



A novel Hyperspectral Camera
and its application in Earth observation

INNOVATIVE

SME COMPANY

SPIN – OFF

of POLITECNICO di MILANO

MAY 2018

INCORPORATION

FACILITIES

BOVISA AREA – MILAN

7 PEOPLE

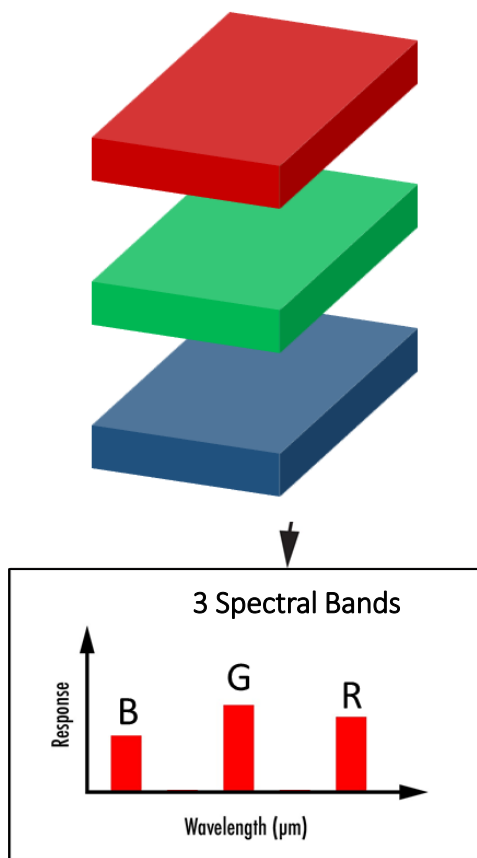
EMPLOYED

> 80 YEARS

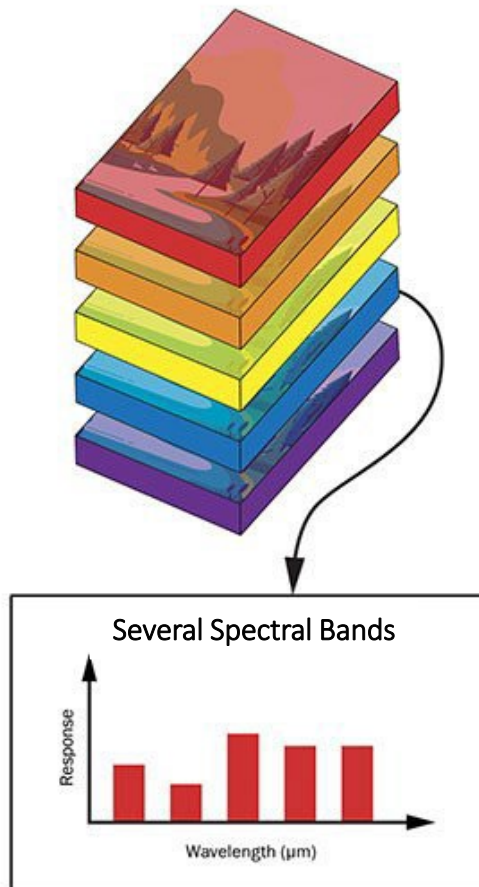
CUMULATIVE EXPERIENCE IN PHOTONICS

We develop and manufacture novel devices for **SPECTROSCOPY**:
interferometers, spectrometers, & **hyperspectral cameras**

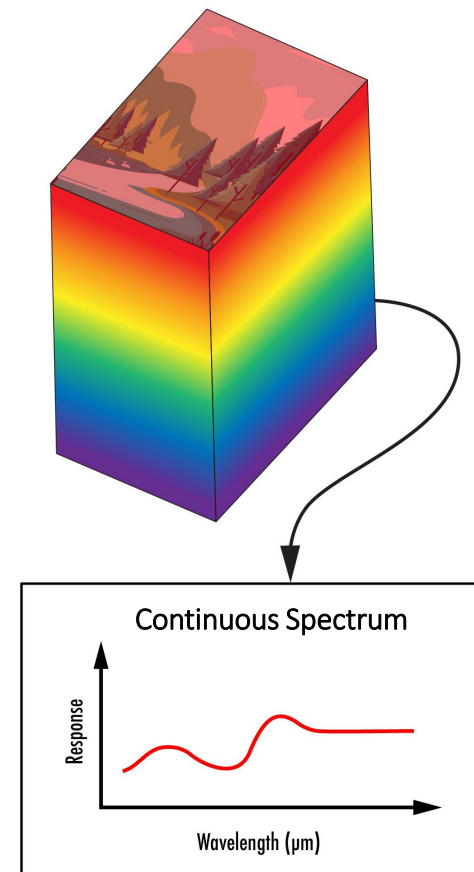
RGB



Multi-spectral Imaging



Hyper-spectral Imaging



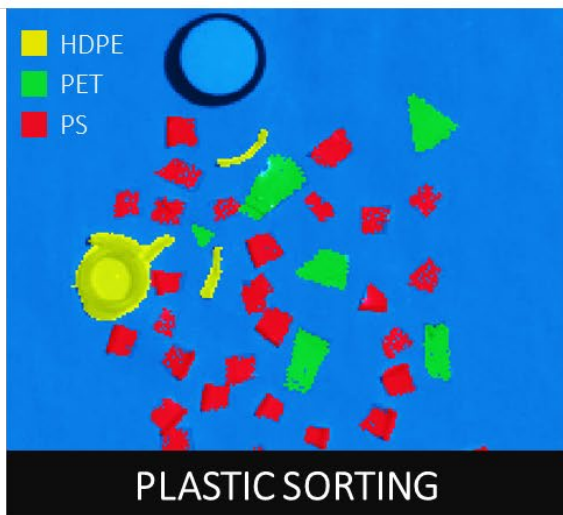
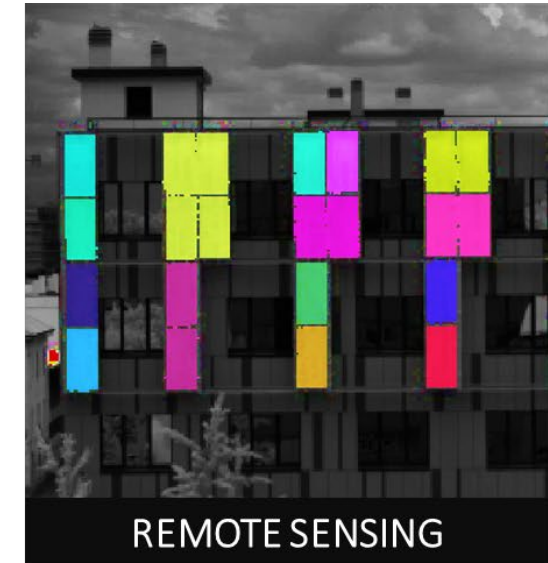
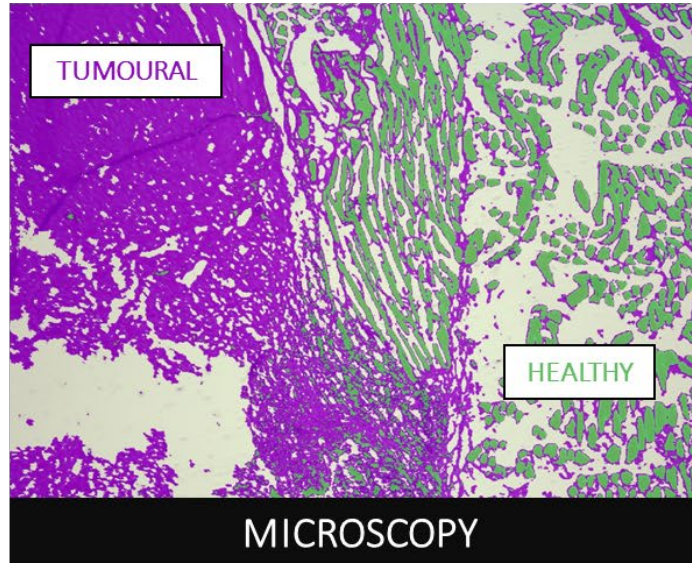
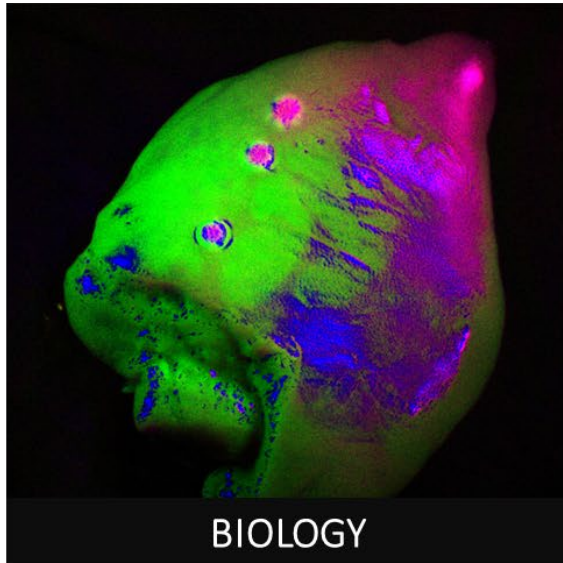
SWIR
(900-1700 nm)



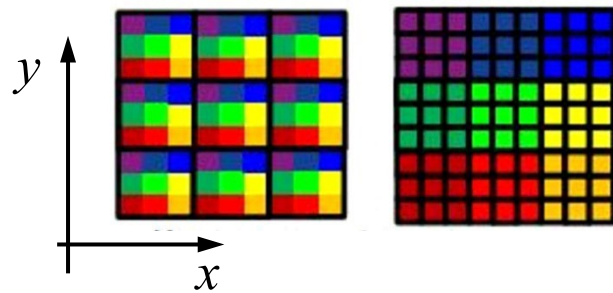
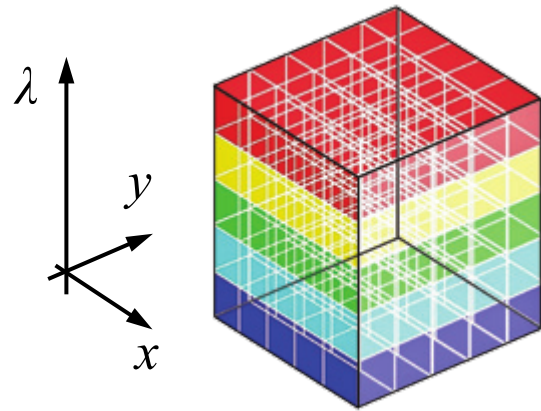
VIS-NIR
(400-1000 nm)



Applications of Hyperspectral Imaging



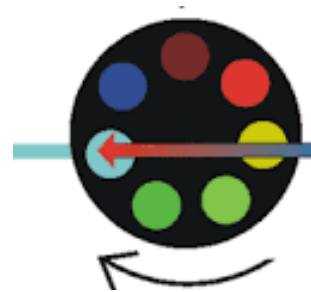
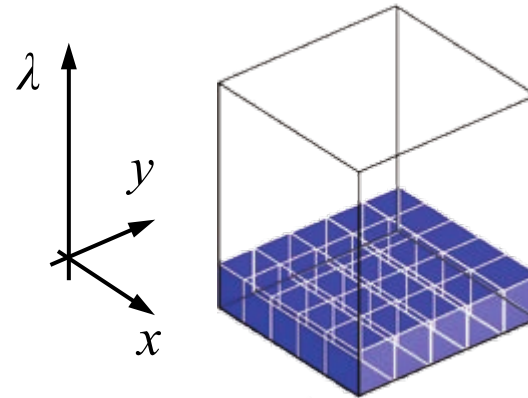
SNAPSHOT



Mosaic 2D sensor

Discrete number of bands

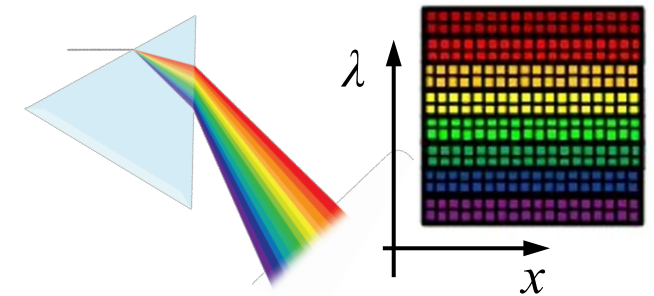
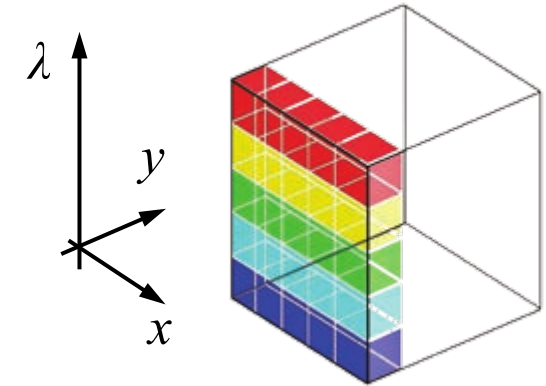
STARING



Tunable filter
Spectral scanning

Discrete number of bands

PUSH-BROOM

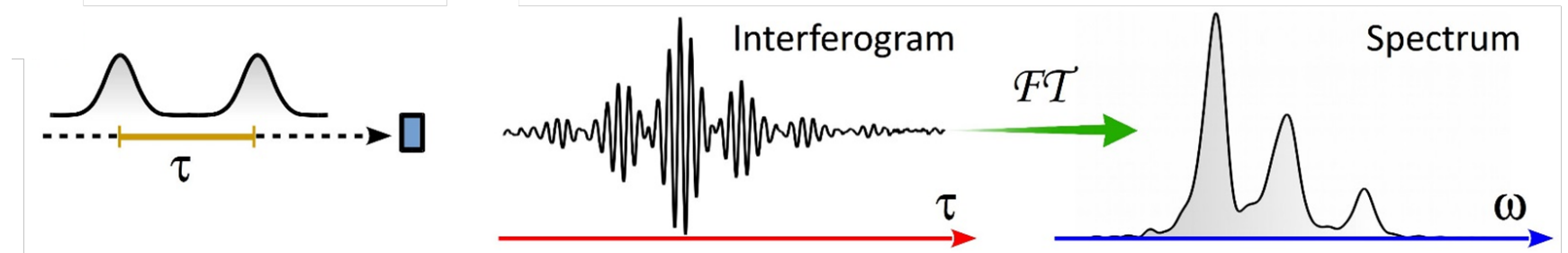


Dispersion + 2D sensor
Spatial scanning

Continuous spectrum

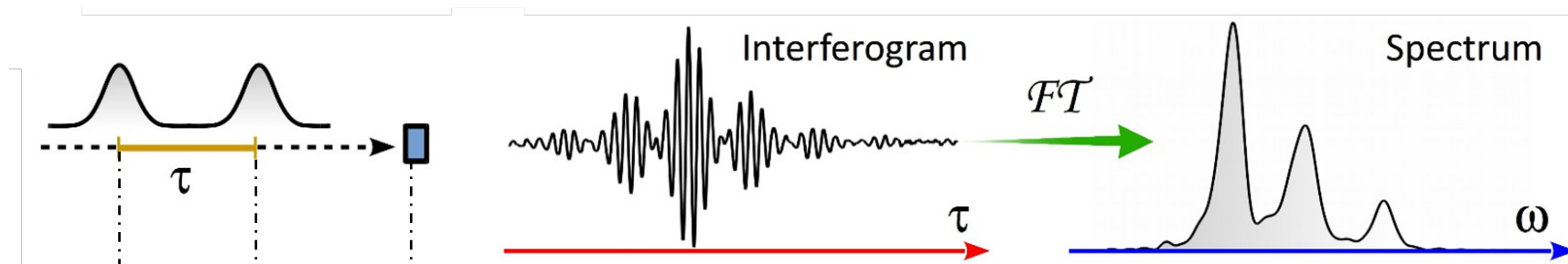
Our approach – Fourier Transform Spectroscopy

FTIR spectrometer
(single pixel detector)

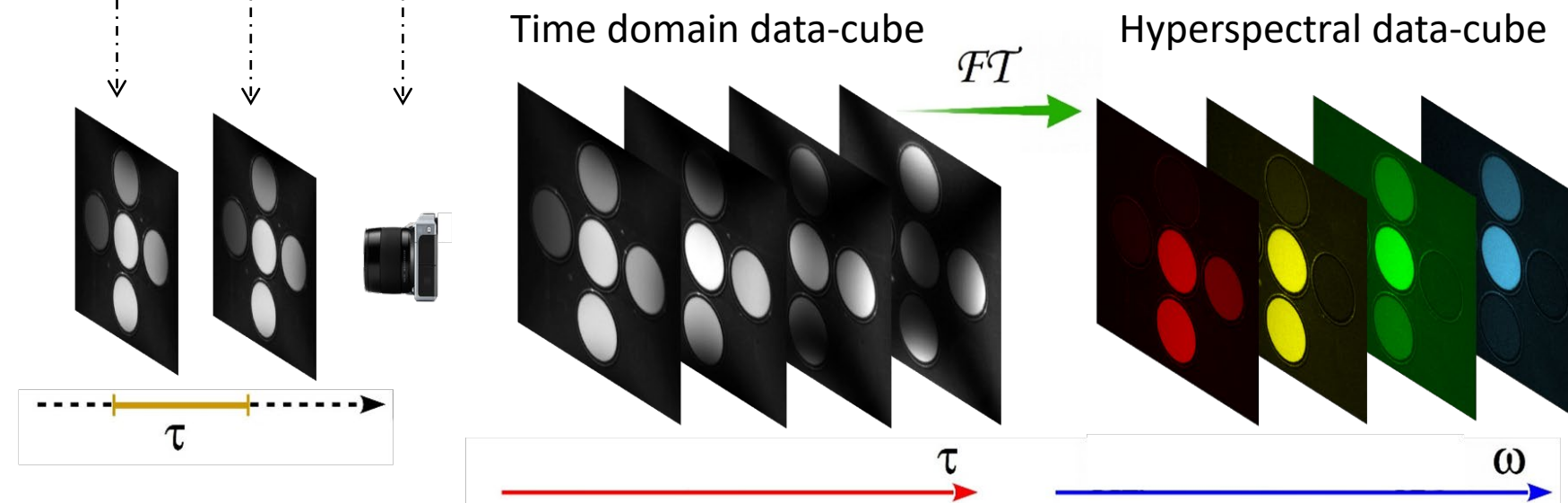


Our approach – Fourier Transform Spectroscopy

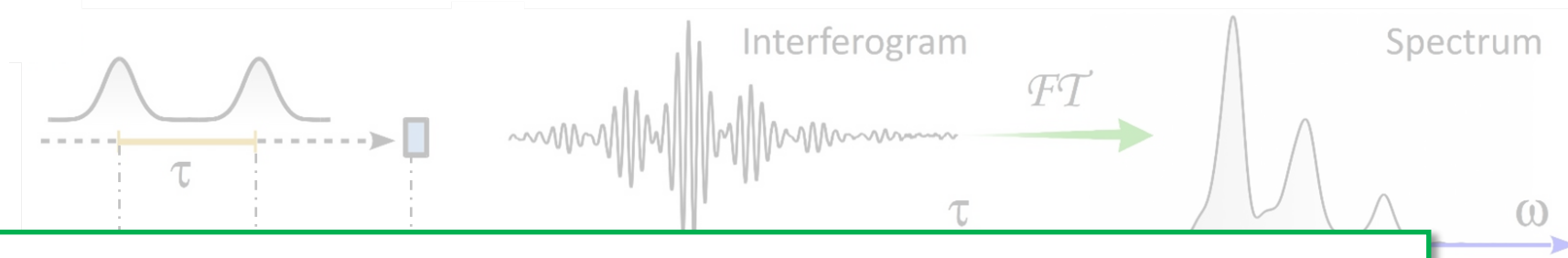
FTIR spectrometer
(single pixel detector)



FTIR Hyperspectral camera
(2D detector)



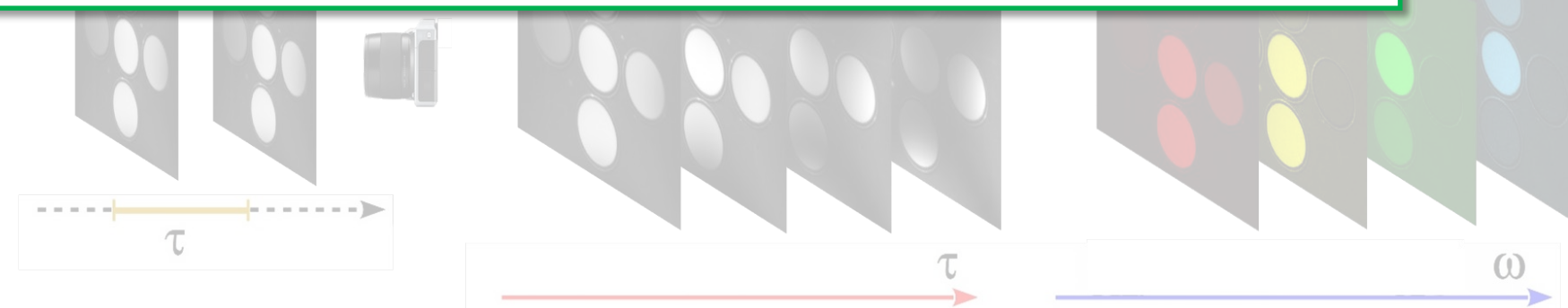
FTIR spectrometer
(single pixel detector)



ADVANTAGES OF OUR FT APPROACH

1. High optical throughput
2. Tunable spectral resolution (via software)
3. Lightweight & Compact
4. Highly stable and broadband interferometer (common-path, based on birefringence)

FTIR Hyperspectral camera
(2D detector)



GEMINI
INTERFEROMETER




NIREOS

“An Ultracompact Hyperspectral imager in the **Thermal Infrared**”
(3 – 14 μm)



The Open Space Innovation Platform (OSIP)



Consiglio Nazionale delle Ricerche Istituto di Fotonica e Nanotecnologie - Milan, Italy



NIREOS S.R.L. - Official Spin-Off company of Politecnico di Milano, Milan, Italy



BBT Materials Processing, Ltd., Prague, Czech Republic

Spectral imaging of Earth surface and atmosphere:
enables monitoring various ecosystem and natural aspects, such as

VOLCANOES AND EARTHQUAKES

- transient thermal anomalies preceding eruptions
- Atmospheric gases (SO_2 , ash and water ice in the eruptive plumes)

WILDFIRES

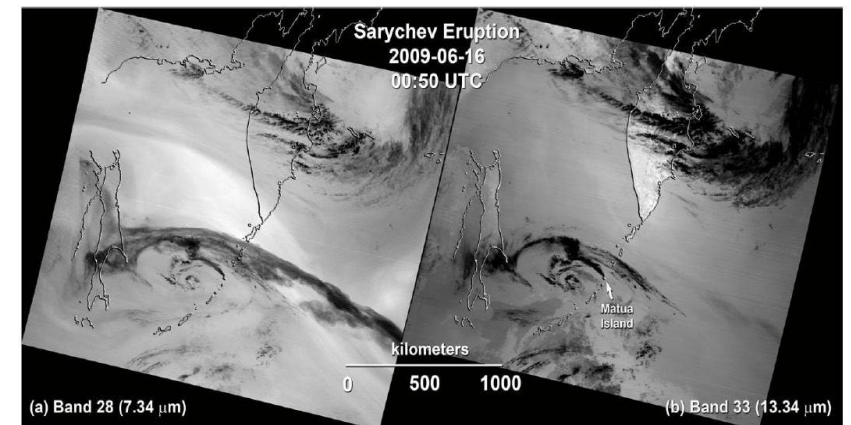
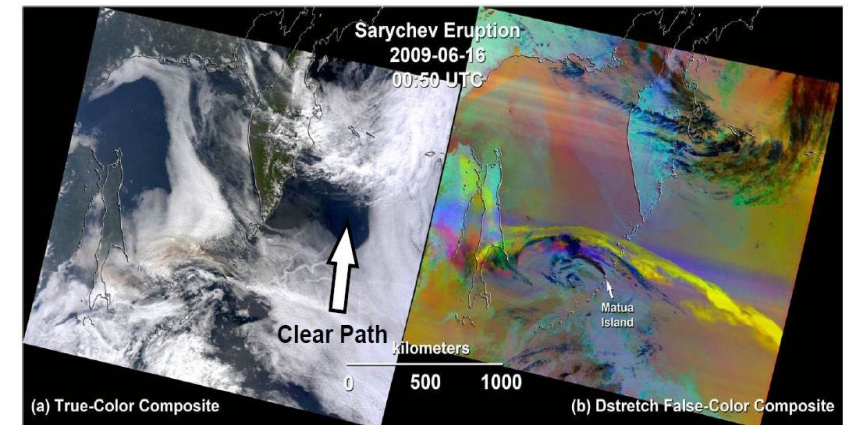
- burning biomass

WATER USE AND AVAILABILITY

- global freshwater supplies
- Water resources
- Ice

EARTH SURFACE COMPOSITION AND CHANGE:

- Composition and thermal properties of the surface of the Earth
- Monitoring of Mining Areas
- Plastic patches, ghost nets, marine pollution



Spectral imaging of Earth surface and atmosphere:
enables monitoring various ecosystem and natural aspects, such as

VOLCANOES AND EARTHQUAKES

- transient thermal anomalies preceding eruptions

MORE INFO:

Dr. Manzoni (CNR) is giving a talk on our technology

@ 4S Symposium (Small Satellites Systems and Services)
Vilamoura (Portugal)

W

W

Water Resources

- Ice

EARTH SURFACE COMPOSITION AND CHANGE:

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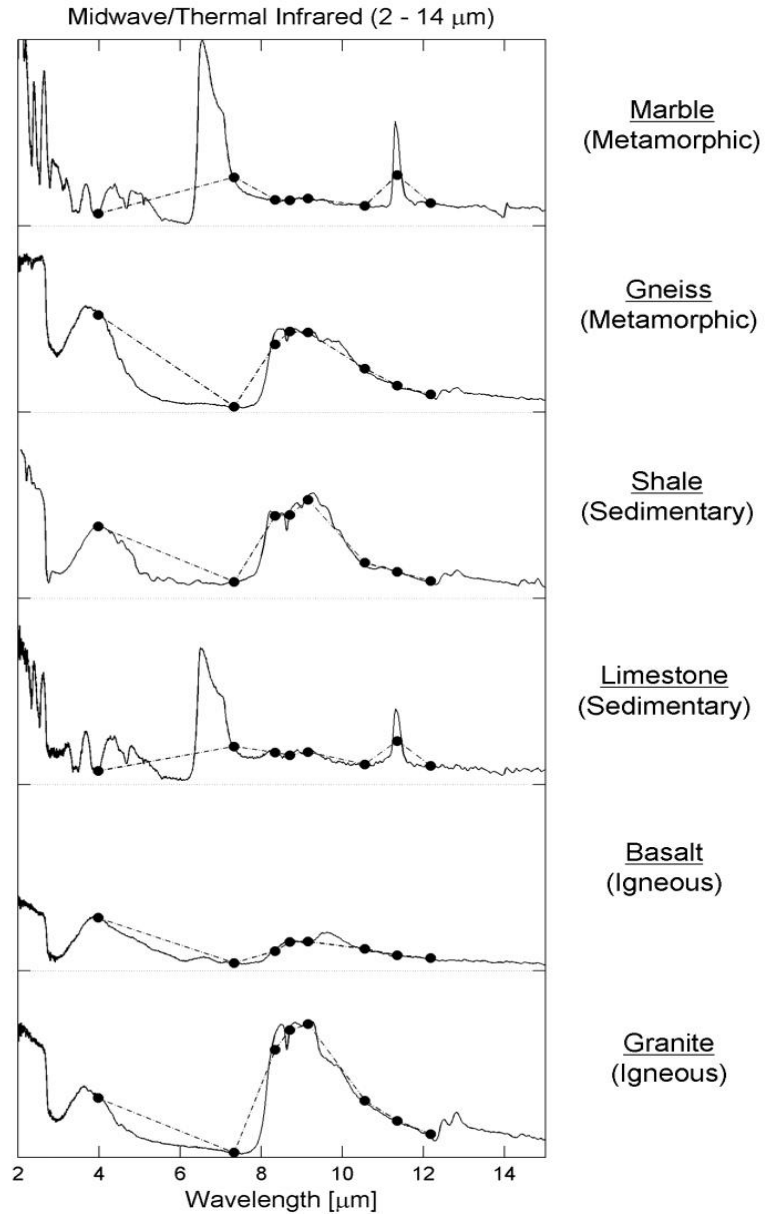




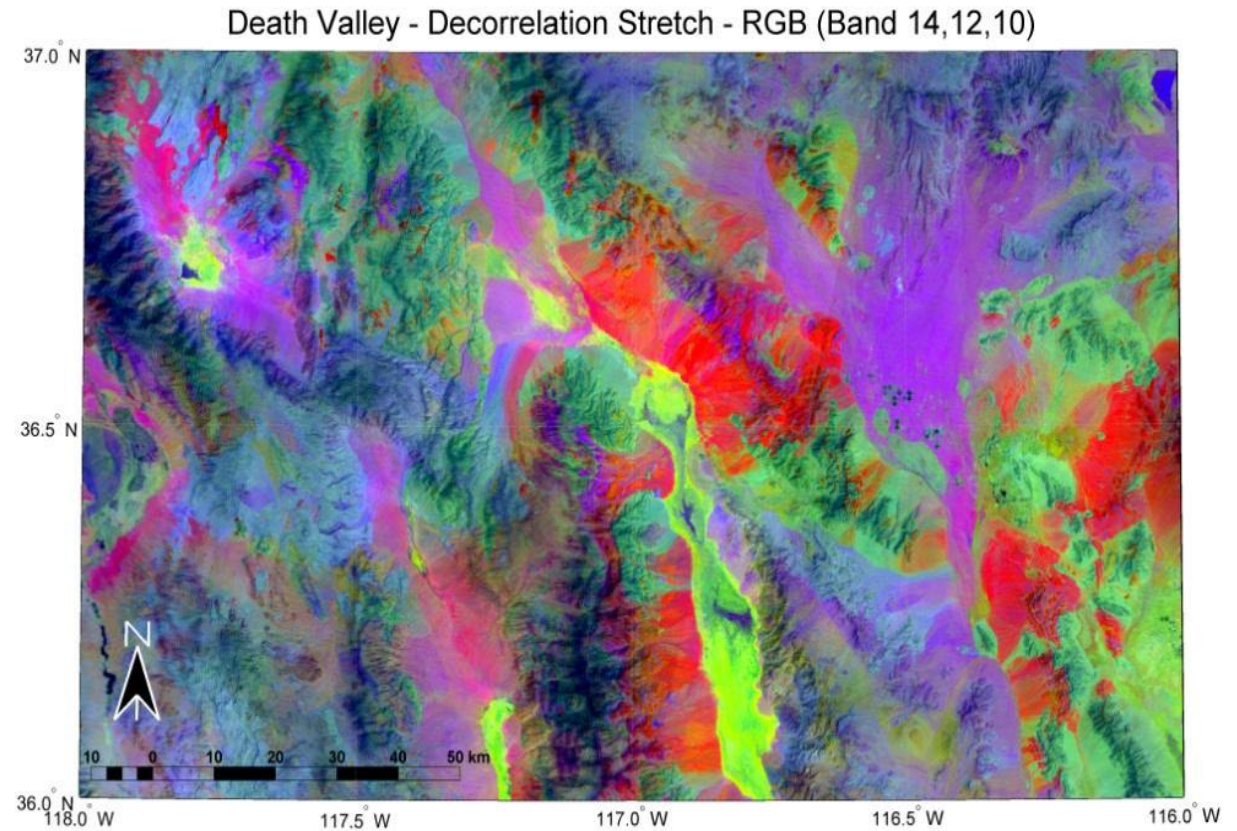
Via G. Durando 39, 20158 Milan, Italy

Phone: +39 327.67.18.100
Website: www.nireos.com
Email: info@nireos.com

 NIREOS SRL – Follow us!



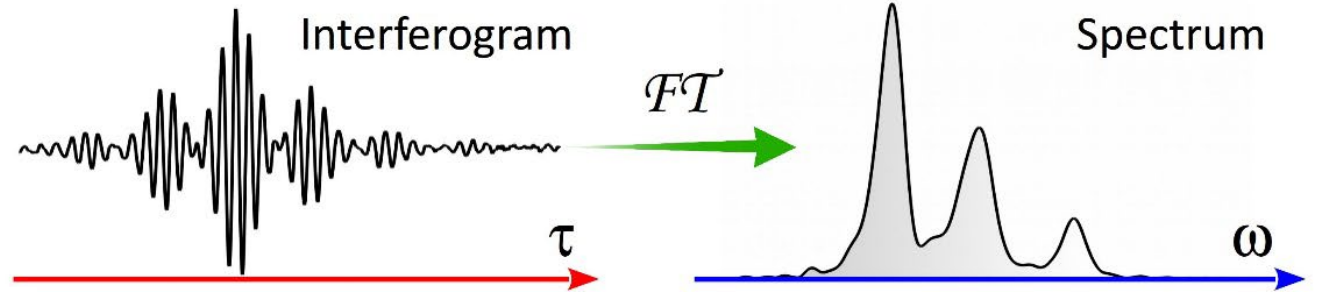
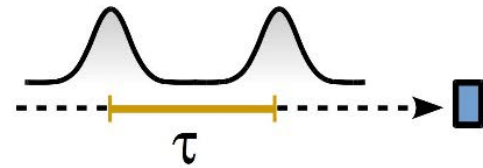
Detection of mineral types (ASTER)
quartz features - **Carbonates** - **quartz-poor regions**



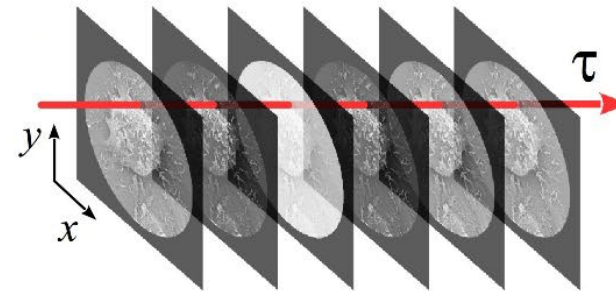
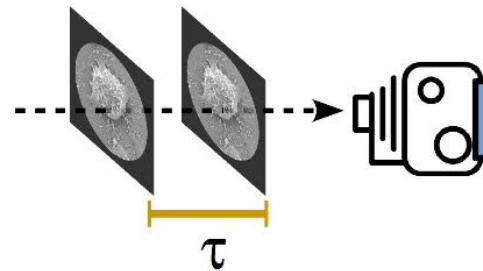
Alternative approach: Fourier Transform spectroscopy

- Interferometry + Fourier-transform

From 1 beam...



...to a 2D field



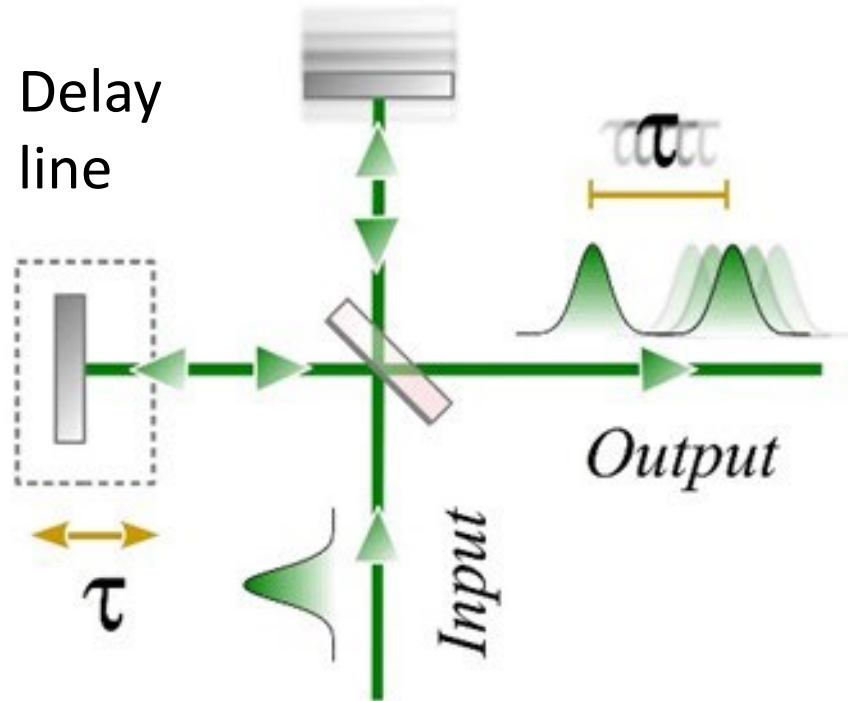
HYPERCUBE

REQUIREMENTS :

- Accuracy of delay: **< 1/100** optical cycle (Phase locking)
- Collinear replicas

Fourier-Transform Spectrometer

STANDARD FT SPECTROMETER: MICHELSON INTERFEROMETER



REQUIREMENTS :

- Accuracy of delay: $< 1/100$ optical cycle
- Collinear replicas

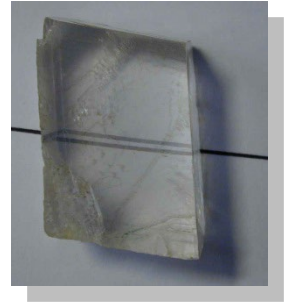
LIMITATIONS OF MICHELSON INTERFEROMETER :

- Vibrations destroy phase-locking
- Need of stabilization strategies
 - ✓ Bulky devices
 - ✓ Active feedback

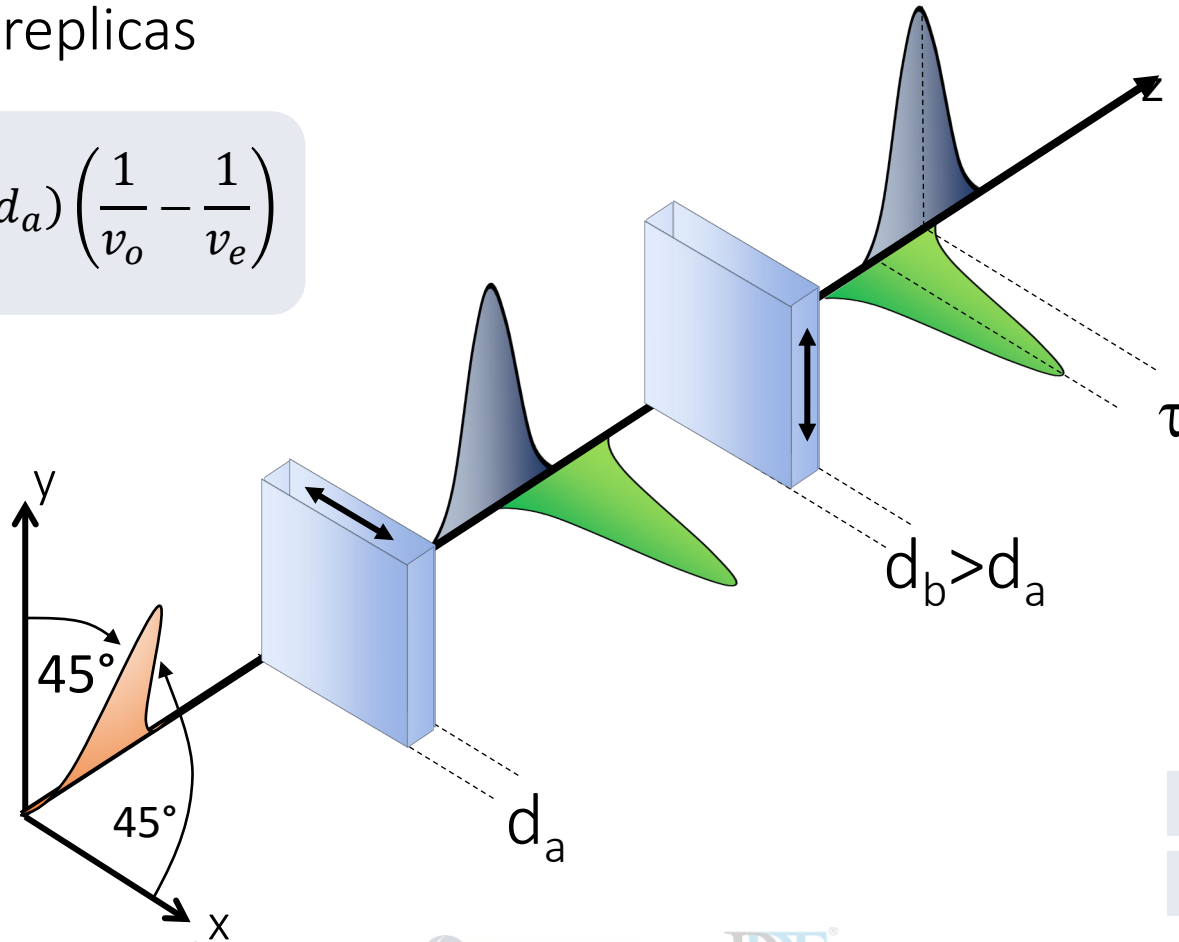
Standard FT spectrometers are cumbersome, heavy and too sensitive for portable devices or for deployment in space applications

CPI: A Common-Path Interferometer

- Generation of phase-locked replicas by birefringence
- **ordinary** and **extraordinary** polarizations: different propagation speeds
- Total delay: proportional only to thickness
- Collinear replicas



$$\tau = (d_b - d_a) \left(\frac{1}{v_o} - \frac{1}{v_e} \right)$$



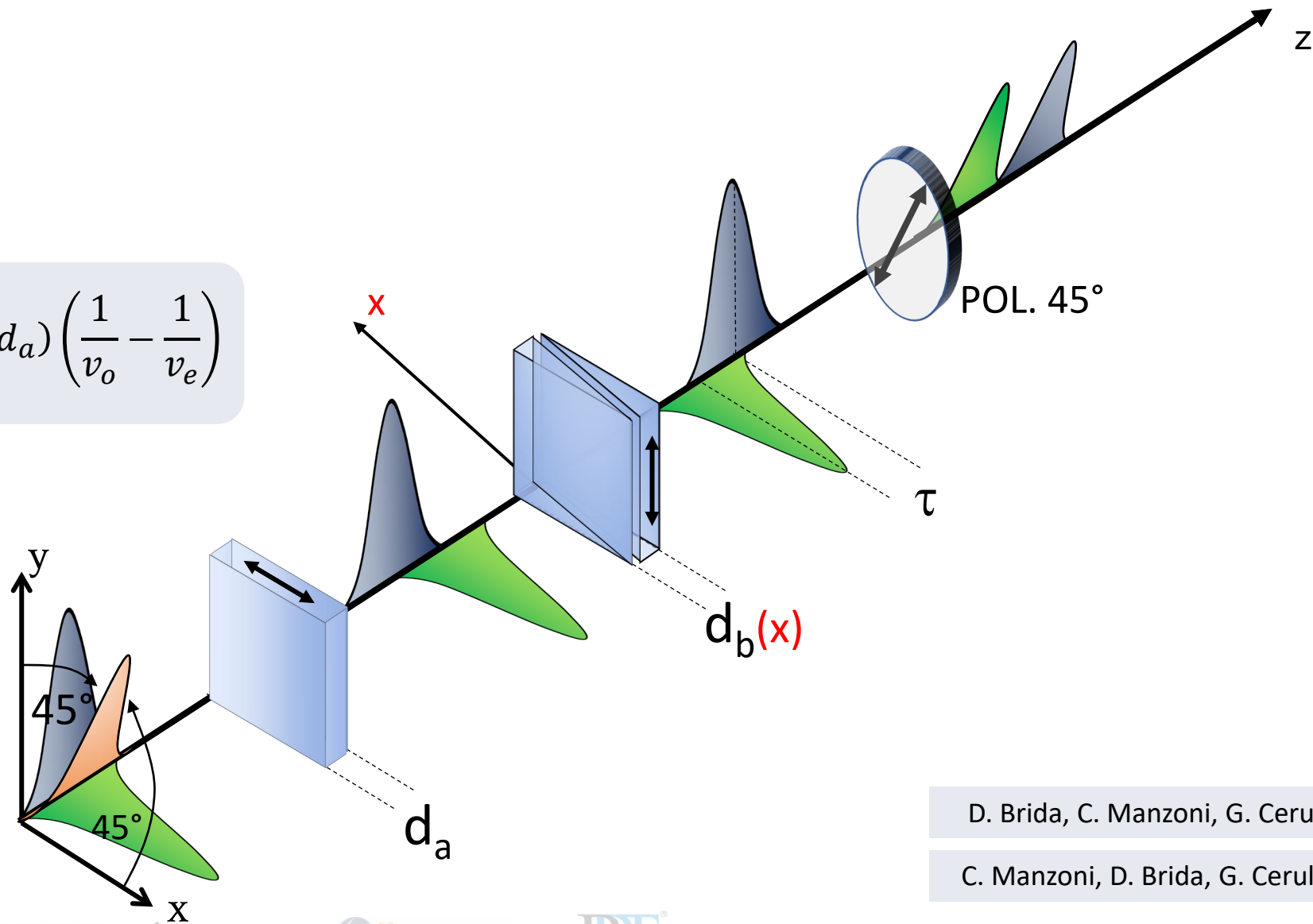
Crystal	Range (micron)
Alpha-BBO	0.2-3.5
Yttrium Vanadate	0.4-5
Lithium Niobate	0.4-5.2
Calomel	0.4-20

D. Brida, C. Manzoni, G. Cerullo, Opt. Lett. **37**, 3027 (2012)

C. Manzoni, D. Brida, G. Cerullo, US Patent: 9182284 (2015)

CPI: A Common-Path Interferometer

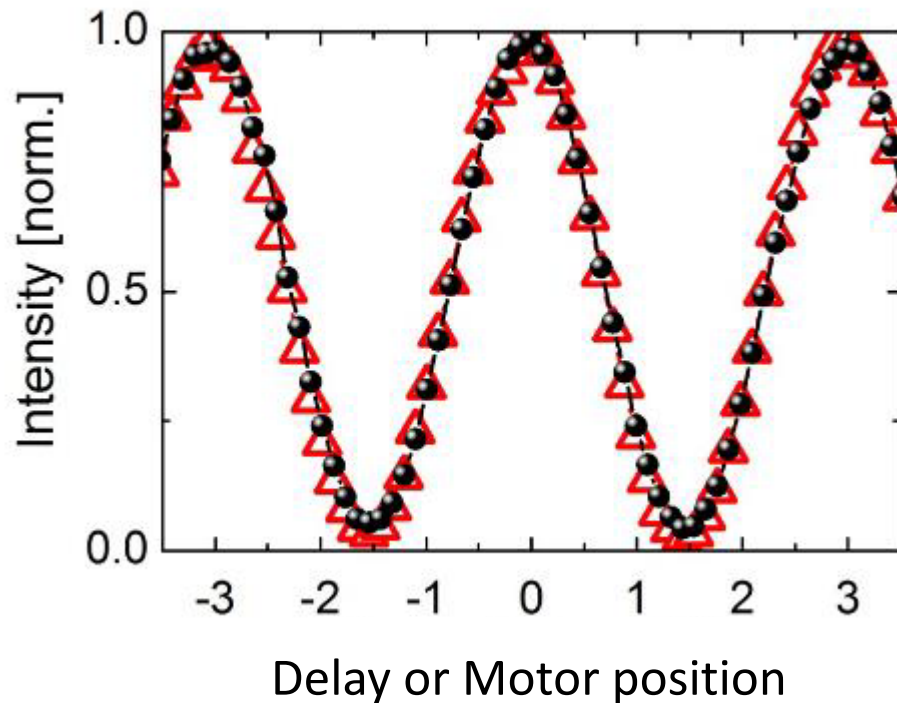
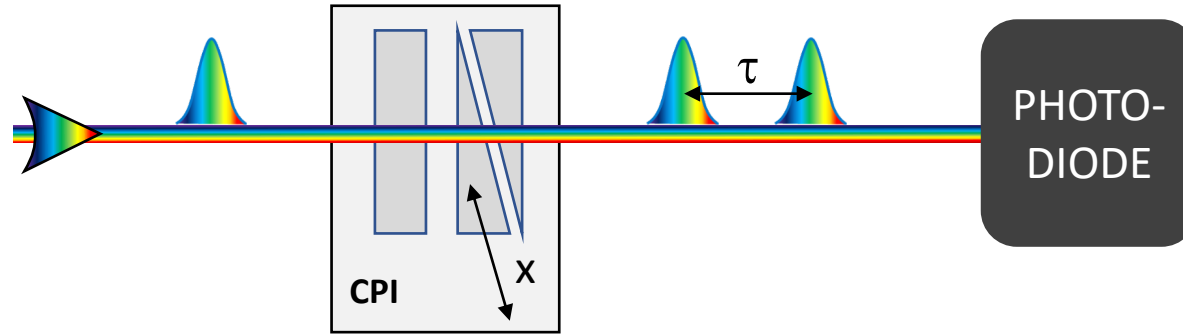
$$\tau = (d_b - d_a) \left(\frac{1}{v_o} - \frac{1}{v_e} \right)$$



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CPI characterization – Dynamic Reproducibility

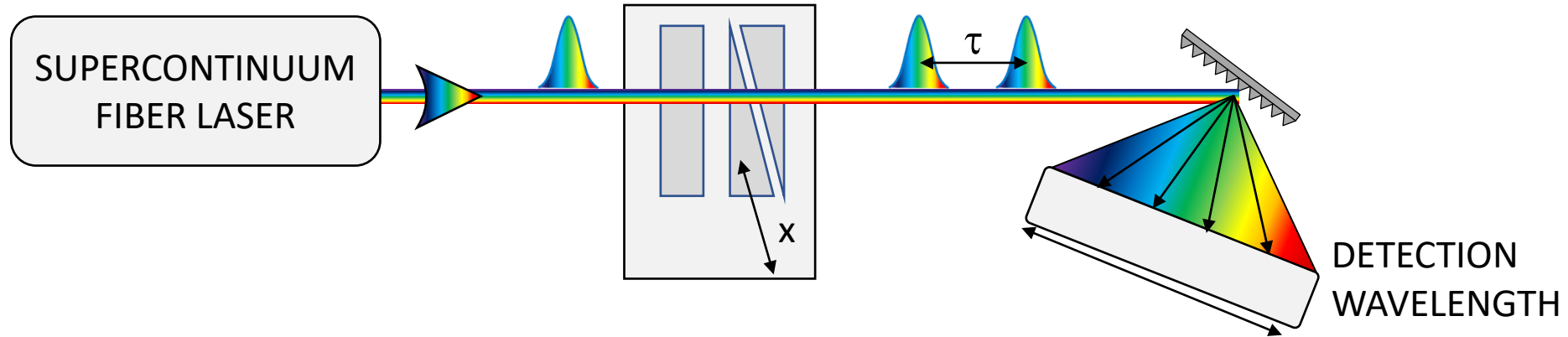


DYNAMIC REPRODUCIBILITY

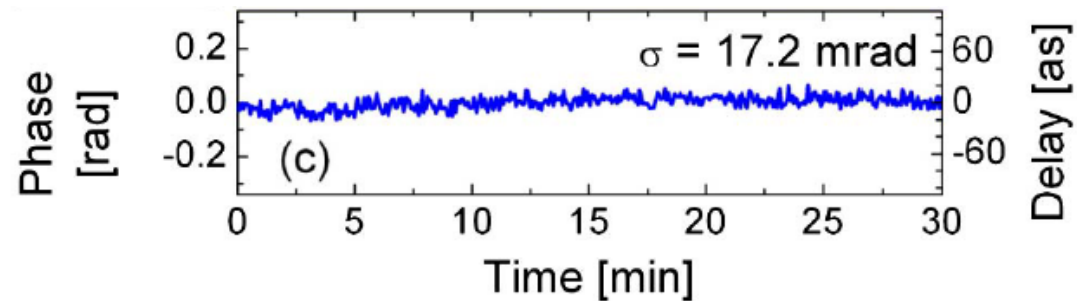
- Interferograms acquired after 30 minutes
- **perfect reproducibility**

D. Brida, C. Manzoni, G. Cerullo, Opt. Lett. **37**, 3027 (2012)

CPI characterization – Static Stability



@ Fixed position of the wedge



STATIC STABILITY

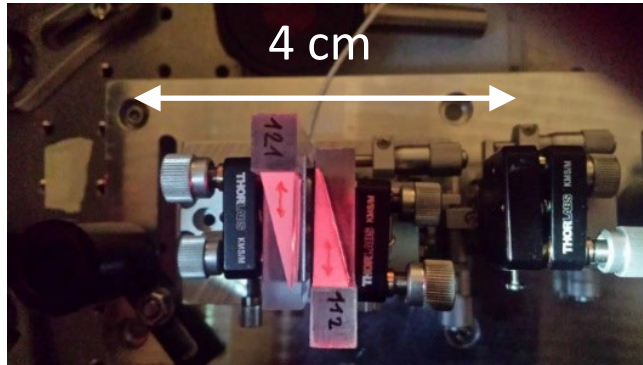
- delay fluctuations:
 $\lambda / 360$ (~ 5 as at 600 nm)

D. Brida, C. Manzoni, G. Cerullo, Opt. Lett. **37**, 3027 (2012)

CPI characterization – Dimensions and Weight

- **SMALL FOOTPRINT**

Few centimeters



- **POWER CONSUMPTION**

< 50 W

- **OPTICAL ALIGNEMENT**
No realignment required

- **LIGHTWEIGHT**

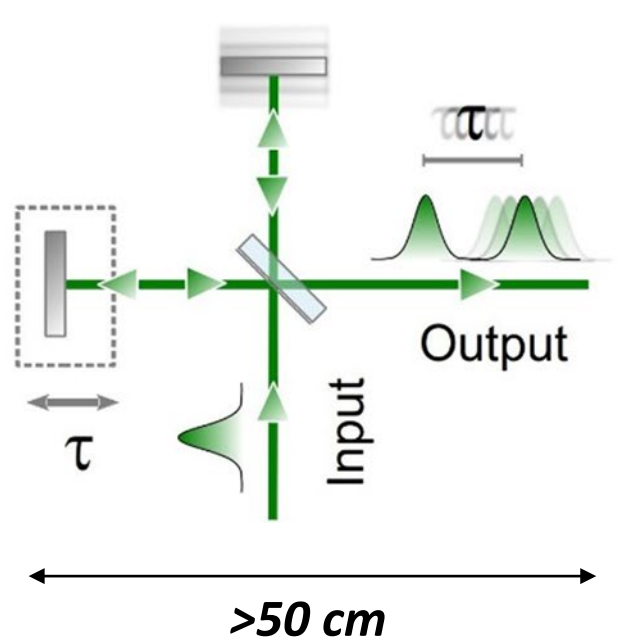
< 1 kg

- **NO ACTIVE CONTROL REQUIRED**

**Ideal device for portable, on field and
spaceborne applications**

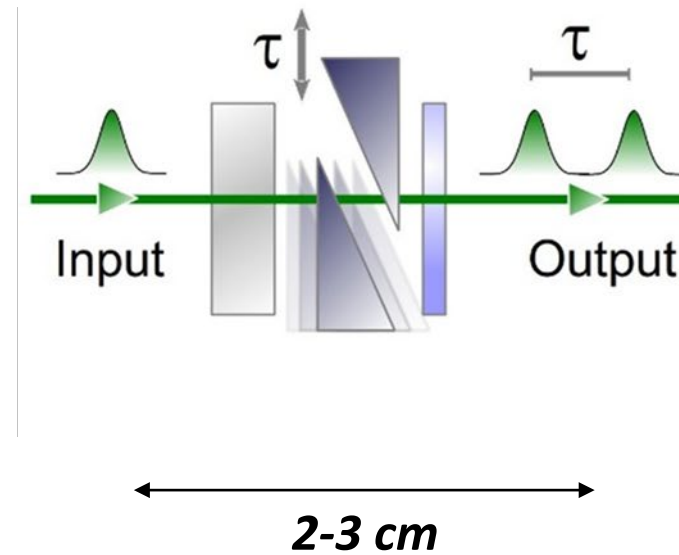
Comparison: Michelson VS CPI interferometers

Michelson Interferometer



Cumbersome and heavy!

CPI



Compact!

EUROPEAN SPACE AGENCY



An Ultracompact Hyperspectral imager in the Thermal Infrared



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