of Xiao and Bass [2]

to allow for cw pumping of the Cr:YAG with the unabsorbed pump light. We applied the modified analysis to our experimental data with excellent agreement as shown in Fig. 2.

The analysis accounts for differing beam sizes in the Nd:YAG and Cr:YAG sections of the microlaser by taking an average value for the beam diameter in each material. In this pump power regime the microlaser is predominantly gain-guided and the laser mode sizes were assumed to match the pump beam. The saturation parameter for Cr:YAG the pump wavelengths was 20 $kWcm^{-2}$. The Nd:YAG absorption for the different pump wavelengths was obtained directly from spectrophotometer data.

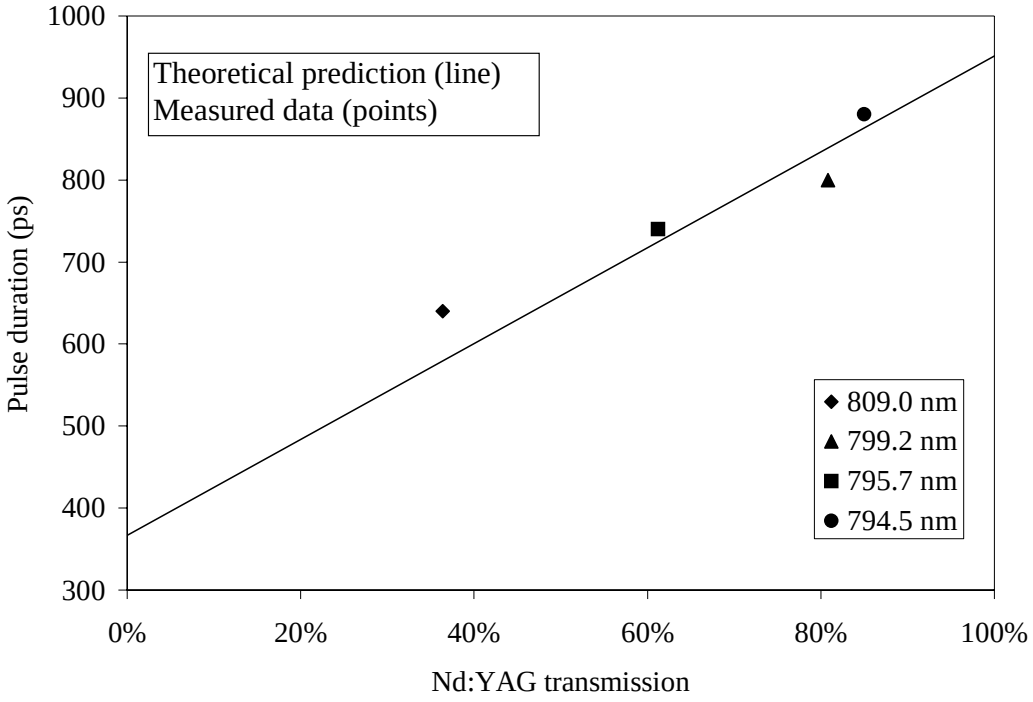

Fig. 2. Nd:YAG/Cr:YAG passively Q-switched microlaser pulse duration as a function of Nd:YAG transmission at a constant pump power. Each data point is for a different pumping wavelength and the zero point limit corresponds to no pump absorption in the Cr:YAG.

Conclusion

We have presented experimental data and theoretical modeling that we believe clearly demonstrates the influence of pump-light induced bleaching of the saturable absorber on the performance of passively Q-switched microlasers. This effect leads to longer, less energetic pulses than would be obtained in its absence.

References

1. J. J. Degnan, *IEEE J. Quantum Electron*., **31**, 1890-1901, (1995).
2. Guohua Xiao and Michael Bass, *IEEE J. Quantum Electron*., **33**, 41-44, (1997).