Long Runtime Investigation of an Injection Seeded Q-Switched Ho:YAG Laser without Active Stabilisation

Günther Renz
German Aerospace Center, Institute of Technical Physics, Pfaffenwaldring 38, 70569 Stuttgart, Germany

The advantage of single axial mode Q-switched lasers for nonlinear optics and high resolution spectroscopy has been known since the invention of lasers. Single mode operation has proved difficult to achieve primarily because of the high gain and resultant short pulse build-up time of the laser photon flux in the lower ns-range. The standard performance to achieve single mode operation of a pulsed oscillator is to seed with a continuous wave single frequency laser. The methods to control actively the cavity length to match the resonance criteria for the seed wavelength are either based on measurements of the pulse properties like the pulse built-up time or measurements of a frequency shifted interference signal down into the 100 MHz-range. Either method operates via a servo system that adjusts the cavity length without an exact reliable single frequency operation.

We report on the investigation of an injection seeding technique that leaves the pulsed oscillator in the single axial mode domain based on a self-organizing technique [1]. The injection seeded laser system is set up of a Tm fiber laser (IPG Photonics) to pump a 5 cm long 2.5% Ho:YAG rod crystal. The resonator length is 40 cm and the cw seed fiber laser (NP Photonics, wavelength 2089.6+/-0.1 nm, bandwidth <50 kHz) delivers 8 mW into the resonator by a dichroic polarizer. For the operation of the laser system the enclosed resonator set-up is purged with nitrogen for a few minutes to reduce the water vapour down to 1/5 of the initial concentration. Then, with a Piezo-electric transducer (PI) the resonator length for single axial mode operation is adjusted and left by itself without any actively external enforcement. In figure 1 (left) the overlapped single mode pulses are depicted for 10 minutes. On the contrary, the right figure shows typical overlapped longitudinal mode beating pulses for a slightly, out of single longitudinal mode, detuned resonator length with short oscillation periods of ~3 ns.

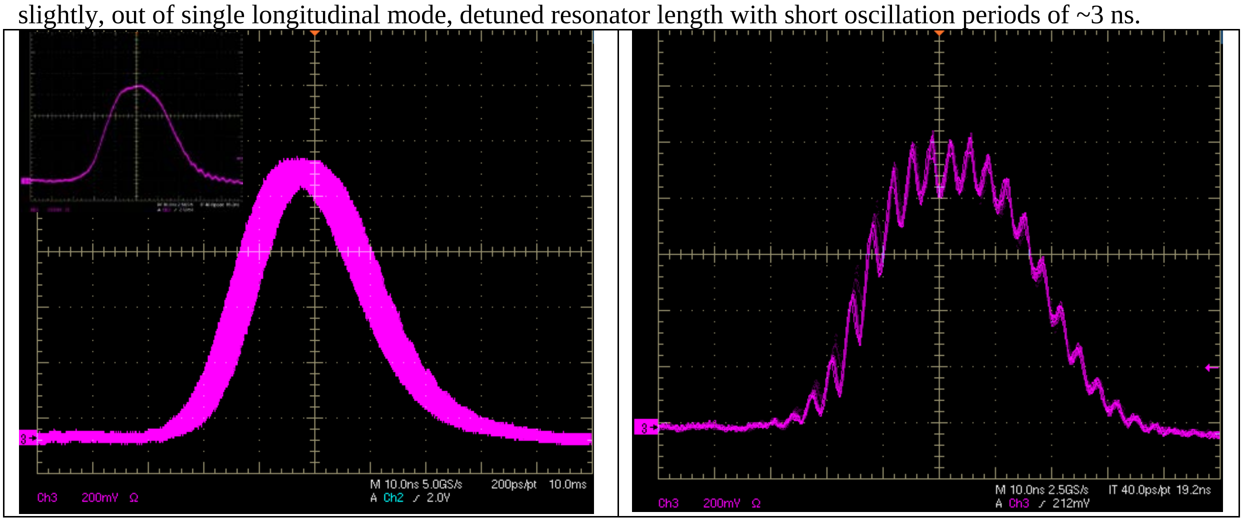

Fig. 1 Overlapped single mode injection-seeded laser pulses up to 10 minutes (left fig.) with inlet of single pulse and 'out of single mode' injection-seeded laser pulses due to a slightly detuned resonator length (right fig.).

In order to get a better insight into the 'out of single mode' injection-seeded behavior (see right fig.) a simplified coupled-cavity laser model will be used [2]. Starting from continuity conditions a secular equation can be deduced which leads to two nearly degenerate longitudinal modes coming from each cavity side of the resonator. From this calculation a change of the refractive index during the pulse built-up of the order of 10^{-6} to 10^{-5} follows. This optically induced refraction index change leads to a shift of the cavity resonances associated with a chirp. From the literature it is known through heterodyne techniques that such refraction index changes will lead to frequency chirps in the lower 100 MHz-range depending on the pulse energy and wavelength [3]. To resolve these nearly degenerate longitudinal modes with a monochromator is hard to accomplish for 2 µm laser wavelengths due to diffraction effects originating from the slit entrance.

References

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[3] P. Bakule et al., '*A chirp-compensated, injection-seeded alexandrite laser*', Appl. Phys. B 71, 11-17 (2000).