HIGH-GRADE, COMPACT SPECTROMETERS FOR EARTH OBSERVATION FROM SMALLSATS

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TNO innovation for life

TNO HAS RECENTLY MADE SEVERAL DESIGNS TO REALIZE ADVANCED EO SPECTROMETERS IN A COMPACT AND COST-EFFECTIVE MANNER. EACH DESIGN REPRESENTS A MODULAR SYSTEM THAT CAN BE EASILY ADAPTED TO OBSERVE DIFFERENT PHENOMENA (E.G. AIR QUALITY, LAND USE OR WATER QUALITY) WITHOUT FULL REDEVELOPMENT AND QUALIFICATION. THIS POSTER PRESENTS THE MOST MATURE DESIGN: A HYPERSPECTRAL IMAGING SPECTROMETER ('SPECTROLITE').

DESIGN RATIONALE

Compact and low-cost instruments offer multiple advantages:

- A compact instrument can be flown on a smaller platform (nano- or microsatellite);
- A low-cost instrument opens up the possibility to fly multiple instruments in a constellation, improving both global coverage and temporal sampling;
- A constellation of low-cost instruments may provide added value to larger operational satellite missions;
- A low-cost instrument may help to break through the 'cost spiral', as lower cost allow to take more risk and progress more quickly; this will lead to a much shorter development cycle than customary for current EO instruments.

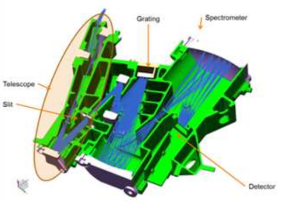

Figure 1: 3D drawing of Spectrolite showing the housing (green), all components (grey) and the optical path (blue).

Figure 2: The 4 free-form Spectrolite mirrors after manufacturing.

SPECTROLITE

Spectrolite is an all-reflective, off-axis design, consisting of only 8 optical components, including 4 free-form mirrors and a flat grating. The design can be applied in wavelength ranges between 270 - 2400 nm (with the exception of the grating and possibly the detector). A Spectrolite breadboard was optimized for the detection of NO_2 concentrations in the atmosphere:

- Spectral range of 320 nm – 500 nm
- Spectral resolution < 0.5 nm
- Spatial resolution of 0.1°
- Field of view of 60°
- Measurement SNR of 700 over urban areas

The Spectrolite housing was manufactured using a relatively novel method for space hardware: 3D printing and investment casting. This combination offers interesting possibilities with regard to design freedom and complex shaping (to increase performance), mass and volume reduction (to reduce launch cost) and cost-effective manufacturing of small series.

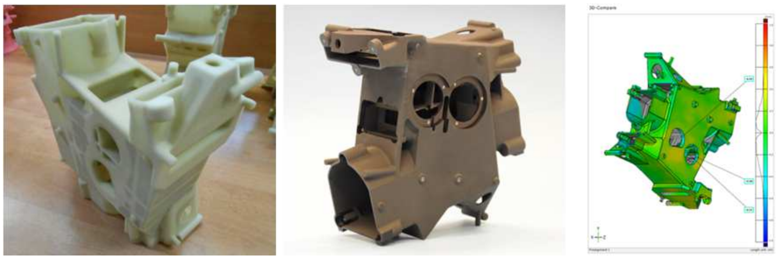

Figure 3: Wax model of the Spectrolite housing made by additive manufacturing (left); cast and post-processed Spectrolite housing with milled interfaces and anodized black (middle); 'best fit' of Spectrolite housing, indicating that most deviations between casting and CAD model vary between -0.30 and +0.30 mm (right).

A short cost evaluation showed that, compared to traditional milling, investment casting gradually becomes more cost-effective for larger series (> 20% for 10 housings).

SPECTRAL PERFORMANCE

The spectral spot size of the Spectrolite breadboard was measured using a HgAr line source coupled into a small integrating sphere. Figure 4 shows a single detector frame from the spectral measurements. The three lines correspond to 365, 405 and 436 nm from top to bottom. From these measurements the spectral resolution was determined, which varies between ~0.2 nm and ~0.33 nm (as shown in Figure 5) and is best for the highest wavelength.

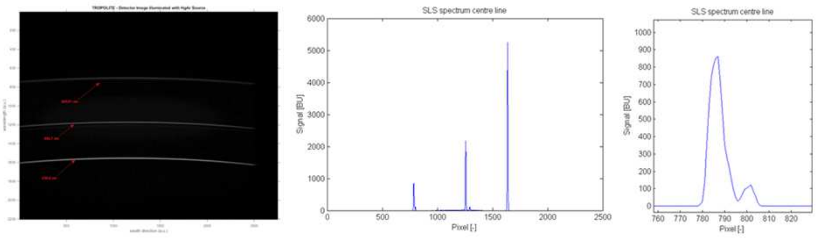

Figure 4: Detector frame with three lines that correspond to 365, 405 and 436 nm from top to bottom (left); cross-section of the HgAr source spectrum (middle); zoom in on the double peak at 365 nm (right).

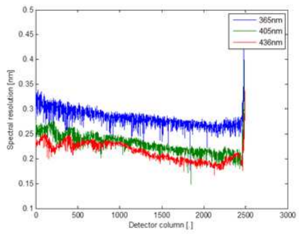

Figure 5: Spectral resolution measured over the full entrance slit.

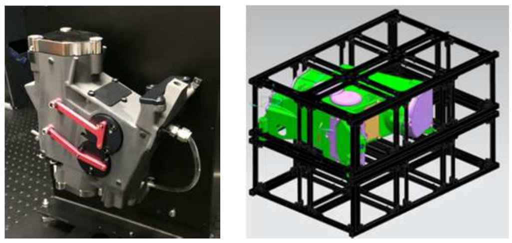

Figure 6: The Spectrolite breadboard (left) easily fits within a 4U volume (right).

CONCLUSIONS With the Spectrolite breadboard, we have successfully demonstrated the possibility to design and manufacture very compact, high-resolution spectrometers. Using advanced technologies, such as free form mirrors, 3D printing and investment casting, these instruments can be built cost-effectively in small series. Given their size and weight they can be also flown on small platforms, e.g. nano- and microsatellites. Finally, they can easily be 'tuned' to observe different phenomena without requiring full redevelopment and qualification.

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