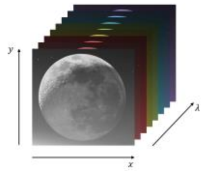
BIREFRINGENT INTERFEROMETER FOR COMPACT SNAPSHOT HYPERSPECTRAL IMAGING

Matthieu Porte*[a], Elisa Baldit[b], Frédéric Bernard[b], Yann Ferrec[a], Nicolas Guerineau[a]
[a]ONERA, BP 80100, chemin de la Hunière, 91123 Palaiseau, France;
[b]CNES, 18, Avenue Edouard Belin 31400 Toulouse, France
*matthieu.porte@onera.fr

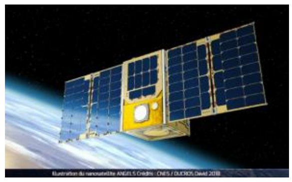
Context :

Hyperspectral image: An image of the scene at a high number of wavelength.

Applications in remote sensing :
→Atmosphere (CO2 concentration measurement), surface (mineralogical studies, agriculture, …)
→Terrestrial or extra-terrestrial.

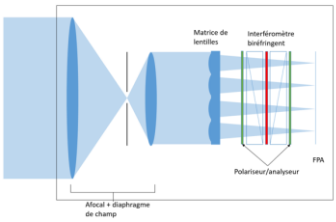


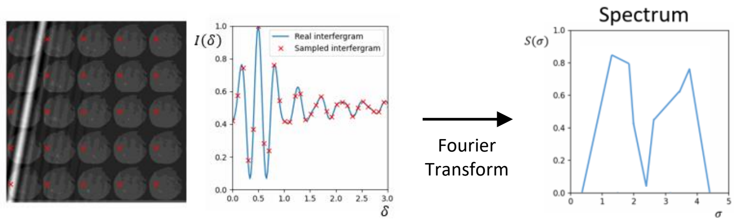
Challenges :
→Cost reduction.
→More compact and robust instruments.



Optical concept

Snapshot 2D imaging spectrometer concept firstly presented by Hirai *et al* [1] :
→The lenslet array divides the scene into several subimages.
→The interferometer produced slanted linear fringes, hence each point of the scene see a different optical path difference (OPD) through each lenslet.
→The interferogram (i.e **the spectrum**) of each pixel of the scene is acquired within **a single frame.**





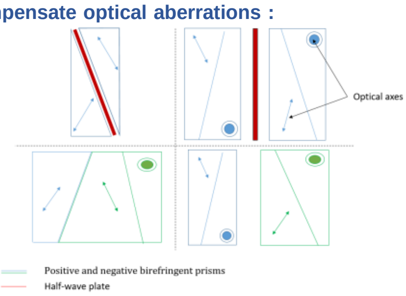
Reconstructed interferogram for 1 point of the scene, from the single frame shown on the top-left insert.

Advantages :
-Measurement of fast phenomena possible (gas detection, jet plumes…).
-Robust and non-scanning system for compact payload (extra-terrestrial mission).

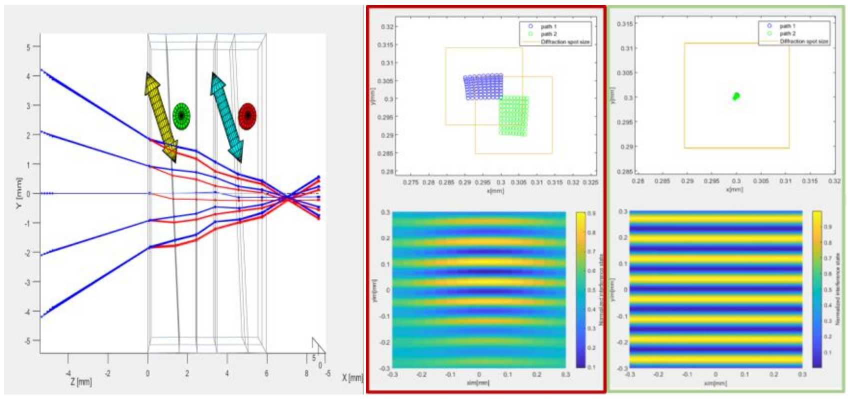
Limitation :
The amount of samples of the interferogram (proportional to the number of spectral bands) for each point of the scene is equal to the number of subimages→ Trade-off between the number of spectral bands and spatial pixels of the hyperspectral image **(x,y,λ).**

Birefringent Interferometer and 3D Simulation

Birefringent interferometer can be used as it enables compactness and robustness to vibration (common path interferometer)[2].
Challenges : The interferometers produce optical aberrations for the two channels and thus deteriorate the spatial quality (shape and size of the image spots) and the spectral quality (contrast and shape of the interference fringes)
→ **Need to find birefringent prism combinations that compensate optical aberrations :**



A 3D rays tracing in birefringent prisms program has been developed [3].
It simulates :
- **Spot diagrams of each path**.
- **Exact optical path difference**.
- **Interferogram, taking into account several parameters** (aperture size, field of view,…).



Experimental instrument

The instrument is made to respects the spectral/spatial needs for a **red-edge observation** (rapid change of chlorophyll reflection). The high number of wavelength achieve by an undersampling of the interferogram.
The interferometer is made of 2 Nomarski prism and an half-wave plate :
→ Compact instrument (interferometer directly placed between the lenslet array and the FPA, distance lenslet array-FPA ≈1cm)
→ Spatial resolution limited by diffraction.
→ Maximum contrast of the fringes.

Optical parameters	
Spectral range	[500 nm :850 nm]
Spectral resolution	70 cm^{-1}
Resolving power (@850 nm)	160
Number of spatial pixel per subimages	86x86

REFERENCES

[1]. A. Hirai, T. Inoue, K. Itoh, and Y. Ichioka. 'Application of Multiple-Image Fourier Transform Spectral Imaging to Measurement of Fast Phenomena', n.d., 3.
[2]. M.W. Kudenov, E.L. Dereniak. 'Compact Real-Time Birefringent Imaging Spectrometer'. Optics Express 20, no. 16 (30 July 2012): 17973.
[3]. H. Sauer, A. Pola Fossi, Y. Ferrec, N. Guerineau, J. Minet, J. Taboury, P. Chavel. 'Numerical Modeling of Nominal and Stray Waves in Birefringent Interferometers: Application to Large-Field-of-View Imaging Fourier Transform Spectrometers'. Applied Optics 57, no. 31 (1 November 2018): 9488.