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SWIFTS and SWIFTS-LA: two concepts for high spectral resolution static micro-imaging spectrometers

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Abstract

SWIFTS (Stationary-Wave Integrated Fourier Transform Spectrometer) represents a family of very compact spectrometers based on detection of standing waves for which detectors play itself a role in the interferential detection mechanism. The aim of this paper is to illustrate how these spectrometers can be used to build efficient imaging spectrometers for planetary exploration inside dm^3 instrumental volume. The first mode (SWIFTS) is devoted to high spectral resolving power imaging (R~10000-50000) for 40x40 pixels field of view. The second mode (SWIFTS-LA) is optimized for its luminosity with a resolving power up to R~2000.

1. Introduction

Since the beginning of space exploration almost all missions have onboard at least one spectrometer and/or one spectro-imager covering various spectral ranges from the UV to the far-infrared. Currently there are barely two lines of spectral instruments depending on their scientific aims: 1) high spectral resolution spectrometers (R> 3000) with a single or a few pixels mostly dedicated to planetary atmospheres studies (e.g. UVS on Galileo, PFS and SPICAM on Mars Express, CIRS on Cassini , VIRTIS-H on Rosetta, …), and 2) medium spectral resolution imaging spectrometers (R=50-500), mostly in the visible and near-infrared (0.4-5 µm) with medium to high spatial resolution (0.1-1mrad: or typically ~1km to ~40m on Mars) which are mostly dedicated to planetary surfaces studies (e.g., NIMS on Galileo, OMEGA on Mars Express, VIMS on Cassini, CRISM on MRO, VIRTIS-M on Rosetta, …). But these spectroscopic instruments, as well as new types of instruments (Raman spectrometers, infrared microscopes…) are now also going down to planetary surfaces aboard Landers and Rovers (CIVA on Rosetta, MicrOmega on ExoMars, MMRS on MSL…).

All these instruments use either optical gratings, Fourier transform or AOTF spectrometers. The two first types need moving mirrors to scan spectrally thus adding complexity and failure risk in space. The interesting solution of AOTF, without moving part (only piezo) is however limited in resolution to a few cm-1 due to limitation in monocrystal size (fragile).

Strong limitations of these instruments in terms of performances (spectral & spatial resolution and range, S/N ratio) come from their already large mass, volume, and power consumption. Further increasing one of these characteristics will be at the cost of even bigger instruments.

For example, although a spectro-imager for surface studies at higher spectral resolution (~1000) is strongly needed to study ices (such as CO2 on Mars, …) and some minerals, there is currently no demonstrated alternative way using the current spectroscopic techniques to reach such resolution without decreasing either the spectral range or the spatial resolution/range and remaining in an affordable mass/volume/power budget for a space mission. This is also in concurrence with the need to increase also spatial resolution (down to a few m) to better resolve geologic features (e.g. "gullies" on Mars with possible liquid water, only a few meters wide).

Very high resolution spectrometers with better imaging capabilities are also needed for atmospheric studies, especially for limb observations in order to finely resolve the atmospheric layers and measure winds by Doppler shift. But also for nadir observations for example for thermal/pressure profiles determination, identifications of possible gas sources from the surface (e.g. origin of CH4 on Mars ?), detection of thermal anomalies, or local clouds and aerosols studies.

For landers and exploration rovers the mass/volume/power budget is even more critical. And moving parts in some harsh environments (gas/temperature/dust/shocks/…) start to be a very critical issue. And instruments such as Raman spectrometers need very high spectral resolution to provide powerful in-situ analysis.

2. SWIFTS

The Stationary-Wave Integrated Fourier Transform spectrometer principle described in [1] is fully developed and used today for high spectral characterization in the visible domain [2]. It is now under development to build an imaging spectrometer. An extension of the spectral domain to the infrared is possible using chalcogenide infrared integrated optics [3]

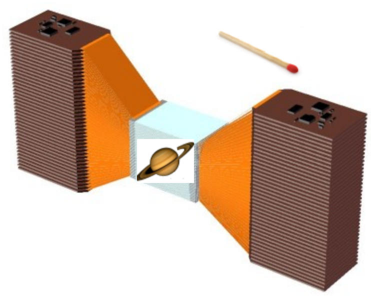

Figure 1: The SWIFTS Imaging spectrometer is built by stacking 40 layers of CMOS detector matrix coupled to 40 optical waveguides fed by a microlens array where the field of view is imaged. The total field of view is 40x40 pixels.

3. SWIFTS-LA

"LA" (stands for "Large Aperture") is a new device belonging to the generation of Static Fourier imaging spectrometers dedicated to high spectral resolution measurements. Inspired from MICROSPOC [4] and SWIFTS technologies

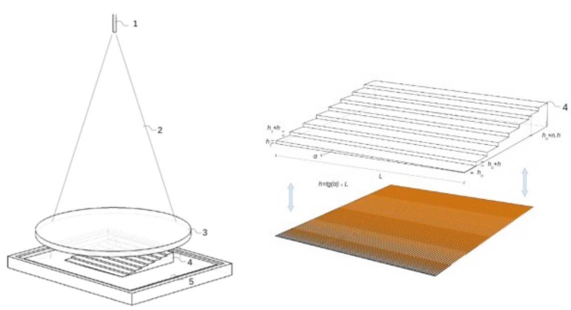

Figure 2: **left** : An optical fiber is collimated in front of detector. **right**, Fizeau fringes are localized at the detector surface. The interferogram is derived from the illumination and the thickness of two-waves interferometer in regard of each pixel

This new device exploits stationary waves in high refractive index materials to get a very small spectrometer with a very high angular acceptance. The principle uses Fizeau fringes formed inside a prism glued to the surface of a detector.

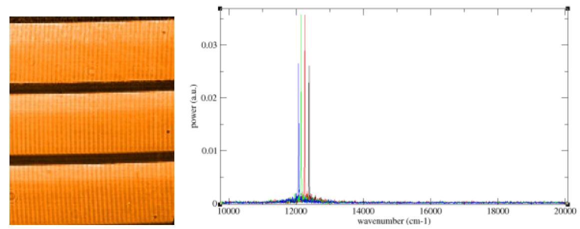

Figure 3: **left** : fringes recorded in a small part of the detector **right** : reconstructed spectra of a tunable laser. The resolving power is R~2000

For both SWIFTS and SWIFTS-LA, the imaging capability can be obtained with transport of image by fiber bundle.

4. Conclusion

We are demonstrating two building blocks of miniaturized static imaging spectrometers capable of generating an image and a high spectral resolution simultaneously which opens new opportunities for in-orbit and in situ planetary exploration by imaging spectrometry.

Bibliography

[1] Le Coarer, E., Blaize, S., Benech, P., Stefanon, I., Morand, A., Lérondel, G., ... & Royer, P. (2007). Wavelength-scale stationary-wave integrated Fourier-transform spectrometry. Nature Photonics, 1(8), 473-478.
[2] Bonneville, C., Thomas, F., de Mengin Poirier, M., Le Coarer, E., Benech, P., Gonthiez, T., ... & Martin, B. (2013, March). SWIFTS: a groundbreaking integrated technology for high-performance spectroscopy and optical sensors. In SPIE MOEMS-MEMS (pp. 86160M-86160M). International Society for Optics and Photonics.
[3] C. D'Amico,1 G. Cheng, C. Mauclair, J. Troles, L. Calvez, V. Nazabal, C. Caillaud, G. Martin, B. Arezki, E. LeCoarer, P.Kern, and R. Stoian, Large-mode-area infrared guiding in ultrafast laser written waveguides in Sulfur-based chalcogenide glasses. Optic Express (in press)
[4] S. Rommeluère, N. Guérineau, R. Haidar, J. Deschamps, E. De Borniol, A. Million, J-P Chamonal and G. Destefanis, "Infrared focal plane array with a built-in stationary Fourier-transform spectrometer: basic concepts", Opt. Lett. 33, pp 1062-1064 (2008).

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