

# Fiber-Based Mode Locking Laser

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## Motivation

For educational and research purposes, a fiber-based passively mode-locked laser was constructed at HMC. The ultimate goal was to create a deliverable mode-locking laser in a transportable package for demonstration purposes.

For the project, we constructed and characterized both linear and ring cavities. Mode-locking was achieved with each cavity, and the mode-locking and pulse characteristics were similar in both. We will only describe the linear cavity, the results of which are representative.

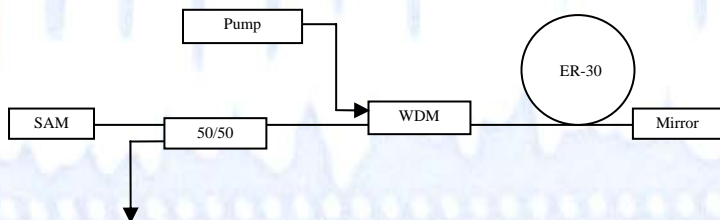
## Background

One technique for achieving ultra-short laser pulses is a technique known as mode-locking. Mode-locking occurs when the longitudinal modes resonating in a cavity lock their relative phases to produce short pulses.

The cavities used in this project were all fiber-based and utilized a saturable absorbing mirror (SAM) as the mode-locking mechanism. SAMs have a high absorbance for low intensity light and a high reflectivity for high intensity light so that short pulses with high intensities are favored in each round trip through the cavity.

Fiber-based lasers have inherent advantages over free space based lasers – no alignment of the components is needed. In a fiber laser, a segment of fiber that is doped with a rare earth metal serves as the gain medium for the laser. In our case, Erbium doped fiber provides 30dB/m of gain for 1560nm lasing within our cavity, pumped with 980nm light.

## Final Laser Cavity Design



The final laser design is the linear cavity shown above. In one round trip, a pulse goes through 170cm of Erbium doped fiber and 186cm of regular, single-mode fiber. These lengths were calculated to minimize spectral dispersion in the cavity. This facilitates mode-locking in the soliton regime.

## Acknowledgements:

We would like to thank Professor Qimin Yang and Mr. Wei Lu of Quantronix Lasers for their time and guidance

## Results

The output of this fiber-laser centers at 1560nm. With a SAM in the cavity, pulses are generated, and can be measured at the laser output. The time domain data for the pulses were captured using a fast-response photodiode. Although this does not adequately depict the pulse shape, it is representative of the pulse period. An autocorrelator is required to characterize the actual pulse width and chirp.

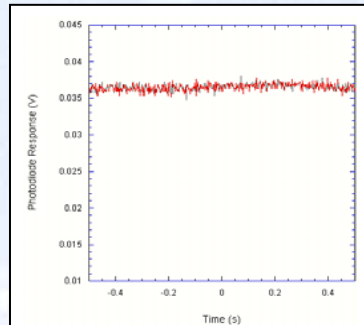


Figure 1: Time Domain, Non Mode-Locked

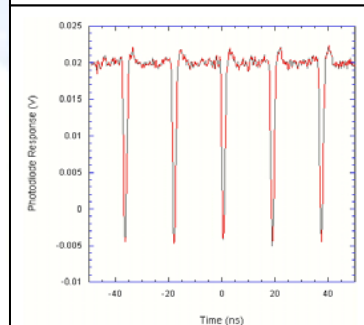


Figure 2: Time Domain, Mode-Locked

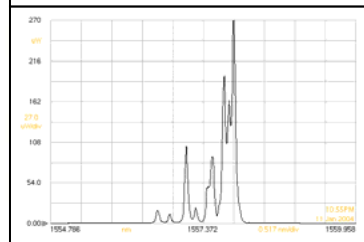


Figure 3: Optical Spectrum, Non Mode-Locked

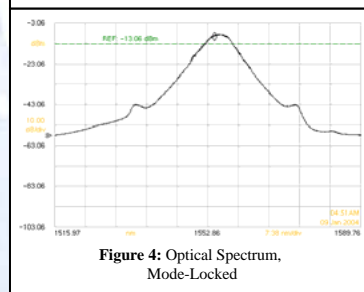


Figure 4: Optical Spectrum, Mode-Locked

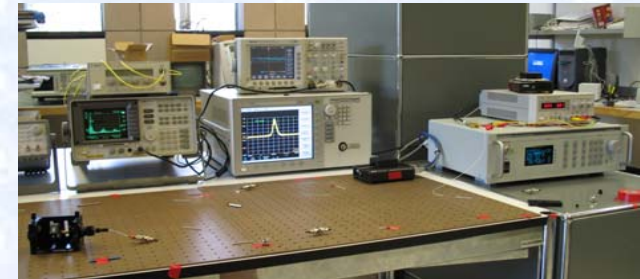


Figure 5: Test bench with measurement equipment in background. Laser is laid out flat on table.

When the laser is not mode locked, the output is a constant power signal, as shown in Figure 1. When there is enough energy in the cavity and the SAM is aligned, the laser will mode lock, with a repetition rate on the order of tens of nanoseconds (Figure 2).

In the Optical Domain, the non mode-locked spectrum (Figure 3) is considerably more narrowband than the mode locked spectrum (Figure 4). This agrees with the theoretical description of mode-locking – phase matching a broadband range of modes to yield closely spaced, coherent pulses.



Figure 6: Final laser cavity in packaged form, SAM stabilized with glue and foam padding.

## Conclusions

The final, packaged laser cavity is fairly stable and will self-start mode-locking with proper pumping power. The mode-locking is mostly-stable, with momentary sputtering every few minutes. The laser has been run continuously for hours with no impact on stability.

Among other things, future work can be done on improving SAM stability, integrating an in-line polarizer to enhance mode-locking performance, and characterizing the pulse shape using an autocorrelator.