

HORIBA
Scientific

200 YEARS
1819-2019
HORIBA JOBIN YVON

Sharing light and passion
200 years of optical innovation

www.horiba.com/en_en/200years

1819 - 2019



**EPIC Technology Meeting
Photonics at the Final Frontier
at European Space Agency (ESA)**

Latest Diffraction Gratings Embedded Solutions on Earth Observation Missions

**William Renard, PhD
Sales Engineer, Custom gratings**

2022/09/13

Summary

- **HORIBA's general presentation with focus on OEM & gratings business unit**
- **HORIBA France – Photonics center of excellence**
 - Focus on our technologies
 - Focus on our capabilities
- **Review of HORIBA's latest diffraction gratings for Earth observation mission**
 - Focus on SENTINEL-5 mission
 - Focus on MICROCARB mission
 - Focus on GEOCARB mission
- **Our vision and our needs for future projects**

HORIBA's group

- **Founded in Kyoto in 1945 by Dr. Masao Horiba**
- **Head Office: Kyoto, Japan**
- **Business content: Manufacture and Sale of Analysis & Measurement Technologies**
- **Company in Few Figures:**



FY2021: 224,3 B¥ / ~2 000 M\$



Employees: over 8 205 (1 000 in France)



~7 % of net sales



Paris-Saclay campus

HORIBA EXPLORE THE FUTURE

Automotive Test Systems



Process & Environmental



Medical



Semiconductor



Scientific



HORIBA France: a Center of Excellence

Initially Jobin Yvon

Created in 1819 from the collaboration between Augustin Fresnel and Jean-Baptiste Soleil

200 years of optical innovation

Acquired in 1997 by the HORIBA Group

Global lead for Raman spectroscopy, AFM, ellipsometry, glow discharge, ICP, VUV spectrometers, gratings, SPRi



European Research at Paris Saclay

HORIBA Scientific

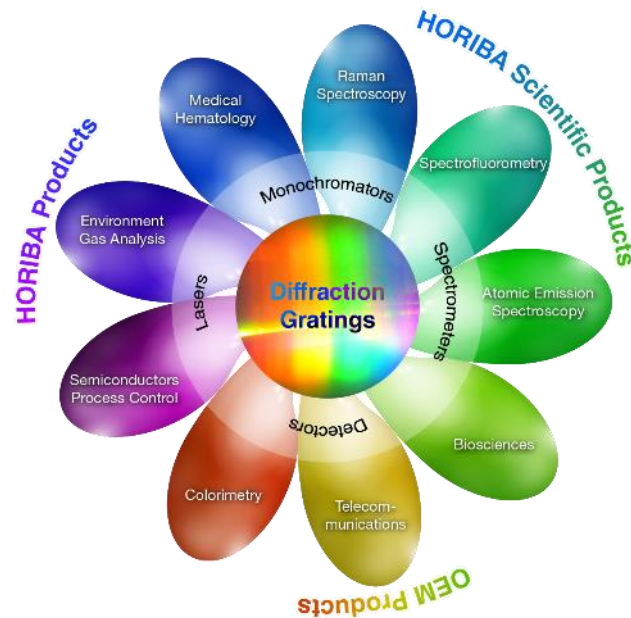
Scientific



Analytical Instrumentation



- **Molecular spectroscopy (Raman + Fluorescence)**
- **Emission spectroscopy (ICP OES, GD)**
- Elemental Analyzers (O, N, C, N)
- Particle size analysis
- SPRi



OEM & CG



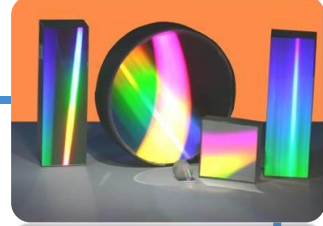
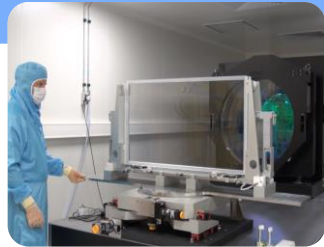
- **OEM Diffraction gratings**
- **Customs gratings**
- **OEM Systems**
 - Spectrometers
 - Monochromator
 - HSI cameras

OEM & gratings business unit

”Standard or unique customized cost effective solutions at Industrial scale“

New custom master gratings development

- Based on customer requirements, HORIBA designs & optimizes the grating parameters and the related manufacturing process.
- **World leader in Space Hyperspectral imaging (>50 mission)**
- UV to IR
- Master or replicas
- Reflection / Transmission
- Ruled or Holographic
- Plane, Concave, Convex, Free form



OEM Diffraction gratings

- **More than 500 OEM master references**
- Replication of Flat / Spherical / Free Form gratings
- **Leader in Type I & IV** (aberration corrected)
Concave\convex grating
- Constant performances & Traceability by datamatrix

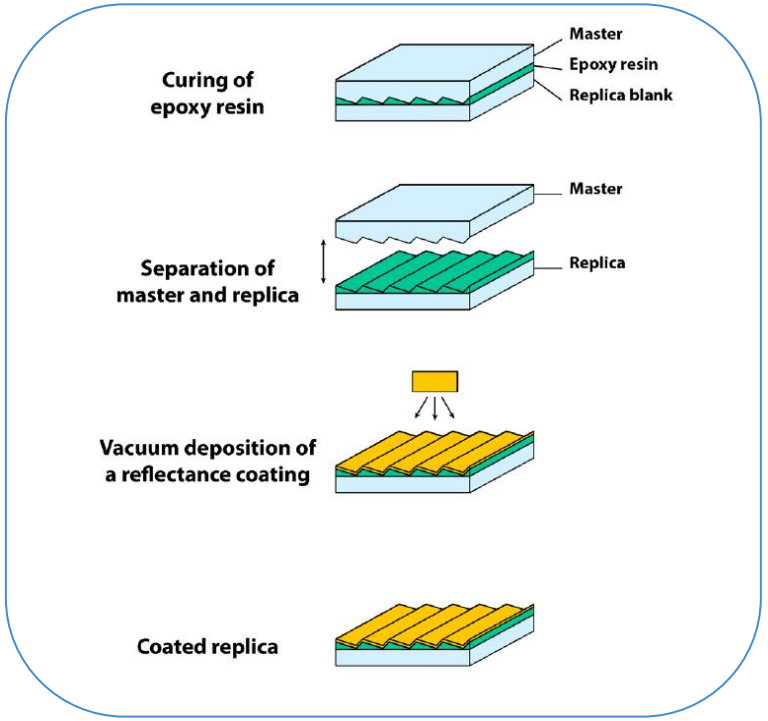
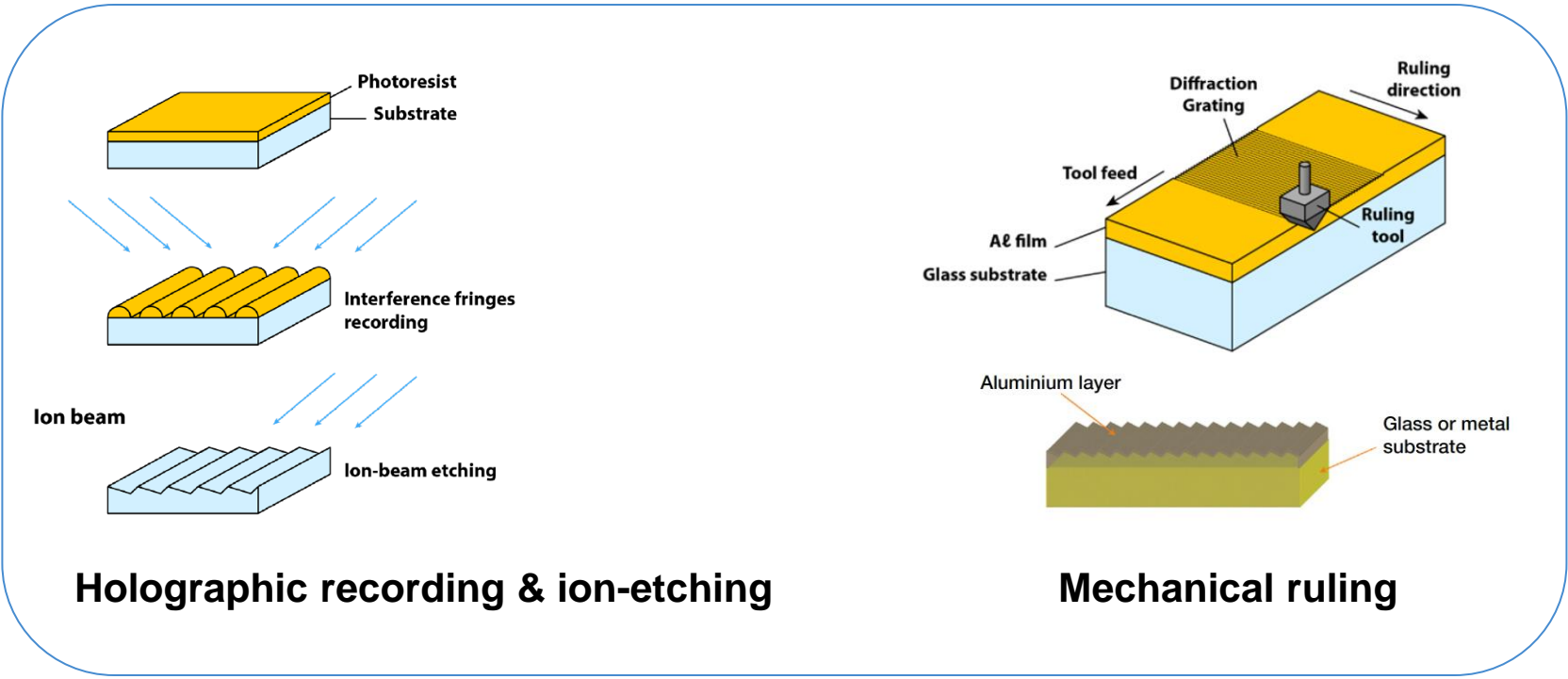
OEM Systems

- Monochromators
- Spectrometers
- Hyperspectral Imaging cameras
- Single component or Full solutions (Electronic board, Detectors/cameras, Fibers, light source...)

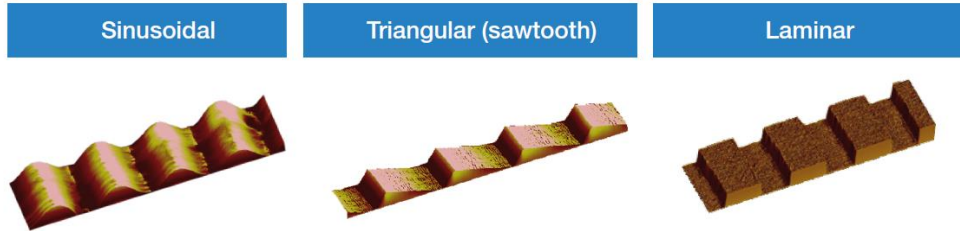


Custom Gratings Technologies

Master & replica gratings Manufacturing technologies



Master transmission or reflection gratings:
 Sinus/Triangular/lamellar groove shapes
 up to 4 800 l/mm groove density
 Different kinds of substrate shapes and material



Custom Gratings Technologies

HORIBA France grating manufacturing facility:

2 productions lines for optical recording:

Large grating size up to 1,45m production line

Holographic rooms for sizes up to 600 mm

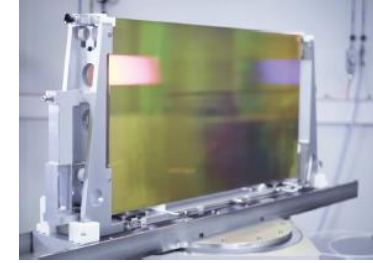
ion etchers for small and large size gratings

Ruling engines for blazed and low line densities gratings

Masters gratings are manufactured in Clean rooms ISO 6 > 1000 m²

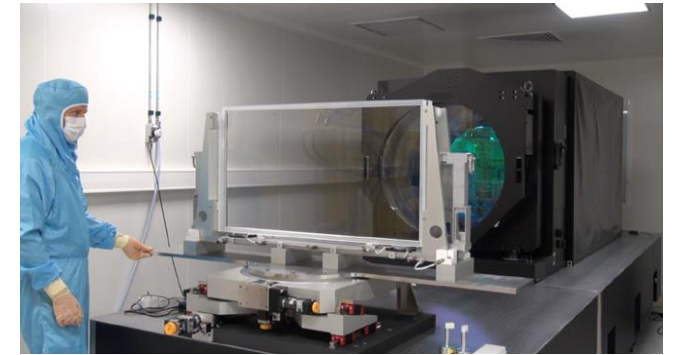
Inhouse chemical operation (for cleaning and stripping gratings and/or coatings)

Large vacuum chamber for reflective coating deposition

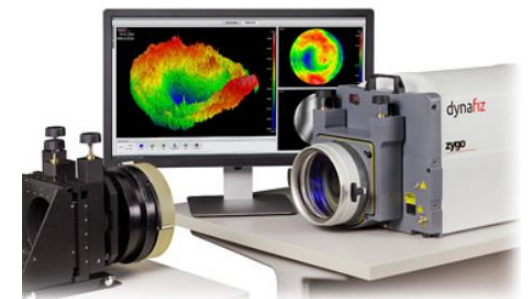


Custom Gratings _ Metrology tests

- **Grating profile characterization** (Atomic Force Microscope)
- **Plane and curved pieces regularity** (Interferometry)
- **Efficiency** (relative or absolute / Mirror with same coating) (Efficiencymeter)
 - 4 different tools for different configuration of use
- **Wavefront error** (Interferometer)
- **Groove number & orientation measurement** (goniometer)
- **Substrate Microroughness** (Microscope)
- Visual inspection

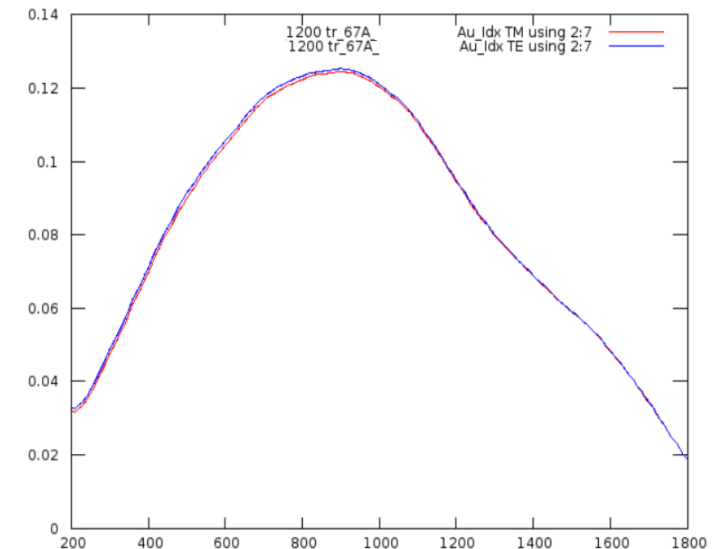


Interferometer



Custom Gratings _ Theoretical Computation

- **Theoretical Computation & Software tools**
 - **Grating ray tracing** (Grating – Complete system)
 - **Recording parameters optimization**
 - **Grating Efficiency calculation**
 - Theoretical profile or real (by AFM)
 - Various conditions: Polarization / incidence angle from VUV to NIR with *any std coating (Al, Au, Pt...)*
 - **Grating layout optimization** (Zemax/optics studio)
 - Aberration optimization
 - Stray light simulations
 - Optimization systems tolerancing
 - **VLS & VGD calculation and simulations**

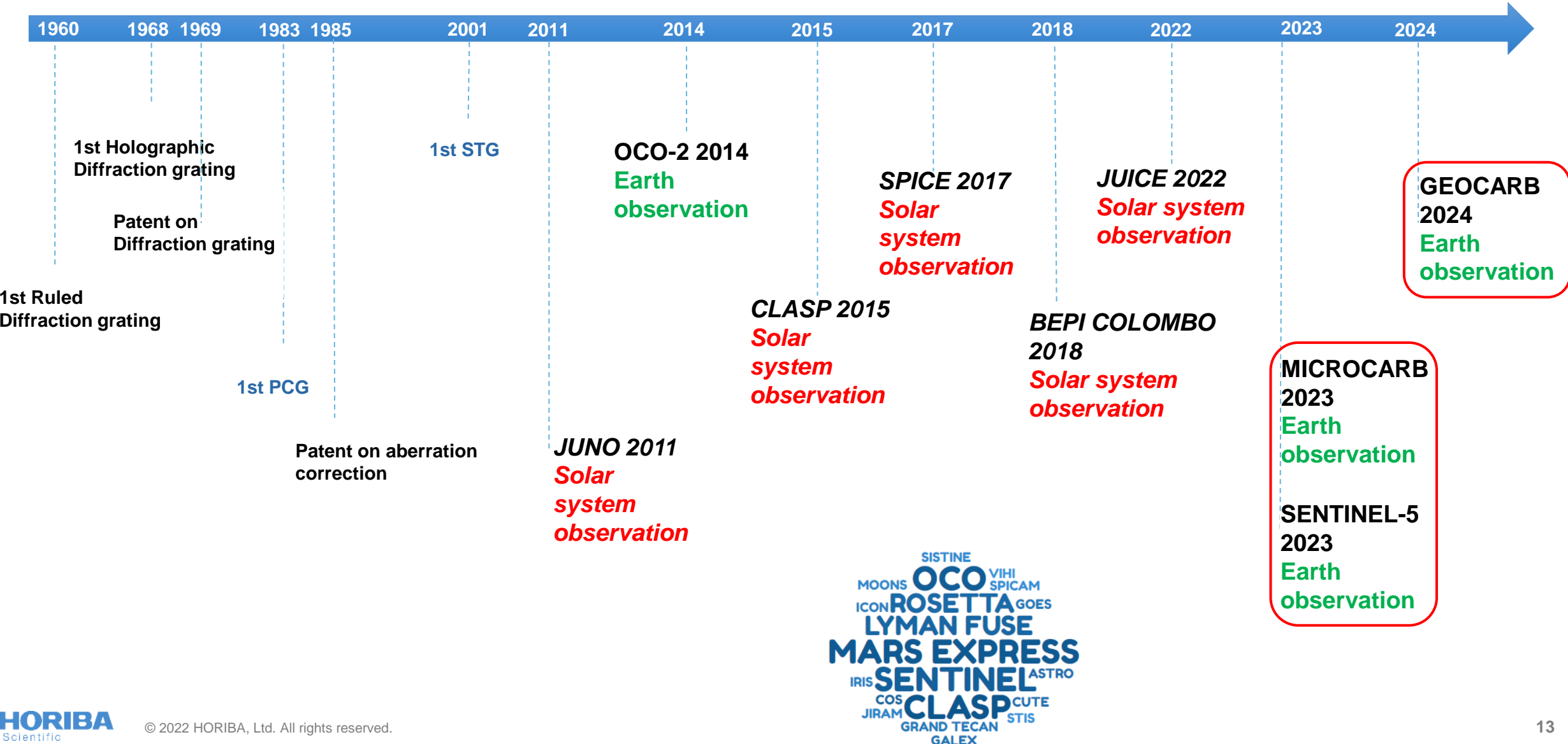


Custom Gratings _ Space qualification

- **HORIBA Scientific gratings were qualified for Space Applications during the Long Duration Exposure Facility (LDEF) mission**
- **Three different kind of gratings were on-board, representative of our capabilities:**
 - 1200 l/mm replica ruled grating, blaze wavelength 250 nm, 40x40 mm, Al coated
 - 3600 l/mm master holographic grating, optimized for 50-150 nm, 40x40 mm, Pt coated
 - 1200 l/mm master holographic + ion-etched grating, blazed at 250nm, 40x40 mm, Al coated
- **Duration in orbit: 69 months**
 - Thermal cycling from -30 to 70 °C
 - Space environment, cosmic dust and sun irradiation for several months
- **Upon the return on Earth, several measurements were done:**
 - Wavefront quality
 - diffraction efficiency
 - Stray-light



Custom Gratings_ Innovation & product Timeline



Custom Gratings_ Sentinel5 - Grisms



- **Mission Sentinel 5 (Launch 2023)**
- **Target / project**
Instrument developed within Copernicus program for environmental control and surveillance.
The instrument is embedded on the MetOp-SG A satellite.
- **Grating to be manufactured**
Grism = Grating recorded on the exit surface of a prism,
entrance surface is AR coated.
The grism works in transmission.
- **Challenges**
 - High efficiency ($> 55\%$) and low polarization ratio ($< 15\%$)
Manufacturing tolerances on the groove profile were strongly tightened.
 - Grism manufacturing / several steps with tight tolerances
Holographic recording & ion-etching: accurate control of many process steps (precise resist layer thickness, precise resist mask groove shape and precise control of the etching process to obtain a nominal groove profile in silica)
- **Grating parameters overview**
 - Grism
 - Spectral range : UV (300-500nm)
 - Groove density : 1499,25 gr/mm ($\pm 0,45$)
 - Dimensions : c.a. 54x47mm (grating clear aperture of 40,2x36,7mm²)



Custom Gratings_ MicroCarb – Echelle gratings

- **Mission** **MicroCarb Mission/Instrument/Staellite (Launch 2023)**

- **Target/Project :**

Mapping of CO₂ emitting and absorbing locations over the world.
MicroCarb is a microsatellite with a unique compact instrument.

- **Grating to manufacture**

an Echelle grating replicated on a SiC weightlighted blank.

- **Challenges**

The blaze angle has to be very precise (@ about +/-0,2°)
and is validated on the replica grating.

→ Iterative process .

4 bands of interest to be covered simultaneously:

B1 758-769nm – k40,

B4 1264-1283nm – k24,

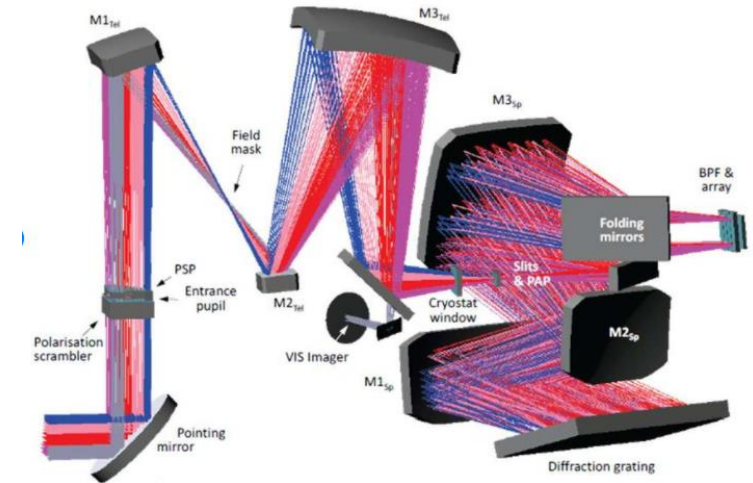
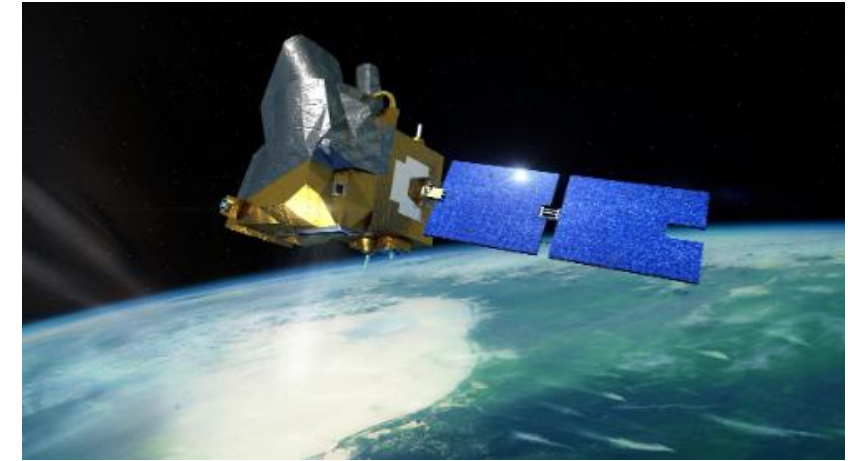
B2 1596-1620nm – k19,

B3 2022-2053nm – k15

- High efficiency (> 40 or 50 %) and low polarization ratio for all spectral bands

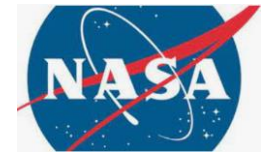
- **Grating parameters overview**

- Ruled masters – Replicas on SiC blanks
- Groove density : 61,43 gr/mm
- Dimensions : 120x110mm²

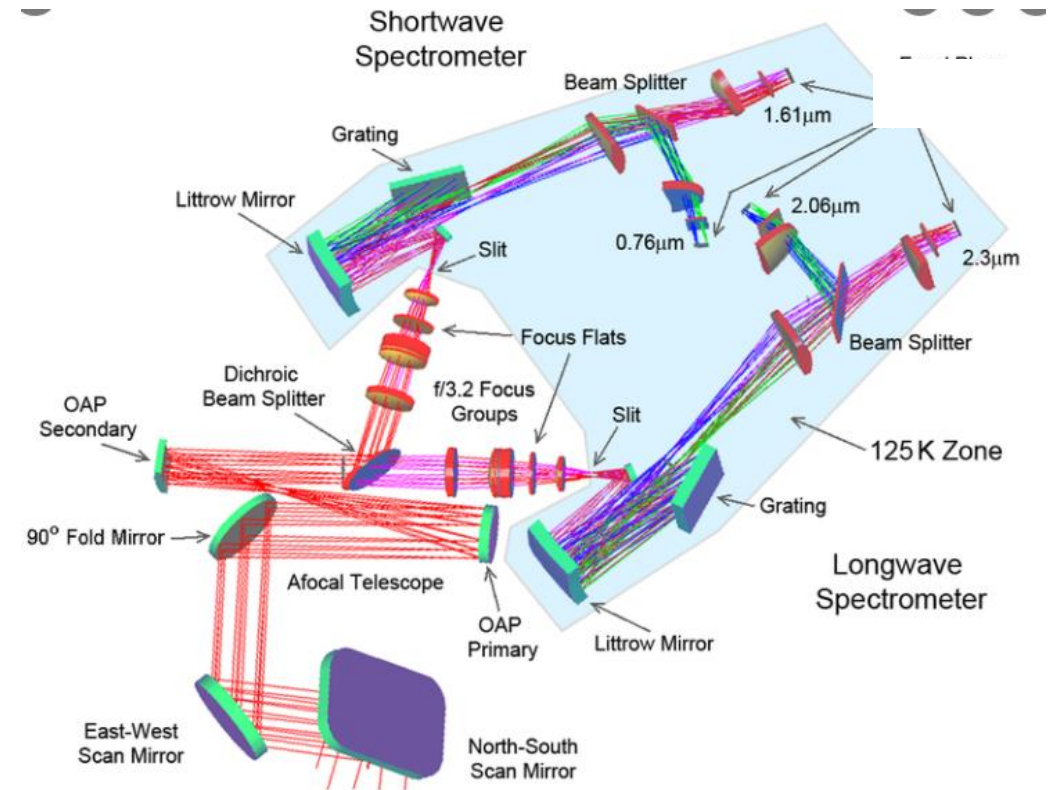


3D architecture of MicroCarb optics.

Custom Gratings_ GeoCarb – Echelle gratings



- Mission **GeoCarb Mission/Instrument** (Launch 2024)
- **Target/Project :**
Daily Americas cartography of the CO2 exchanges
- **Gratings to manufacture**
Two Echelle grating replicas on weightlighted Zerodur blanks.
Two types of Echelle gratings : SW and LW
- **Challenges**
The blaze angle has to be very precise (@ about +/-0,2°) and is validated on the replica grating.
→ Iterative process .
 - 2 bands of interest per grating type:
 - SW (Short Wave) :
B1 758-772nm – k21,
B2 1592-1621nm – k10
 - LW (Long Wave):
B3 2045-2085nm – k9,
B4 2301-2346nm – k8
 - High efficiency and low polarization ratios for all spectral bands
- **Grating parameters overview**
 - Ruled masters – Replicas on Zerodur weightlighted blanks
 - Groove densities : 107gr/mm (SW) and 92 gr/mm (LW)
 - Dimensions : 80x110mm² weightlighted Zerodur



Omoshiro-okashiku
Joy and Fun



Terima kasih
谢谢
Gracias
Σας ευχαριστώ πάρα πολύ
धन्यवाद
شُكْرًا
Danke
Tack ska du ha
Grazie
THANK YOU
Obbrigado
Большое спасибо
Cảm ơn
Merci
감사합니다
ขอบคุณครับ
ありがとうございました
Dziękuję