HySpex High resolution, high speed hyperspectral cameras for laboratory, industrial and airborne applications.

Introduction:

Hyperspectral imaging, or imaging spectroscopy, combines the power of digital imaging and spectroscopy. For every pixel in an image, a hyperspectral camera acquires the light intensity (radiance) for a large number of contiguous spectral bands. Every spatial pixel in the image thus contains a continuous spectrum (in radiance or reflectance) and this can be used to characterize the objects in the scene with great precision and detail.

HySpex:

The HySpex line of hyperspectral cameras (or imaging spectrometers) is a result of the knowledge and experience accumulated through more than a decade (since 1995) of research activities (initially space and military projects) in the field of imaging spectrometry at Norsk Elektro Optikk AS. HySpex aims to be a compact, low-cost, high performance and versatile instrument for military and as well as civilian airborne, laboratory and industrial applications of imaging spectroscopy.

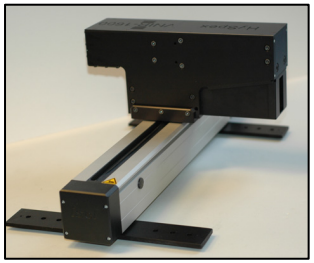

Figure 1. HySpex VNIR-1600 mounted on translation stage

The camera working principle is illustrated schematically in Figure 2. The aspheric focusing mirror projects an image of the scene onto a slit which only allows light from a narrow spatial line to pass. After the aspheric collimating mirror, a transmission grating separates the different wavelengths, and the light is focused by a lens system to an image on a 2d detector array, where one dimension is used for spatial separation and one dimension for spectral separation. The second spatial dimension is obtained by scanning the FOV in the direction across the slit.

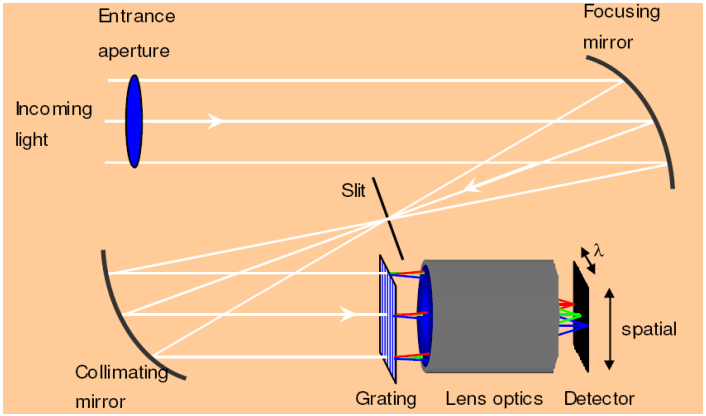

Figure 2. Schematic drawing of the HySpex optical system.

HySpex main specifications:

	VNIR-640	VNIR-1600	SWIR-320i	SWIR-320m
Detector	Si CCD 640*480	Si CCD 1600*1200	InGaAs 320*256	HgCdTe 320*256
Spectral range	0.4-1µm	0.4-1µm	0.9-1.7µm	1.3-2.5µm
Spatial pixels	640	1600	320	320
FOV across track(with field exp. fore optics)	18.4° (36.8°)	17° (34°)	14° (28°)	14° (28°)
Pixel FOV across/along tr.	0.5mrad/ 0.5mrad	0.18mrad/ 0.36mrad	0.75mrad/ 0.75mrad	0.75mrad/ 0.75mrad
Spectral sampl.	5nm	3.7nm	5nm	5nm
# of bands	128	160	160	256
Binning modes	1, 2, 4	2, 4, 8	-	-
Digitization	12bit	12bit	12bit	14bit
Max frame rate	500fps	135fps	350fps	100fps
Sensor head wgt	3.5kg	4.6kg	6.9kg	6.9kg
Sensor head dim. (lwh in mm)	315*84* 138	315*84* 138	320*140* 152	320*140* 152
Sensor head power cons.	~6W	~6W	~30W	~150W
FPA cooling T	-	-	~260K	~195K
Camera Interface	Camera-Link	Camera-Link	USB2.0 or Camera-Link	Camera-Link

Specifications are subject to change due to ongoing developments

Some of the main features of the spectrometer design are:

- Minimization and equalization of point spread function across the FOV and throughout the wavelength range (optimized in Zemax)
- Good matching of point spread function with pixel size
- Low stray light
- Low smile effect and spectral keystone effect
- Low polarization dependence
- 2nd order suppression (CCD cover glass replaced by filter mask)
- High sensitivity and low noise
- High acquisition speed and data rates
- Real time calibration of responsivity and dark offset
- Close-up lenses available for operation at short object distances
- Field expander available for doubling FOV
- Customized instrument versions are available upon request

All HySpex instruments are delivered with a dedicated camera control and acquisition software package, spectral and radiometric calibration data, a detailed test report, a users manual and necessary accessories such as cables, power supply and frame grabber. Optionally, an API (Application Programming Interface) in Visual C++ can be supplied for application specific software development. Exact synchronization with external events (e.g. navigation systems or illumination) is possible through TTL level trigger signals.

Airborne operation:

Figure 3 Aircraft used for HySpex operations

All HySpex camera models are very well suited for airborne data acquisition due to the high resolution combined with low weight and power consumption. For airborne systems, a special software and touch screen interface for easy operation can be supplied along with a high performance rack computer. Position/attitude logging systems from all leading navigation system suppliers can also be supplied and integrated with the HySpex system. The HySpex systems can also interface with the customer's existing navigational hardware. Airborne HySpex systems have been in operation since 2003.

Ground based field or lab operation:

All HySpex camera modules can be supplied with a rotation or translation stage which scans the FOV across the scene) making them ideal for acquisition of hyperspectral images of static scenes, either in the field or in a laboratory or a clinical environment. The scanning is fully integrated In the camera control software.

Figure 4. HySpex mounted on rotation stage and tripod.

Industrial applications:

Due to their extremely high acquisition speeds and real-time image correction features, the HySpex cameras (particularly the VNIR-640 and the SWIR-320i) are well suited for a wide variety of industrial applications such as material inspection or quality control. In a typical industrial application, the HySpex camera is mounted statically above a conveyer belt using the belt motion for scanning.

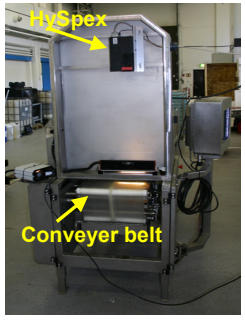

Figure 5. Industrial HySpex application

Custom solutions:

We also design and deliver customized solutions with specifications and performance adapted to specific applications. Please contact us to discuss your requirements and needs.

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HySpex application examples:

Military applications

NEO's HySpex instruments have participated in several multinational airborne and ground based defence research campaigns, through a close cooperation with the Norwegian Defence Research Establishment. The main study areas have been:

- Target/anomaly detection
- Target classification
- Signature analysis
- Application studies

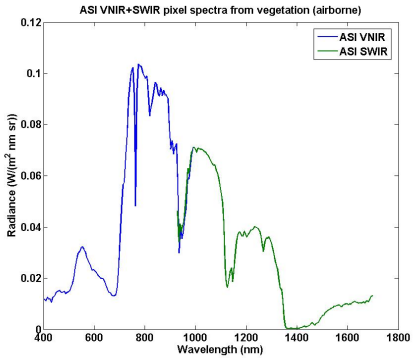

Figure 1. Airborne HySpex (ASI) pixel spectrum (VNIR+SWIR)

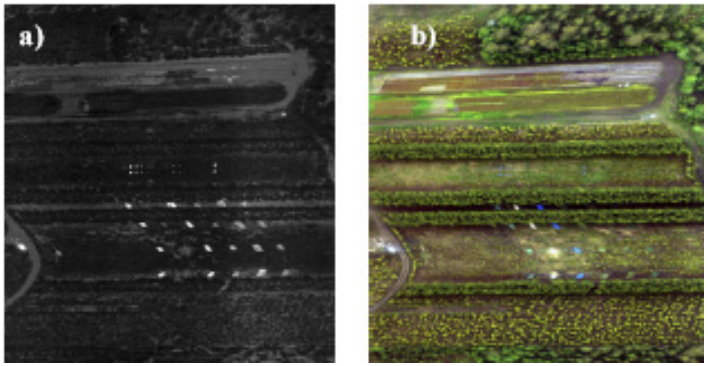

Figure 2. Airborne HySpex image (not georeferenced) of an array of simple ground targets of different colours located in sun and shadow. a) Sample anomaly image. Brighter shades mean lower probability of measuring the corresponding spectrum in the background. b) Three bands (RGB) from the corresponding hyperspectral image. [1] Note that even the green targets located in shadow are detected.

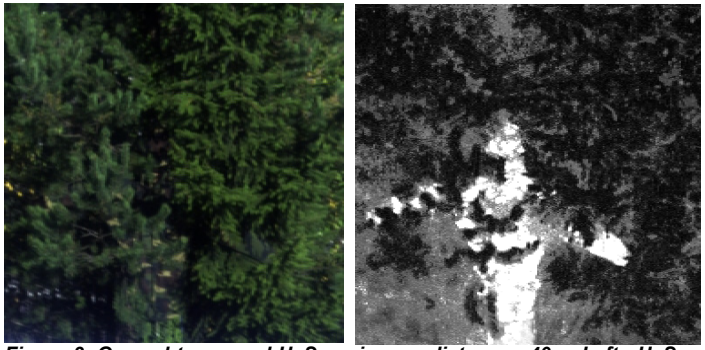

Figure 3. Ground to ground HySpex image, distance ~40m. Left : HySpex RGB image of camouflaged person. Right : Anomaly detection image.

Civilian airborne applications

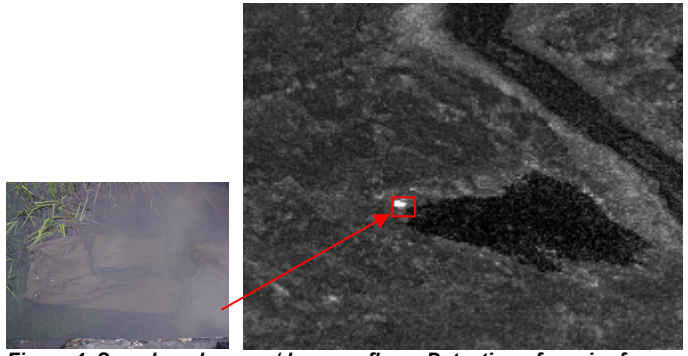

Figure 4. Search and rescue/decamouflage; Detection of a pair of trousers submerged in a mointain lake[2]. Left: Ground image of trousers in lake. Right: Airborne HySpex detection image, altitude:~1000m.

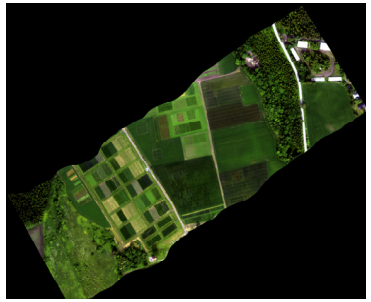

Figure 5. Precision farming project, Norwegian Crop Research Institute

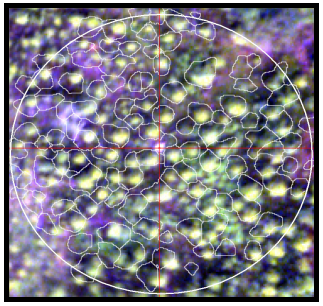

Figure 6. Tree crowns segmented from LIDAR data overlaid on hyperspectral HySpex image[3]

Geology:

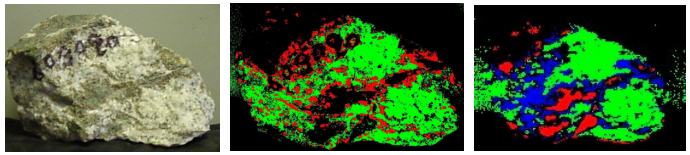

Figure 7. Mineral classification: Left: HySpex image of rock, middle: VNIR classification image, right: SWIR classification image.

Lab/medical:

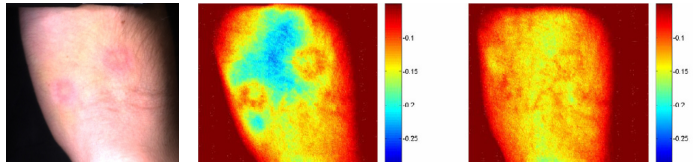

Figure 8. Biophysics/forensics: Age determination of bruised skin[4]. Left: HySpex VNIR RGB image. Right: Bilirubin index after 66h and 180h.

Industrial applications:

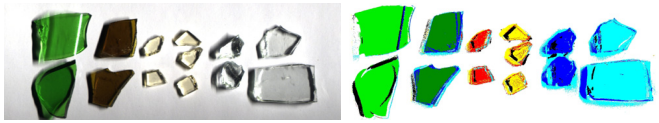

Figure 9.Glass cullet sorting: Left:HySpex RGB image of glass samples, right: VNIR classification image.

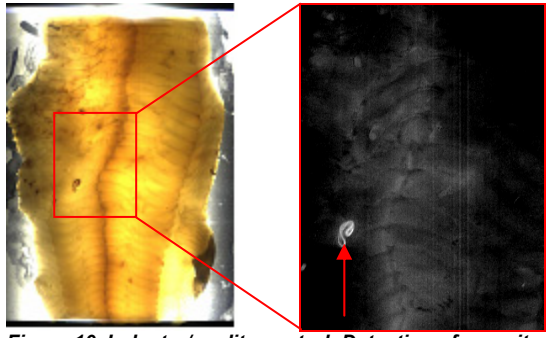

Figure 10. Industry/quality control: Detection of parasites in fish fillet, Fiskeriforskning. Left: HySpex RGB, right: HySpex detection image

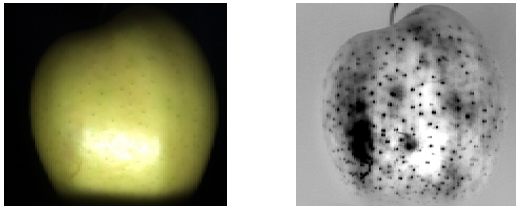

Figure 11. Detection of bruises on apples. Left: HySpex RGB image, right: PCA analysis image

Other applications:

Industrial:
- Paper industry
- Color printing
- Textile industry
- Mineral sorting
- Pharmaceuticals
- Chemical industry
- Chemometrics

Research/laboratory:
- Tissue sample analysis
- Blood analysis
- Chemical analysis
- Diagnostics/screening
- Cosmetics
- Fluorescence
- NIR-spectroscopy

Remote sensing:
- Geology
- Vegetation
- Glaciology
- Oil spills
- Environmental
- Urban planning
- Governmental

References:

1) "Target detection in hyperspectral images based on multi-component statistical models for representation of background clutter", Kåsen, et al, presented at SPIE European Symposium on Optics/Photonics in Security&Defence, October 2004.
2)" Hyperspectral target detection using the Airborne Spectral Imager", Skauli et al, presented at SPIE DSS Orlando, March 2005.
3) "Monitoring forest health by remote sensing of canopy chlorophyll: first results from a pilot project in Norway, Solberg et al, Journal of Arid Environments, April 2005.
4) "Hyperspectral Imaging of Bruised Skin"
Lise L. Randeberg, Ivar Baarstad, Trond Løke, Peter Kaspersen, Lars O. Svaasand, Proceedings SPIE BIOS 2006