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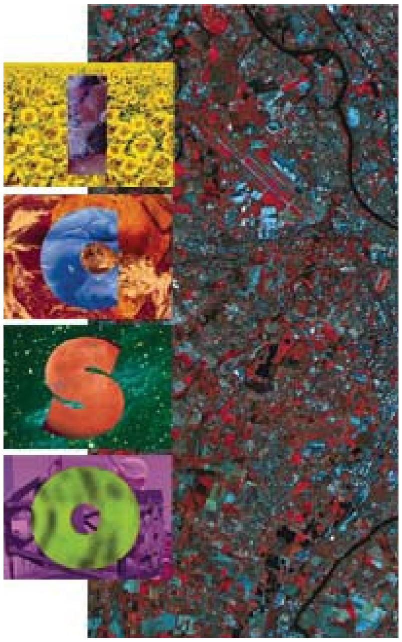

FTIS compact Fourier transform imaging spectrometer for remote sensing

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FTIS

Compact Fourier Transform Imaging Spectrometer for Remote Sensing

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Abstract. *The feasibility of a compact Fourier-Transform-Imaging-Spectrometer (FTIS) for small satellite remote sensing missions is currently being studied under ESA contract. Compared to classical hyperspectral imagers using dispersive spectrometers the major advantages of the FTIS is the compact optics module and the tolerable higher detector temperature, thus easing the instrument thermal design. The feasibility of this instrument concept will be demonstrated by breadboarding.*

Instrument Concept

Baseline technology for the FTIS instrument is a fixed mirror Michelson interferometer which will generate spatially modulated interferograms. In this type of interferometer the OPD is generated by optical means, e.g. a wedge or tilted mirror, over the field of view in flight direction (along track direction). This will result in a constant phase difference between the two wavefronts behind the beamsplitter, which are originating from each object point perpendicular to the flight direction. As the instrument propagates in flight direction the two wavefronts originating from the same object point will be phase shifted. The “white light” interferogram of each object point will be recorded along the corresponding column of the array.

FTIS consists of two modules operating in the VNIR and SWIR spectrum. Some important instrument requirements are compiled in the following table:

	VNIR	SWIR
Spectral Range [µm]	0.45 – 0.90	0.90 – 2.40
Spectral Resolution [cm-1]	120	60
Spatial Resolution [mrad]	0.1 x 0.1	0.1 x 0.1
Detector Array Size	1024 (spatial) x 440 (spectral)	

A schematic figure of the optical configuration of the instrument is given in Figure 1. Figure 2 shows the interferometer layout principle. The optical path difference in the detector plane will be generated by a glass wedge in one of the two interferometer arms. The glass wedge and mirror 2 have a reflective coating on their rear side. This instrument concept will need front optics with a good intermediate image quality near the retro-reflector surfaces. The intermediate image will be focused on the detector by means of a relay optics.

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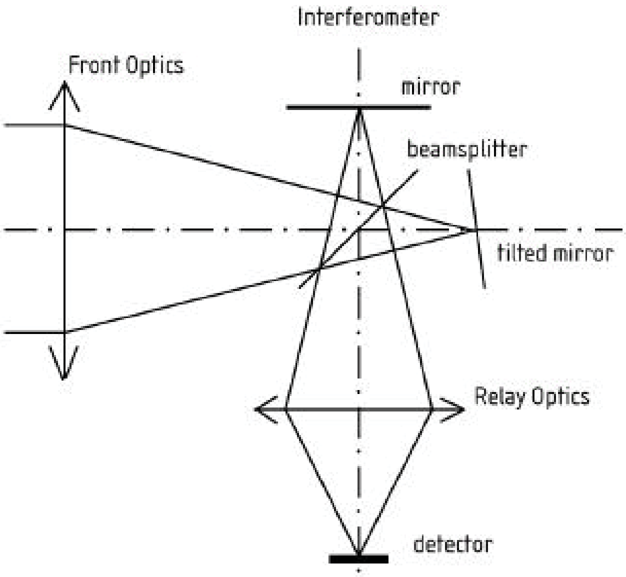

Figure 1: Instrument optical configuration using an interferometer with fixed mirrors. One mirror is slightly tilted.

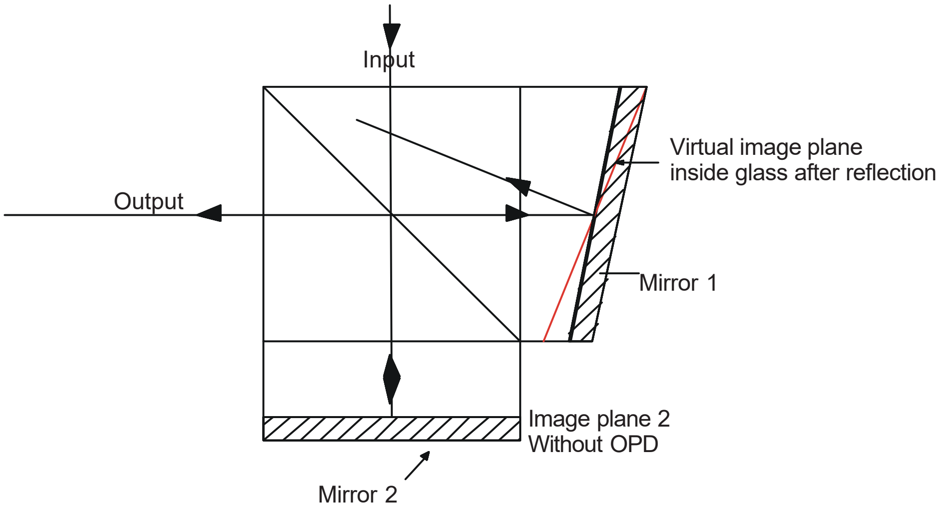

Figure 2: FTIS interferometer with two fixed mirrors (one being tilted)

Optical Design

As one of the mirrors in the interferometer is tilted with respect to the other to create an optical path difference, a defocusing error could possibly degrade the MTF at off-axis angles. However, for the small OPD required for FTIS, it is possible to tune the numerical aperture of the front optics in such a way that the depth of focus at the tilted mirror is large enough (the defocus term is negligible for a Numerical Aperture < 0.1). Then, the magnification of the relay optics has to be adapted to achieve a focal length matched to the detector pixel size. The only drawback of the tilted mirror is the induced wavefront tilt with the related impact on the mixing efficiency.

A basic optical design for this type of interferometer is shown in Figure 3. It consists of a Three-Mirror-Anastigmat (TMA) lens with three conical mirrors combined with an Offner Relay system with spherical mirrors. There is an aperture stop at the secondary mirror of the lens, and an image of the stop at the secondary mirror of the Offner relay. The field stop could be at or near the detector.

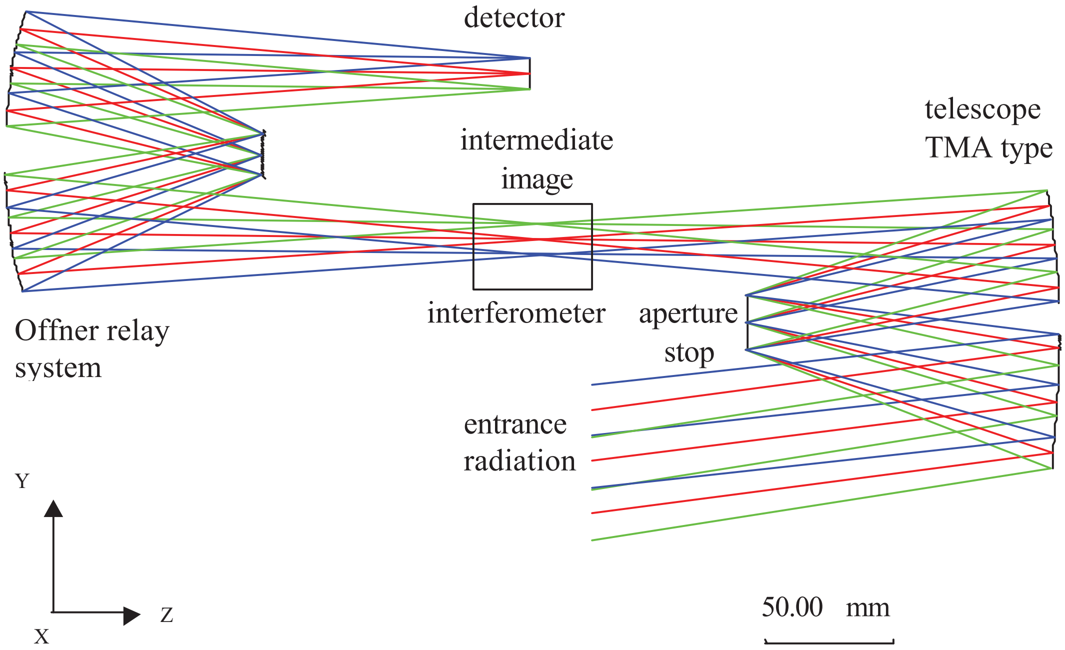

Figure 3: Principle optics design (field of view = 6.4°, f = 250 mm, F# = 6.25). The interferometer will be placed at the intermediate image

Performance

A possible mission for FTIS is a moon orbiter with high spatial (1m) and moderate spectral resolution (120 cm^{-1} in VNIR and 60cm^{-1} in SWIR). The radiometric performance of such a mission was assessed in terms of Noise Equivalent Difference in Reflectance (NEΔρ), and shown in Figure 4. Typical albedo values for lunar highlands and lunar mare have been entered into the model.

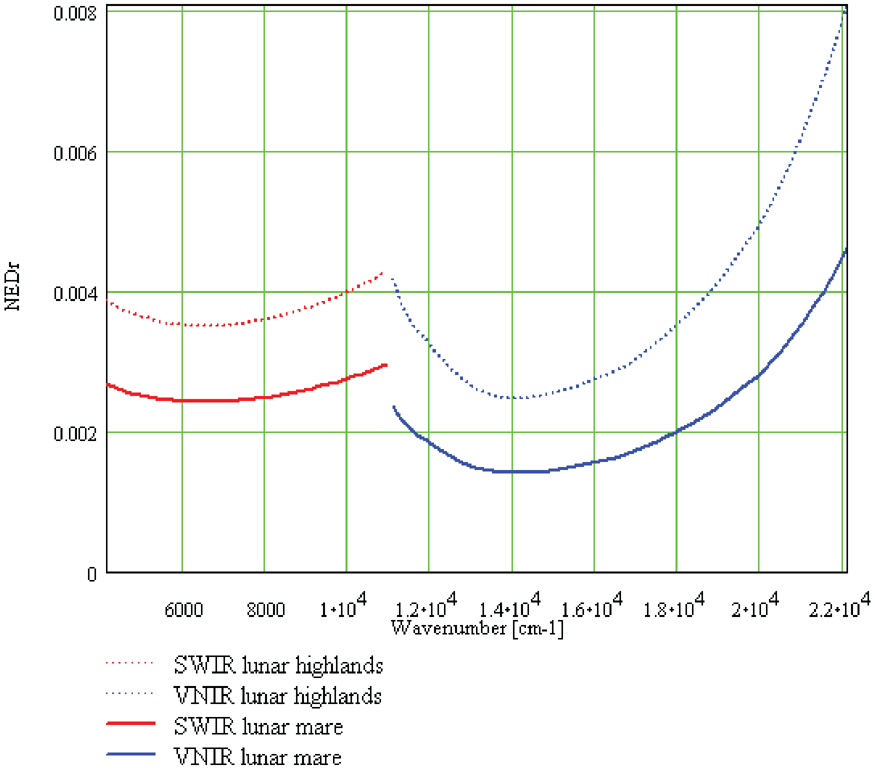

Figure 4: Estimated FTIS performance of a lunar orbiter in terms of Noise Equivalent Difference in Reflectance (NE$\Delta\rho$, absolute values) vs. wavenumber.

Conclusion

Major advantage of this novel interferometer principle is its simplicity: there are no moving parts and no optical path difference sensor is needed. Compared to dispersive spectrometers such an instrument is very compact and the detector cooling requirements in the IR region are considerably relaxed (a much higher dark current is tolerable). The compact design makes the interferometer stiff and insensitive against environmental influences.

The development risks and costs are considered low, making such an instrument perfectly suited as a hyperspectral imager for low budget small satellite missions.