Mode-Locking in an Erbium-Doped Fiber Laser

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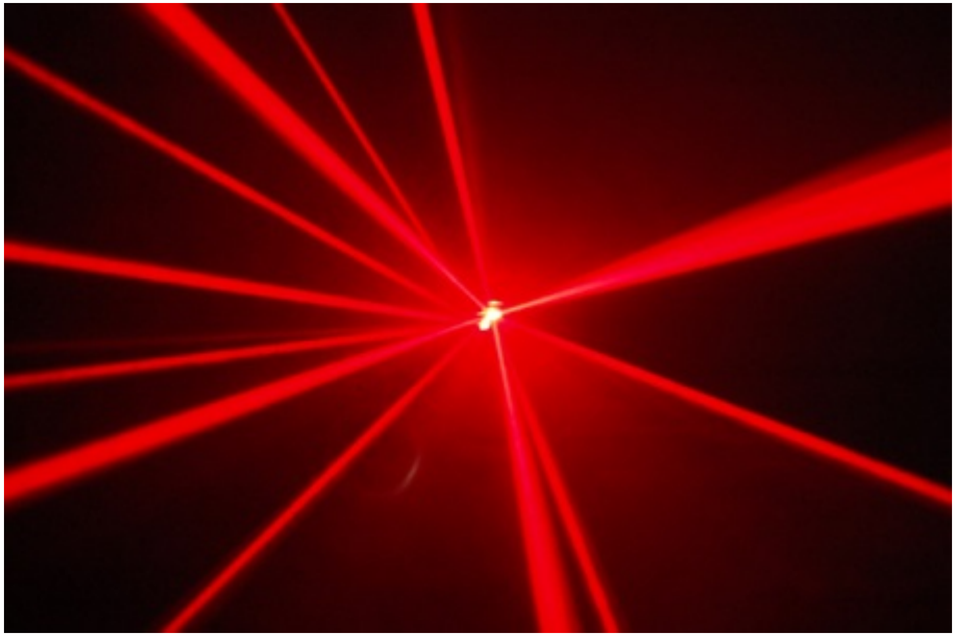
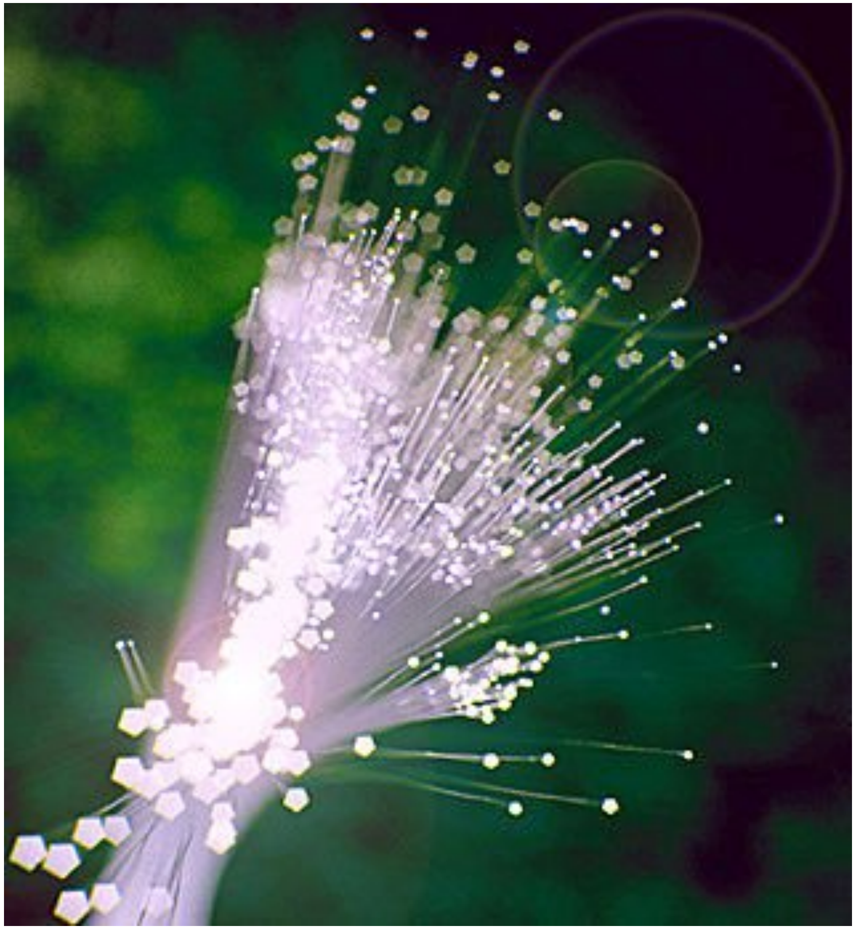
Overview

- Purpose
- Theory
  - Lasers
  - Mode locking
- Piecewise testing of fiber laser parts
  - Amplifier
  - Enclosed laser
  - Mode locked laser
- Conclusion



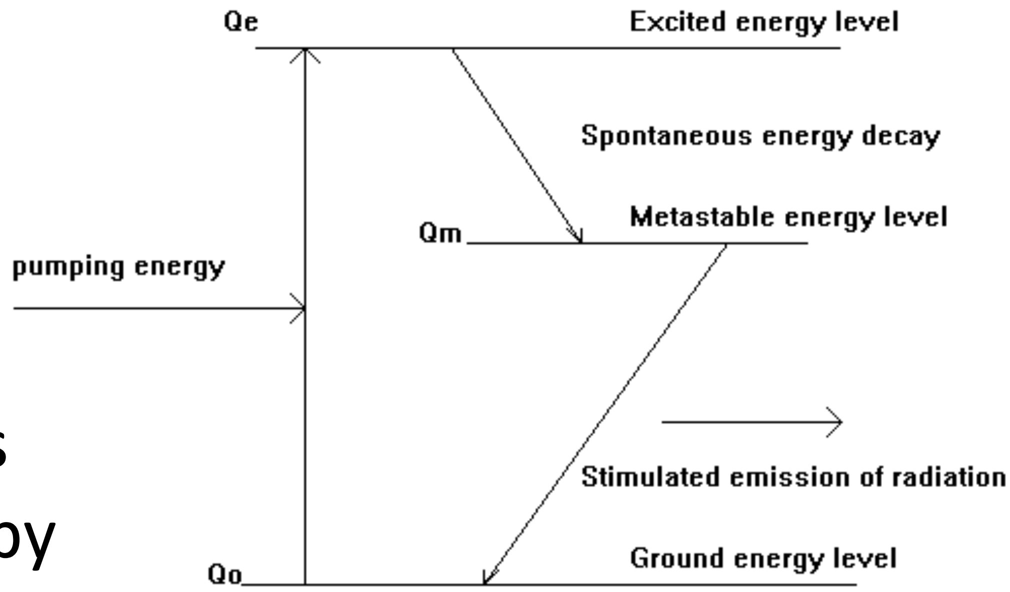
Purpose- Why Erbium?

- ~femtosecond pulses from large bandwidth
- Erbium is cheaper due to the telecommunication industry
- Erbium doping offsets dispersive effects from standard fiber

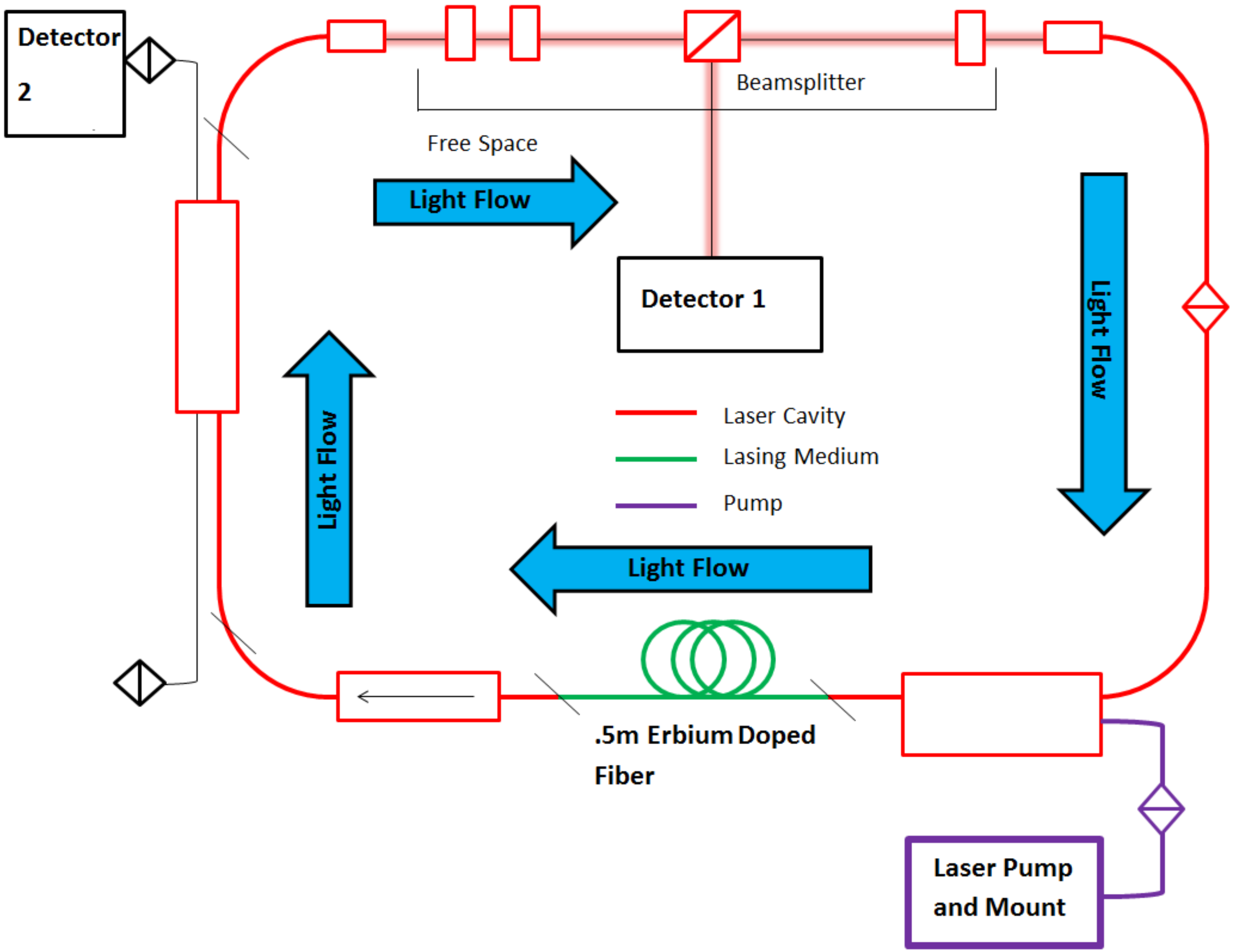


Theory

- Parts to a laser
  - Pump
  - Lasing material
  - Optical cavity
- Lasing occurs in the erbium-doped fiber as electrons are excited by pump light

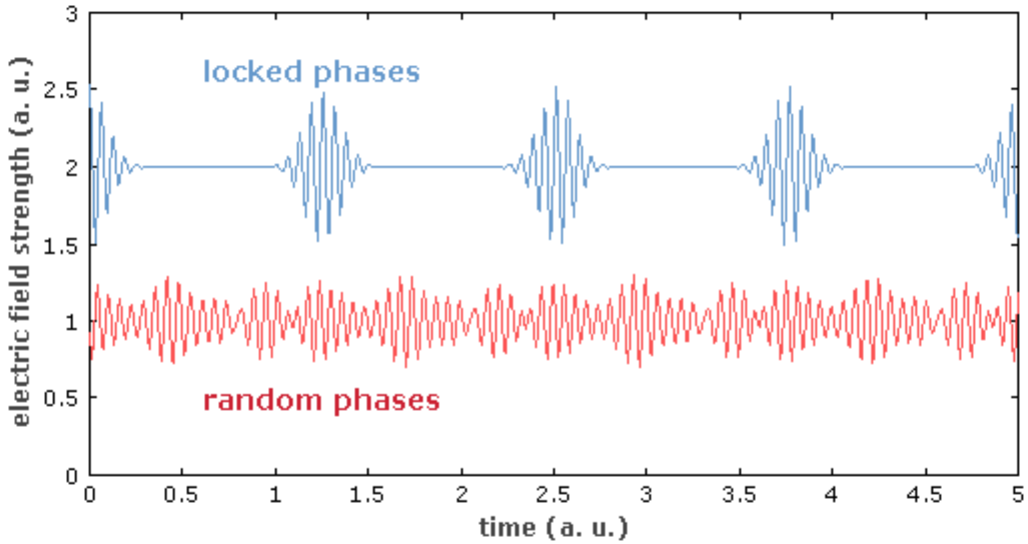


Laser Schematic



Mode Locking Intro

- The most common way to get picosecond or smaller pulse durations is through mode locking
- Mode locking works by locking all of the different modes within a laser cavity to a fixed phase
- In our case, achieved with wave plates

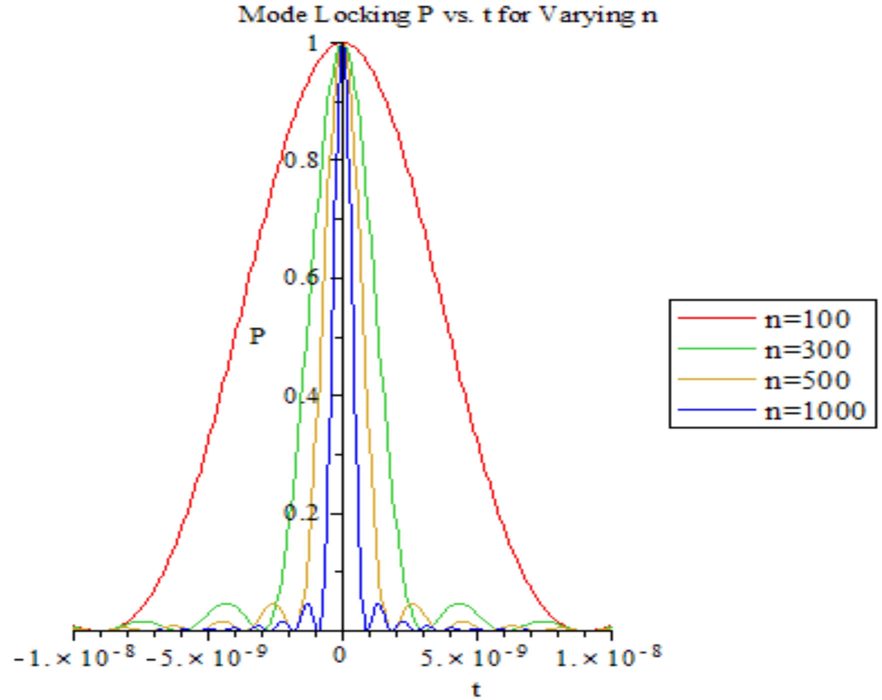


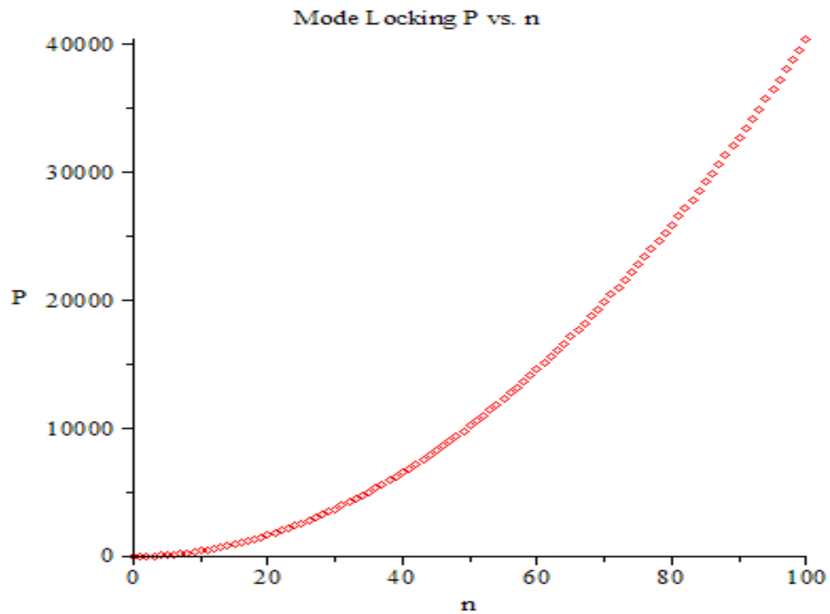
Mode Locking Continued

- The sum of the time-domain powers of each mode reduces to: $P(t)=P_0 \sin^2[(2n+1)*\pi*f_{rep}*t]/\sin^2[\pi*f_{rep}*t]$
- The top figure shows the normalized time-domain power for different n.

  - Notice the decrease in peak width for increased n.
- The bottom figure shows the power dependence on n at t=0 (the max power)

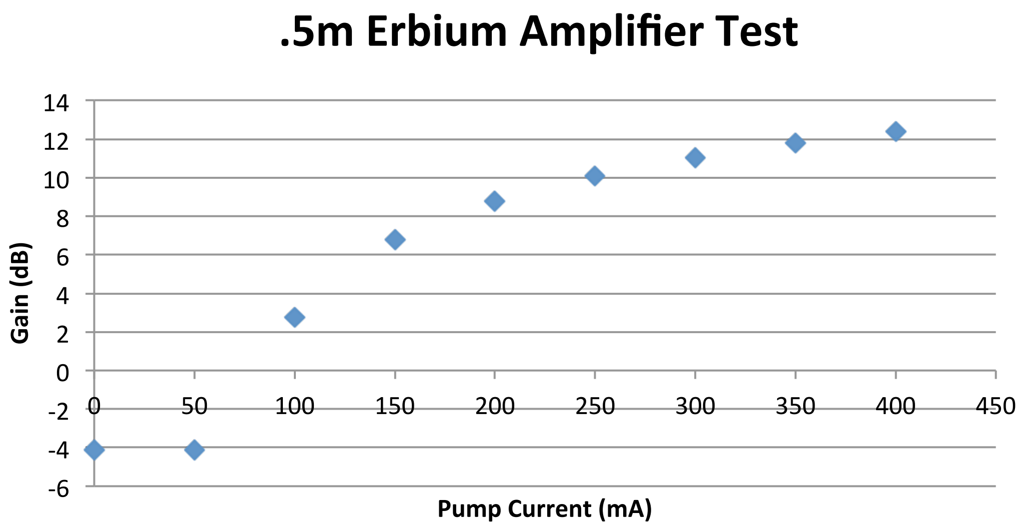
  - This shows the large increases in peak power as more wavelengths are added.
- **MORE BANDWIDTH = MORE WAVELENGTHS = MORE POWER + SHORTER PULSES**

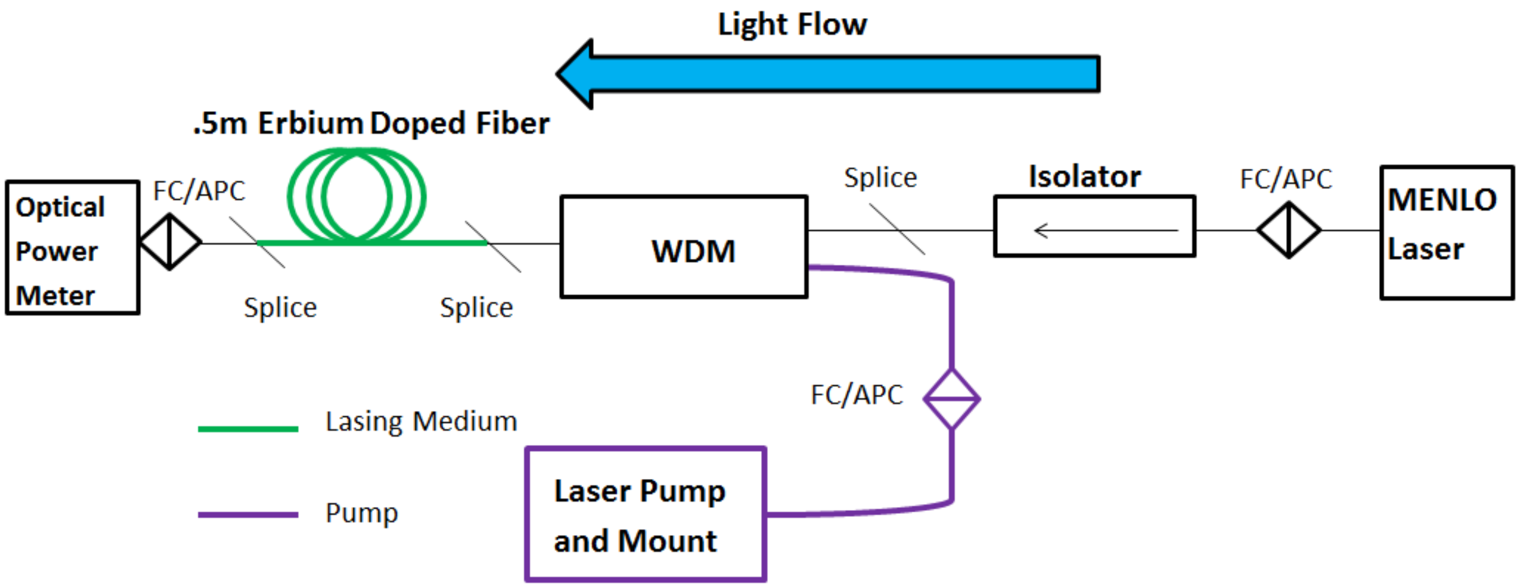




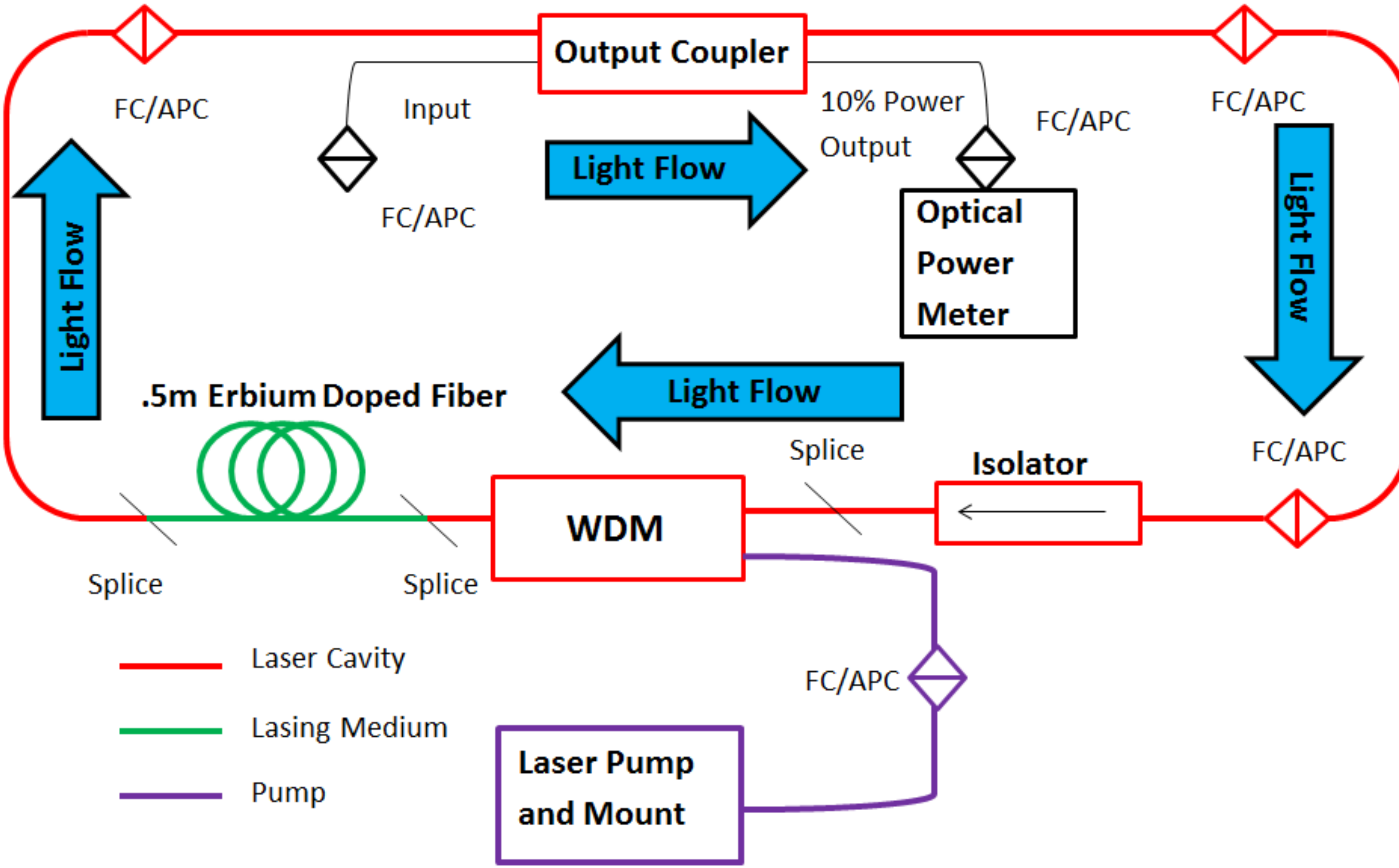
EDFA (Erbium-Doped Amplifier) Test

- Use pump to excite erbium fiber and a 1550 nm Menlo laser to stimulate photon emission
- Able to measure pump power vs. input current
- Close to 15 dB theoretical value



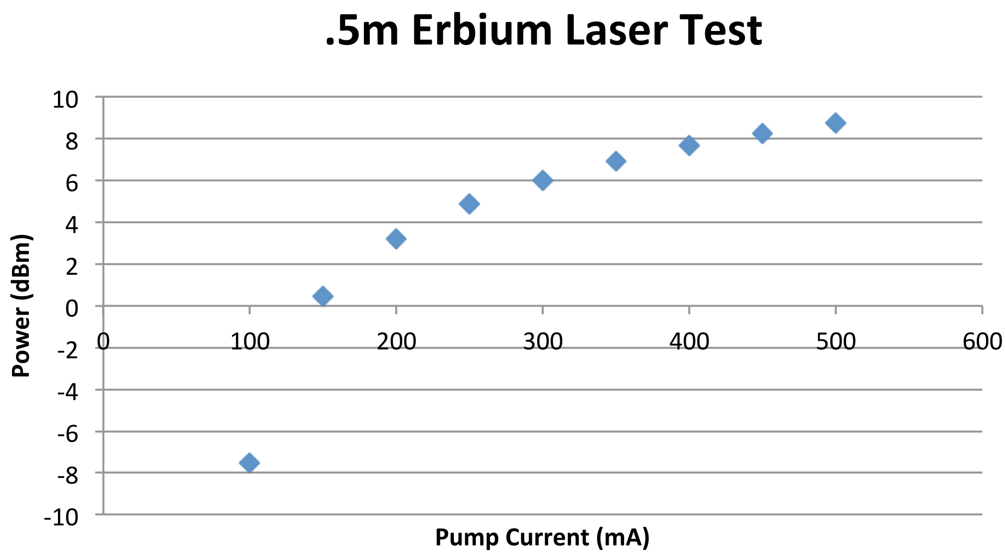


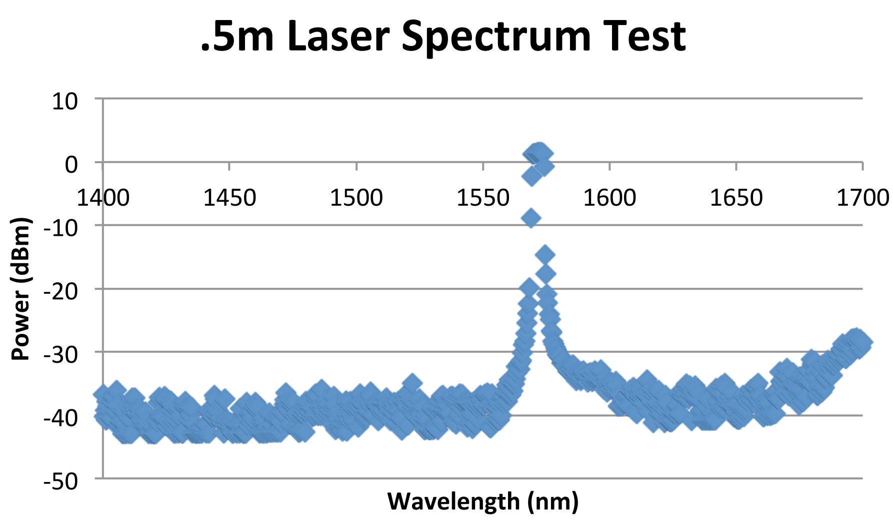
Enclosed Laser Schematic



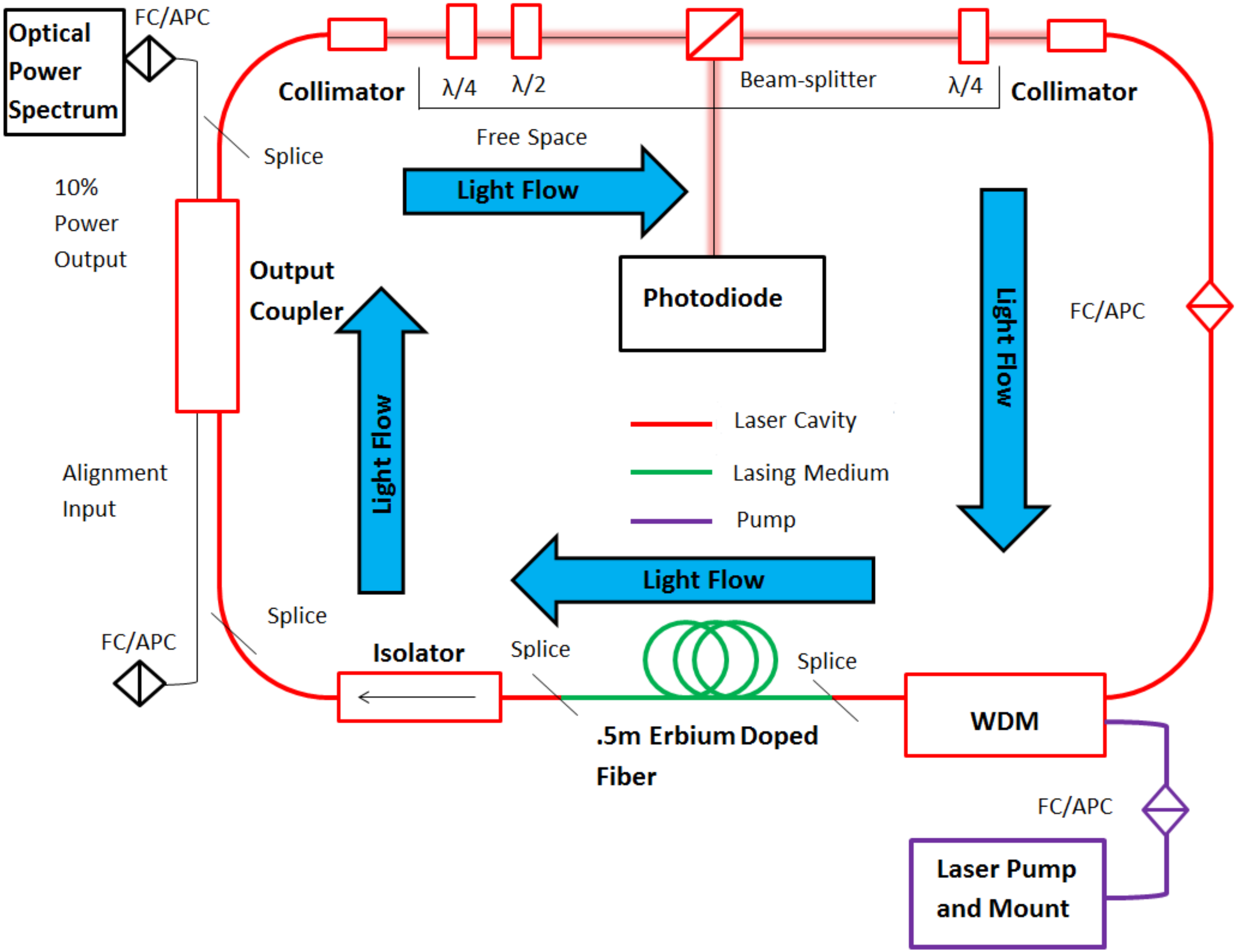
Enclosed Laser Test

- Output coupler installed and a loop created to make a laser cavity.
- Creates a loop from the amplifier for amplification of power with every pass.
- Limited in maximum power by gain saturation

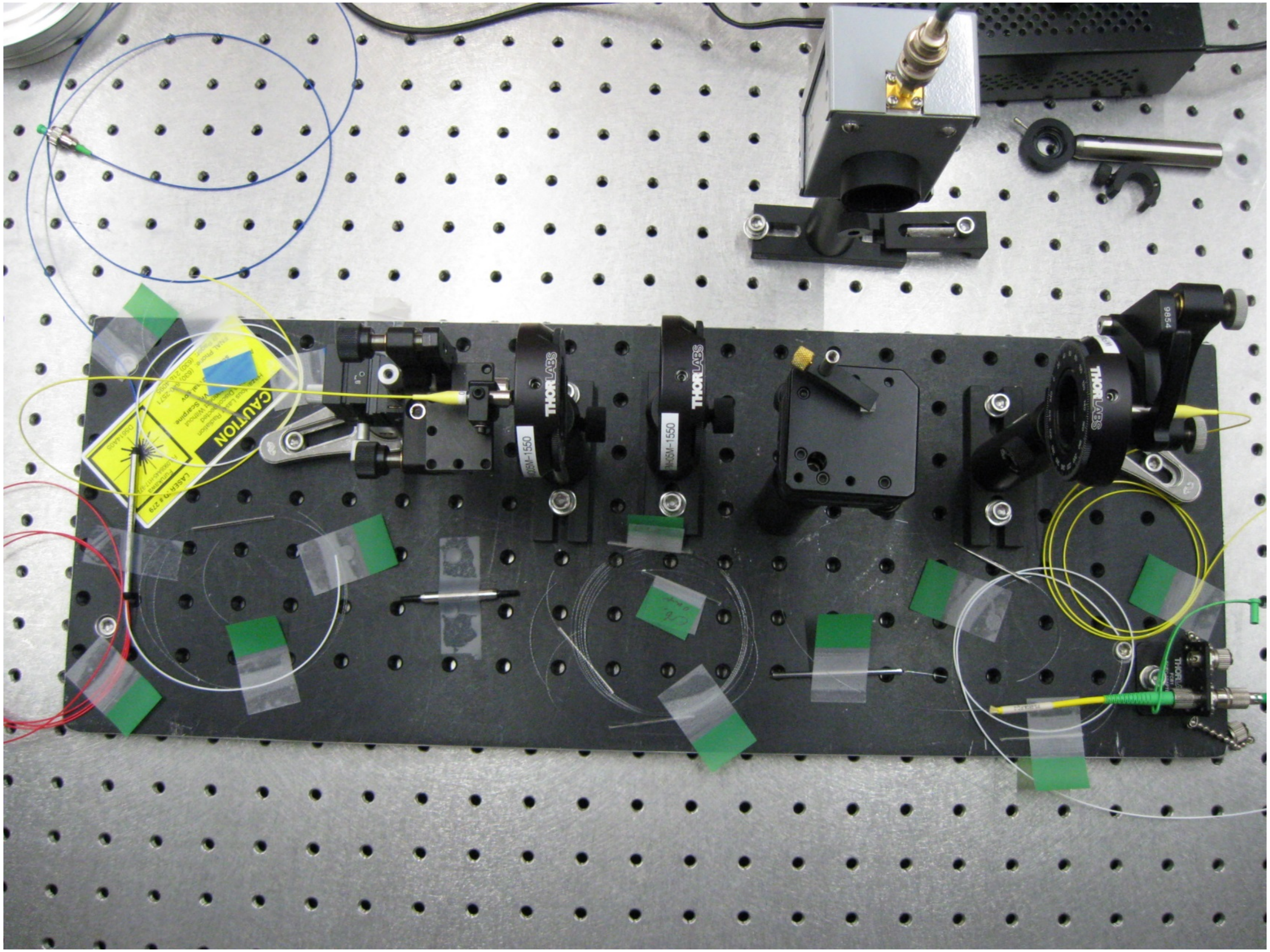




Mode-Locked Schematic

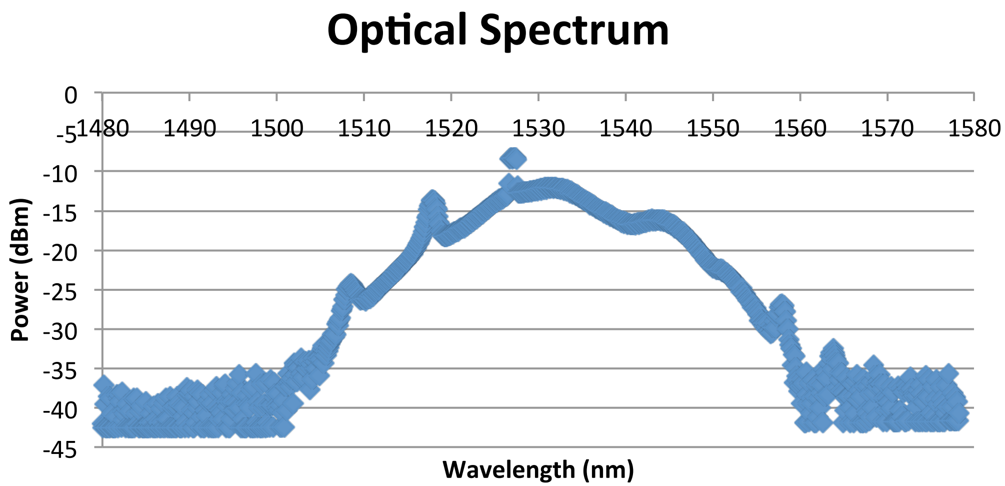


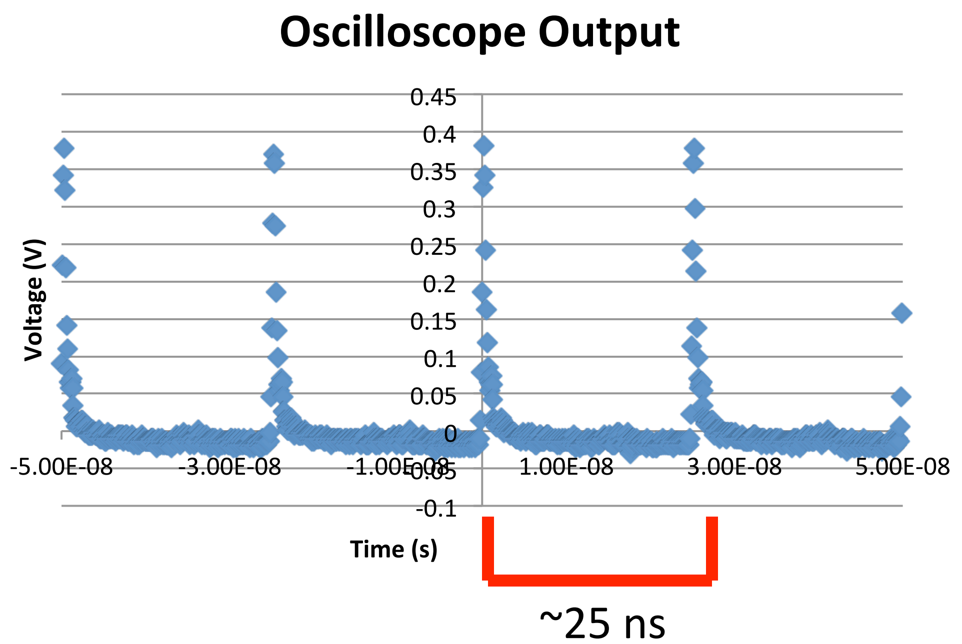
The Final Product



Mode Locking Tests

- Polarizers installed and rotated to achieve mode locking
- Broad optical spectrum consisting of many wavelengths
- Oscilloscope output shows pulse travelling in cavity; depends on cavity length
- Data taken at 254 mA of pump laser current
- ~400 femtosecond pulse width measured





Conclusion

- Currently have a working mode locked erbium fiber laser with a 2.66 mW power output and pulse width of ~400 femtoseconds.
- Future plans to optimize the system further to yield shorter pulse widths by attempting to get a broader optical spectrum.

Acknowledgments

Winter, Axel. *Fiber Laser Master Oscillators for Optical Synchronization Systems*. Diss. Zugl.: Hamburg, Univ., Diss., 2008, 2008. N.p.: n.p., n.d. Print.

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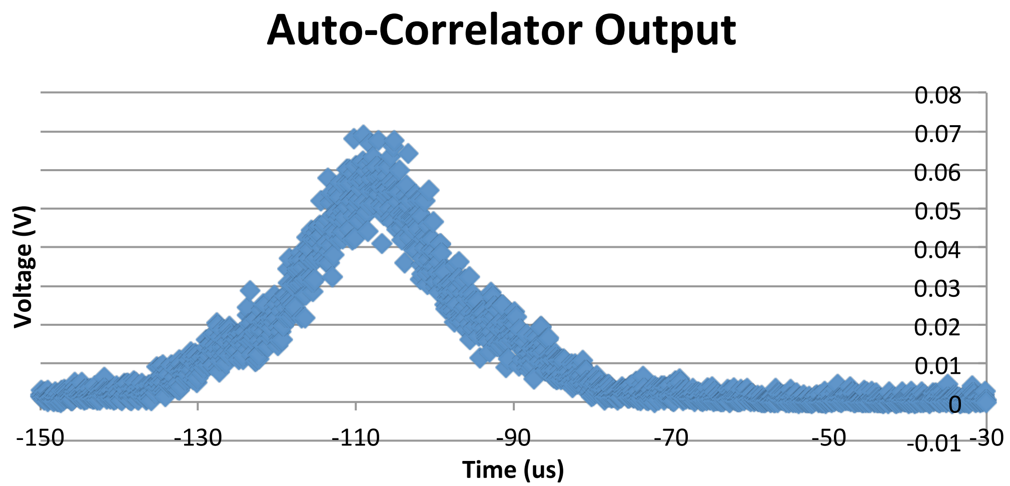
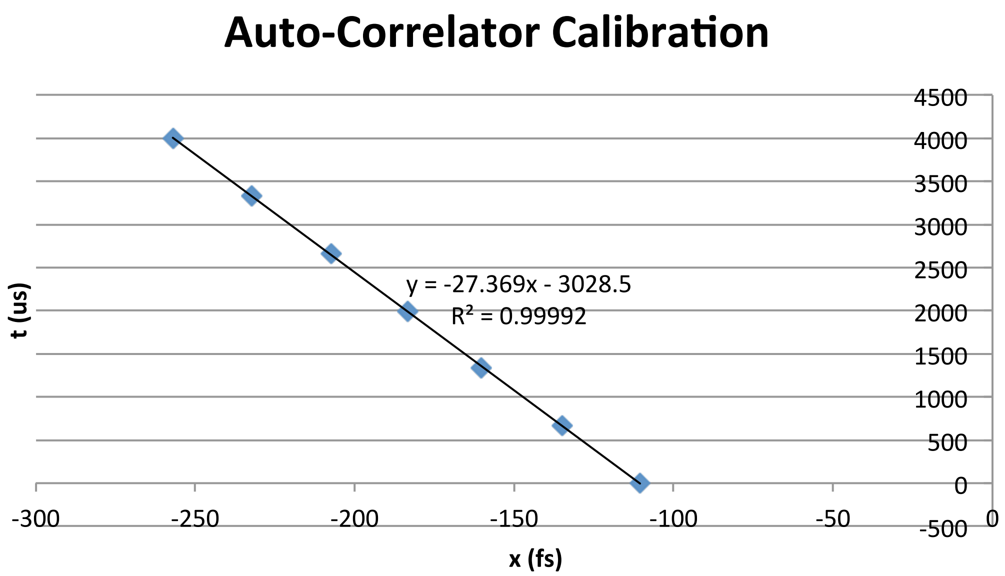
Autocorrelation and Pulse Width

- Achieving a small ~fs pulse width for this fiber laser is one of the main goals
- Autocorrelator used to convert the small pulses into something measurable.
- Works much like a Michaelson interferometer
- Measured pulse width of ~400 femtoseconds



Autocorrelator Calculation

- Conversion from mirror distance into time traveled:
  - $1/v = 1/c = 1/3*10^{14} = 3.33*10^{-15}\ s/\mu m = 3.33 fs/\mu m$
- Full-width half-maximum from autocorrelator is -19.839 µs
- Slope from calibration is -27.369
- $Pulse\ Length = (FWHM)(Slope)(.7) = (-19.839)(-27.369)(.7) = 380.1\ fs$



Radiofrequency (RF) Spectrum

- Shows the frequency at which laser light circulates within the cavity
- Peak location depends on the cavity length
- This plot was obtained as a final optimization of the laser parameters.
- A good RF spectrum will resemble a single, sharp peak and have no fringes