Hyperspectral Spectrometer Survey for State of Art Concept Identification

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Introduction

Over the past twenty years, a very high number of different space hyperspectral imagers have been designed, developed. We thus decided to make a survey to analyze the most recent designs with the objective to select the concepts that will provide the best compromise between the volume and the performance.

We have categorized the different systems in five categories:

- Classical prism or grating based spectrometer
- Offner spectrometer
- Three-Mirror Anastigmat (TMA) spectrometer
- Dyson spectrometer

We selected one to two interesting designs of each category to present here.

Survey

Prism and Grating based spectro-imager:

Compact Hyperspectral Prism Spectrometer (CHPS):

- Design: One curved aplanatic prism and one spherical mirror as a dispersive element and two fused silica lenses as field lenses.
- Dimension: 500 x 500 x 500 mm^3 (30 times < Landsat-8)

Offner spectro-imager:

Freeform Offner spectrometer:

- Design: Two freeform concave mirrors with one freeform convex grating
- Volume: 70 x 50 x 30 mm^3

TMA spectro-imager :

Double-pass TMA:

- Design: Two OAPs, one freeform mirror and a plane grating
- Dimension: 120 x 190 x 240 mm^3
- There is also a possibility to integrate two OAPs onto a common substrate

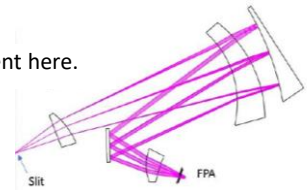
Dyson spectro-imagers :

Compact Wide Swath Imaging Spectro-imager CWIS:

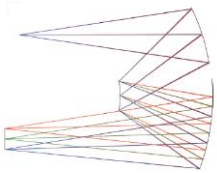
- Design: Doublet Dyson lens with one spherical concave dual-blazed grating
- Dimension: 325 x 150 x 150 mm^3 (<7 kg)
- Low aperture number at 1.8

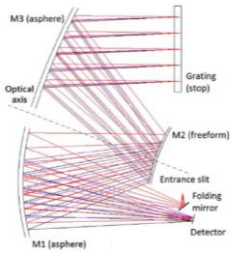
LWIR Dyson:

- Spectral domain: 7.8-13.4 µm
- However, the authors propose to introduce an aspherical surface onto the grating or on the additional lens in front of the grating to correct the aberrations that are induced by the separation of the entrance slit and focal plane from the back of the Dyson lens.

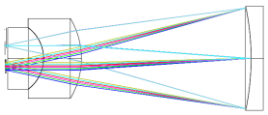


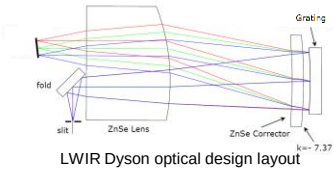
CHPS optical design layout


Freeform Offner optical design layout



Double-pass TMA optical design layout


CWIS optical design layout



LWIR Dyson optical design layout

Table 1 Trade-off of the freeform Offner, TMA and CWIS systems

Design	Advantage	Drawback
Freeform Offner	Very compact system and excellent image quality over wide spectral domain → Best ratio performance versus volume identified in the literature	Three freeform surfaces → High cost, difficult to align and manufacture
Double-pass freeform TMA	Plane grating → Minimum risk and cost, eases the alignment M1 and M3 on one common substrate → Simplify the assembly and alignment process, relax the tolerances, minimized the risk and the cost Only one freeform surface → Reduce the risk on the manufacturing capability and eases the optical alignment	Incident beam of light reflected by seven optical surfaces → Tighten the requirements on surface quality and stability → Reduce the throughput of the instrument
CWIS Dyson	Wide swath and fast aperture are provided → Recent compact system with specifications in line with the needs of the study No freeform surface → Minimum risk and cost, eases the alignment	Big and thick lenses are used. CaF2 material → Fragile and sensitive to the thermal variations Detector and Slit located close to the image plane → Increase the system complexity Grating → special profile to manage the very large spectral band

Conclusion

We have been made a survey of thirty hyperspectral systems. We summarized the range of the common parameters that are used to define spectrometer as following. The aperture number range comprises between 1.2 and 10. The mostly used aperture number is equal to 3. The GSD range comprises between 2.5 m and 45 m. The swath range comprises between 1.5 km and 300 km. Noted that the GSD and swath depend on the mission of the instrument. The spectral resolution comprises between 0.5 nm/pix to 15 nm/pix. The most compact system is the freeform Offner spectrometer in the dimension of 70 x 50 x 30 mm^3.