Development of Novel, Optically-Based Instrumentation For Aircraft System Testing and Control

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PROJECT SUMMARY

The newly developed device comprises of an AOTF and a tunable Electro-Optic Fabry-Perot (EOFP) etalon. Since the AOTF is a mature technology and its integration with EOFP etalon is more of an engineering issue, we concentrated our effort mainly in the development of EOFP etalon. During Phase-I, we fabricated EOFP etalons with thickness as small as 25 μm in order to achieve a wide free spectral range (FSR) but encountered a narrow tuning range of the order of 0.7 nm limited by the properties of the $LiNbO_3$. During phase-II we developed an elegant novel scheme of operation so that this physical property is no more a limitation for achieving a continuous tuning of the combined filter. The solution that we developed is to use a dual FPE instead of a single one in combination with one AOTF, all three components can be conveniently integrated in one single device.

The fabrication of thicker FP etalons, required in dual Fabry-Perot operation, was relatively straightforward while there were other technological constraints that we encountered during phase-II. In order to achieve high reflectivity of two optical surfaces of FP etalon we developed new capability of multi-layer dielectric optical coating at Brimrose, and we achieved very low loss optical mirrors with reflectivity as high as 99%. The other important requirement for fabricating high resolution FP etalons was to polish the optical surfaces to flatness better than $\lambda/100$, which needed us to develop special techniques. During the course of fabrication we developed several new schemes and technologies, which are discussed in detail in this report.

For the experimental testing of the developed devices, we confirmed the operation of the Fabry-Perot devices' free spectral range and optical throughput. The coupled transmission windows of the FP devices show spectral narrowing and a significant increase in effective finesse. The dual FP device was also shown to be electro-optically tunable where the shape of the combined spectra clearly changed and shifted spectrally with applied voltage. A theoretical model of the dual FP device with AOTF filter was constructed and showed good sensitivity to infrared absorbing species. Measurement of the concentration of combustion product gas species was performed by optical absorption at high pressure using the AOTF to confirm its utility for wide-band spectral sensing.

In order for the dual FP tuning to achieve continuous tuning, the electro-optical tuning range of both FPs together needs to be greater than the full width at half maximum (FWHM) of one of the individual FP devices. For the best devices tested in this effort, the FWHM near 1530 nm was 0.05 nm; however, the average value for the entire tuning range approached 0.2 nm over the range from 1380 nm to 1650 nm. The tuning of a single FP device using a uni-polar source allows for a maximum tuning range of 0.16nm at 10 kV (which is difficult to achieve considering breakdown issues). However, if bi-polar HV sources are utilized and both FP devices are tuned, then a maximum relative tuning range of 0.32 nm is possible, and the theoretical dual FP tuning would be much more evident. With the final dual FP FWHM of 0. 06 nm (or 0.24 cm^{-1}), the combined device would be sufficient for the resolution of spectral absorption for typical species at pressures above 0.5 atm. The details of the combined operation of the AOTF with dual FPE are discussed in this report, and it can be seen that the technology developed in this program provide the platform for achieving the goal of the project – engineering an instrument incorporating a narrowband filter tunable in a wide spectral range with high spectral resolution.