Imaging Spectroscopy in ASI

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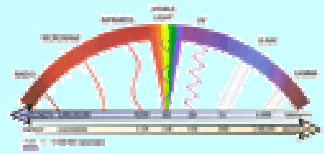
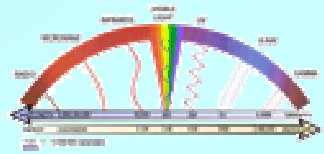
Presentation Outline



- Introduction
- COSMO/SkyMed
- ROSA
- Imaging Spectrometer
- Fourier Spectrometer
- Dispersing Spectrometer
- Conclusion

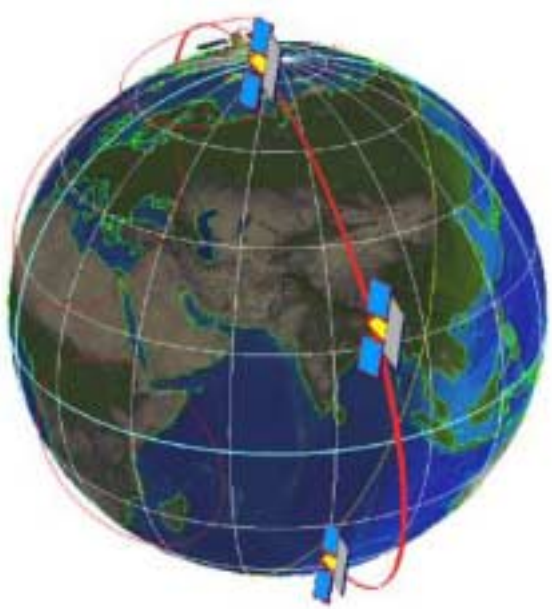
Introduction



- **Earth Observation is a top priority of the Italian Space Agency**
- **A better understanding of the Complex Physical Systems, like the Earth System, will require more and more sophisticated sensors with better spatial, temporal, radiometric and spectral resolution.**
- **Since long time ASI is promoting and funding the development of very challenging sensors for studying the Earth System:**
  - **COSMO/SkyMed Mission;**
  - **ROSA Radio Occultation Sounder for Atmosphere ;**
  - **Imaging Spectrometers .**

COSMO/SkyMed Mission

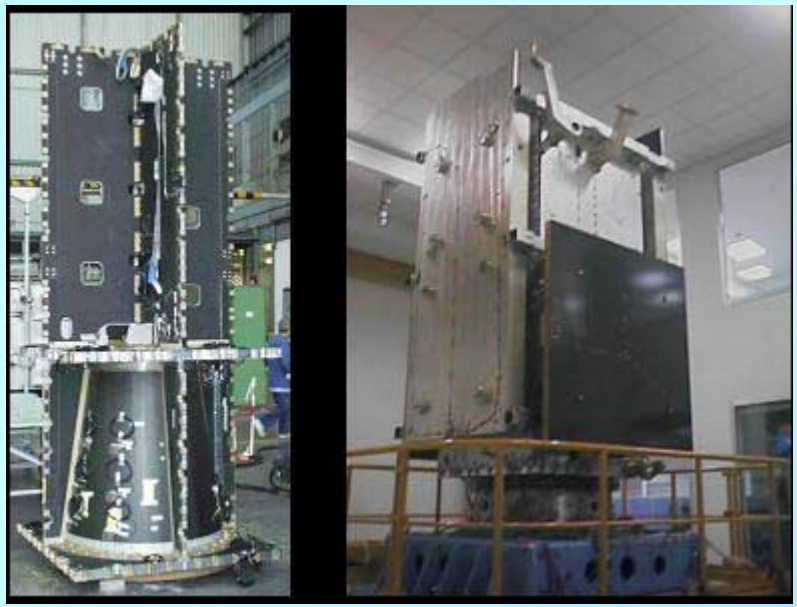
- Dual Mission
- Every–Time Global Coverage ;
- Very short Revisiting Time;
- High Spatial Resolution images
- Data Products with different spatial resolution and different view angle
- Time Frame : 2006-2013.

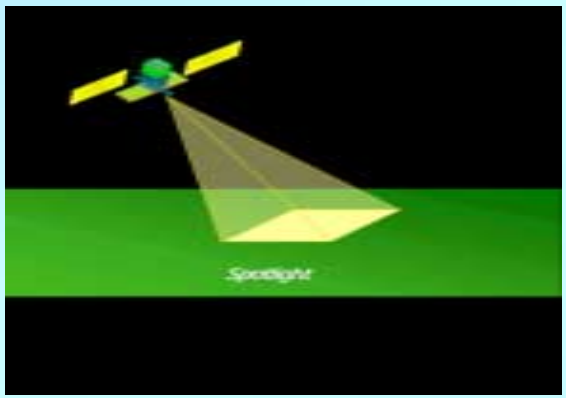


- Risk Management
- National Security
- Environment Monitoring ;
- Agricolture
- Geology
- Forestry
- Cartography

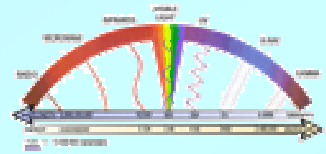
COSMO/SkyMed Mission

- Constellation of 4 LEO satellites ;
- Very performing Satellites;
- Sintetic Aperture RADAR
  in X band, multi-modes,
  with electronic scansion
  of the beams;



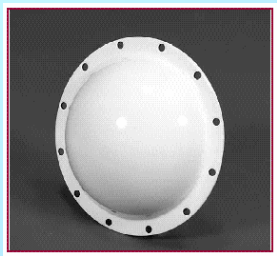


ROSA



One of the ASI Contribution to the understanding of Climate Change is the GPS Radio Occultation Experiment

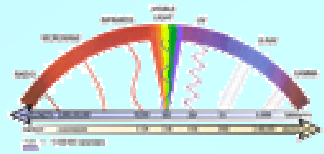
ROSA (Radio Occultation Sounder for the Atmosphere) is the ASI Radio Occultation Instrument



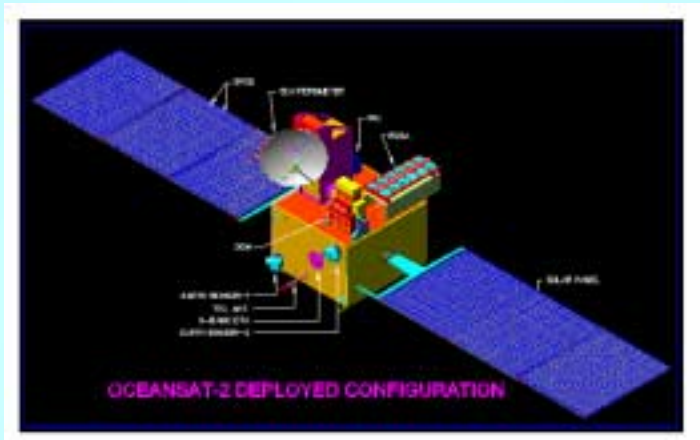
Main objectives :

- **Meteorology/Climatology (temperature and Humidity profiles)**
- **Space Weather (electrons density profiles in the ionosphere)**
- **Solid Earth Physics (POD)**

ROSA

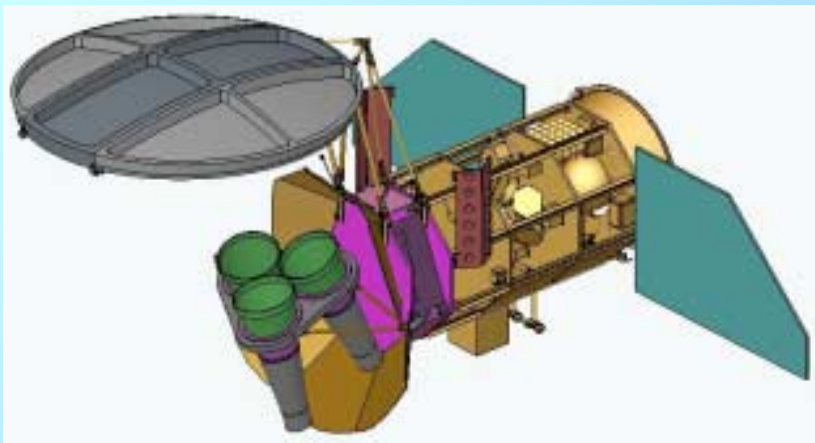


The needs of global and very large number of occultations require many ROSA like instruments

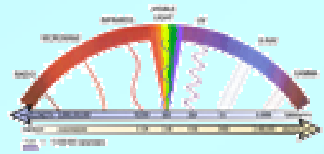


ASI is looking to install ROSA on several missions:

2007	**OCEANSAT-2**
2009	**Aquarius/SAC D**
2010	**BISSAT**



Imaging Spectrometers



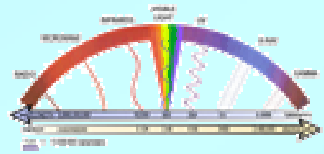
A complete knowledge of the spectral signature of complex land ecosystem based on:

- **Large number of spectral channels**
- **Contiguous spectral channels**

in many cases can be more useful than the knowledge of its very detailed geometrical property

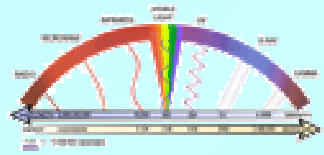
The number of potential data-products obtainable by these sensors could be very high, useful and of benefit in several fields of Earth Observation

Imaging Spectrometers

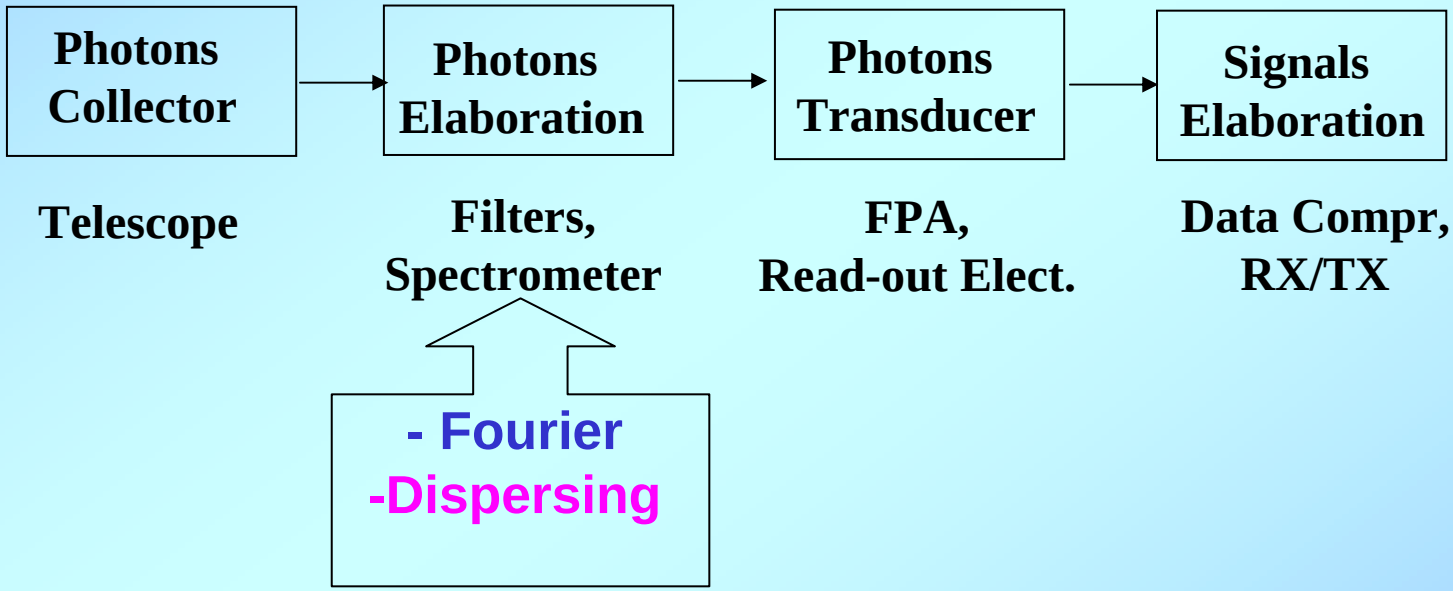


	LAND			SEA	SECURITY
	Geology	*Vegetation*	*Other App.*		
Spectral Range (μm)	0.4-2.5	0.4-2.5	0.4-2.5	0.4-2.5	0.4-12
Spectral resolution (nm)	10	10	10	5-10	10
S/N VIS (0.4-1.0 μm)	300	400	300	1000	500
S/N SWIR (1.0-2.5μm)	200	200	200	500	300
GSD (m.)	20	10-50	20	20-100	<1-30
Swath (Km.)	20-50	20-50	20-50	100	Variable
Revisiting Time	3m.	1w.	1w-1m	1w	1d-1w

Imaging Spectrometers



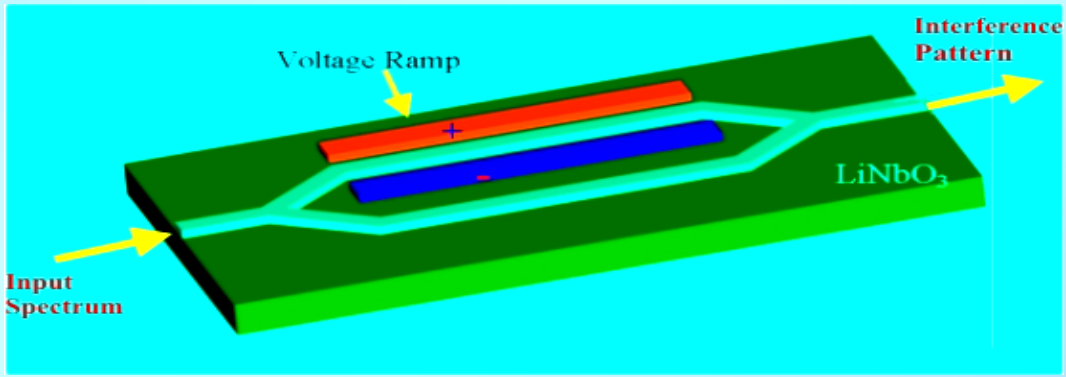
Any Sensor, like Imaging Spectrometer is made up, mainly, of the following blocks :

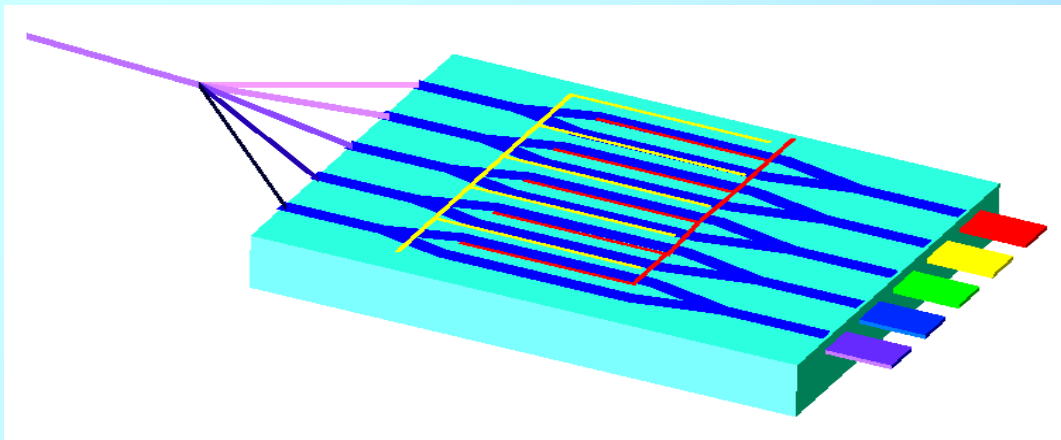


Fourier Spectrometer

Mach-Zehnder Interferometer
MEOMS

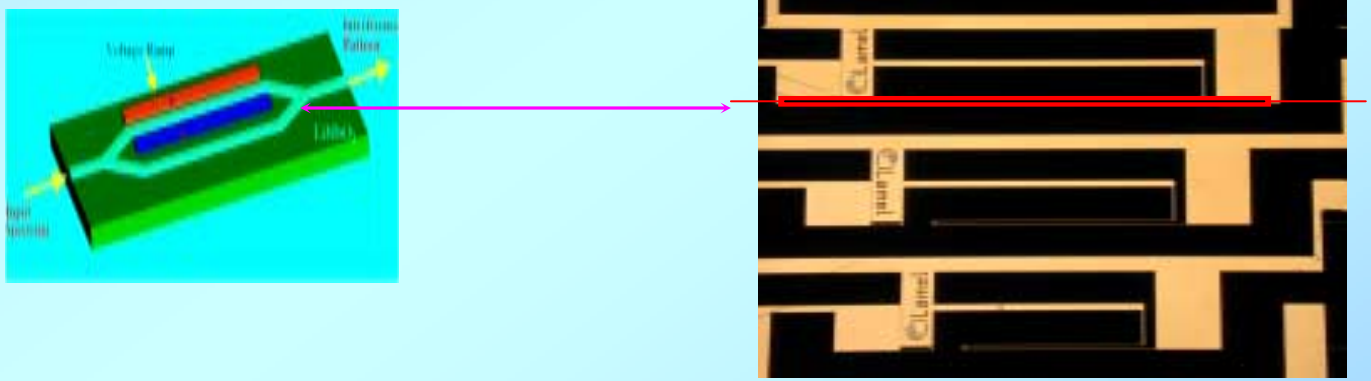
This instrument, a MOEMS (Micro Opto-Electro-Mechanical System) has been developed to work in the spectral band 0.4-4.5 mm, with an expected spectral resolution of about 0.1 nm. It is made up of an array of Mach-Zehnder micro-interferometers integrated on the same hybrid chip together with the driving electronics





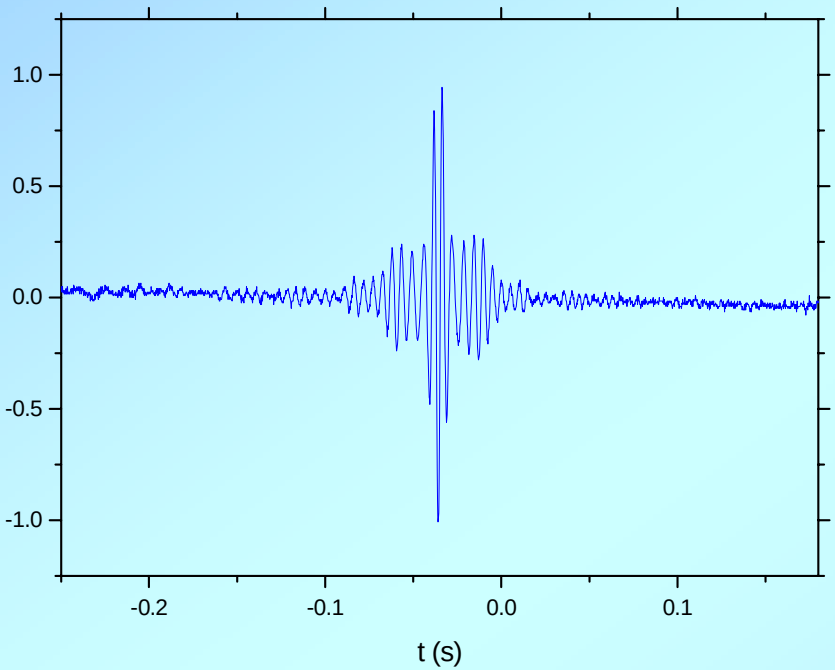
Fourier Spectrometer

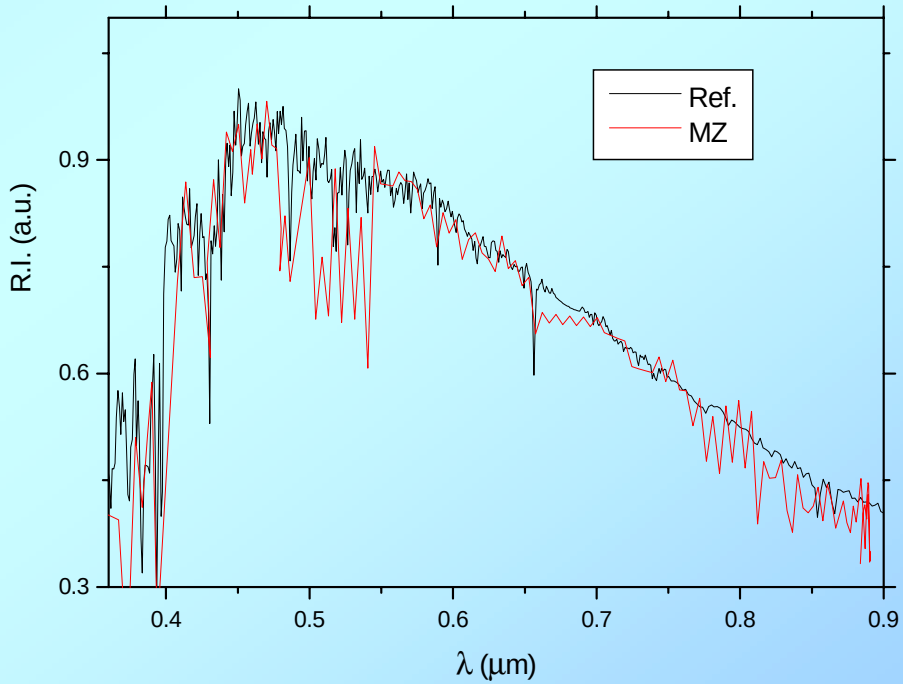
Mach-Zehnder Interferometer



Fourier Spectrometer

Solar Spectrum



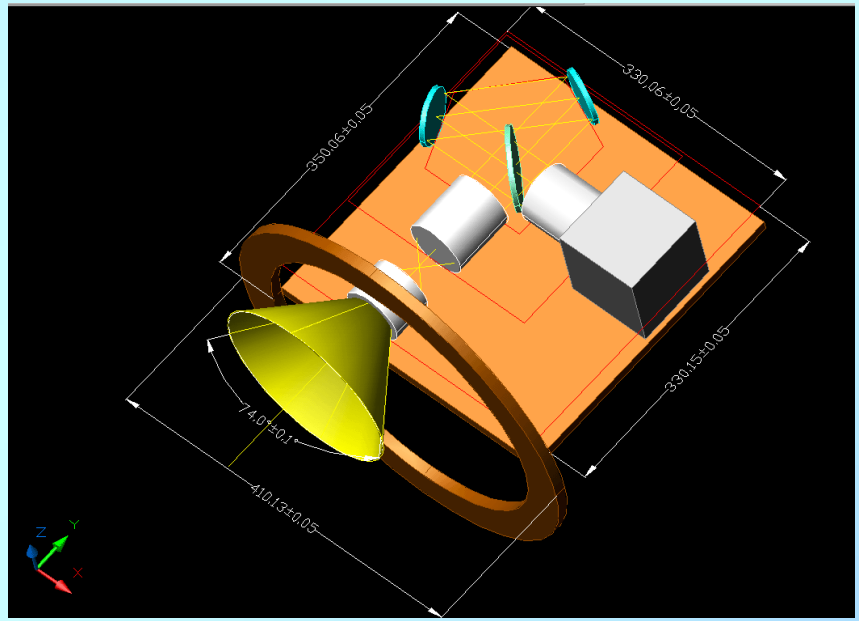


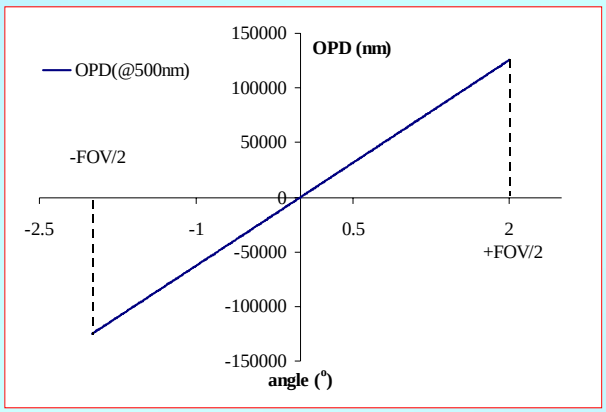
Fourier Spectrometer

SAGNAC

This device uses a new image plane interferometer geometry to produce "autocorrelation function modulation" in the focal plane of the 2D array detector

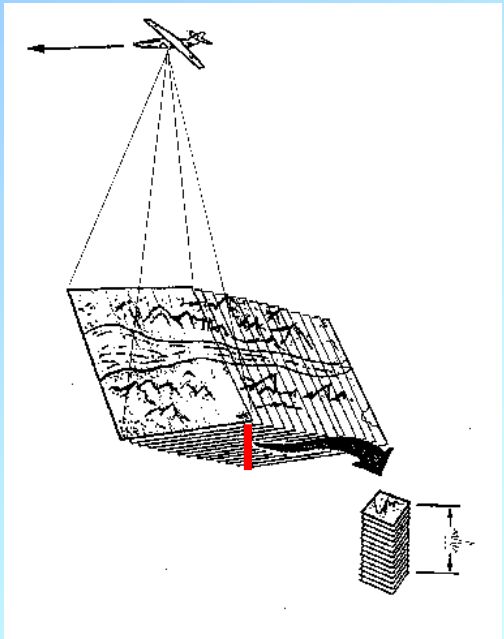
The fundamental component of this kind of interferometers is a beam splitter (semitransparent plate) that provides phase delay between the two interfering rays





- **The Optical Path Difference (OPD) linearly changes by varying the angle of the incoming ray with respect to the instrument optical axis.**

Fourier Spectrometer

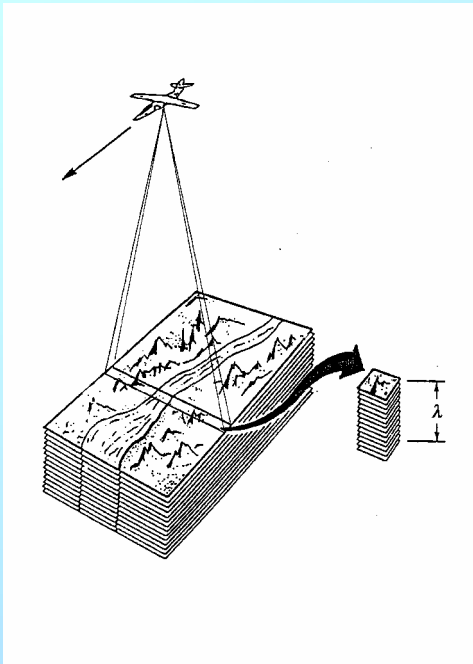


Leap-frog Technique

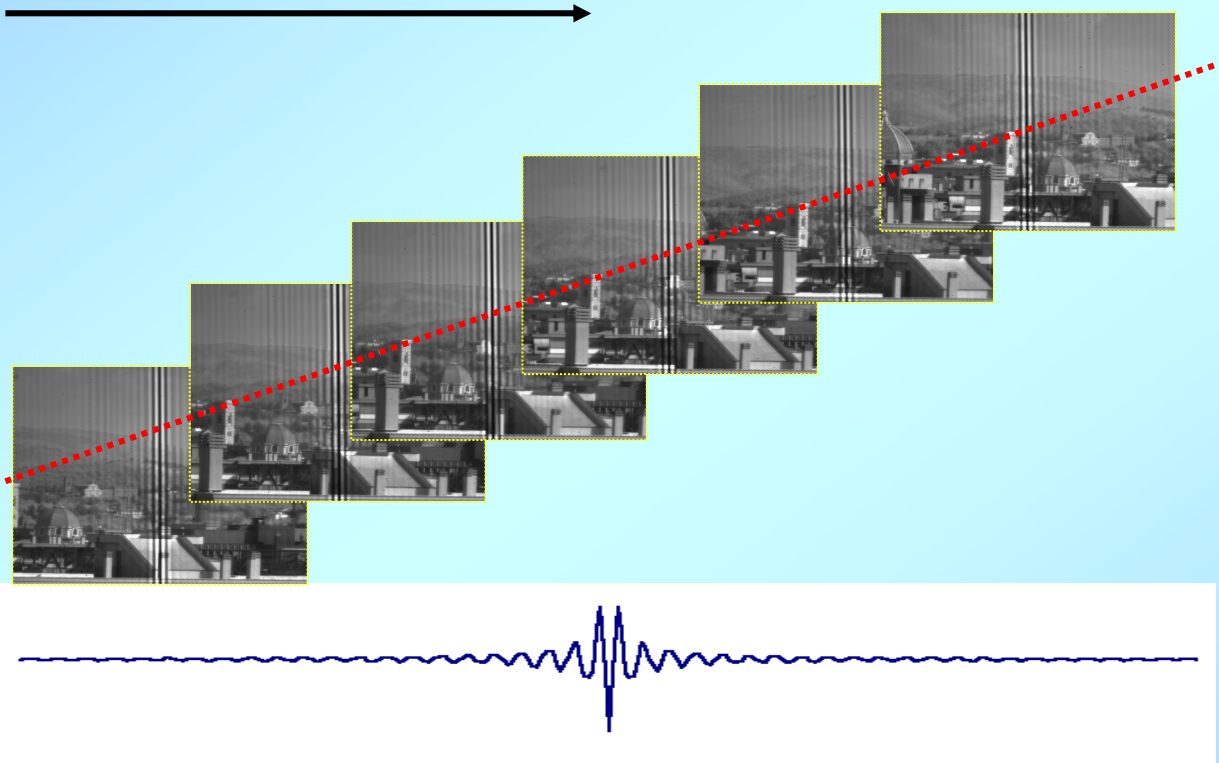
- Every frame contains the observed scene superimposed to the stationary interference pattern
- The interferogram related to the same pixel is dispersed along the diagonal of the data-cube

Dispersive Technique

- Energy from each pixel is dispersed spectrally and every plane is a monochromatic image of the scene



Fourier Spectrometer

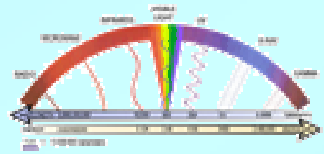


Spatial resolution = 22 cm/pixel

FOV = 4º (225 m @ 4 km)

1024 X 1024 pixel

Fourier Spectrometer



The Mach-Zehnder and the Sagnac spectrometers , with others technological payloads are planned to flight on the ASI Small Tecnological Mission .
The foreseen launch date of this mission is the first quarter of 2008

Dispersing Spectrometers

HERITAGE

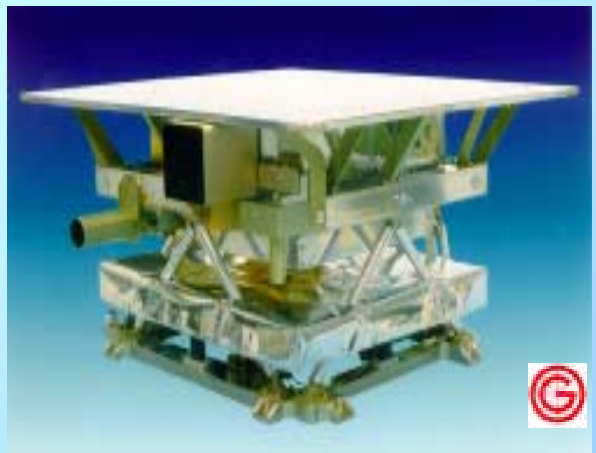
VIMS
Visible InfraRed Mapping
Spectrometer

VIMS-V is ASI contribution to the CASSINI Mission

VIRTIS

Visible InfraRed Thermal Imaging
Spectrometer

VIRTIS is ASI contribution to the ROSETTA Mission and to the next planetary Mission VENUS Express



Dispersing Spectrometers

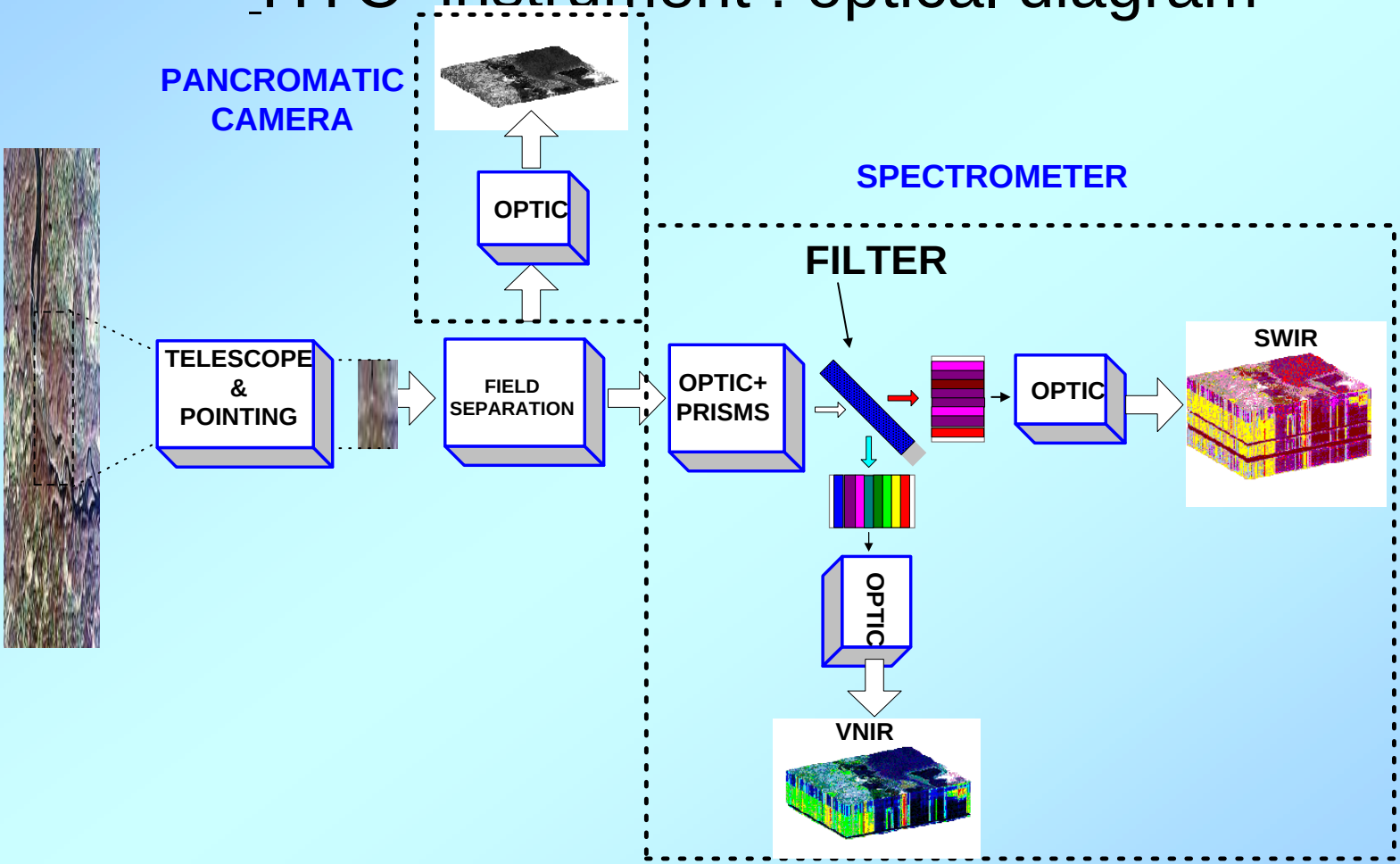
In 2001 ASI decided to perform the Phase B activities of a demo and low cost hyperspectral mission called HypSEO (HyperSpectral Earth Observer)

<u>main tasks</u>

- **validation of the Hyperspectral Sensor**
- **testing of the hyperspectral data capabilities**
- **Italy's know-how improvement and interest to have a p reeminent role in the imaging spectroscopy field.**

Dispersing Spectrometers

HYC instrument : optical diagram



Dispersing Spectrometers

HYC instrument : Electro-optical characteristics

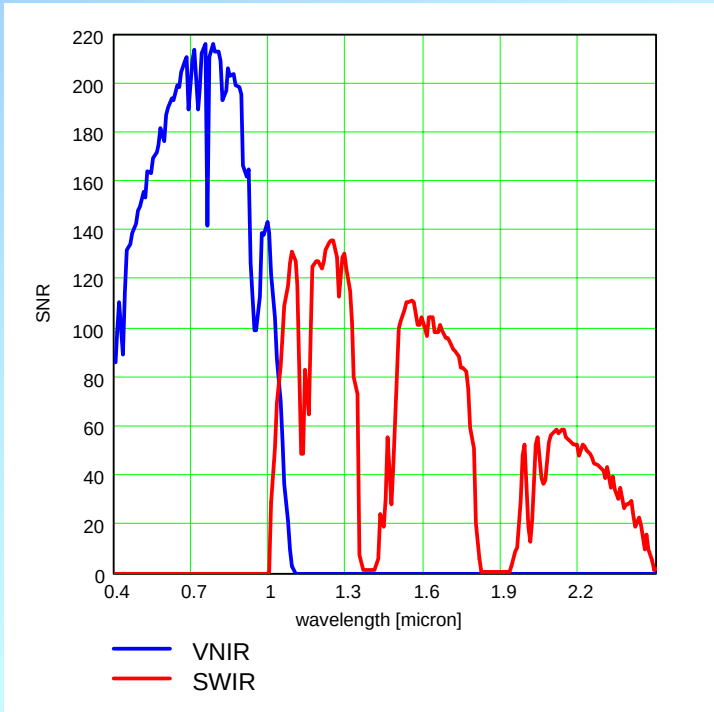
CAMERA	Spectral Range	Spect. Res.	N° channels	S/N
VNIR	400-1000 nm	≤ 10 (40) nm	≥60	200
SWIR	1000-2500 nm	≤ 10 (40) nm	≥150	100
PAN	500-900 nm	NA		160

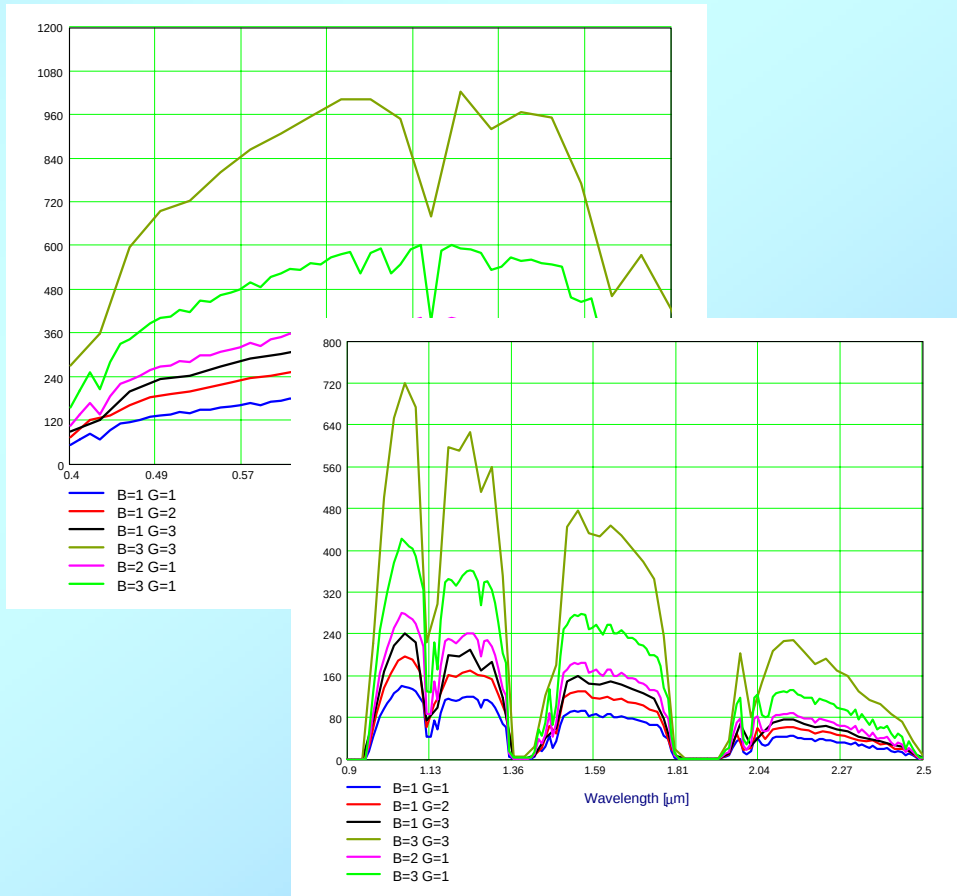
Scanning technique : Pushbroom

Swath width @619 Km	≥ 20 Km
PAN Spatial Resolution. @619 Km	≤5 m.
Hyper Spatial Resolution@ 619 Km	≤20m (80m)
MTF tot.@ Nyquist freq.	≥ 0.2
F.o.R	±22 °

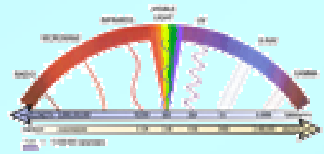
Dispersing Spectrometers

VNIR-SWIR Typical SNR with binning and grouping





CIA

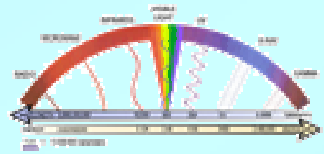


In 2003, the interesting results achieved during the demonstrative program HypSEO convinced ASI to stop the activities in favour of an operational Hyperspectral Mission based on a new advanced payload CIA (Advanced Hyperspectral Camera)

The first step was to investigate possible improvements of the HYC payload in terms of:

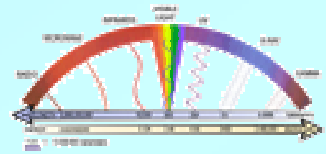
- **Spatial coverage (Swath) of the hyperspectral channels**
- **Spatial resolution (GSD) of PAN channel**
- **Spectral coverage extension by means of auxiliary instruments (MIR and TIR)**
- **Simplification of the overall configuration by using agile satellite (no scanning mirror need)**

CIA



	PAN Channel	*VNIR / SWIR Channel*	*MIR Channel*	*TIR Channel*
Scanning Mode	**Pushbroom**			
Spectral Range [nm]	**500-900**	**400-1000 / 1000-2500**	**3000-5000**	**8500-12000**
N° Spectral Bands	**1**	**210**	**3**	**4**
Spectral Resolution (average) [nm]	**NA**	**10**	**200**	**500**
Selectable up to		**40**		
Spatial Resolution [m] @H	**4**	**20**	**100**	**100**
Selectable up to		**80**		
Swath [Km]	**40**	**40**	**100**	**100**
Field of Regard (FOR)	**± 22.5°**			
Spectrometer	**NA**	**Prisms**	**NA**	**NA**
MTF Fnyq	**> 0.2**			
SNR (typical)	**200**	**200 VNIR 130 SWIR**	**NA**	**NA**
NEDT [K]			**0.1**	**0.1**
Quantization [bit]	**12**			
Average Power [W]	**tbd**			
Mass [Kg]	**350**			
Operating Life	**> 5 years**			

Conclusion



Based on the previous independently performed significant activities in the hyperspectral field (HypSEO,CIA, HERO etc.) the Presidents of CSA (Canadian Space Agency) and ASI (Agenzia Spaziale Italiana) on the 18° of October 2005 have signed an agreement on Cooperation in a Joint Definition Phase of a Hyperspectral Mission.

The expected launch date is 2009

Thanks for your attention