Multi-FOV Hyperspectral Imager Concept

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ABSTRACT

There is increasing interest in imaging spectrometers working in the SWIR and LWIR wavelength bands. Commercially available detectors are not only expensive, but have a limited number of pixels, compared with visible band detectors. Typical push broom hyperspectral imaging systems consist of a fore optic imager, a slit, a line spectrometer, and a two dimensional focal plane with a spatial and spectral direction. To improve the spatial field coverage at a particular resolution, multiple systems are incorporated, where the “linear fields of view” of the systems are aligned end to end. This solution is prohibitive for many applications due to the costs of the multiple detectors, coolers, spectrometers, or the space, weight, or power constraints. Corning will present a cost effective solution utilizing existing detectors combined with innovative design and manufacturing techniques.

Keywords: hyperspectral, imaging, spectroscopy

1. INTRODUCTION

Although hyperspectral imaging has been around for years, improvements in data processing and spectral libraries are leading to many new opportunities for the technology. There is particular interest in SWIR and LWIR wavelength bands for certain applications. The recent oil spill in the gulf is an example. Commercially available detectors for these wave bands are not only expensive, but have a limited number of pixels, compared with visible band detectors. Typical push broom hyperspectral imaging systems consist of a fore optic imager, a slit, a line spectrometer, and a two dimensional focal plane with a spatial and spectral direction.

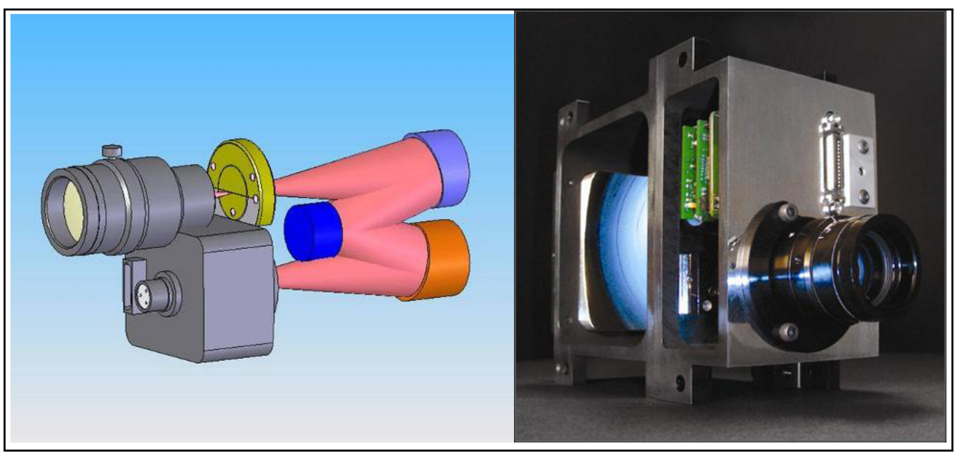

Figure 1: Offner based Spectrometer Example[1,2]

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Dyson Spectrometer Example[3,4] (Courtesy of The Aerospace Corporation) Reflective Fore Optic

Figure 2:

To improve the spatial field coverage at a particular resolution, multiple systems are incorporated, where the "linear fields of view" of the systems are aligned end to end. This solution is prohibitive for many applications due to the costs of the multiple detectors, coolers, spectrometers, or the space, weight, or power constraints. Corning presents a cost effective solution utilizing existing detectors combined with innovative design and manufacturing techniques.

2. CONCEPT

Many hyperspectral systems do not take advantage of the full detector area in the spectral dimension. In some cases less than 20% of the available area are active. The concept presented here takes advantage of the unused detector area, the imaging performance of the spectrometer's optical system, combined with innovative grating design, image splitting techniques, and multiple fore optics to cover multiple hyperspectral fields of view with a single spectrometer and detector.

The concept is particularly applicable to the optical performance of many "semi-symmetric" spectrometers such as Offners and Dysons to cover extended fields in the spectral direction, but can also be applied to other refractive and reflective designs. The basic concept is to have two or more slits at the entrance to the spectrometer, separated by more than the "diffracted field" at the final focal plane. (on a 1 to 1 system)

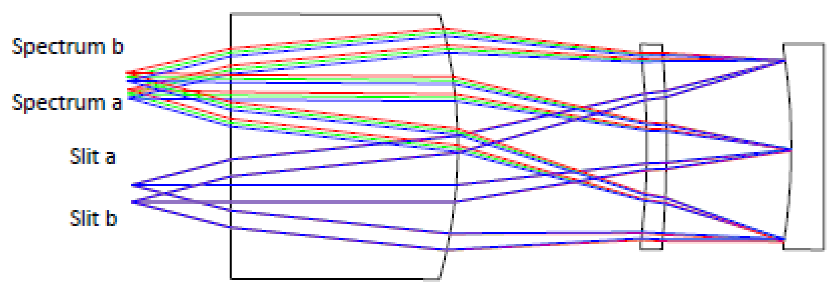
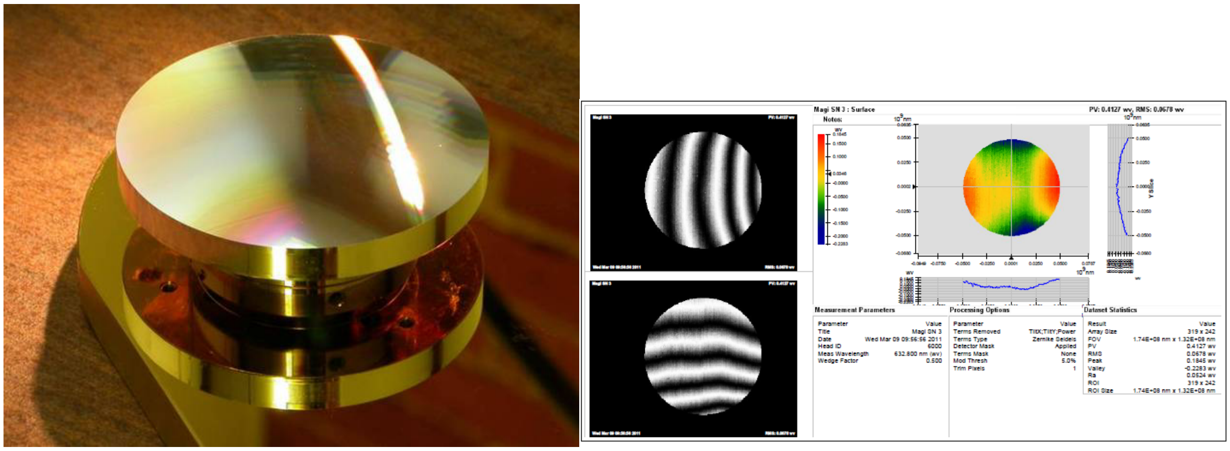


Figure 3: Dyson with dual slit and two spectral images on a common detector[3]

The grating profile can be designed to optimize efficiency and minimize "noise" between spectral fields.[5] Band pass filters, order sorting filters, or other techniques may also be incorporated. Corning has developed manufacturing processes to create a variety of grating geometries with precise mechanical alignment features in an aluminum substrate to assure thermal performance. Systems have been produced for applications for wavelengths from 380 nanometers through 12 microns.



Aluminum grating with integral mounting

Sample figure

(Courtesy of L3 Corporation)

Figure 4

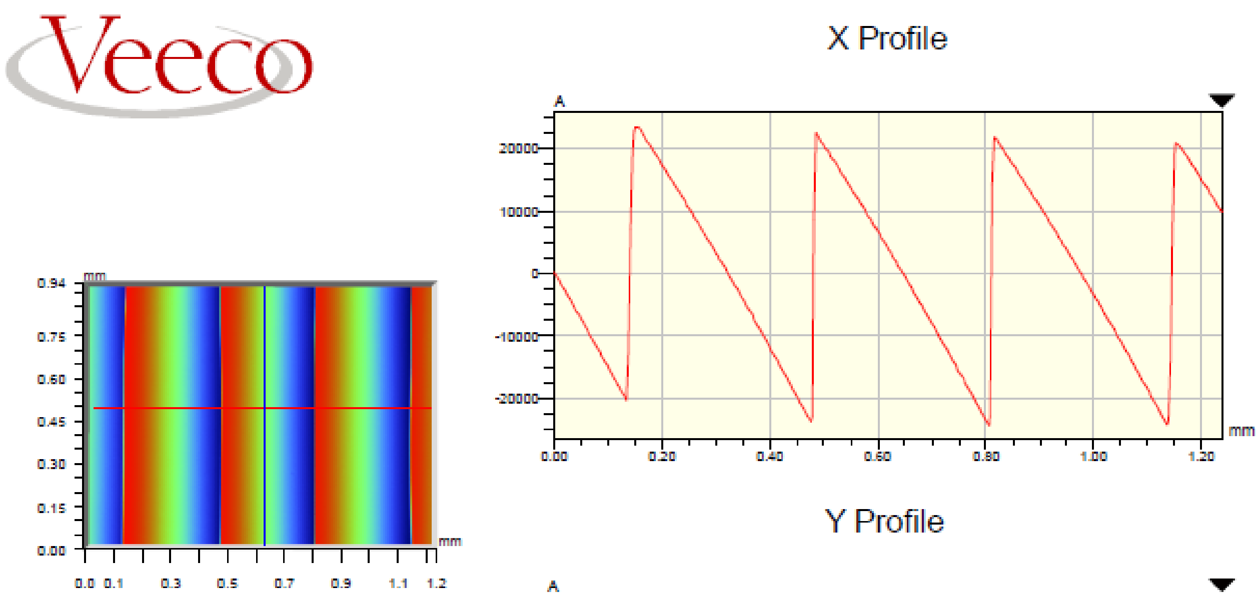


Figure 5: Single blaze grating profile data

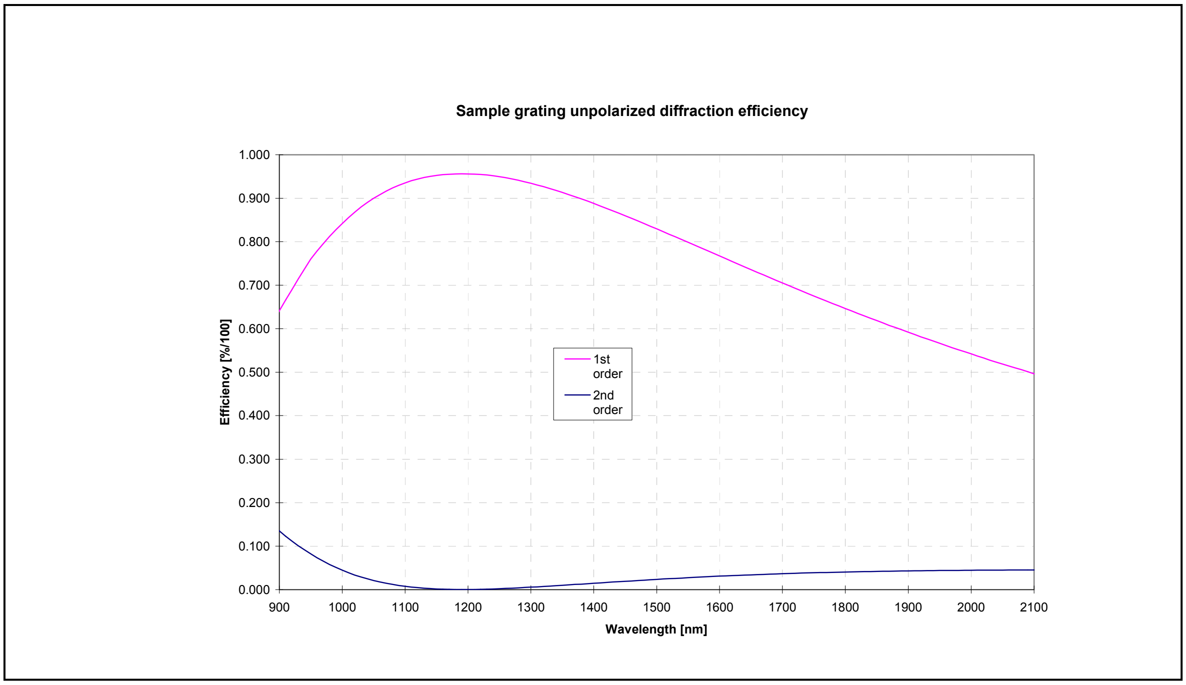


Figure 6: Grating efficiency optimized to minimize order overlap

"Pick off" mirrors are used between the slits and the multiple fore optics, to couple each fore optic to a single slit. Adjustments are incorporated to align one field to the other.

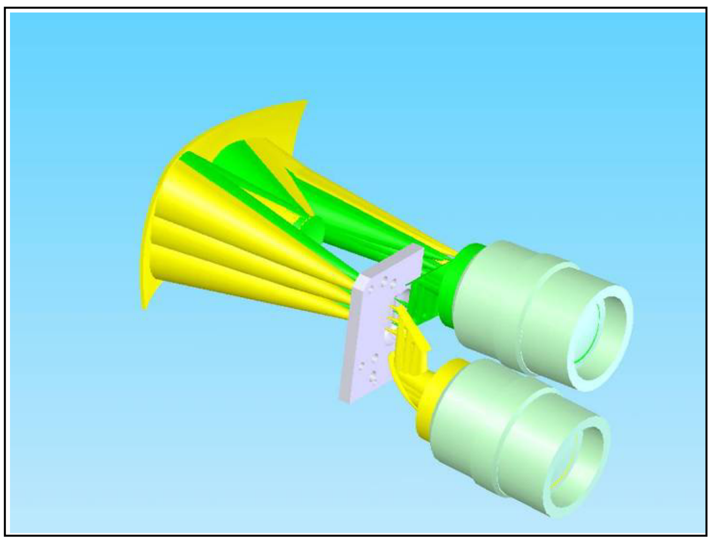
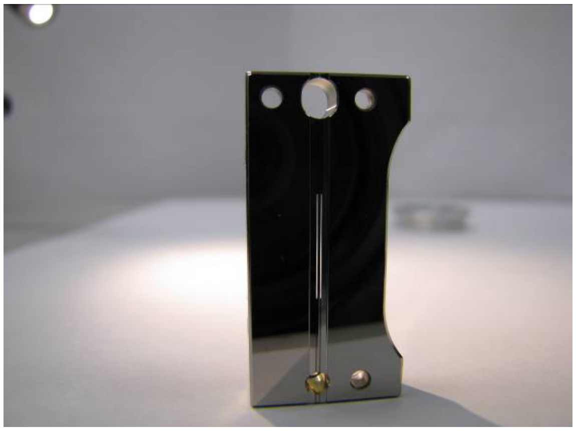
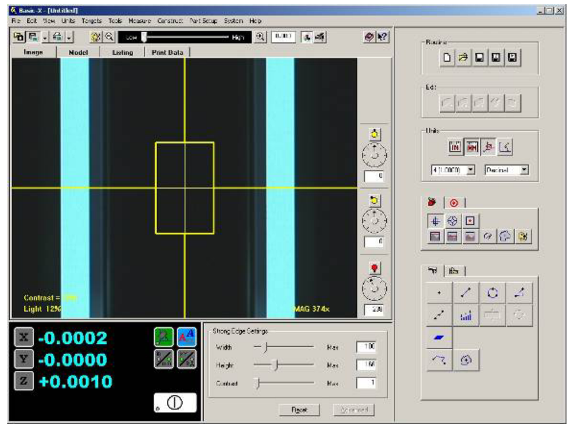


Figure 7: Dual slit Offner with two fore optics

For optimum performance, a spectrometer requires precise alignment between the slit, grating and detector. In this concept, the grating and detector are common to both optical systems. This means that the slits must be precisely aligned to each other. Below is an example produced with two "knife edge" slits in a common substrate, parallel to each other to well less than 1/10 of a pixel. These components are also manufactured in an aluminum substrate to be thermally compatible with a precision housing.



Monolithic knife edge dual slit



400x image of dual slit

Figure 8

Corning believes this approach provides a very cost competitive option to improve spatial resolution while reducing size and power requirements.

Corning has many units in the field and continues to manufacture hyperspectral units for multiple applications utilizing its proprietary manufacturing processes and designs. Corning's design capabilities can be applied to your application. If you have interest please contact Kevan Taylor at taylorkp@Corning.comor 603-903-6174.

REFERENCES

[1] Abe Offner, "Unit Power Imaging Catopric Anastigmat", patent # 3,748,015, Perkin Elmer Corporation, Norwalk, Ct, July 24, 1973

[2] J. M. Cobb, L. E. Comstock, P. G. Dewa, M. M. Dunn, and S. D. Flint, "Innovative manufacturing and test technologies for imaging hyperspectral spectrometers," Proc. SPIE 6233, 62330R (2006)

[3] J. Dyson, "Unit magnification optical system without Seidel aberrations," J. Opt. Soc. Am. 49, 713–716 (1959)

[4] David W. Warren, David J. Gutierrez, and Eric R. Keim, "Dyson spectrometers for high-performance infrared applications", Optical Engineering / Volume 47 / Issue 10, published online Oct 14, 2008

[5] Pantazis Mouroulis, Daniel W. Wilson, Paul D. Maker, and Richard E. Muller, "Convex grating types for concentric imaging spectrometers", Applied Optics/Vol. 37, No. 31/1 November 1998