A Fabry-Perot etalon filter system for a Visible light Imager and Magnetograph on-board Solar Orbiter

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Abstract. We propose a solid state (Lithium-Niobate) voltage tunable Fabry-Perot etalon filter system for the VIM instrument on the Solar Orbiter. The design parameters, advantages and limitations over other types of etalons and the needed 'space qualification' of the etalon are discussed.

1. Introduction

The Visible light Imager & Magnetograph (VIM) on-board the Solar Orbiter will provide magnetic and velocity field maps at a spatial resolution better than 100 km on the sun (for more info. on Solar Orbiter, http://solarsystem.estec.esa.nl/projects/solar_orbiter.htm). A tunable spectral filter is required to extract portions in the red and blue wings of a magnetically sensitive line profile for Doppler and magnetic measurements. Single and multiple Fabry-Perot etalons have long been used as narrow band-filters in many fields such as astronomy and solar physics (Vaughan, 1989). Often the interferometers are of air-spaced type, though in recent times the trend has been to use solid-spacer etalons, especially in space-based experiments, because of their compactness and absence of need for complex electronics and mechanical structures to maintain parallelism and spacing. Some early examples used mica and silica as spacer layer, but most recently lithium niobate ($LiNbO_3$) proved to be a good substrate. Advantages of lithium niobate are that it is electro-optic, and thus can be tuned by the application of an electric potential across the spacer, and its refractive index is relatively high, making the filter useful over large angular fields.

2. Dual Etalon systems

In order to avoid the use of very narrow band blocking filters, the etalon is preferred to have a large Free Spectral Range (FSR) compared with its pass-band $\Delta\lambda$. A combination of two etalons with different plate separation is

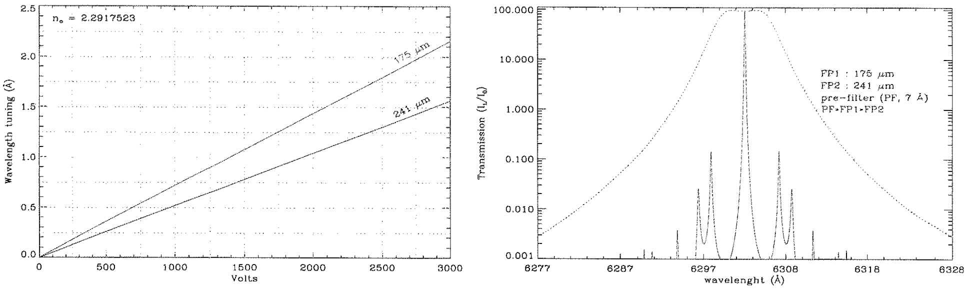

Figure 1. (Left) Voltage tunability curves for $LiNbO_3$ etalon filters @ 6302.5 Å. (Right) The resultant profile of two-etalon and a 7 Å interference filter system.

used to enlarge the FSR. The resulting Airy function for a combined system can be approximated by a Lorentz function T_L given by (Kentischer *et. al.*, 1998),

$$T_L = \frac{T_F}{[1 + F(1+\epsilon^2)\Delta\psi^2]} ,$$

where T_F is the pre-filter transmittance, $\epsilon = d_2/d_1$ the ratio of the spacer thickness, and $\Delta\psi = 2\pi\mu d_1(\lambda - \lambda_0)/\lambda_0^2$, where μ and λ_0 are the refractive index of the spacer and central wavelength respectively. The best spacing ratio for the combined FP/pre-filter system can be calculated by using a method described by Darvann & Owner-Peterson (1994).

The etalons under consideration are solid with active electro-optic Lithium Niobate ($LiNbO_3$) crystal substrate. The tuning constant for the etalon mainly depends on the refractive index change due to the applied voltage to the substrate (Bonaccini & Smartt, 1988, Mathew, 1998). Figure 1 (right) shows the tuning curves for 175 and 241 μm substrates.

3. Filter specifications

We consider using two 50mm FP etalons in tandem, which are made of y-cut lithium niobate substrate. The specifications of the filter system is given in Table 1. Figure 2 shows the resultant profile of the FP/pre-filter system. The filter will be placed near the proposed f/66 telecentric image plane, which will slightly reduce the spectral resolution but maintain spectral uniformity over the entire field of view. Experience with $LiNbO_3$ etalons shows that the voltage tunability remains stable for very long time. Over the course of tuning, the misalignment of FP pass-bands can be corrected by a peak detection method and also the critical parameters can be derived by tuning through a specified portion of the solar spectrum. The etalons are temperature sensitive and an oven with a stability of $0.01K$ needs to be

Table I. FP system @ 6302.5 Å

Crystal thickness	:	175 & 241 μm	Spectral range	:	500-700 nm
Transmission	:	80%	Finesse	:	30
Combined FSR	:	15 Å	FWHM	:	95 mÅ
Resolution	:	66000	Tunability	:	±1 Å
Tuning res.	:	0.5mÅ/V	Pre-filter (FWHM)	:	3 cavities, 7 Å

used to limit the wavelength shifts to 10 mÅ. For correcting the wavelength drift a feed back mechanism has to be designed which monitors the etalon temperature with a very high sensitivity sensor and generates appropriate correction voltages.

4. Survival in space

An etalon in space is exposed to a variety of radiations and operational stresses. Therefore we intend to carry out,

- Vibrational tests with sample wafers of lithium niobate, since the thickness of the etalon, which is more brittle than glass, is only around 0.2mm.

- Radiation damage test of the crystalline structure of the etalons, by exposing sample wafers to radiation, simulating the harsh, environment near perihelion. The laboratory experiments on $LiNbO_3$ samples showed no change in transmission or refractive index after exposure to radiation expected near the Sun-Earth L1 point (Rust, *et.al.*, 1988).

5. Conclusion

A voltage tunable Fabry-Perot etalon filter system has several advantages that make it an attractive solution for the VIM instrument on Solar Orbiter. The voltage tunability of the etalon makes it suitable for space applications, since tilt-tuning is not required and thus movable parts can be avoided. These robust narrow band filters have low weight, are compact and can be fine-tuned within any spectral line of interest. This makes them extremely promising for other space missions as well.

References

Bonaccini, D., Smartt, R. N., 1988, *Applied Optics*, **27**, 5095
Darvann, T., Owner-Petersen, M., 1994, *LEST Technical Report*, **57**
Kentischer, T. J., Schmidt, M., Sigwarth, M., Uexküll, M. v., 1998, *A&A*, **340**, 569
Mathew, S. K., 1998, *Ph D Thesis*
Rust, D. M., Appourchaux, T., Harris, T. J., 1988, *NASA Technical Memorandum*, **4048**
Vaughan, J. M., 1989, *Adam Hilger, Bristol*