Characterizing Optics with White-Light Interferometry

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Introduction

Ultrashort laser pulses have helped us understand processes on the atomic scale. However, these pulses are very fragile, and can be stretched due to the wavelength-dependent responses of the optics they interact with.
White-light interferometry and Fourier transform spectral interferometry lets us measure the distortion caused by these optics. By measuring certain properties of the light beam, we can characterize these optics, and determine whether they are suitable for laser use.

Keywords: White-light interferometry, dispersion, spectral phase.

White-Light Interferometry and FTSI

White light interferometry uses a broadband light source and an interferometer- a device that superimposes two beams of light to create an interference pattern- to measure certain properties of an object.

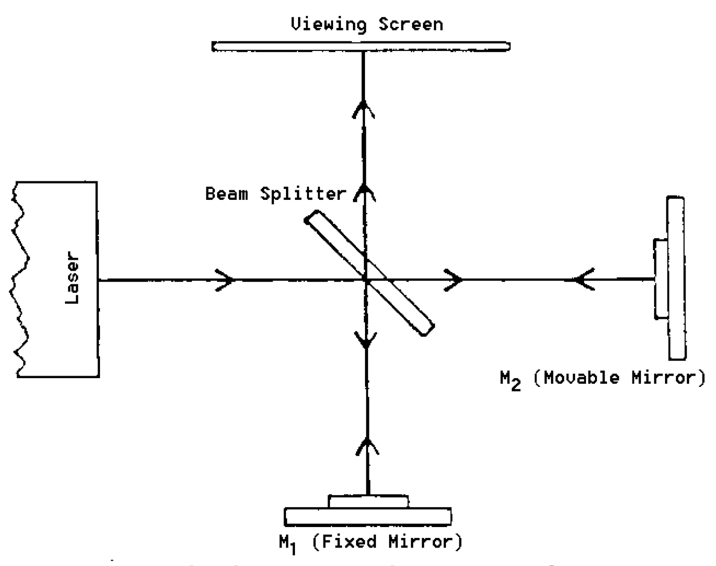

Fig 1. Michelson-Morley Interferometer

Fourier transform spectral interferometry (FTSI) uses the Fourier transform of the spectrum to determine important optical properties, such as the spectral phase. It is being used to characterize the optic.

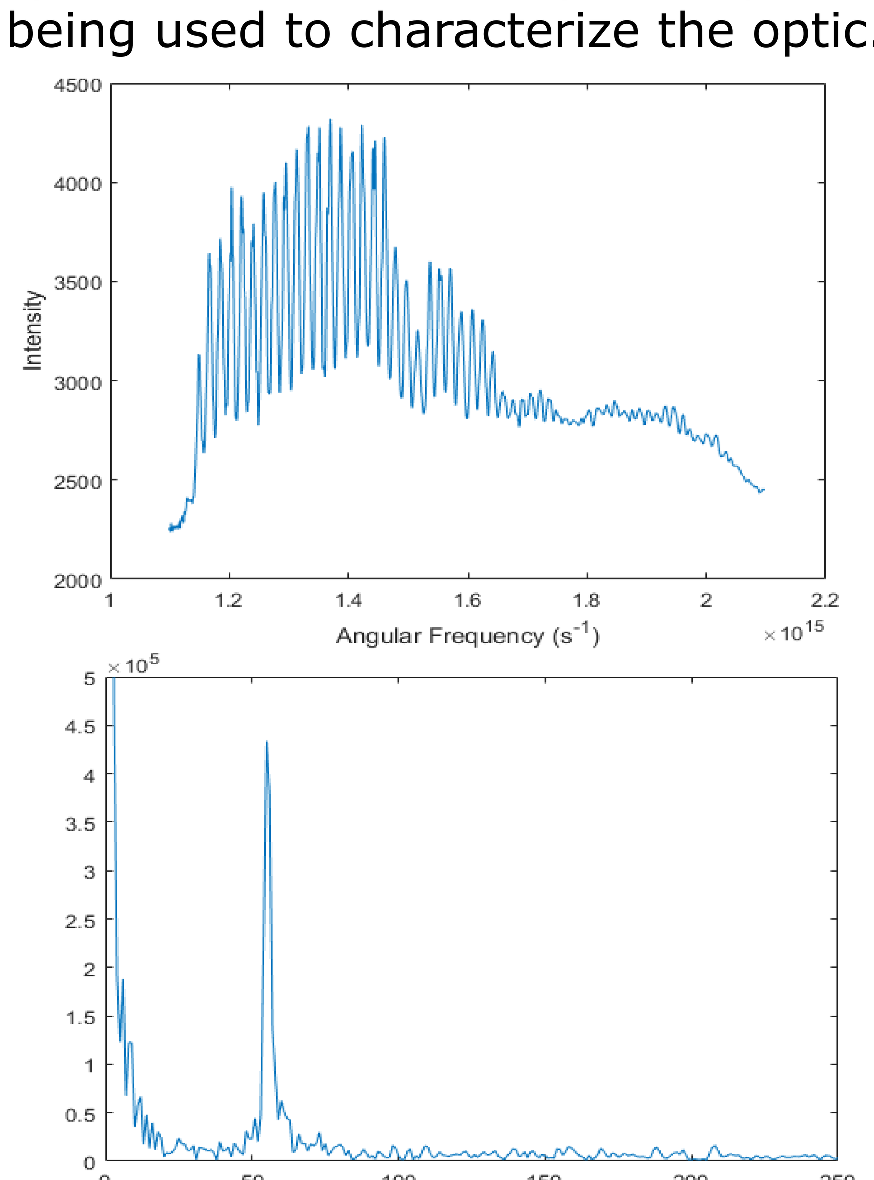

Fig 2. Spectrum and Fourier Transform

Measuring Optics

The first step to characterizing the optic is to find the spectral phase of the light beam. To find it using FTSI, extract the spike corresponding to the fringes on the interferogram from the Fourier-transformed spectrum, then inverse transform it back to the frequency domain. The complex angle of the resulting function is the phase.

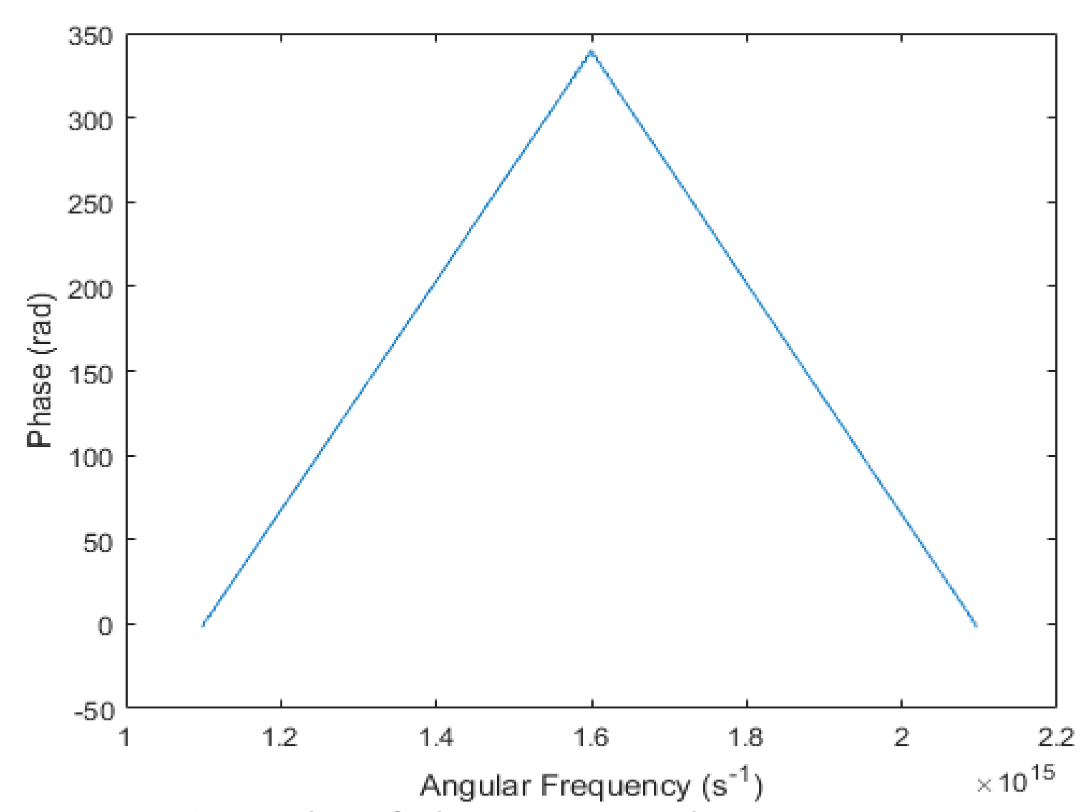

Fig 3. Plot of Phase vs. Angular Frequency for Near-Infrared Spectrum

I wrote a MATLAB script and graphical user interface to perform this analysis in real time, using input from a spectrometer. The code has several key features which streamline the analysis, such as adaptive windowing and data logging.

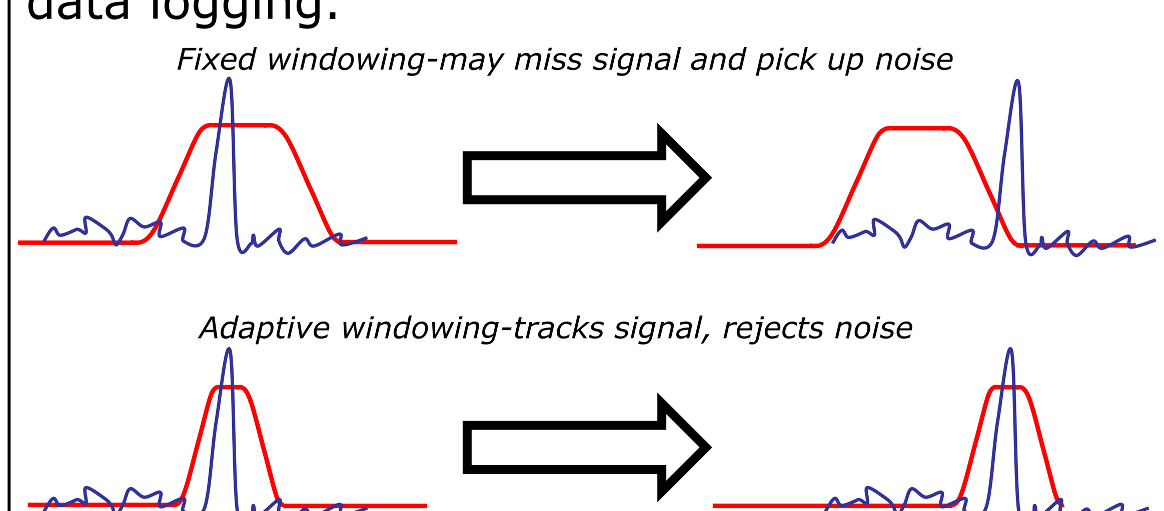

Fig 4. Fixed vs Adaptive Windowing

Another script was written to conduct a more granular analysis of the optics. It analyzed the phase to plot the GVD of the optic with respect to the wavelength of the light.

Four dielectric mirrors from Eksma Optics were tested in visible and near-infrared wavelengths, and the group velocity dispersion (GVD) and third-order dispersion (TOD) were measured for each configuration.

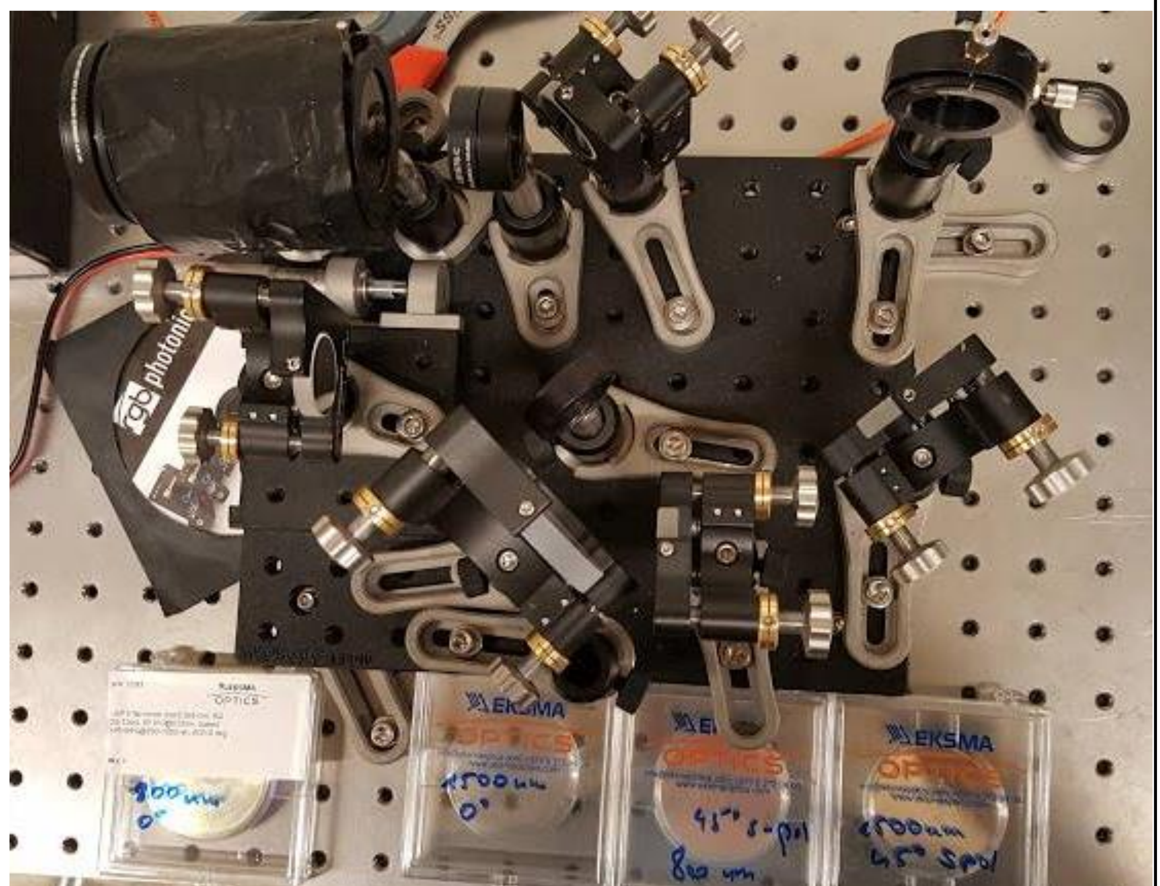

Fig 5. Mirrors and Experimental Setup

Results

After collecting data for each configuration, the results are as follows:

Optic Type	Wave-length	Mean GVD (fs^2/mm)	SD GVD (fs^2/mm)	Mean TOD (fs^3/mm)	SD TOD (fs^3/mm)
Control	VIS	36.6424	0.7489	38.4494	4.9207
800nm Mirror	VIS	25.4103	6.7798	36.4603	8.1809
800nm 45° mirror	VIS	9.1742	1.6414	53.7953	10.4156
Control	NIR	-8.8001	3.0862	39.1523	17.8757
1500nm Mirror	NIR	-14.2071	2.631	25.1688	17.9743
1500nm 45° mirror	NIR	-9.1637	5.0992	82.0899	42.4817

Table 1. Optic Data

Below are plots of the spectral phase (with the linear component removed) for each of the four mirrors.

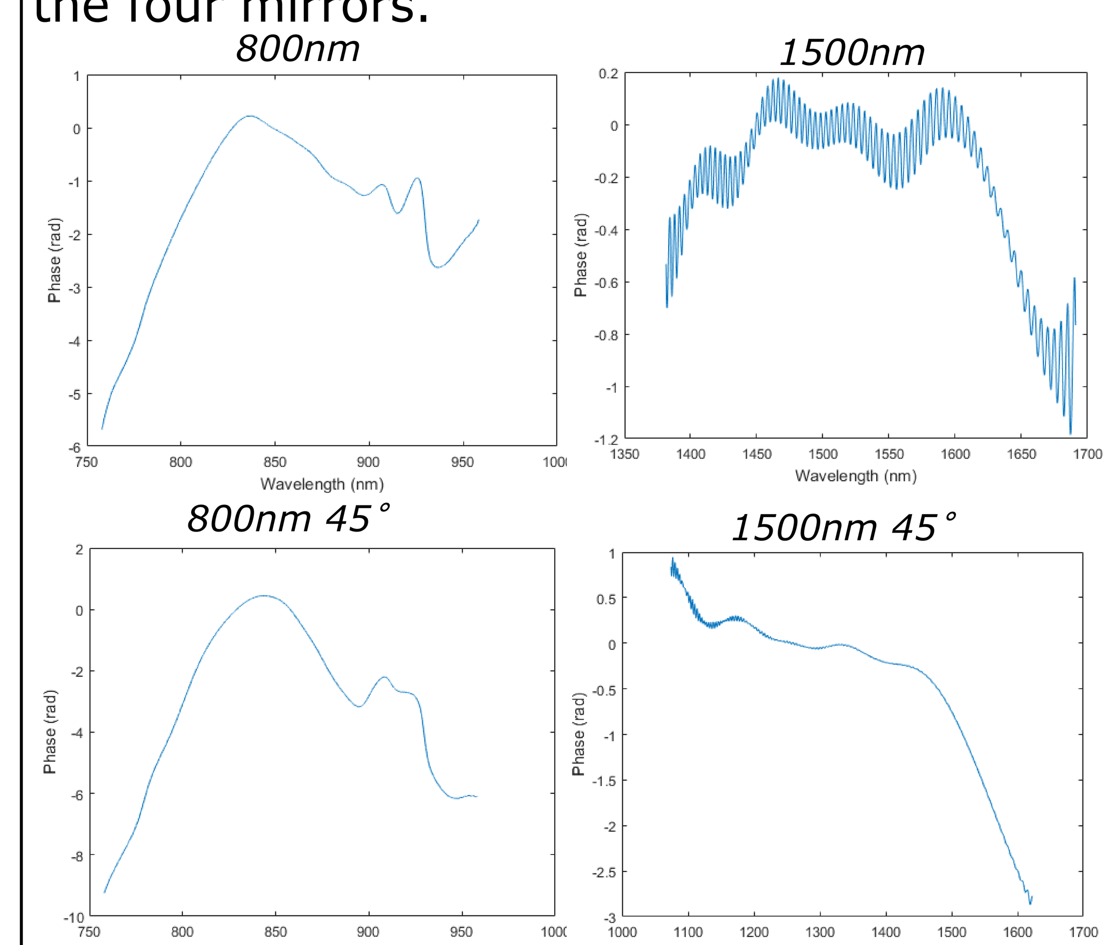

Fig 6. Nonlinear Phase of Dielectric Mirrors

The 1500nm mirrors can be used in the laser at wavelengths around 1500nm. However, the 800nm mirror should be used with caution, and I cannot recommend using the 800nm 45° mirror with the laser.

Conclusions

Over the course of this project, I built and tested a stand-alone measuring device that quickly characterizes various optics for use with ultrashort pulsed lasers. I also wrote several pieces of software to perform the various analyses associated with such a characterization.

A useful future addition to this project would be a motorized stage that automatically finds the point of zero delay in the interferometer. This is a very time-consuming process if done manually, but with a motorized stage and software, it could be done much more quickly.

Acknowledgments

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