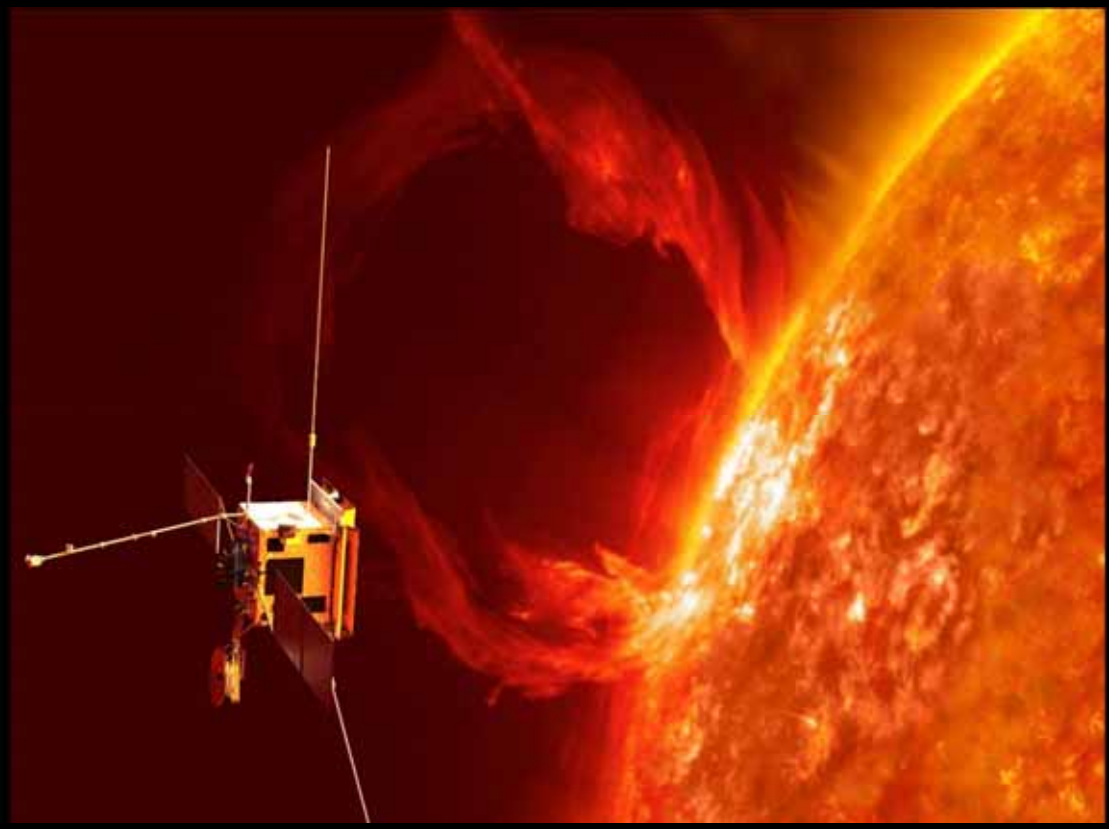
V Reunión de Ciencias Planetarias y Exploración del Sistema Solar

cpess5

The Solar Orbiter mission: INTA contributions to PHI and METIS instruments

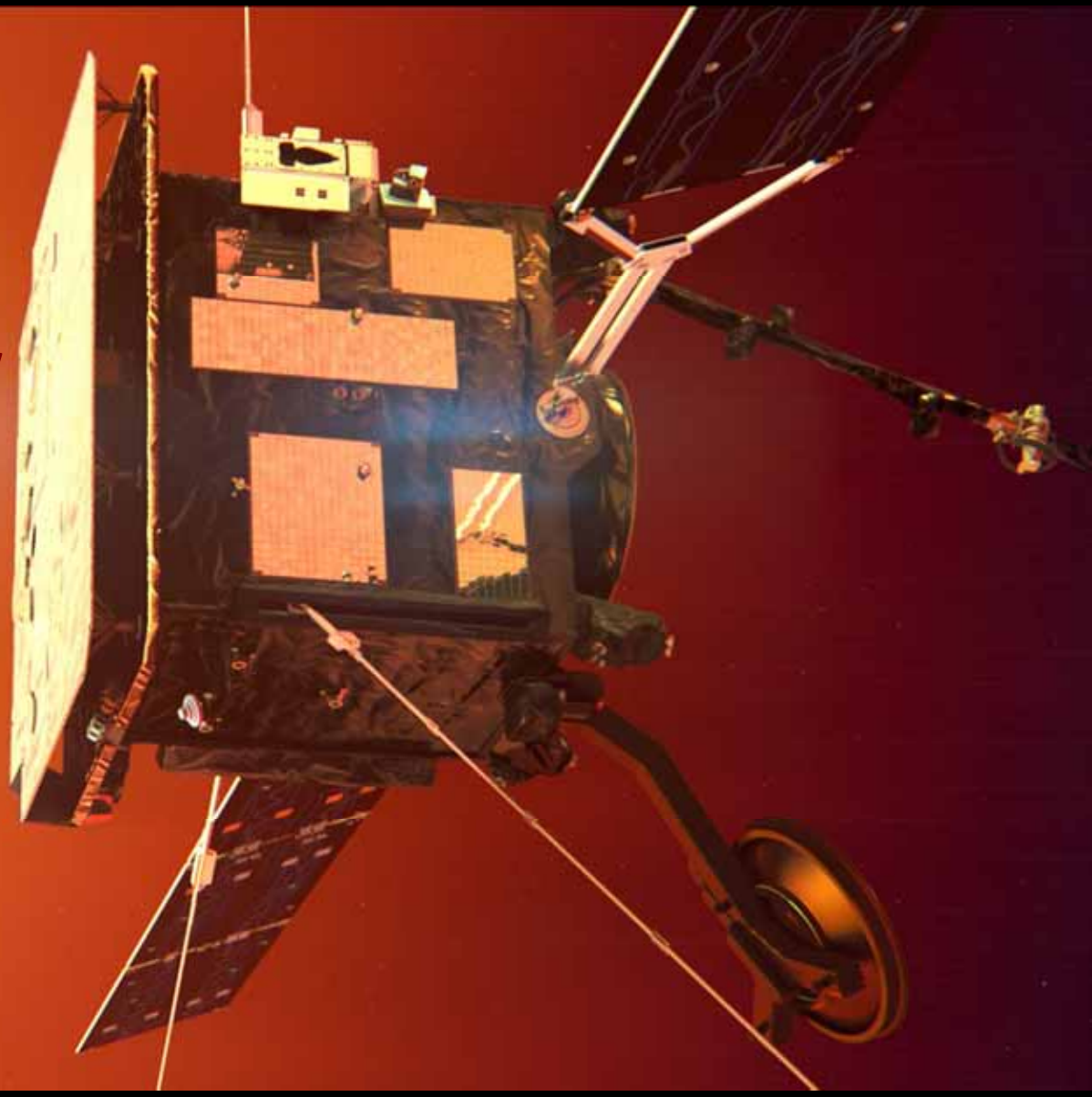


A. Alvarez-Herrero, A. Nuñez, D. Garranzo, M. Silva, A. Fernández, P. García Parejo, J. Barandiarán, A. Sánchez, L. Bastide, R. Navarro, I. Vera, M. Cebollero, H. Laguna, J. A. Martín, J. Villanueva, B. Dávila, P. Gallego, S. Ibarmia, C. Campuzano, M. Royo

Space Optical Intrumentation Area
Instituto Nacional de Técnica Aeroespacial

Outline

- Introduction
- Full Disk Telescope
- FDT Heat Rejection Entrance Window
- Refocusing Mechanism
- Polarization Modulation Package
- Qualification of the Etalon
- PHI E2E
- METIS E2E



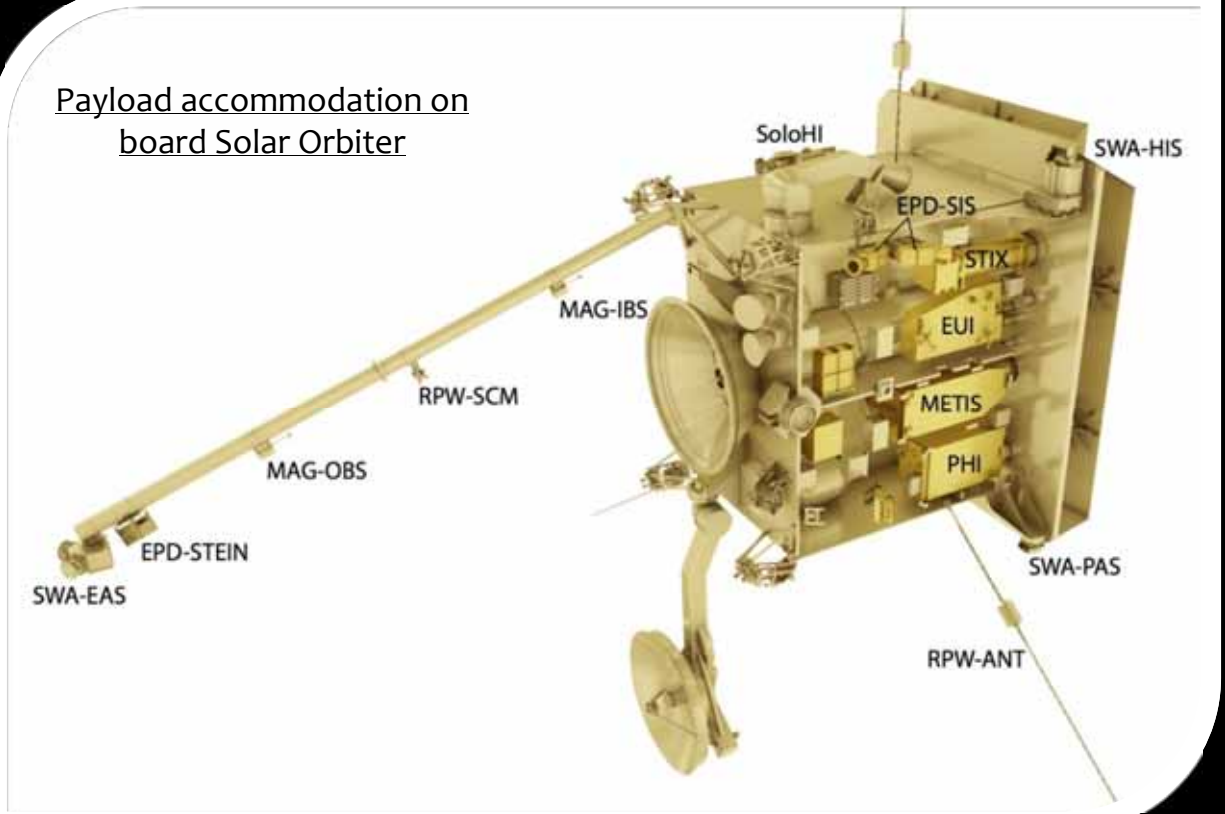
Introduction: Solar Orbiter

Payload:

6 remote-sensing instruments

4 in-situ instruments

Payload accommodation on board Solar Orbiter



Solar Dynamics

Space Weather

Corona heating

Magnetic fields

ESA-NASA joint mission

Launch 2019

Atlas V-Delta IV (backup Ariane 5)

Perihelium 0.28 AU

Aphelium 0.91AU

Out of the ecliptic(>30°):

The poles will be observed

Co-rotation with the Sun

S/C mass 1800kg

payload mass 181kg

Total duration >9.5 y

–Cruise phase: 3 y

–Nominal mission: 3.5 y

–Extended mission: ~3 y

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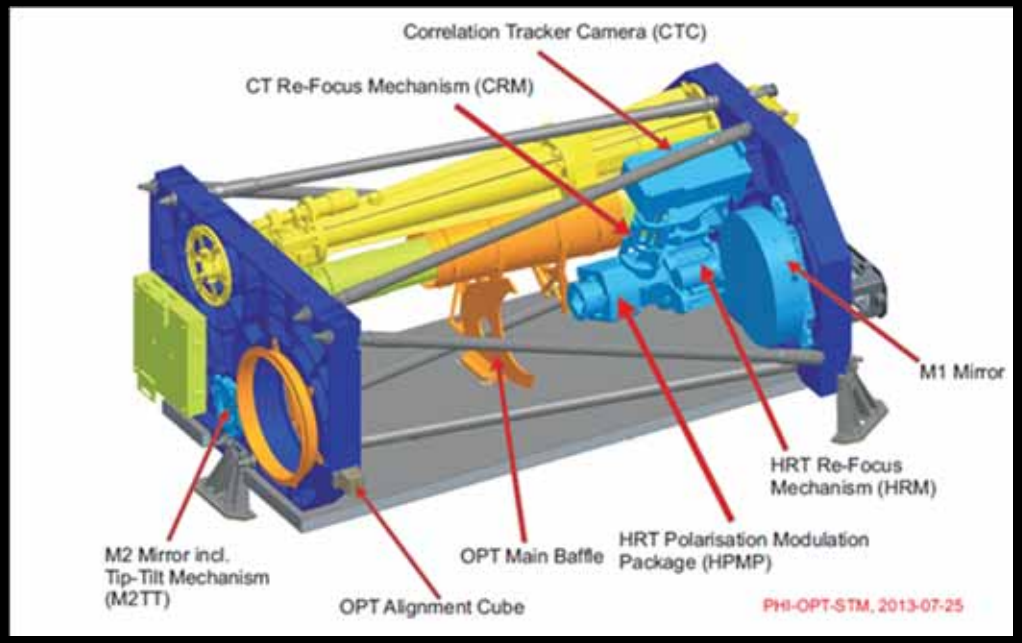
Introduction

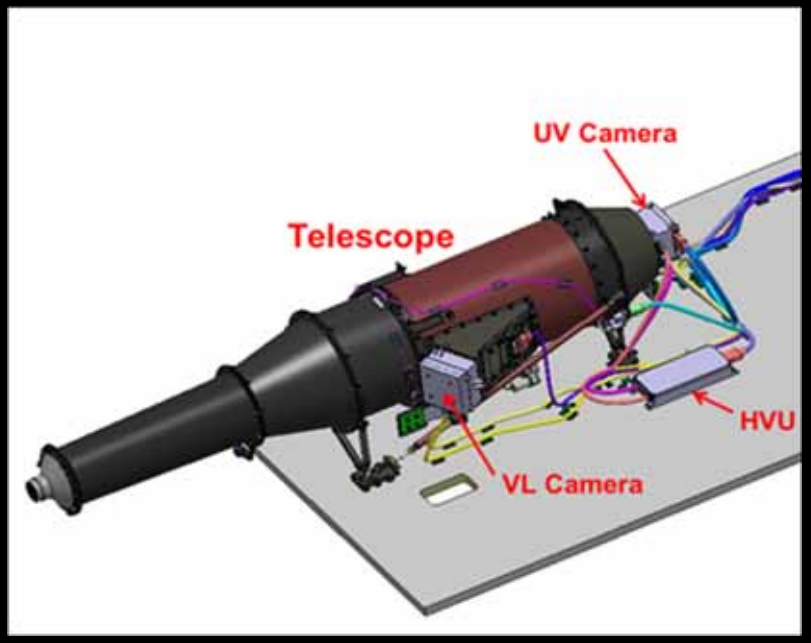
Solar Orbiter will be the **first space mission using LCs** for polarimetric measurements:

SO/PHI: Polarimetric and Helioseismic Imager
→ solar magnetograph



- High sensitive polarimeter (<10^{-3})
- High resolution spectrometer (<100mÅ)
- Diffraction limited Imager(<1 arcsec)

METIS : Multi Element Telescope for Imaging and Spectroscopy
→ solar coronagraph

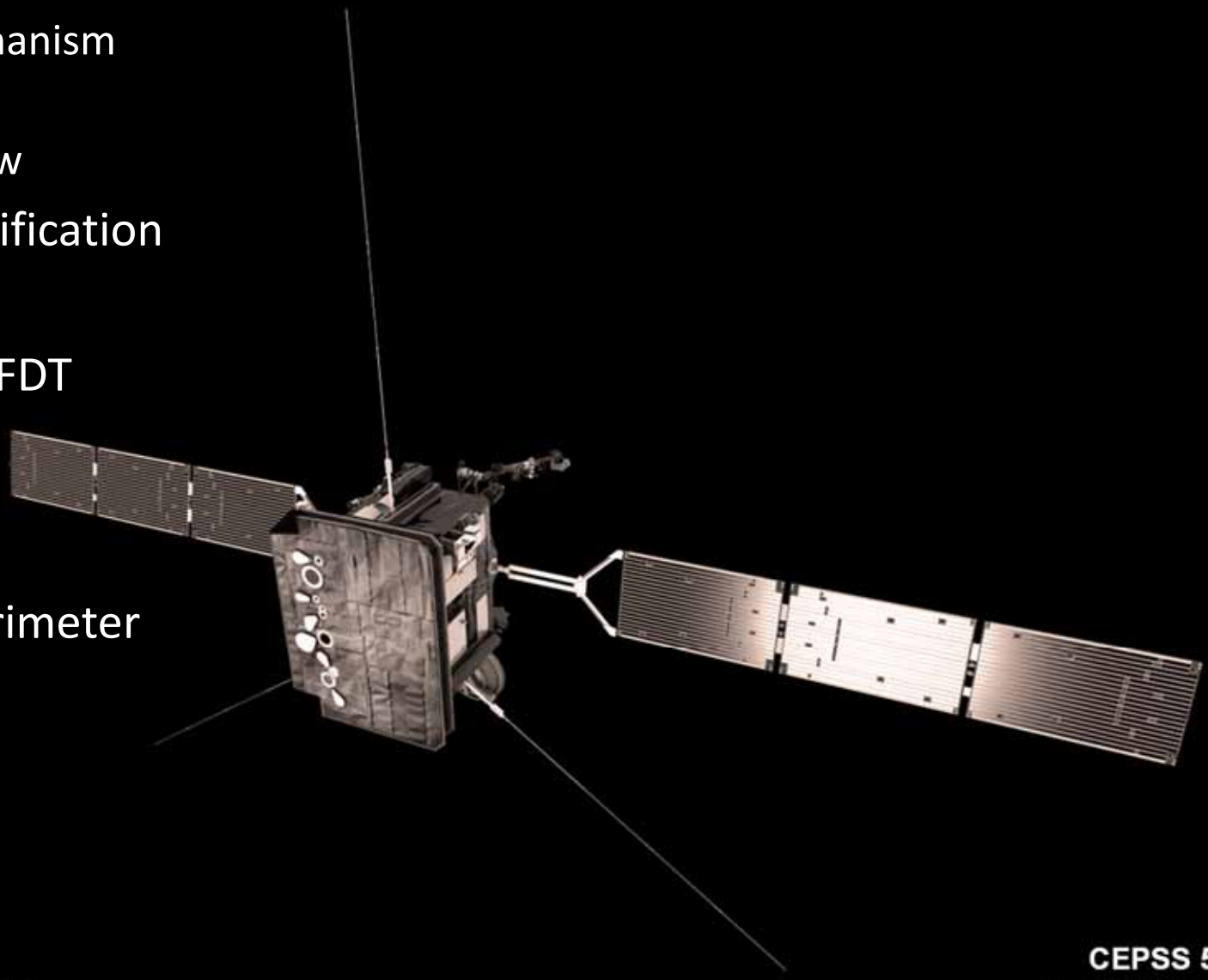


- UV coronagraph
- VIS polarimeter : linear polarization for observations of the visible-light K-corona

Introduction: INTA participation in Solar Orbiter

- **PHI**
  - Full Disk Telescope including:
    - Refocusing mechanism (algorithm)
    - Entrance Window
  - $LiNbO_3$ etalon qualification
  - Radiation Analysis
  - PMPs for HRT and FDT

- **METIS**
  - PMP for the polarimeter



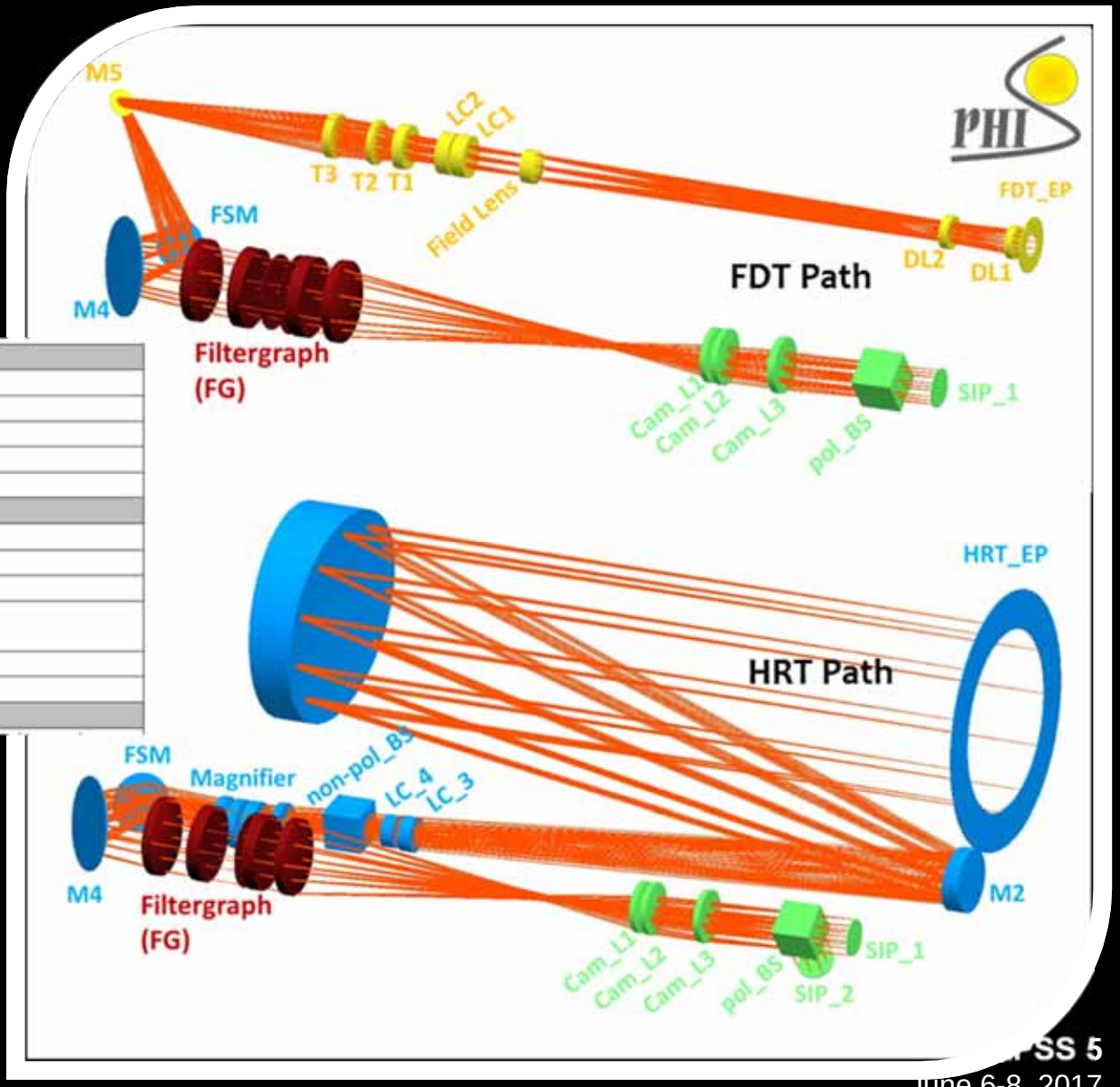
Introduction: PHI instrument concept

PHI is a high resolution spectrometer, a high sensitive polarimeter and a diffracion-limitted imager that will perform polarimetric measurements of the solar surface

Within PHI two telescopes can work sequentially:

- Full Disk Telescope (FDT)
- High Resolution Telescope (HRT)

FDT	FOV	± 1degree (round)
	Focal length at science detector	586.6mm
	Focal length at Etalon focus	1127 mm
	Entrance Pupil Diameter	17.5 mm
	Operating Wavelength/ Bandwidth	617.3 nm ± 1.5Å
HRT	FOV	± 0.14 degree (rectangular)
	Focal length at science detector	4125.3 mm
	Focal length at Etalon focus	7920 mm
	Focal length of HRT mirror telescope (M1 +M2)	2475 mm
	Entrance Pupil Diameter	140 mm
	Operating Wavelength/ Bandwidth	617.3 nm ± 1.5Å



They share a common path:

- Feed selection mechanism (FSM)
- Fabry-Perot narrow-band filter with LiNbO3 etalon
- Detector

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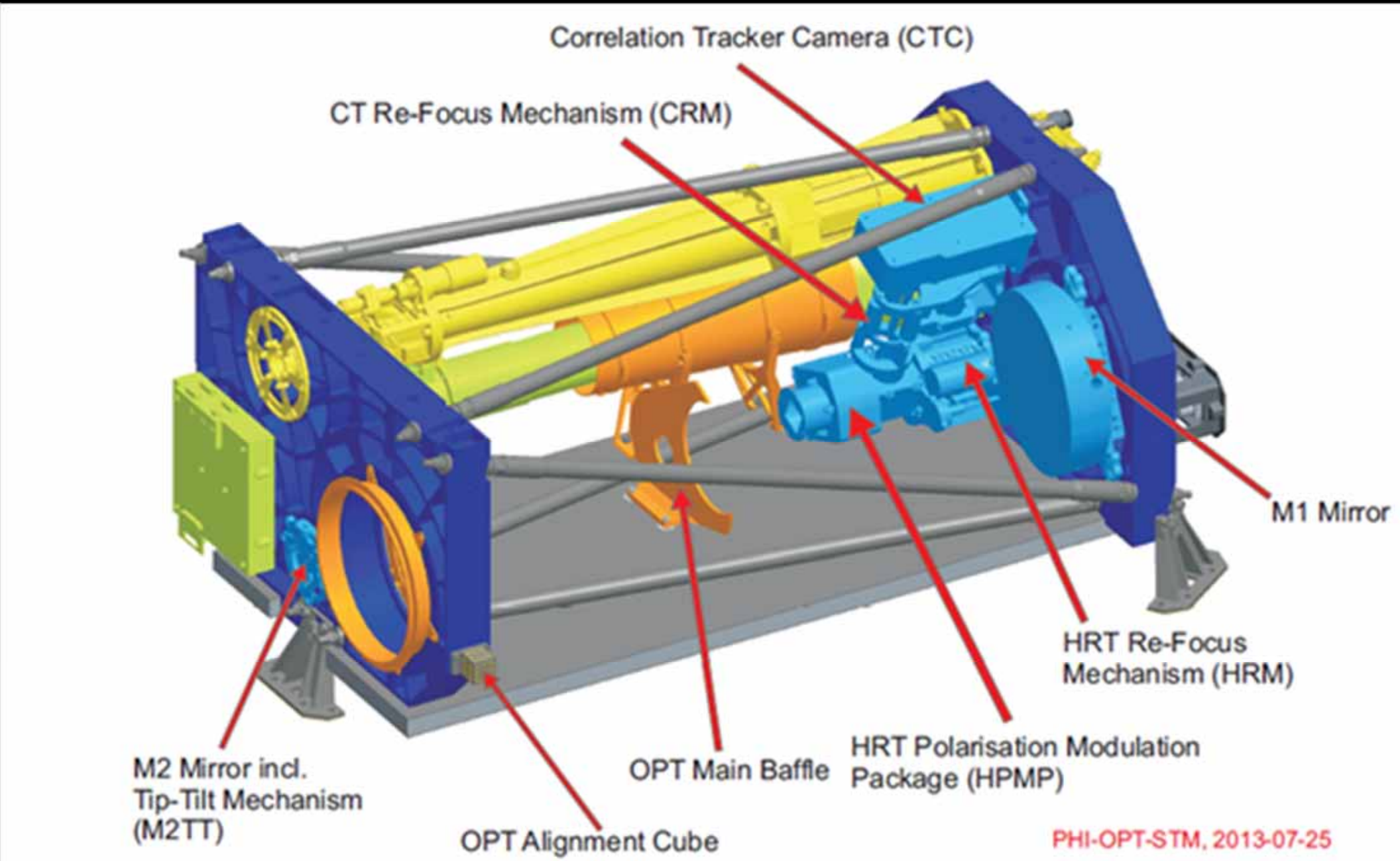
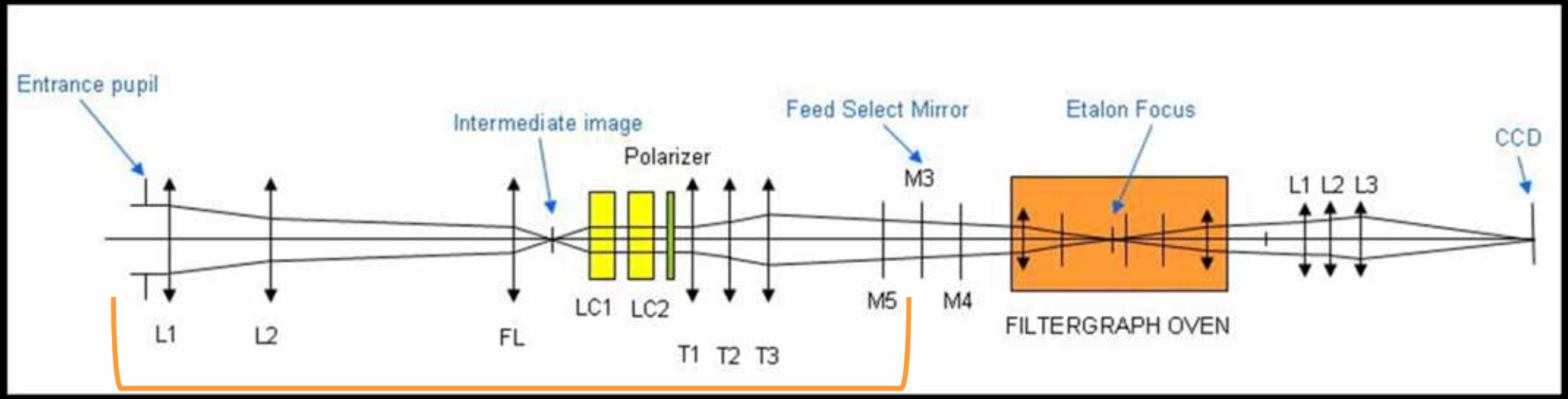
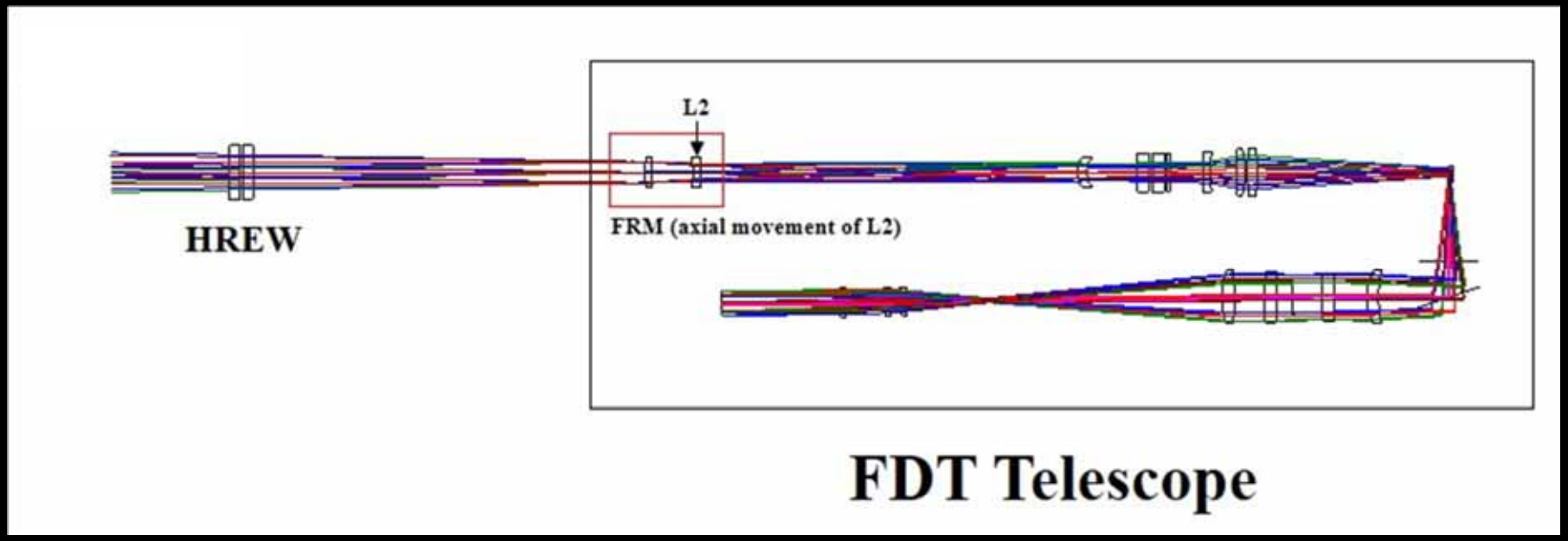
Introduction: PHI instrument concept



Full Disk Telescope



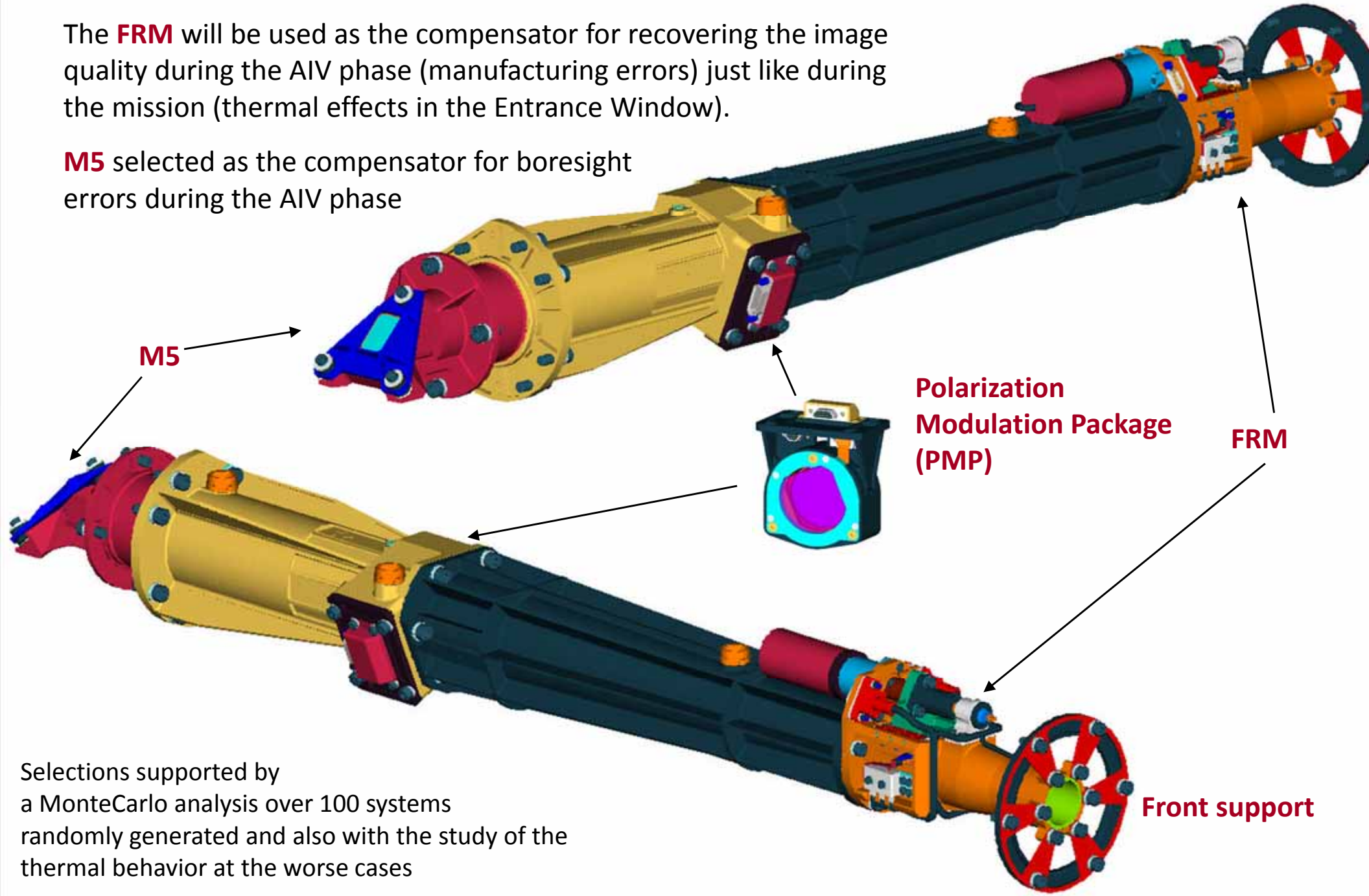
FDT Assembly *(Under INTA responsibility)*



Full Disk Telescope

The **FRM** will be used as the compensator for recovering the image quality during the AIV phase (manufacturing errors) just like during the mission (thermal effects in the Entrance Window).

M5 selected as the compensator for boresight errors during the AIV phase



Selections supported by a MonteCarlo analysis over 100 systems randomly generated and also with the study of the thermal behavior at the worse cases

Full Disk Telescope

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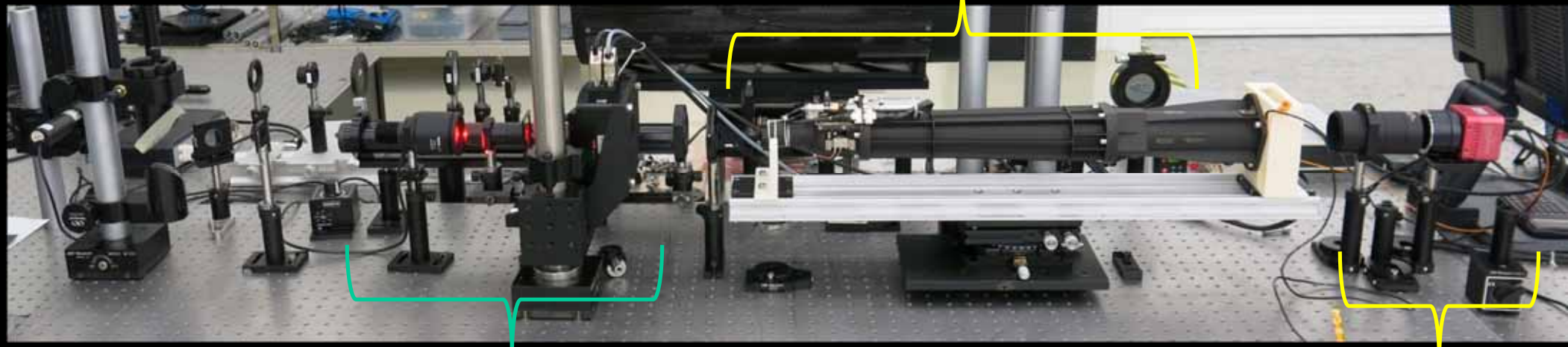
Polarimetric calibration and verification

FDT Assy. (PSA)

Polarization State Analyzer

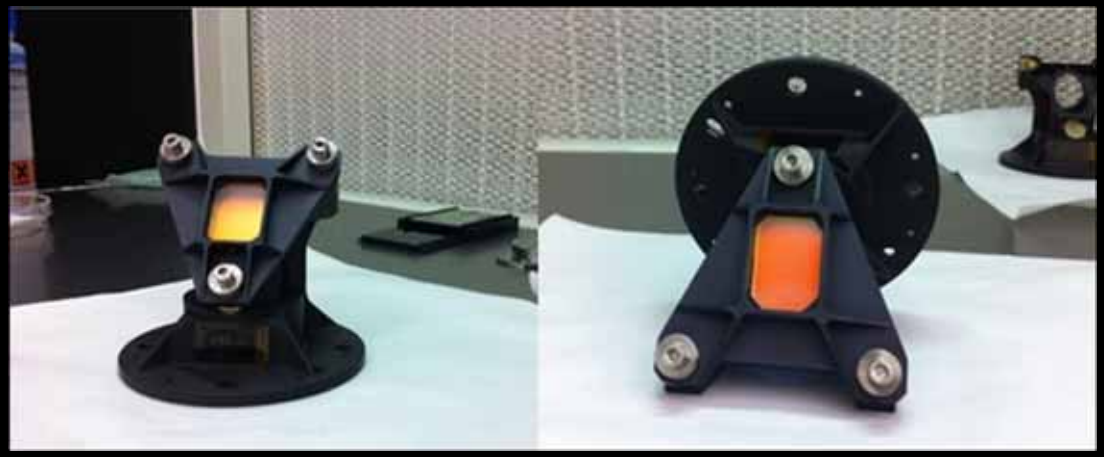


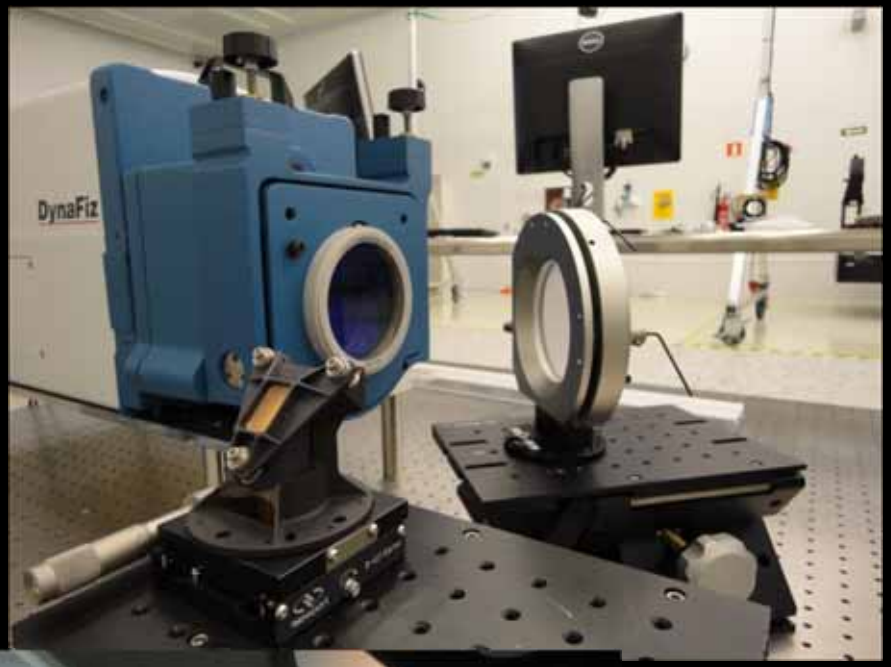
PSG

Polarization State Generator

Imaging optics

Full Disk Telescope: M5





T op
[+70,-25] ºC

T non-op
[+70,-35] ºC

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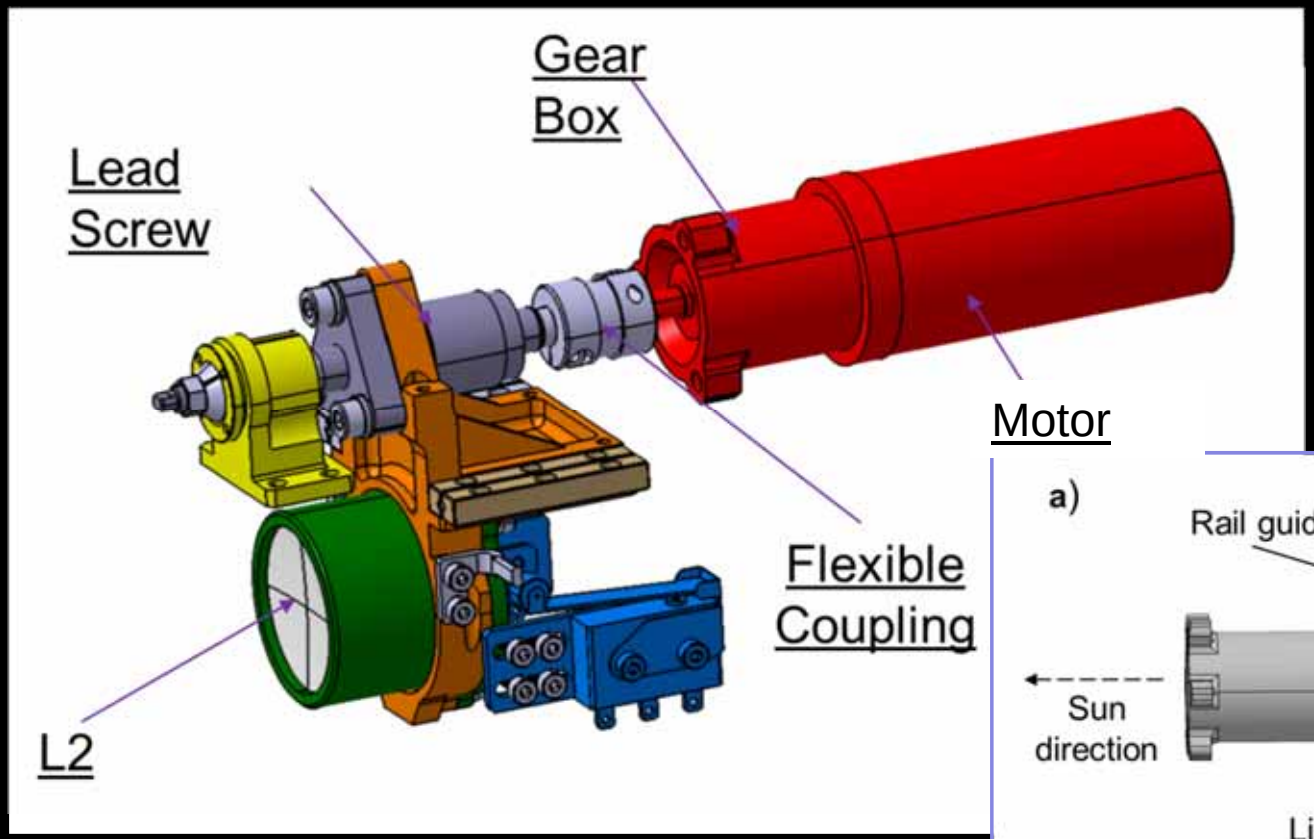
Refocussing Mechanism

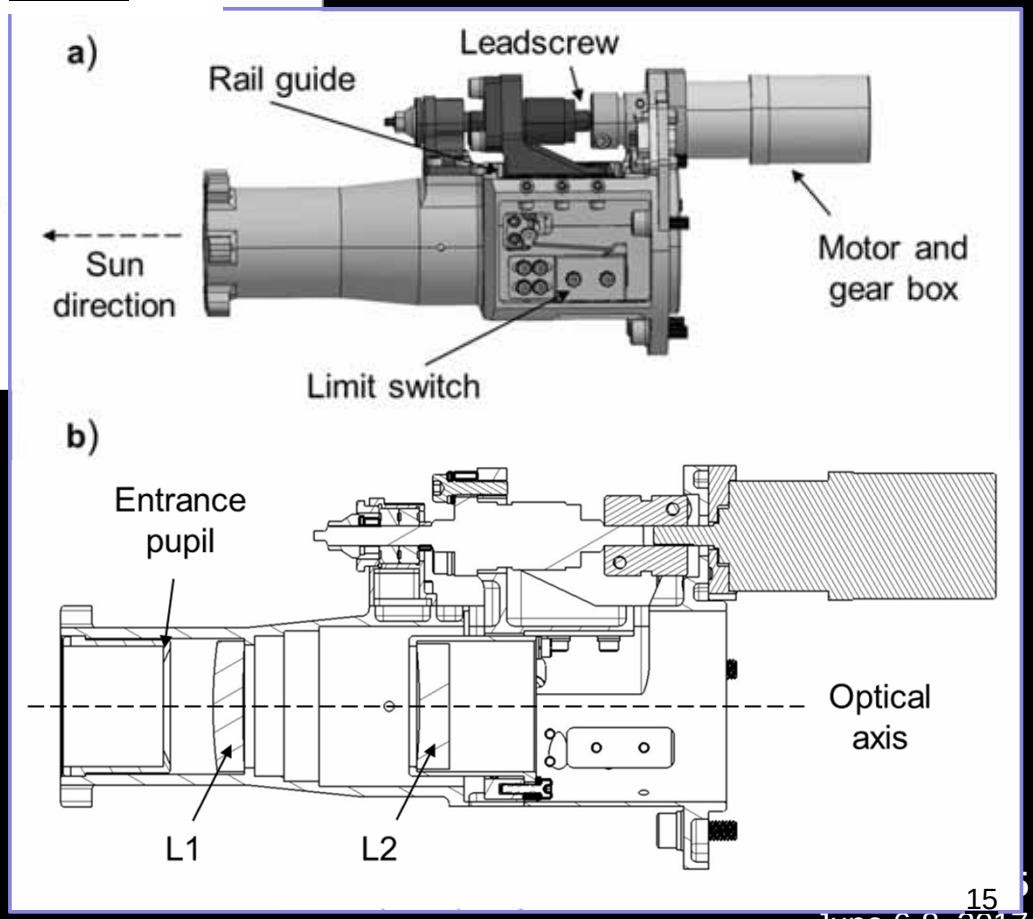


4 mm travel range

±25µm linear accuracy

-30°C to 80°C operational temperature

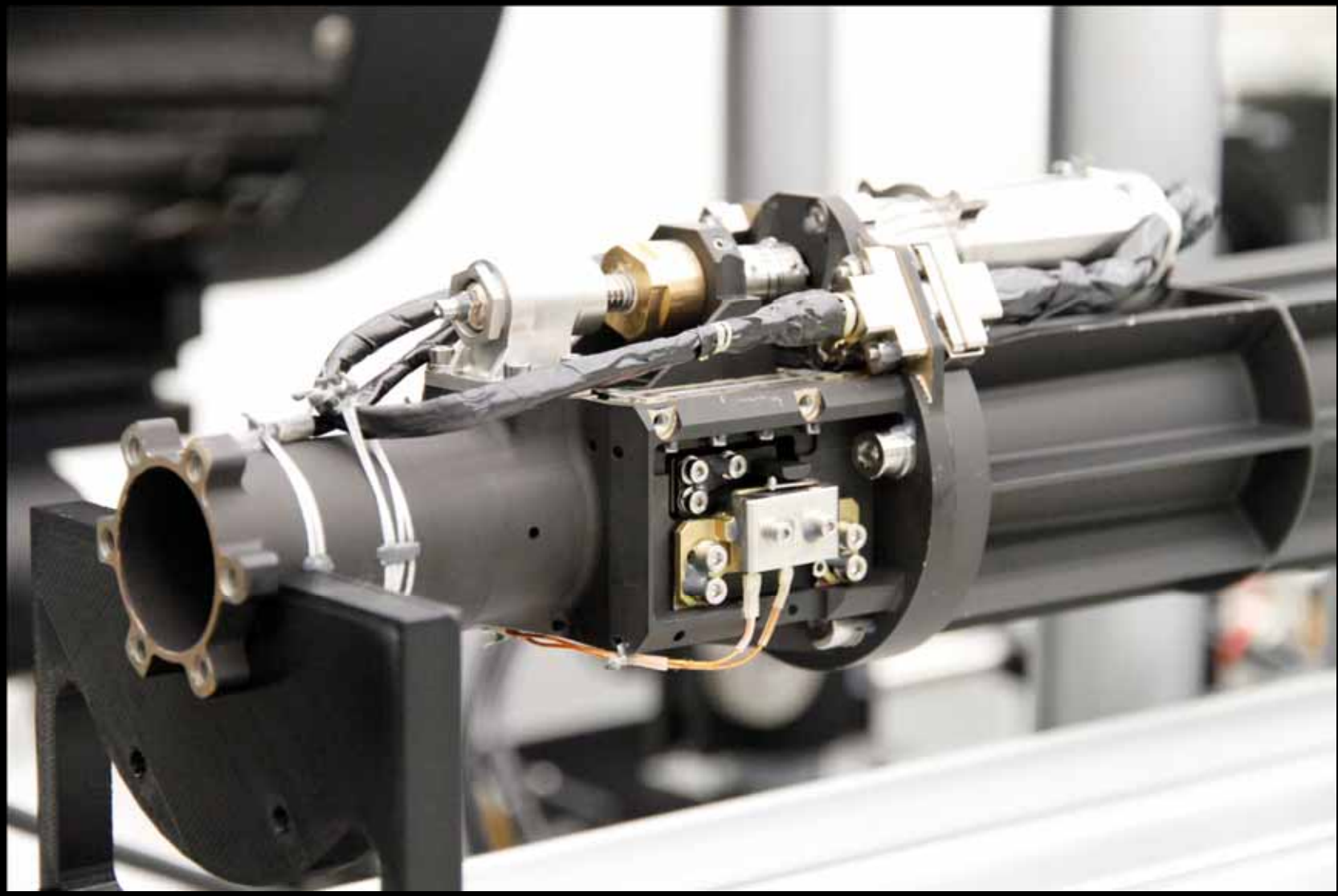
1020 operational life cycles



The lens L2 is mounted on a motorized platform which locates it at the exact point to perform the correct focusing of the system at any situation

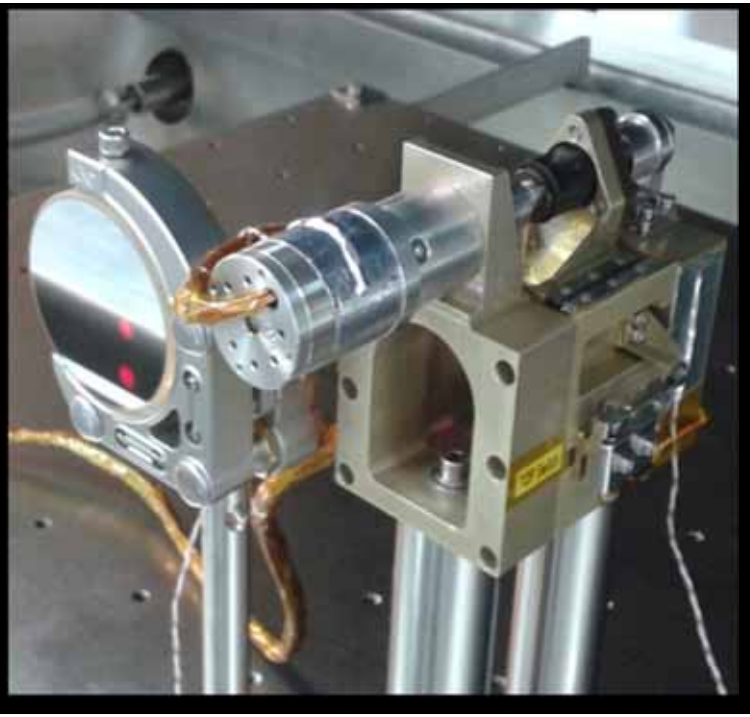
Two limit switches to prevent over travel

Refocussing Mechanism



Refocussing Mechanism

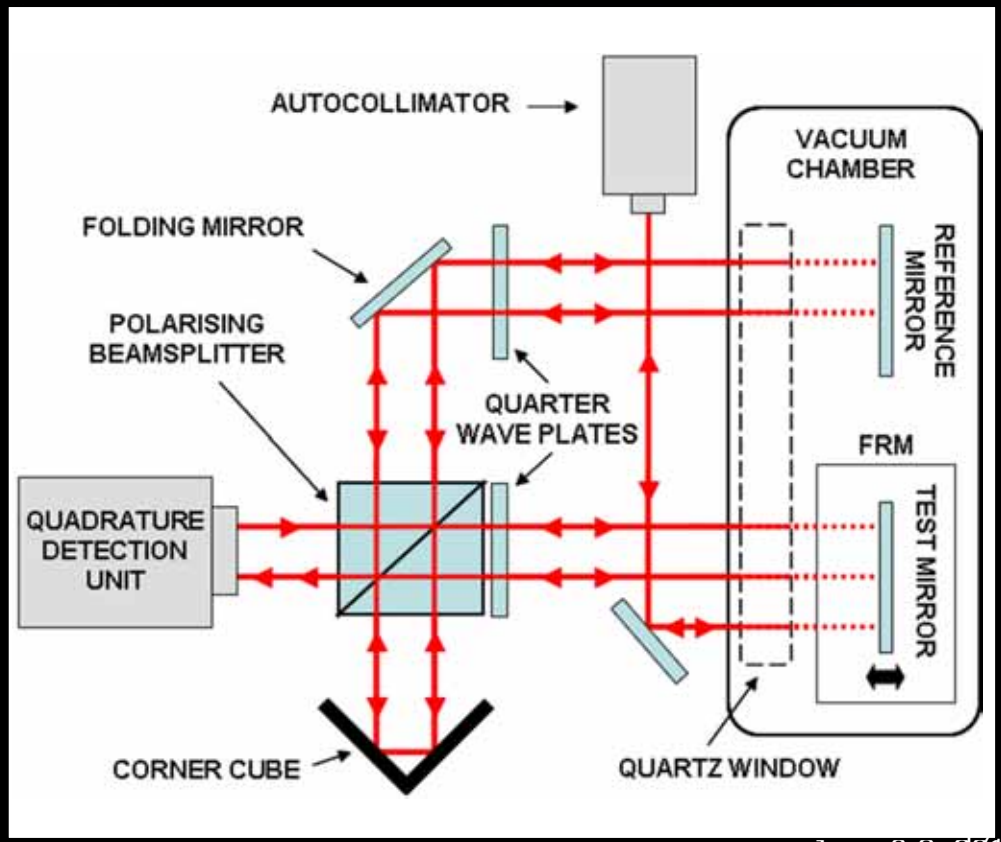
BB



A double-pass double beam interferometer is used to measure axial displacement with nm resolution

An autocollimator monitor pitch and yaw

A theodolite checks run-out

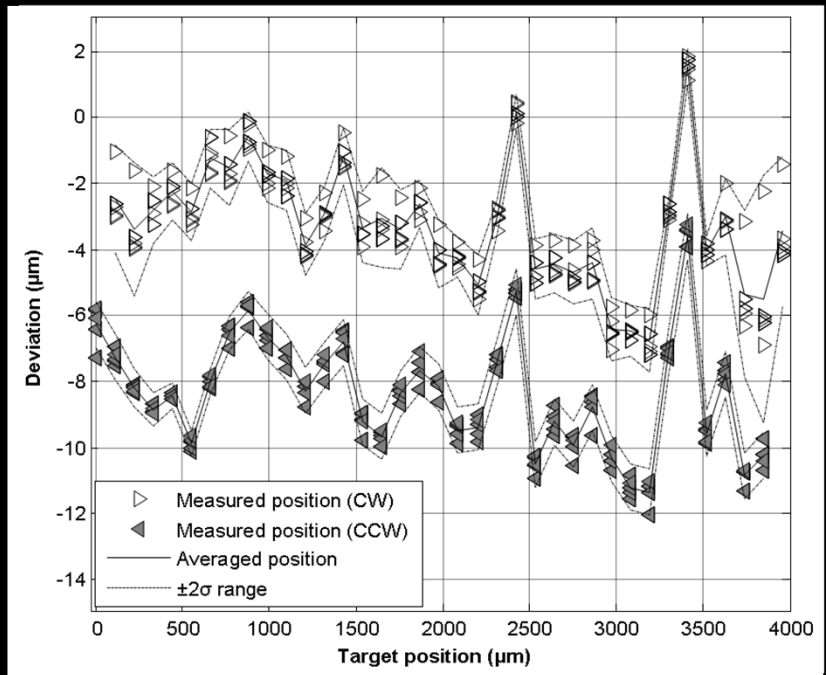


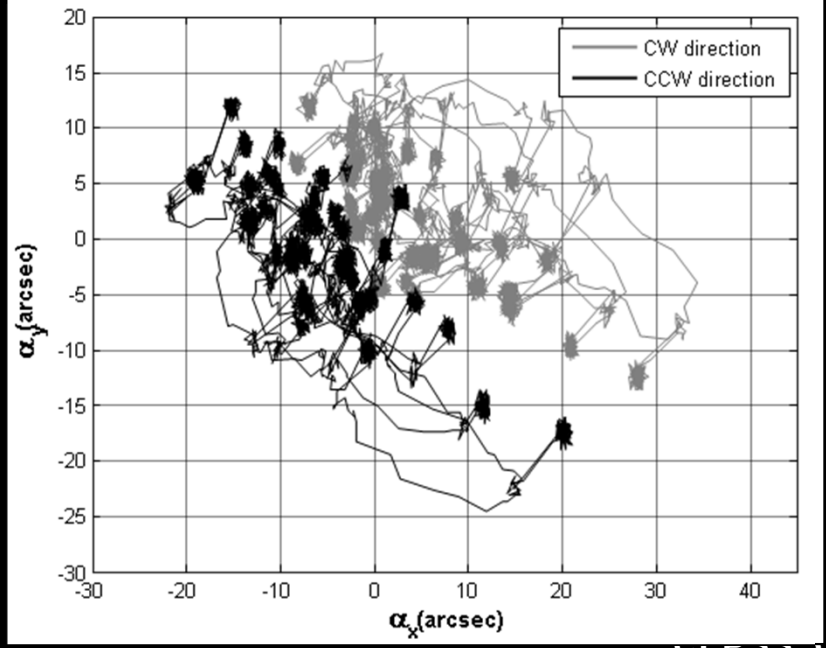
Refocussing Mechanism

Uni and bi directional repeatability, bi-directional accuracy and reversal value were derived and analysed according to the ISO 230-2.

Table 2 Measurement results (all units are μm).

Parameter	Air 20°C	Vac. 20°C	Vac. 80°C	Vac. -25°C	Vac. 20°C
CW uni-directional repeatability	2.40	2.55	7.46	14.21	5.79
CCW uni-directional repeatability	2.74	1.89	1.90	16.62	2.03
Reversal value	6.89	7.23	7.01	6.95	3.77
Bi-directional repeatability	9.26	9.01	11.42	19.79	7.19
Bi-directional accuracy	14.81	13.24	14.24	22.37	21.30
Top switch (σ)	0.26	0.58	4.18	6.42	1.78
Bottom switch (σ)	0.09	0.18	0.87	3.70	0.52



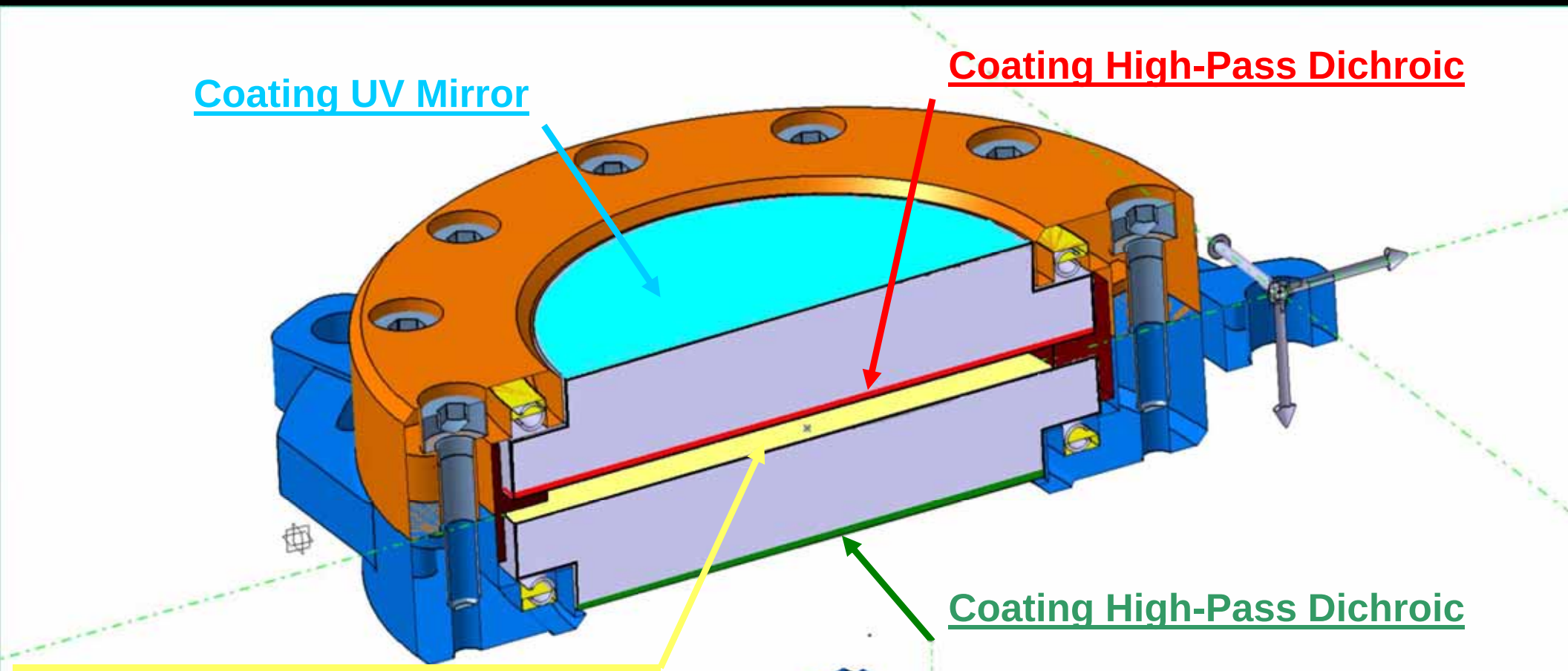


Pitch and yaw trajectories

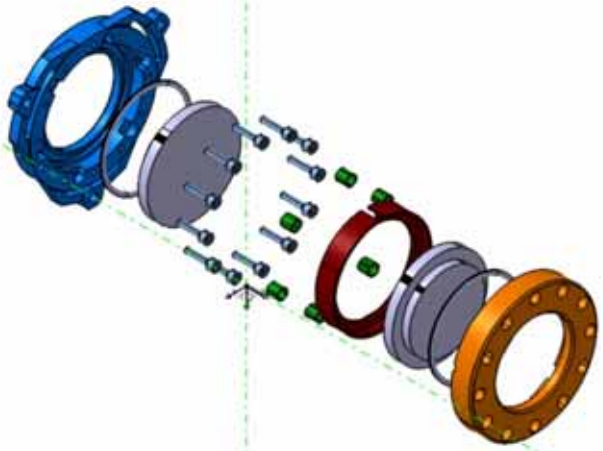
All parameters are within the requirement ranges

Linear guides tested in vibration. Life tests in progress

FDT Heat Rejection Entrance Window



Operational	[250,-65]ºC
Non-operational	[250,-105]ºC



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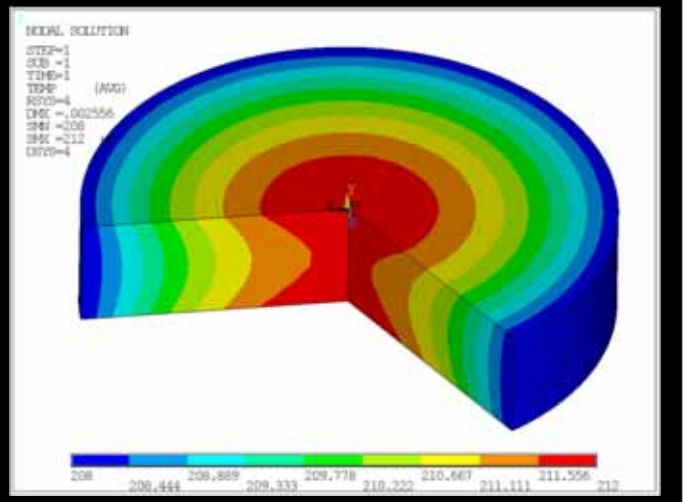
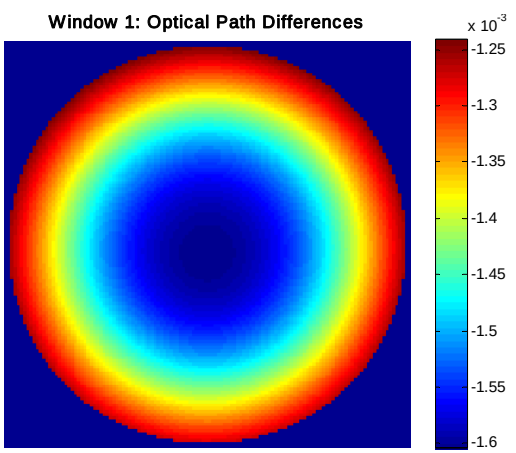
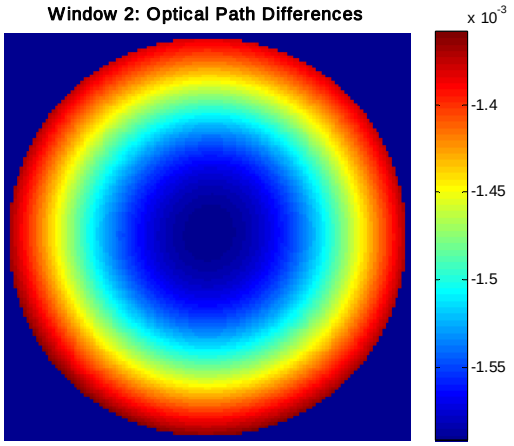
FDT Heat Rejection Entrance Window

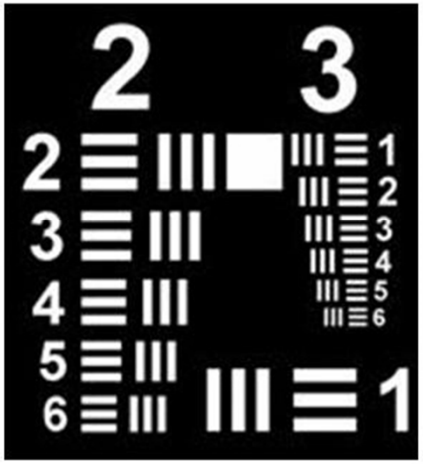
Defocussing effect



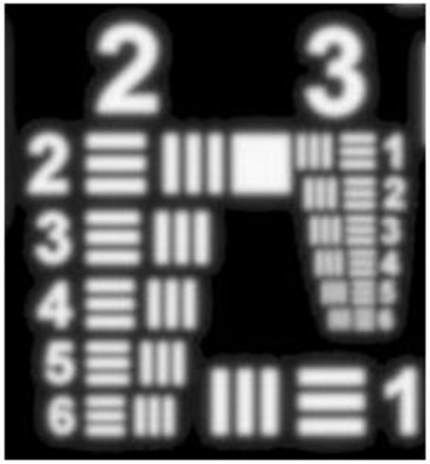




HREW with HOT-5 + FDT hot case



Object



Defocused Image

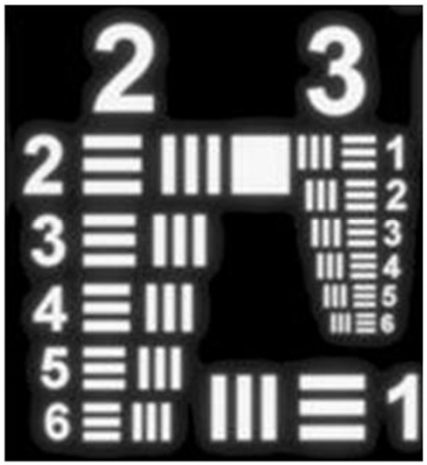
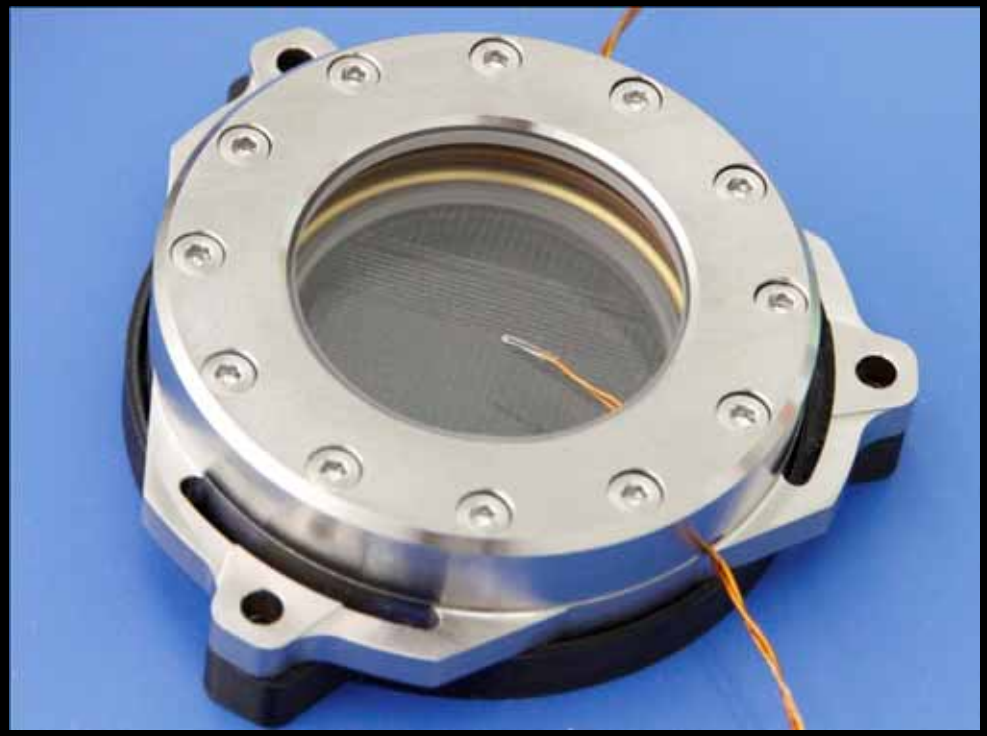
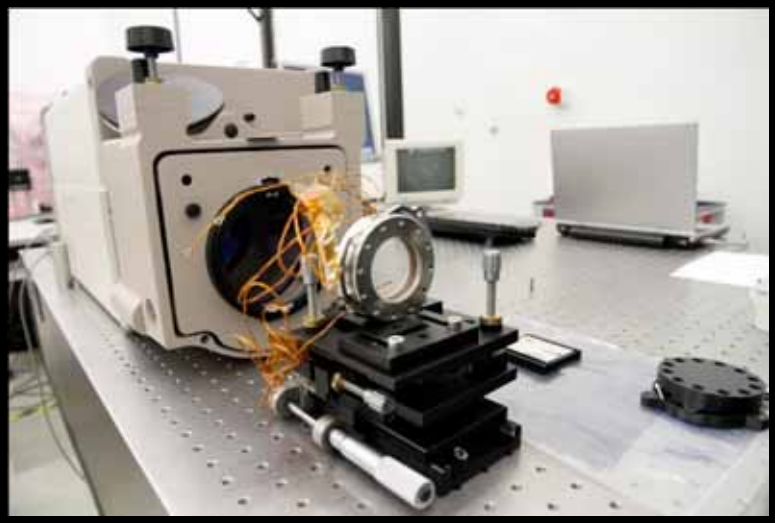


Image focused by L2

FDT Heat Rejection Entrance Window

STM & EBB





Birefringence effect

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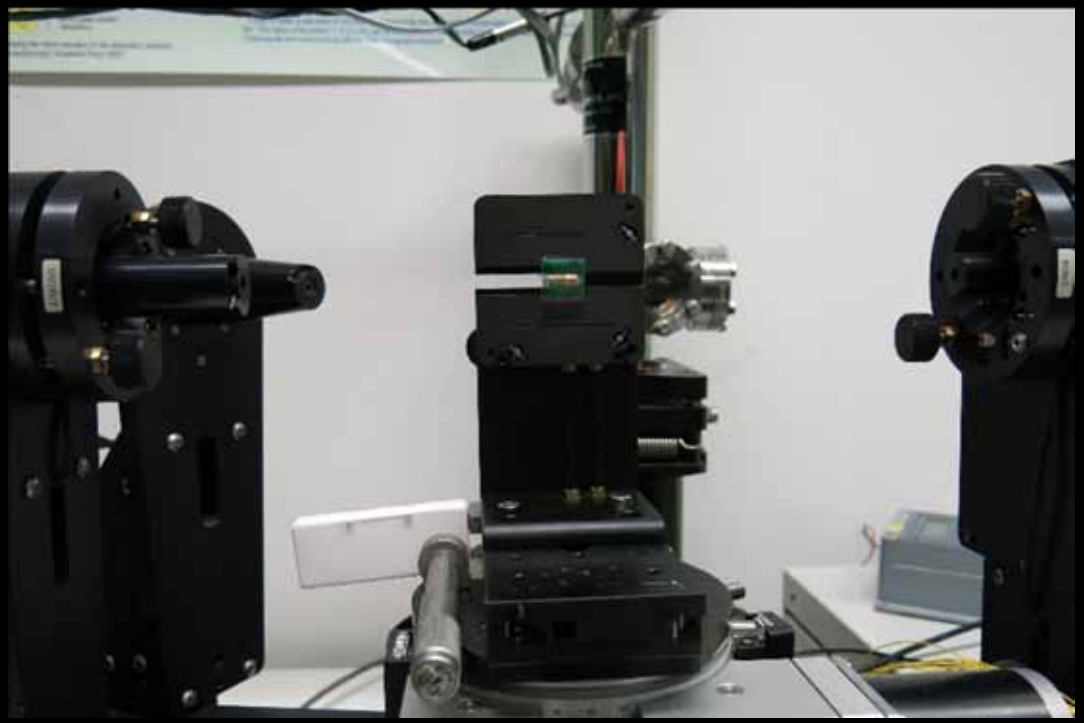
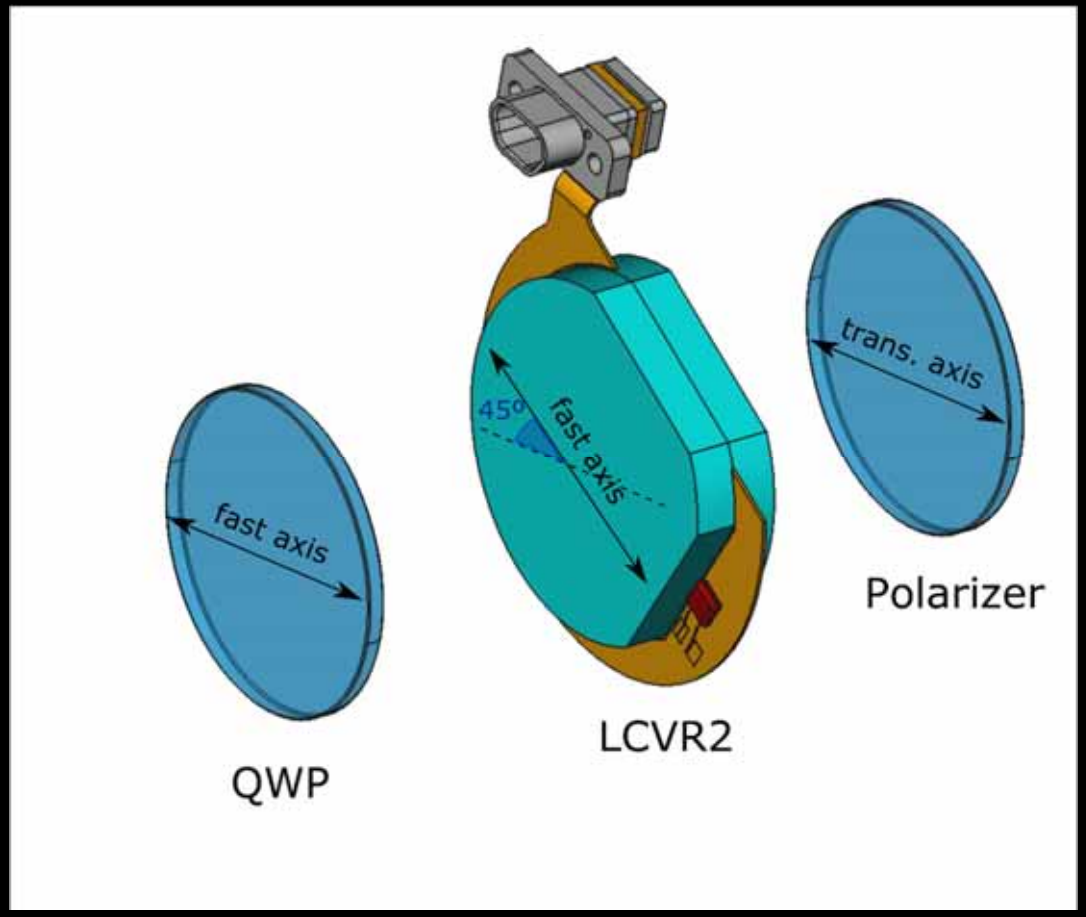
FDT Heat Rejection Entrance Window

UV + high T



PMPs based on LCVRs



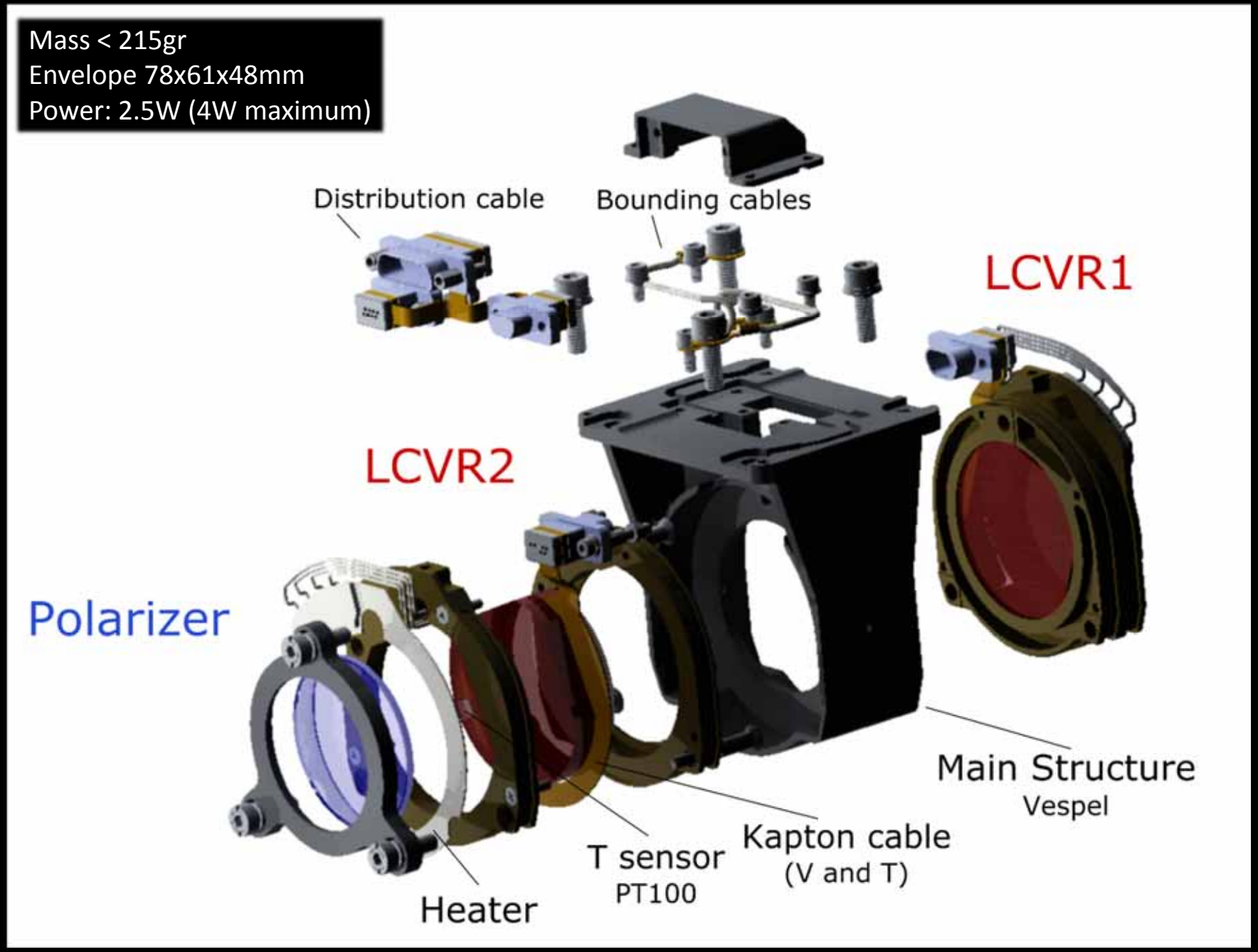
METIS PMP

Two anti-parallel nematic (APAN) LCVRs oriented with their fast axes parallel with respect to each other but opposite molecular tilt angle followed by a linear polarizer at 45° with the fast axes of the LCVRs.

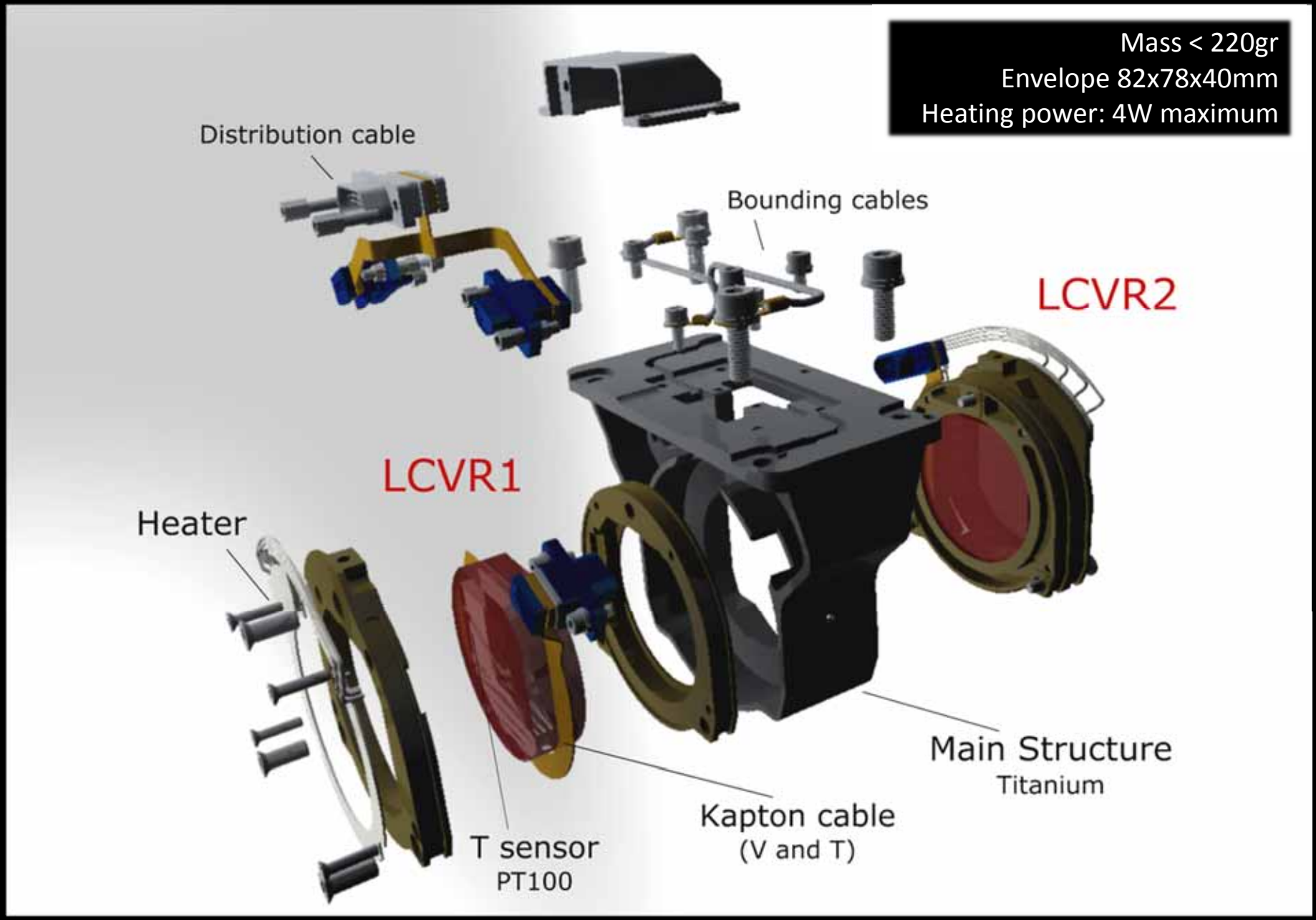
Wide acceptance angles

PMP design: optomechanical

Mass < 215gr
Envelope 78x61x48mm
Power: 2.5W (4W maximum)



PMP design: optomechanical



METIS PMP

Linear polarization

Wide acceptance angles

SO/PHI PMP

Full Stokes vector

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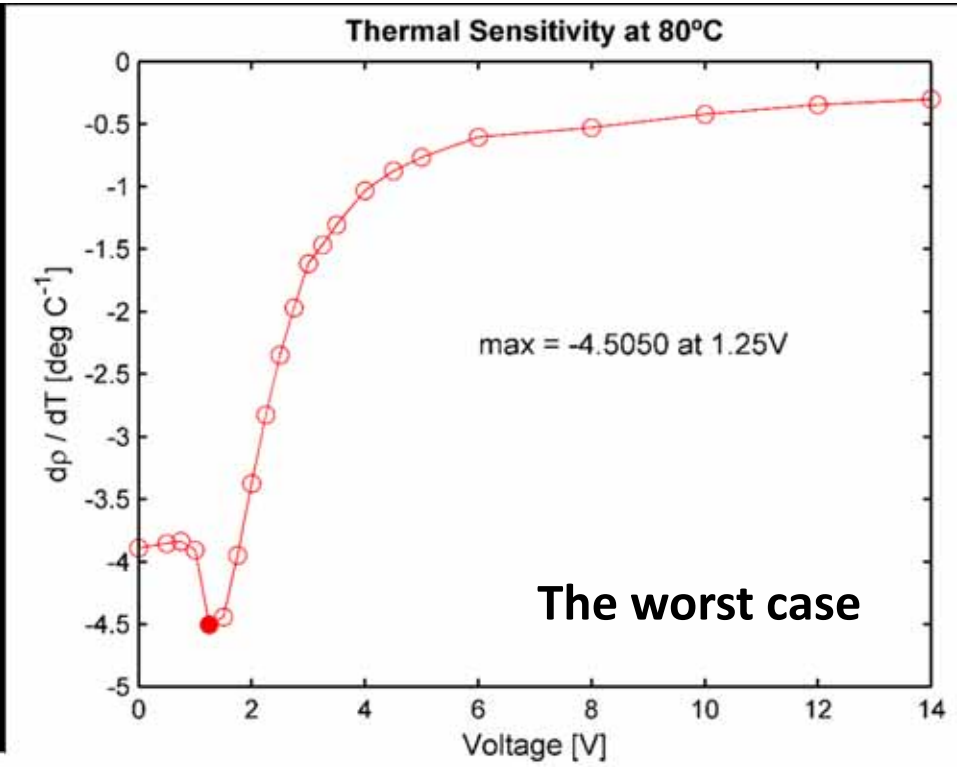
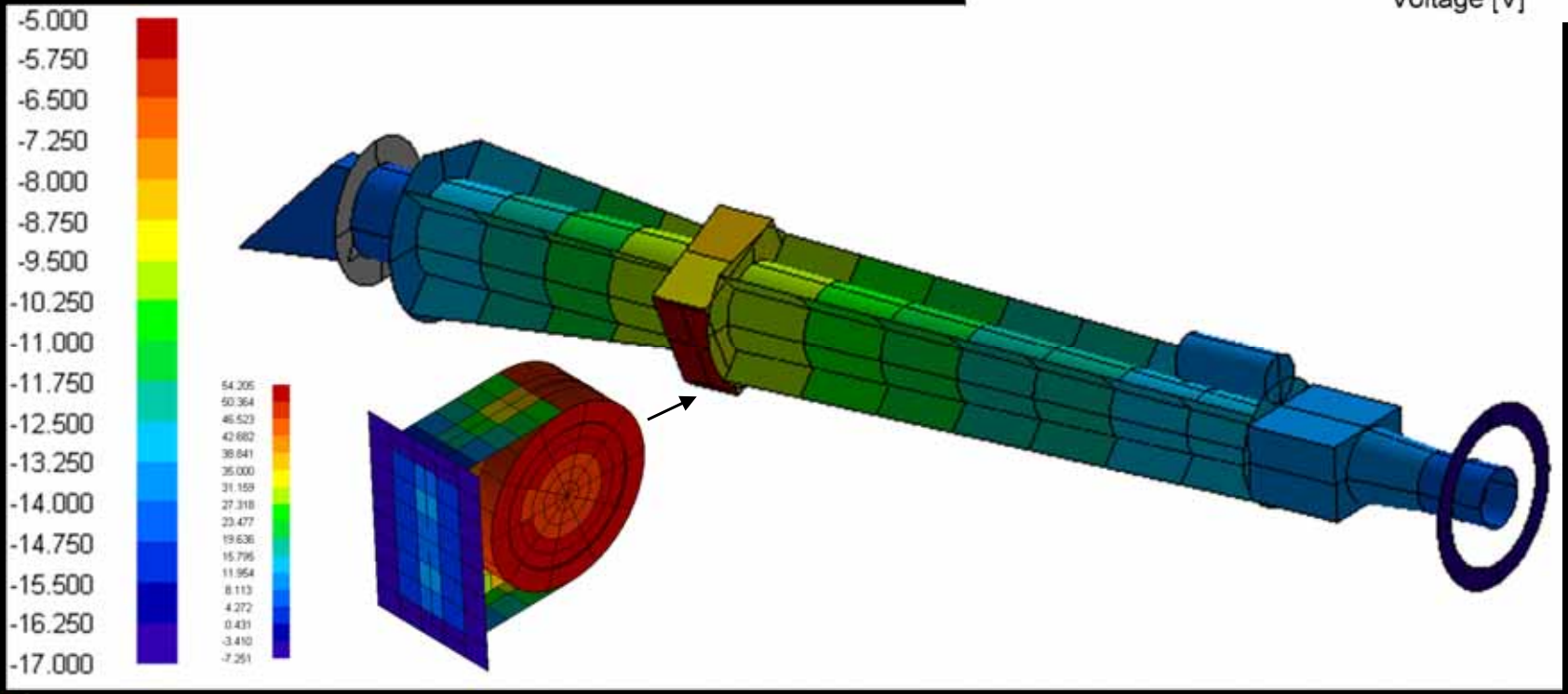
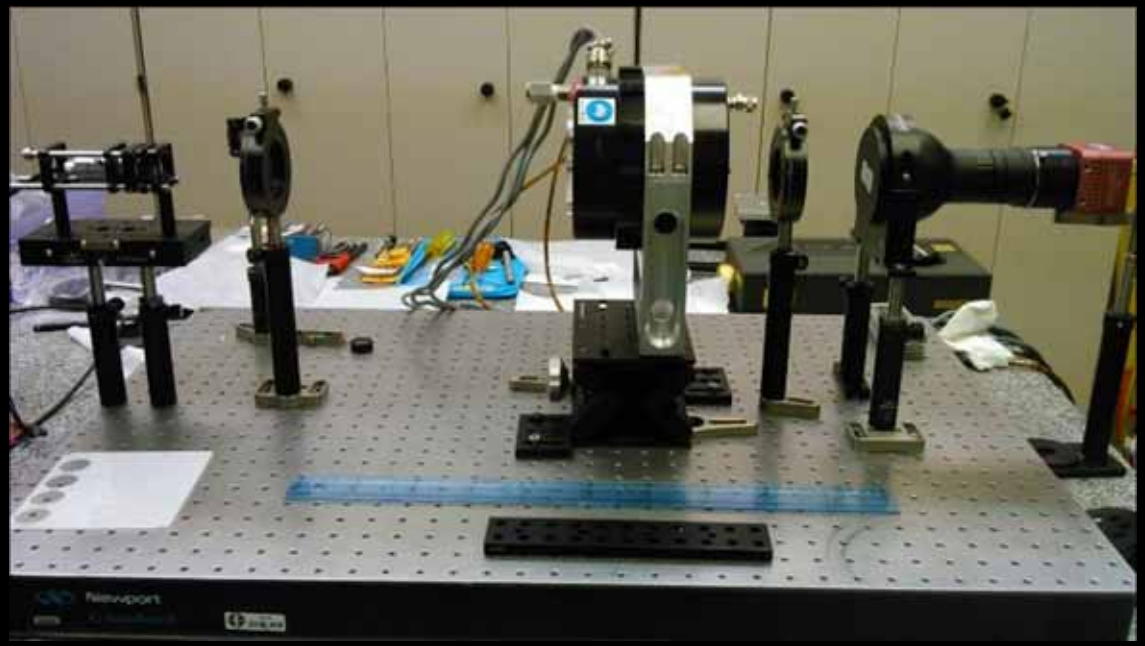
PMP design: thermal

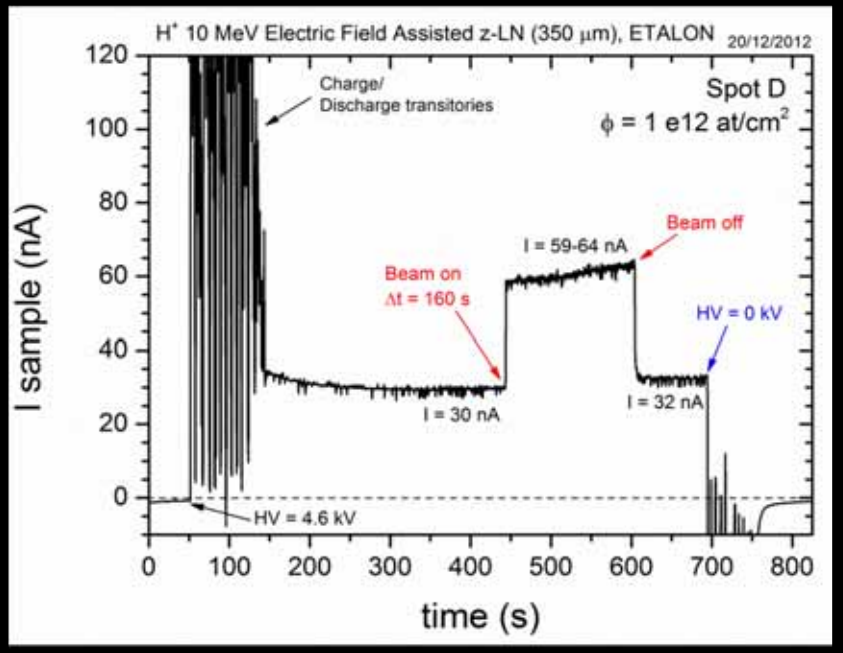
Power (W)	Time to reach 40ºC
1.8	∞
1.85	10000 s = 2h 47min
1.9	6100 s = 1h 48min
2.1	3350 s = 56min
2.3	2650 s = 44min
2.5	2200 s = 37min

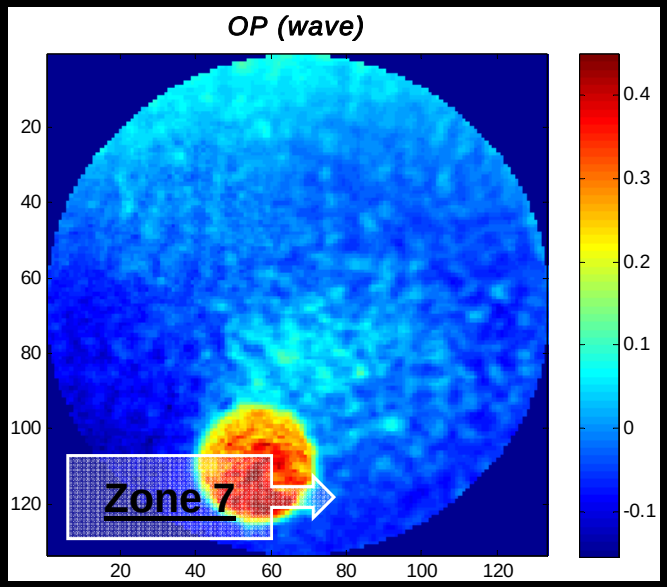




Qualification of the LiNbO3 etalon







Robust against:
(ion radiation)

- Dielectric rupture
- Finesse changes

Collaboration with CMAM-UAM

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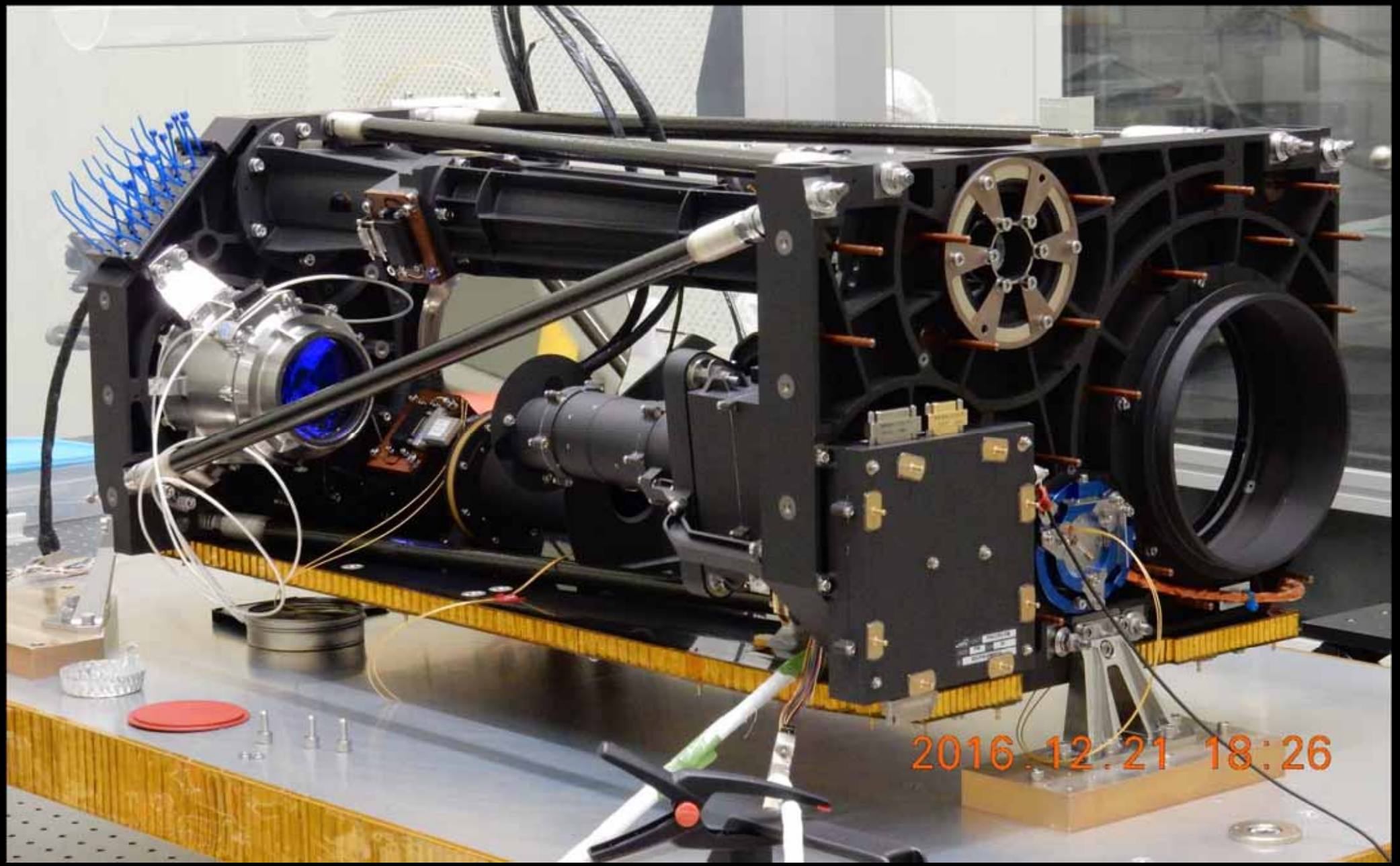
PHI FM



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PHI FM

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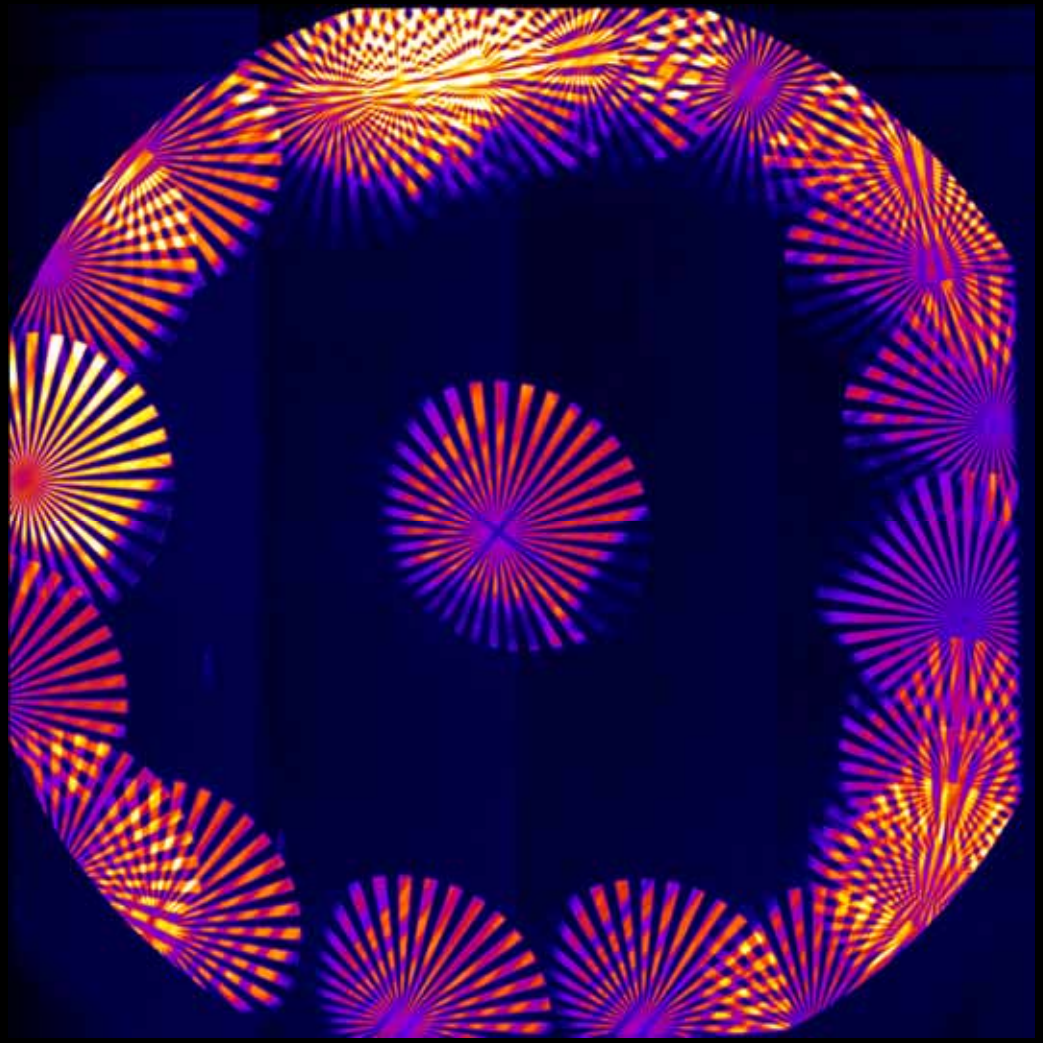
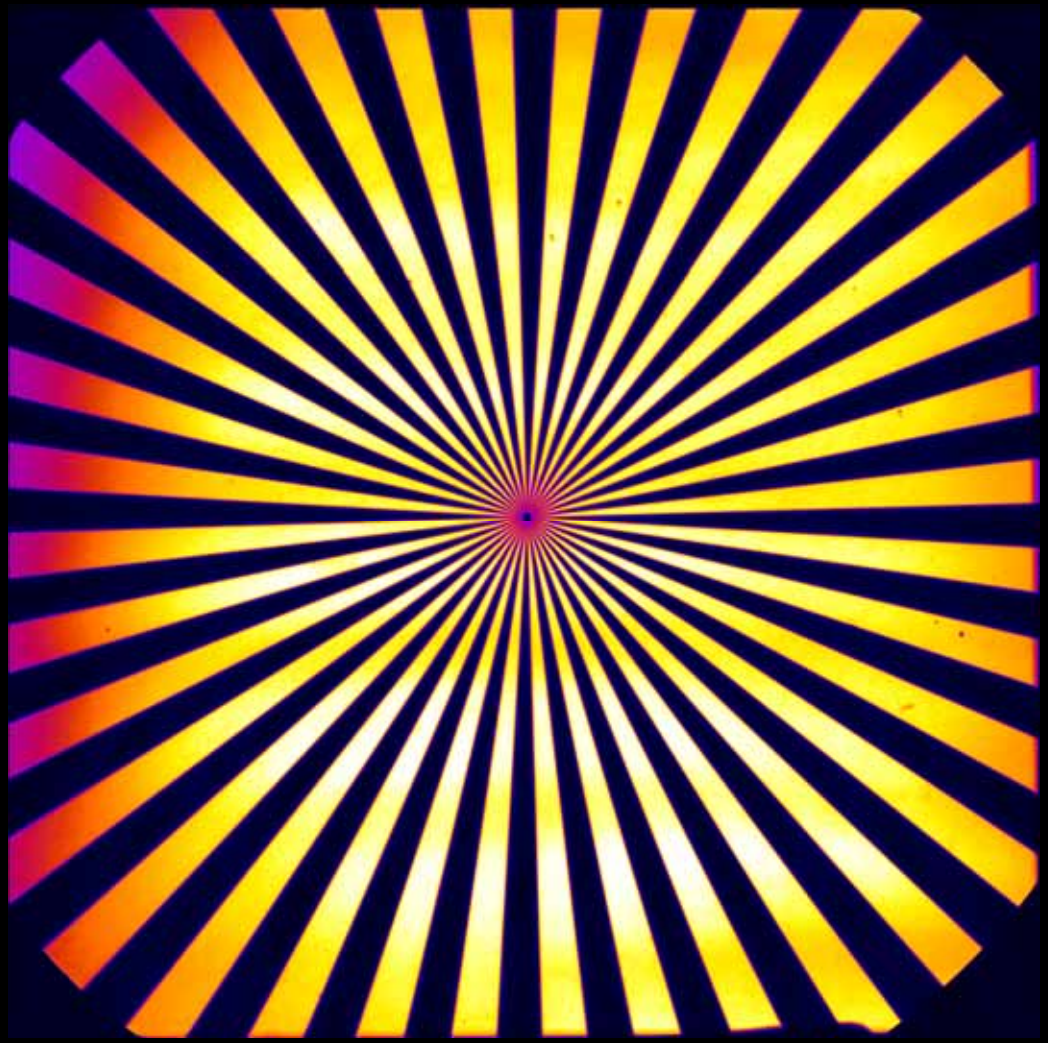
First light

FDT



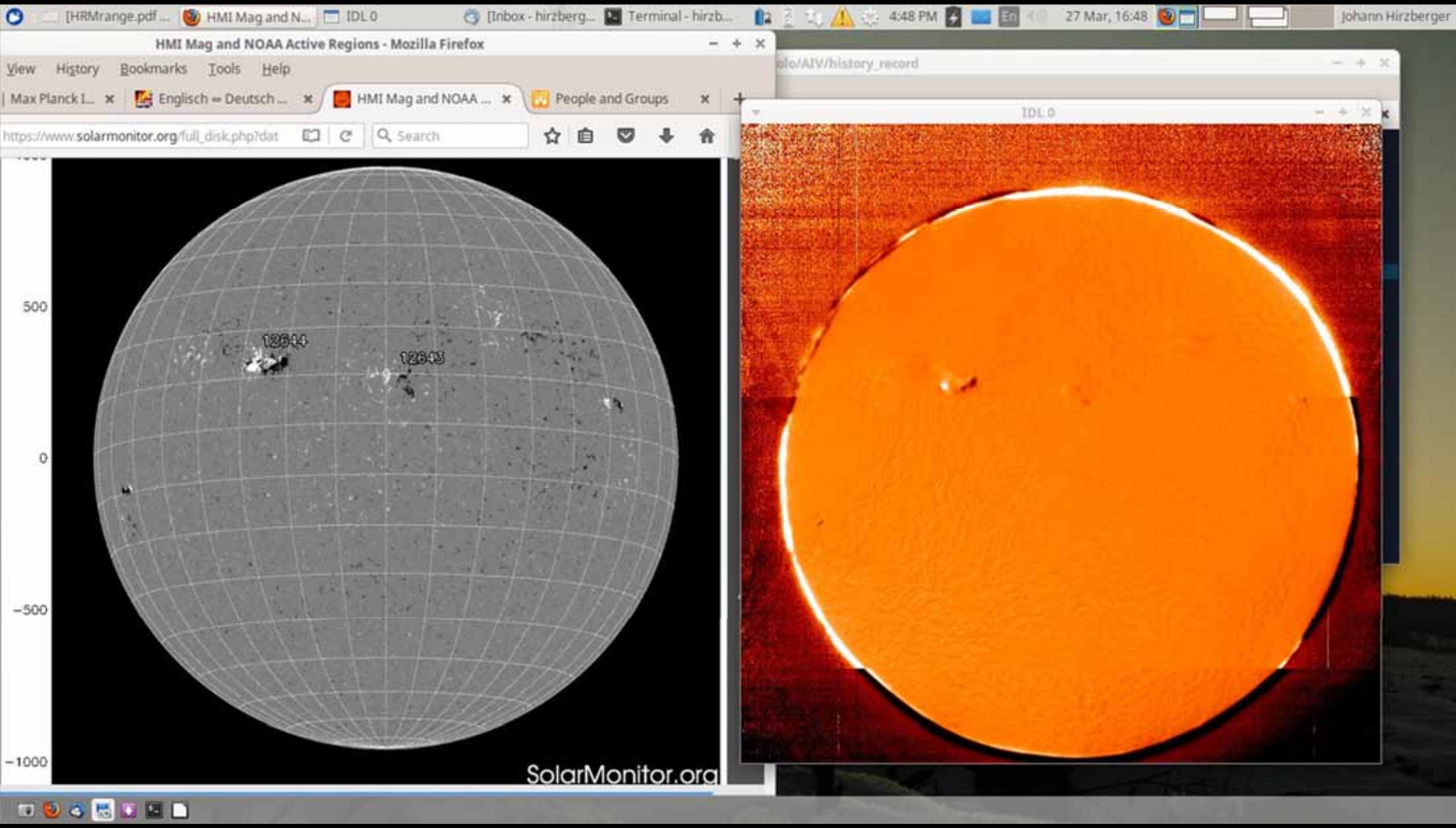
HRT



Excellent alignment and optical quality

Polarimetric efficiencies achieve the theoretical maximum (0.57)

Solar light test at vacuum conditions



Excellent spectroscopic performances

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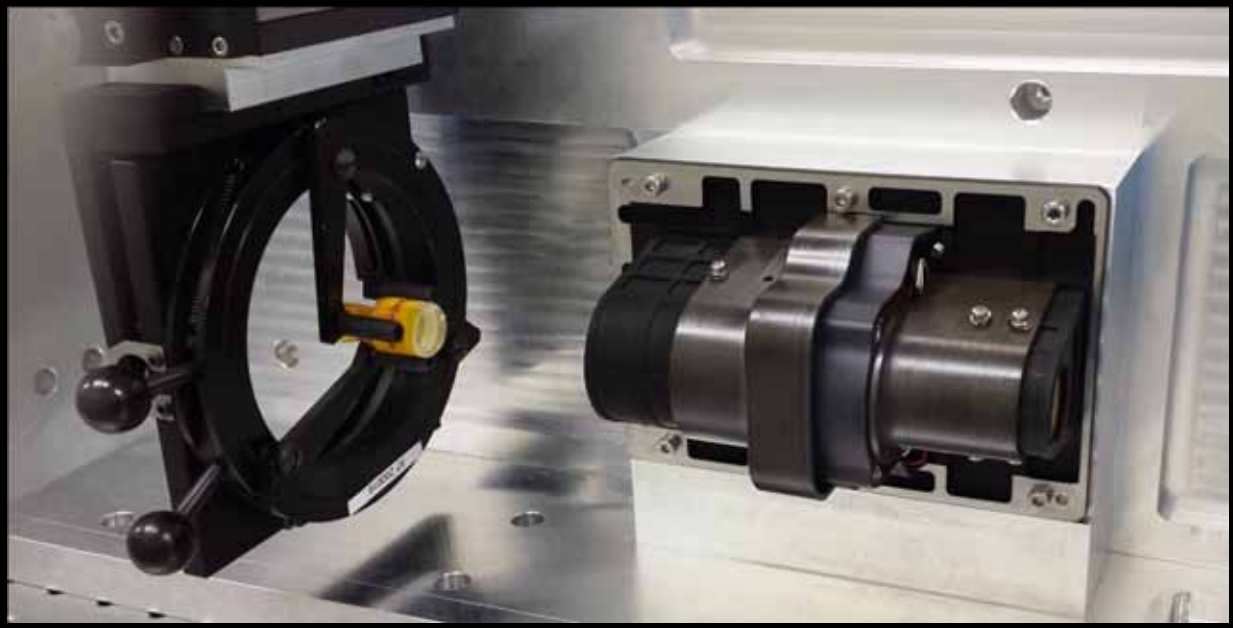
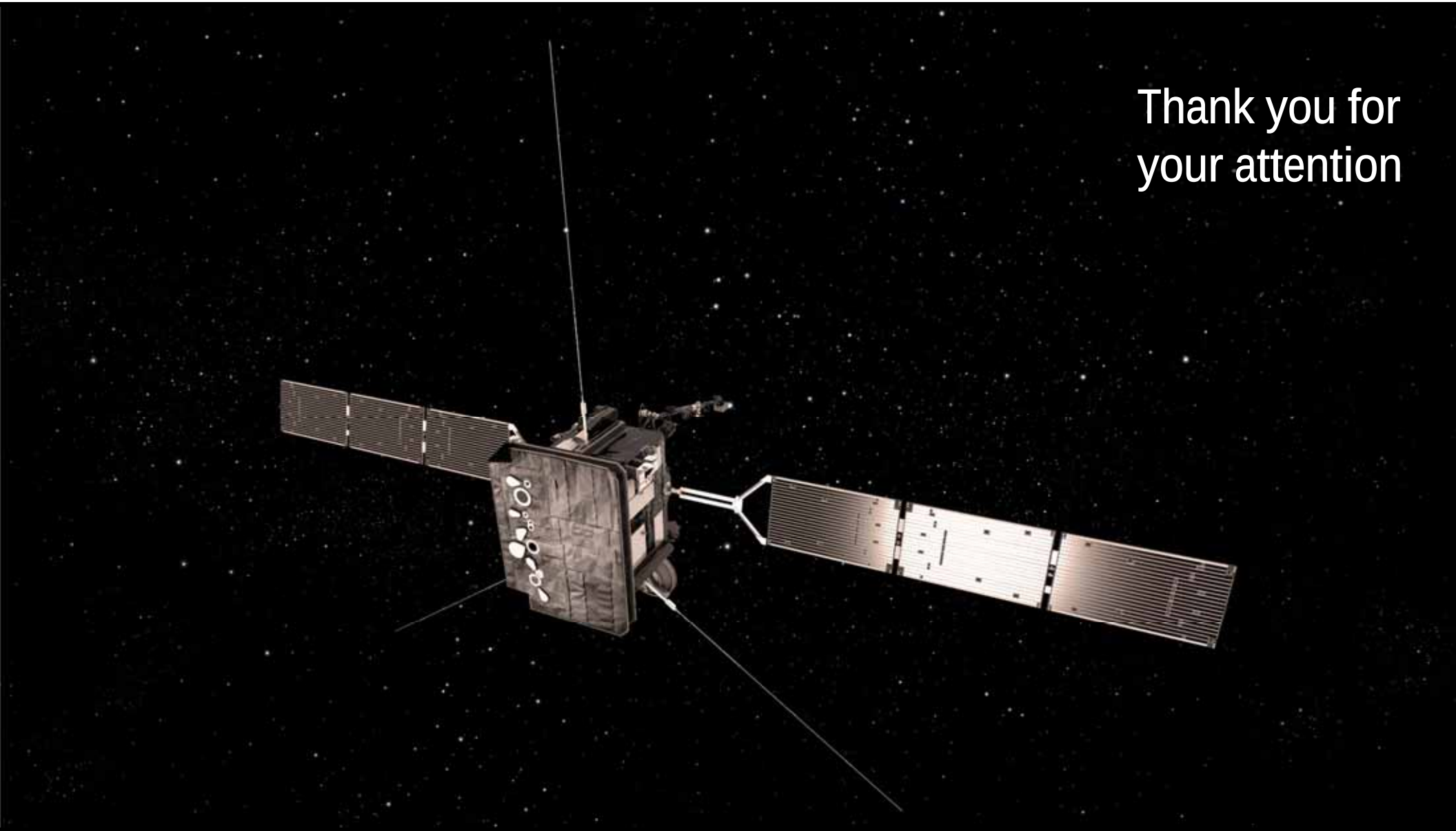
METIS FM

Excellent optical quality and polarimetric modulation performances



Conclusions

- INTA has strong contributions to SO/PHI development including responsibilities in the analysis, design, manufacturing, integration and verification of the instrument.
- FM units under INTA responsibility have been successfully delivered and integrated (October-December 2016). Our team participated in the integration at instrument level and final verifications and calibrations.
- PHI and METIS have been delivered to ADS (UK), April 2017.
- Roadmap from 2002 (IMaX background, INTA O-Unit responsible).
- Deliveries 2017: Flight Spare (FS) and FEW FM.



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