



Spectrally-Quantified Chemical Reactivity of Optical Fluids and Materials in the GMACS Spectrograph for GMT

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Preemptive Quality Engineering

The Giant Magellan Areal Camera and Spectrograph is a wide-field optical spectrograph for GMT. GMACS will aid GMT in its science goals of observing galaxy assembly, dark energy, first light, and reionization. GMACS is an integral part of GMT and because of this, it is imperative to ensure the integrity of the GMACS spectrograph for the decades that it will be in operation. Recently, several spectrographs have been compromised by the corrosive nature of optical fluids with some materials. Some have taken a preemptive approach to this problem. When designing DEIMOS, the team at UCO/Lick Observatory did a preliminary 3-month test of several optical fluid and material candidates for DEIMOS. With their research, they qualitatively identified and avoided many incompatible fluid and material pairs. In our research, we seek to select index-matching fluids suitable for GMACS and to conduct similar tests as those conducted by the UCO/Lick team. We want to augment these tests by measuring the absorption spectra of the fluids to obtain exact quantitative results.

Optics Modules

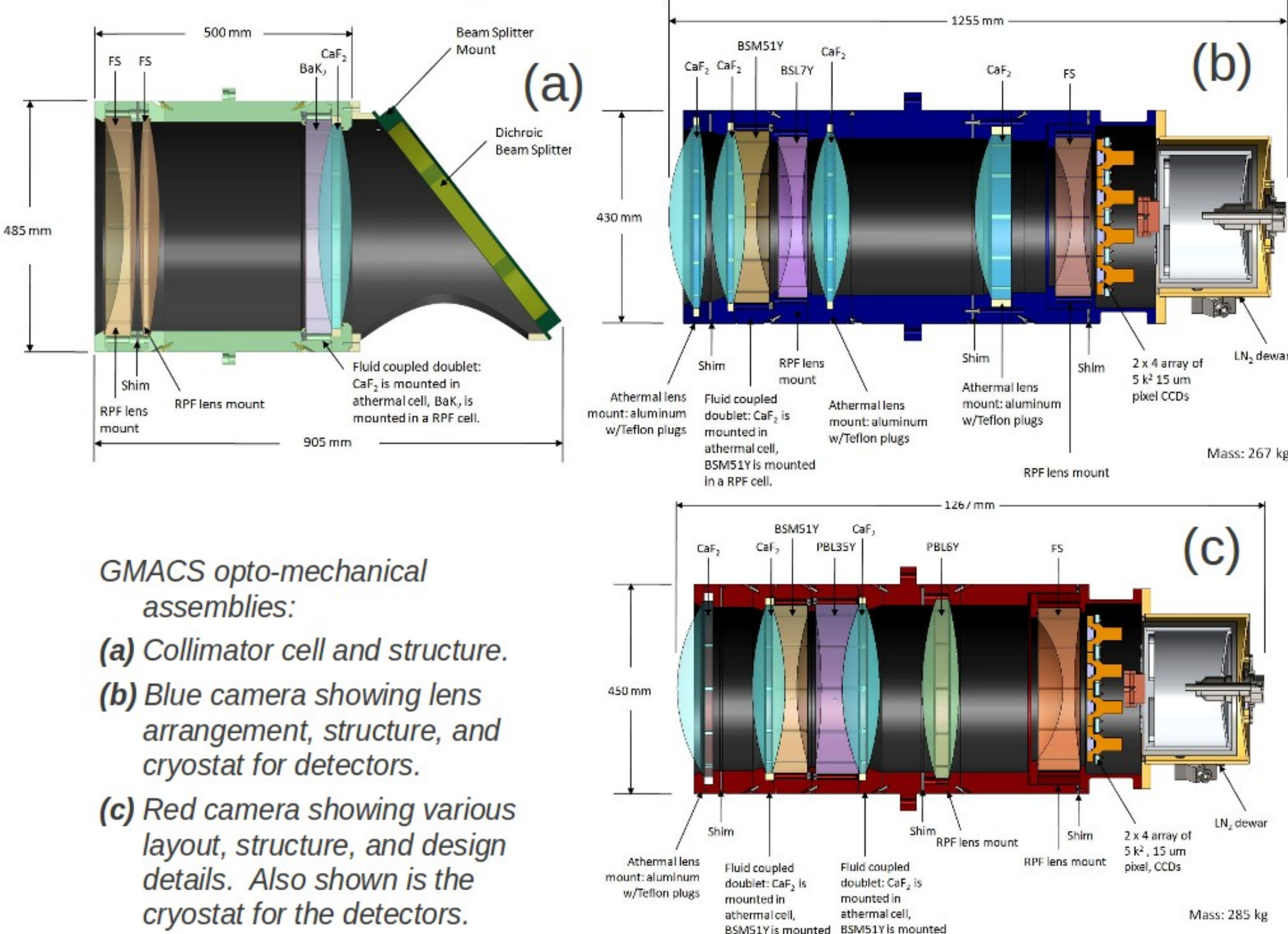


Figure 1. The GMACS optical design contains many different lens elements. It is very important that we fill the gap in the middle of the doublet with index matching fluids so that air does not get in and distort the optics.

Fluids and Materials in Other Instruments	
Fluid	Instruments that Use Them
Glycerin	None
Cargille Laser Liquid Code 1075	DEIMOS ² , SDSS ³
Cargille Laser Liquid Code 5610	IMACS ⁴ , EST ⁵ , Goodman ⁶ , RSS ⁷ , Binospec ⁸
Material	
Delrin	ESI
Polyethylene	DEIMOS
Polyurethane	None
Kapton	None
Teflon	RSS
Silicon	LRIS ⁹ , RSS

Table 1. Many of these fluids and materials are popular for instrument making. (Hilyard, Laopodis, Faber 1999)² (Clemens, Crain, Anderson 2004)³ (Epps, Sutin 2003)⁴ (Sheinis et. al. 1999)⁵ (Buckley et. al. 2008)⁶ (Brown, Fabricant, Boyd 2002)⁷

Fluid	Index at 589.3nm and 25°C
Glycerin	1.4729
Cargille Laser Liquid Code 1074	1.5358
Cargille Laser Liquid Code 5610	1.51484
Cargille Optical Gel Code 081160	1.52
Glass	
BK7	1.509
CaF2	1.43385
BSM51Y	1.60311
BAK2	1.53996
PBL35Y	1.58159

Table 2. For an index-matching fluid to work as optical coupling for a lens doublet, it must have an index of refraction between those of each lens element.

Abstract

We present a preview of compatibility tests for index-matching fluids with commonly used optical assembly materials. Although we focus on fluid candidates for GMACS, the results of the conducted experiments are applicable to all instruments that use optical index-matching fluids. The experiment presented here aims to identify potentially corrosive matchings of fluids and materials. In the experiment, a material (RTV, polyethylene, delrin, etc.) is submerged in a quartz cuvette of fluid (Cargille liquids, glycerin, etc.). Contamination is observed by using a spectrometer to measure the absorption spectrum at various post-submersion times. The current results have large measurement errors compared to the signal, and no contamination appears to have taken place. We detail the source of these errors and make suggestions for similar future experiments.

Procedure

We tested six different materials (delrin, silicone, teflon, kapton, polyethylene, polyurethane) in combination with three different fluids (glycerin, Cargille LL1074, Cargille LL5610). Each material was cut into uniform pieces and submerged in a flask containing a different fluid. Thus there were 18 combinations of fluids and materials to test.

Prior to filling the cuvettes with fluids, we cleaned them with distilled water, acetone, and pressurized nitrogen to remove any residue. Upon filling the cuvettes, we found that air bubbles in the fluids scattered a noticeable fraction of light so we waited for the air bubbles to disperse. After the measurements, we poured the fluids back into their flask to continue aging.

The measurements were performed using the following method. An empty cuvette was placed in the cuvette holder, and its spectra was measured. This measurement served as our control to help remove day to day changes in our setup (for example lamp instability). Then we filled the cuvette with fluid to be tested and recorded a background subtracted spectra. We repeated the measurement for the different material-fluid combinations several times over a period of 3 weeks to record the evolution of the transmission with time.

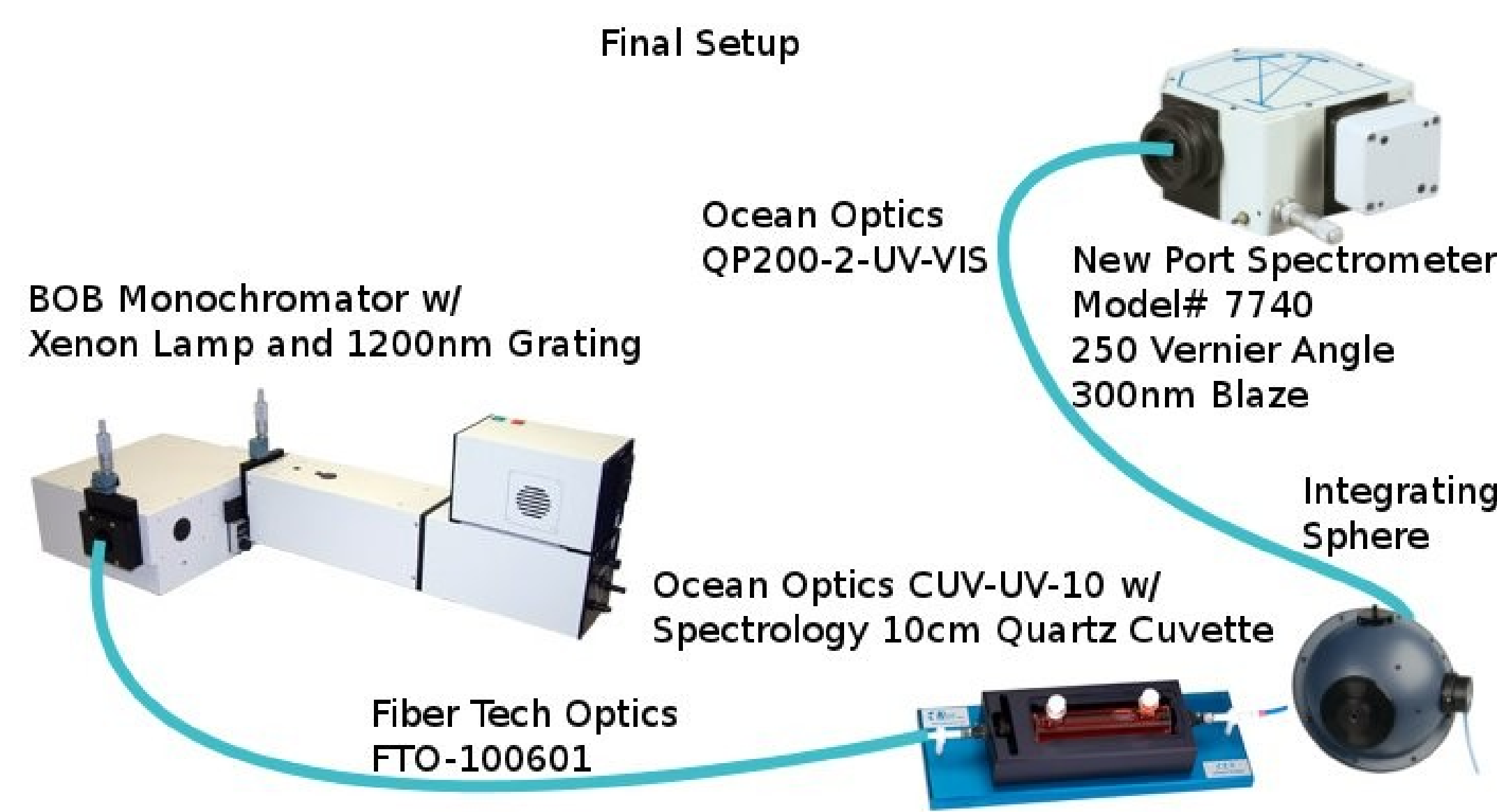


Figure 2. Experimental Setup. Light generated by the lamp is coupled by the monochromator into the fiber. It then passes through the sample and is coupled by the integrating sphere into the second fiber and then the spectrometer where its spectra is measured.



Results

Even though our measurement error did not allow us to detect UV throughput degradation, there is still some information to be gathered by considering a simple binary approach to the data: did it transmit UV light or not. It could be that the liquids were not given sufficient time or the proper environment in which to be contaminated. In Nordsieck, Nosan, and Schier 2010, they found the contamination set in after 200-300 hours when the reaction was accelerated by allowing the samples to age in a heated environment (35°C). Our samples were aged at standard temperature and pressure so the reactions happened much slower. Though if there were any small change in the UV throughput, our setup would detect it because of the 100mm long path length used to measure the absorption spectra.

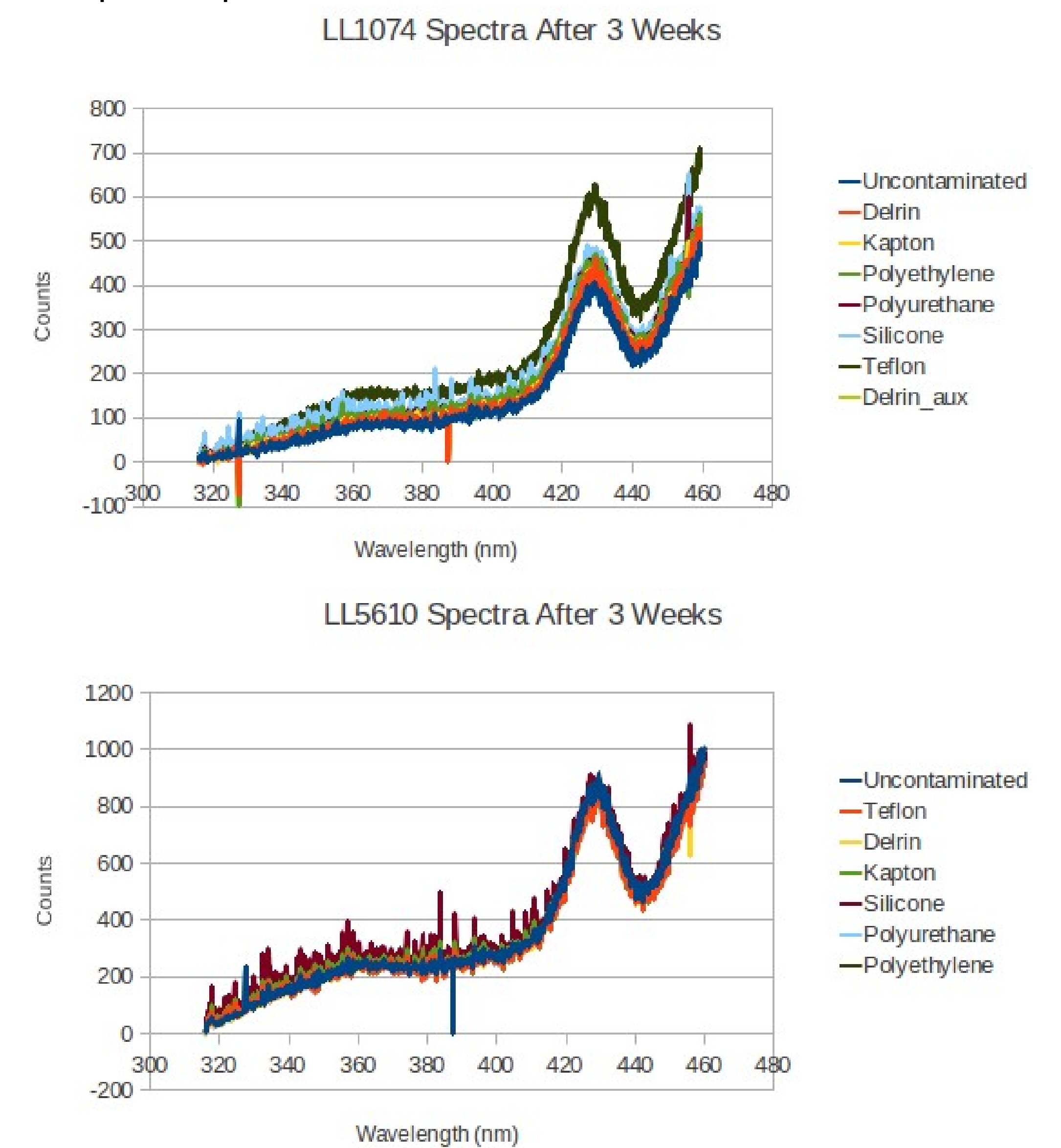
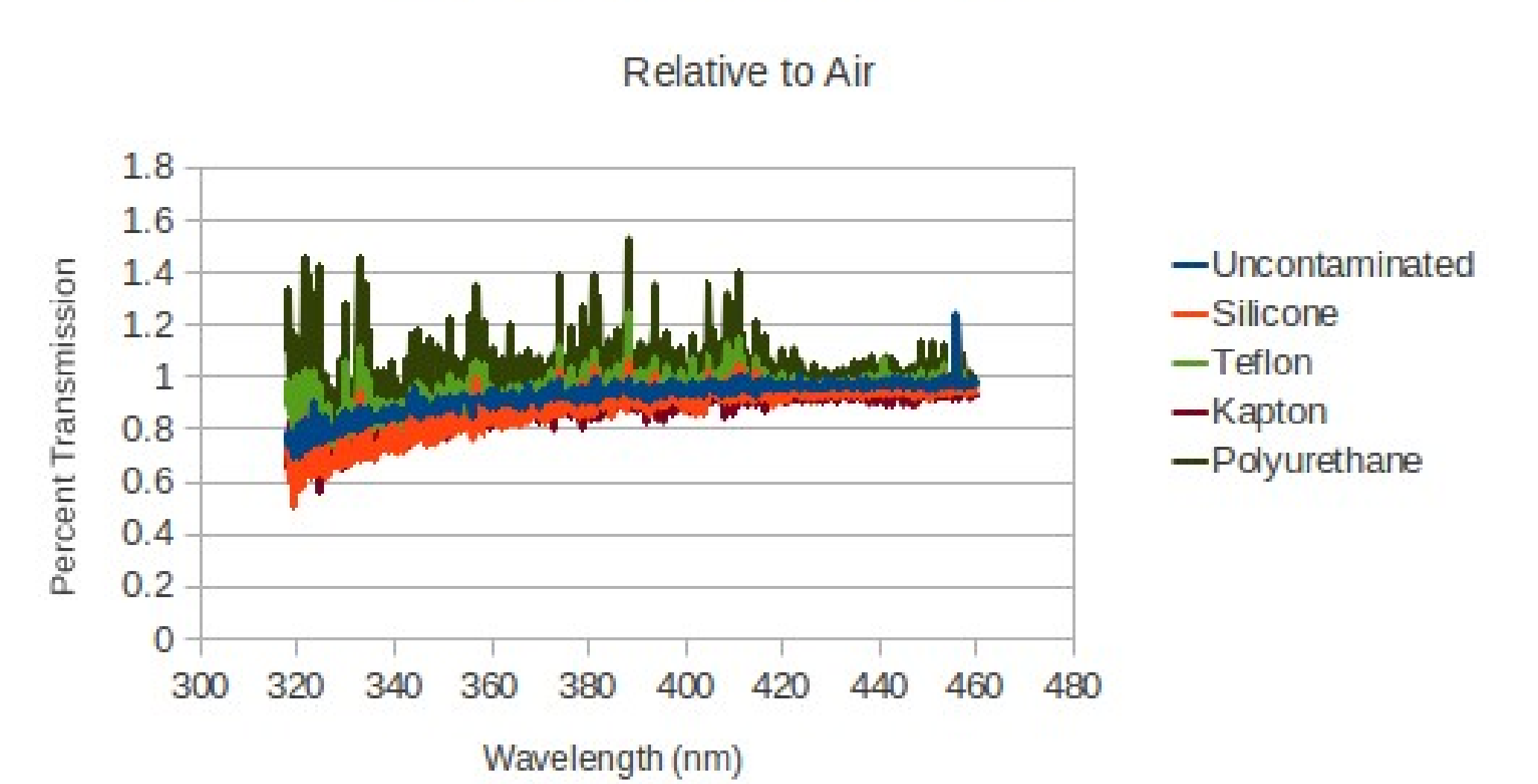


Figure 4. We included the combination of LL5610 and polyurethane in our test as a control sample because it is a pair known to produce contamination. The fact that we did not see a measurable effect in this case indicates that the samples did not have enough time to age.

Glycerin Spectra After 3 Weeks



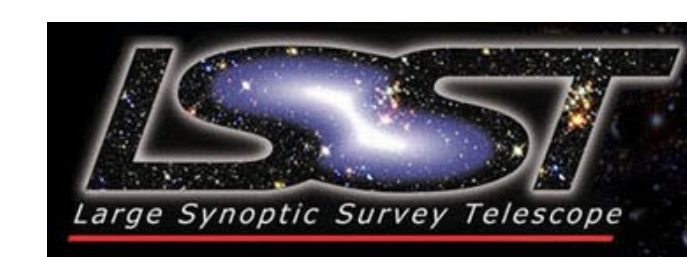
Discussion

For future experiments, we shall make several suggestions that will reduce measurement error and costs. Short path length cuvettes reduce the optical coupling problems and require less optical fluid to fill. We suggest storing the fluid in the same container that it will be tested in because pouring loses fluids and reduces repeatability. Even though glycerin is not a viable optical fluid because of its hygroscopic nature, it is two orders of magnitude less expensive than Cargille fluids, and thus it is an excellent test sample. Finally, we suggest that the samples either be given ample time to age or be placed in a high temperature environment to accelerate any chemical reactions.

Acknowledgments

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