ESA-NASA Working Meeting on LIDAR

ALADIN Instrument:

Key Issues & Technical Challenges

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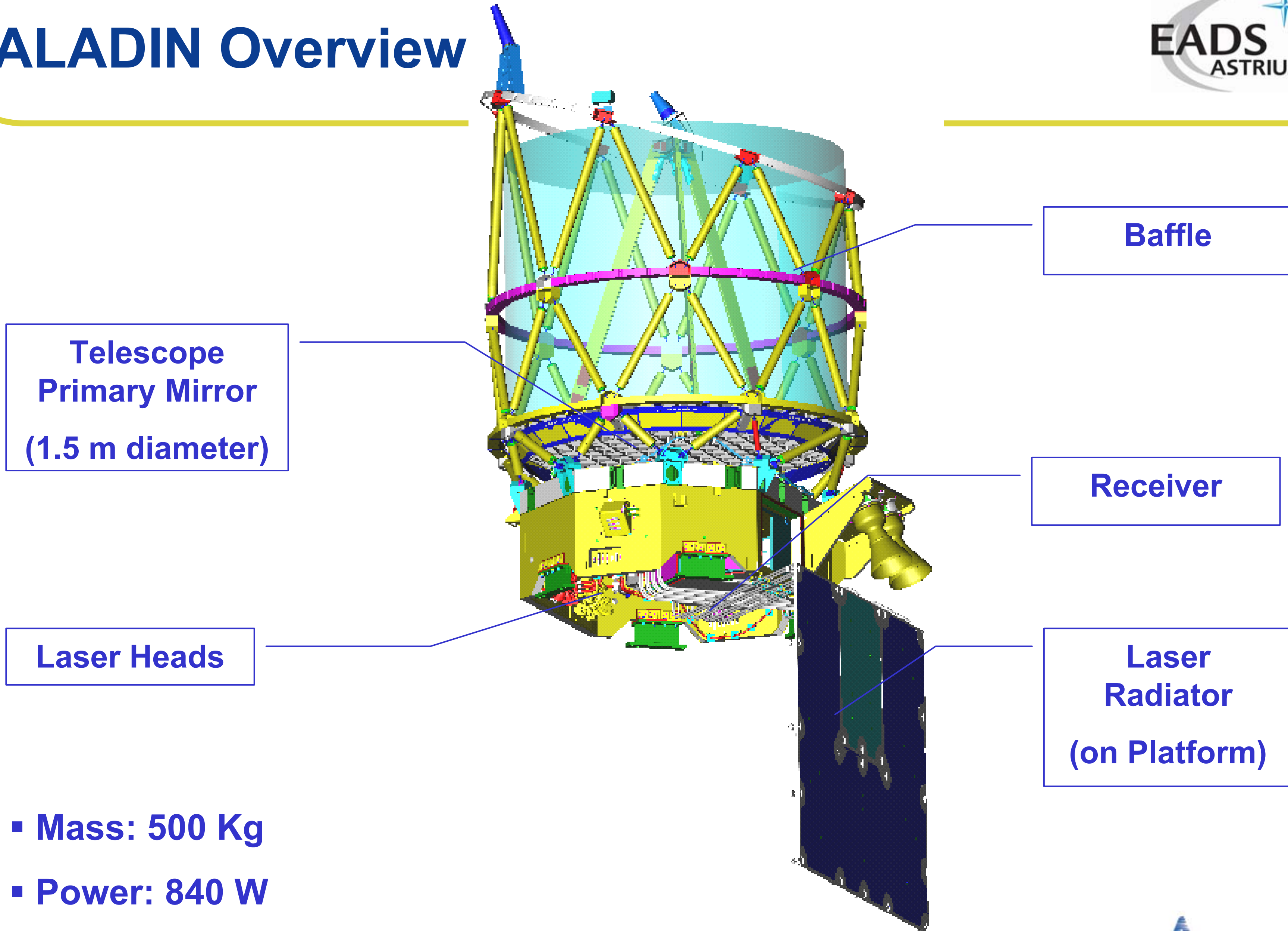
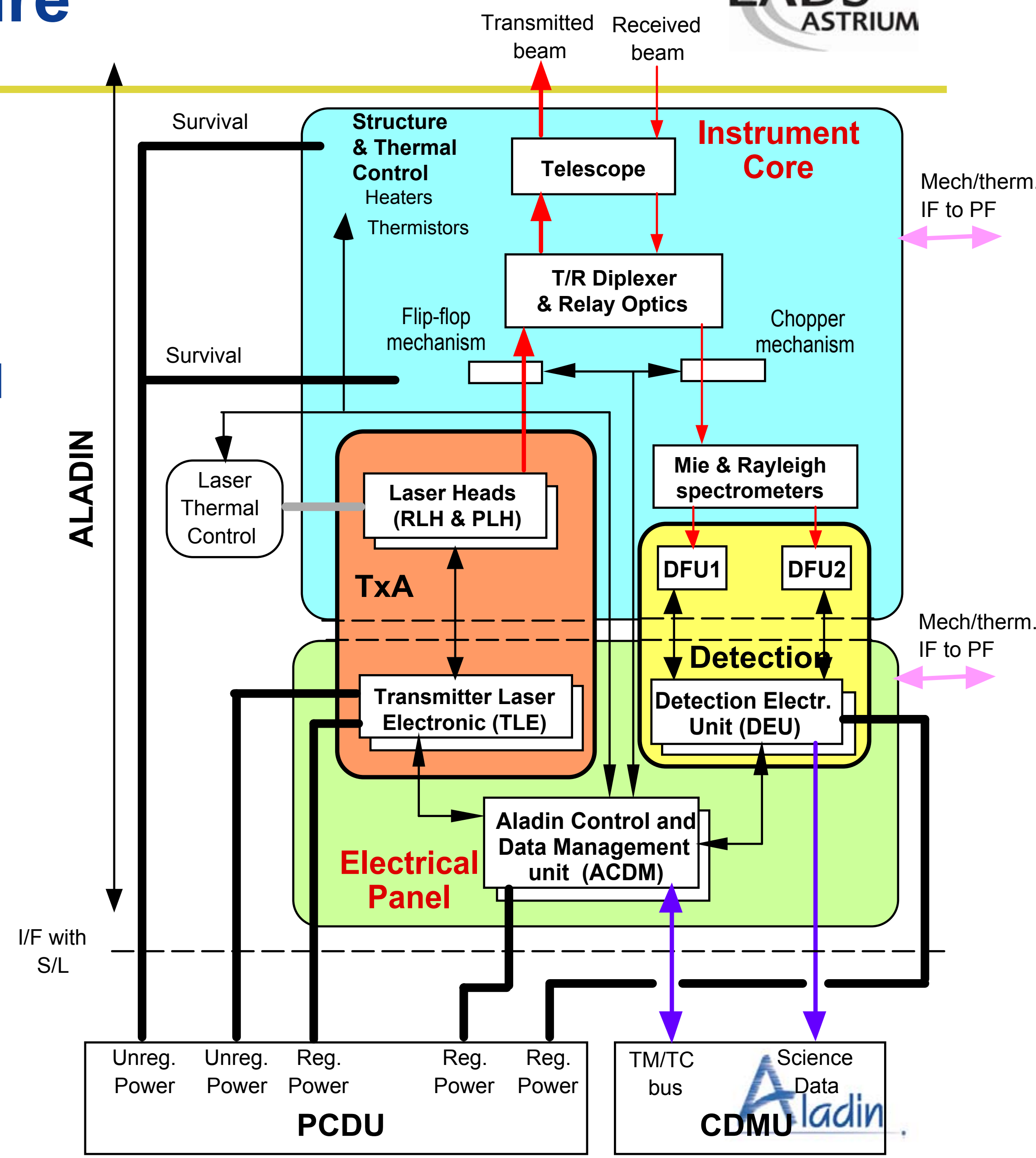
ALADIN Overview



- Mass: 500 Kg
- Power: 840 W

Functional architecture

- The laser beam is transmitted and received through the telescope (1.5 m)
- Two laser heads are embarked (redundancy)
- Two spectrometers and associated CCD detectors are within the instrument (Mie & Rayleigh receiver)
- Thermal control and synchronisation is performed by the instrument (hardwired logic)

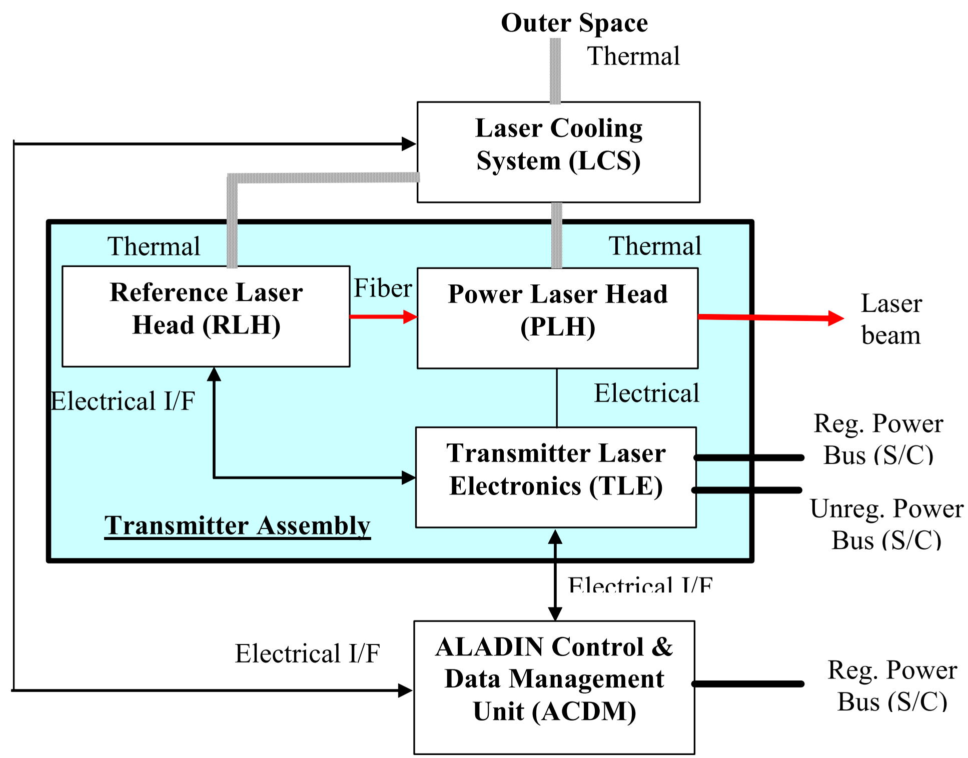


Key issues at instrument level

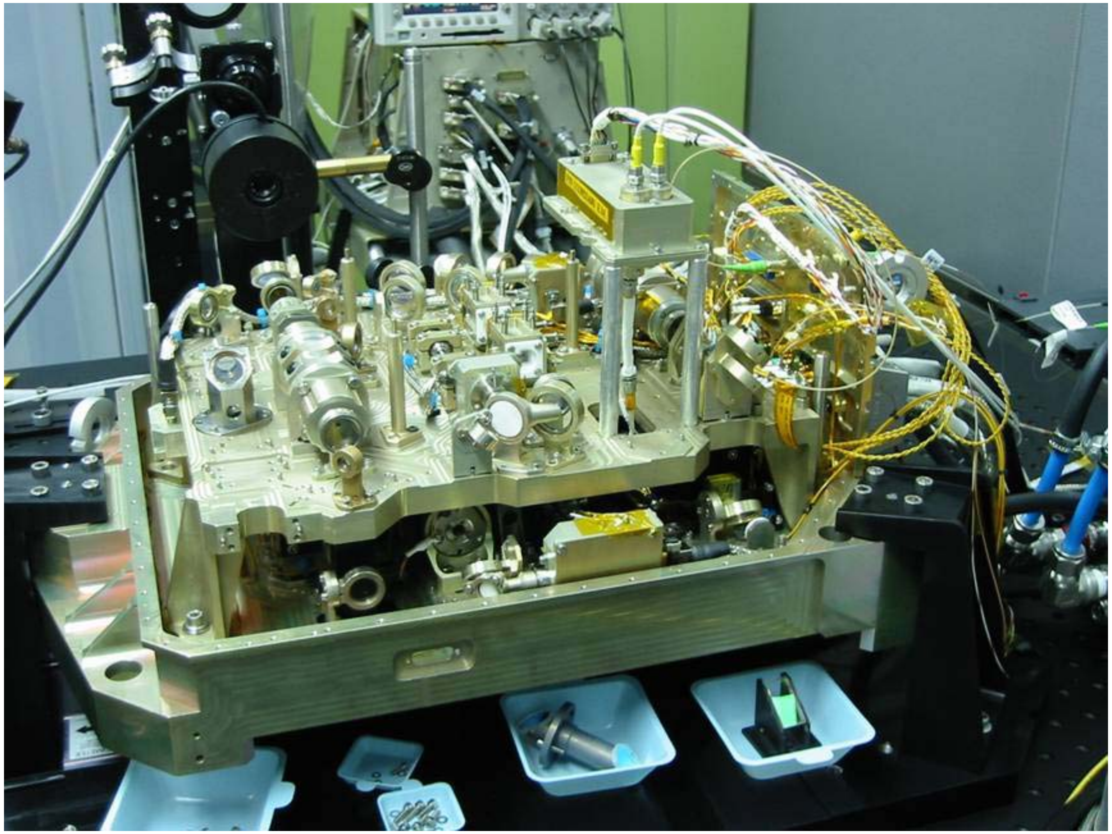
- **Contamination risk on laser optics**
  - Bake-out of all glued components within the Power Laser Head and Transmit/Receive Optics
  - Bake-out of all materials (structures, MLI,..) located close to the PLH and TRO
  - Purging of PLH from box closing until launch
- **« Laser straylight » within the instrument**
  - No damage/saturation on detector during firing -> Chopper mechanism and anti-backreflection surface on M2 mirror
  - No laser « hot spots » within the instrument on optics or structure -> Specific protections (field stops, baffles) to avoid high energy illumination outside laser optics and low energy source for laser alignment
- **Thermal control**
  - High laser power dissipation -> Numerous Heat pipes on instrument and platform: orientation versus gravity vector to be managed thoughout all integration and test programme

Transmitter Laser Assembly (TxA)

- The TxA is composed of:
- Power Laser Head (PLH)
  - **Diode-pumped Nd-YAG laser**
  - **Emits 150 mJ pulses @355 nm**
  - **Pulse repetition frequency 100 Hz**
  - **12 s "bursts" every 28 s**
- Reference Laser Head (RLH)
  - **Highly stable seeder laser (a few MHz)**
  - **Tunable over 7 GHz**
- PLH and RLH conductively cooled
- Transmitter Laser Electronics (TLE)
  - **High current and voltage driver**
  - **Transmitter control and synchronisation**



Transmitter Laser – PLH



The Power Laser Head (PLH) includes:

- Injection seeded Master Oscillator Section (MO)
- Amplifier Section with two slab amplifiers
- Harmonic Generation Section with doubling and tripling crystals

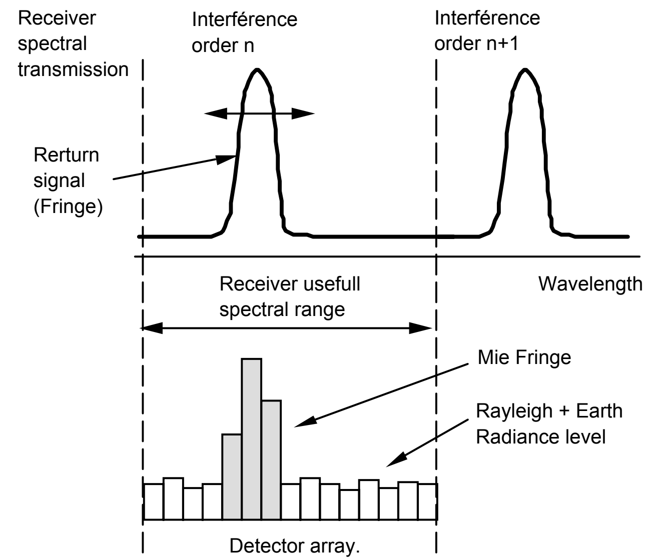
Transmitter issues: see specific presentation from A. Cosentino

Receiver

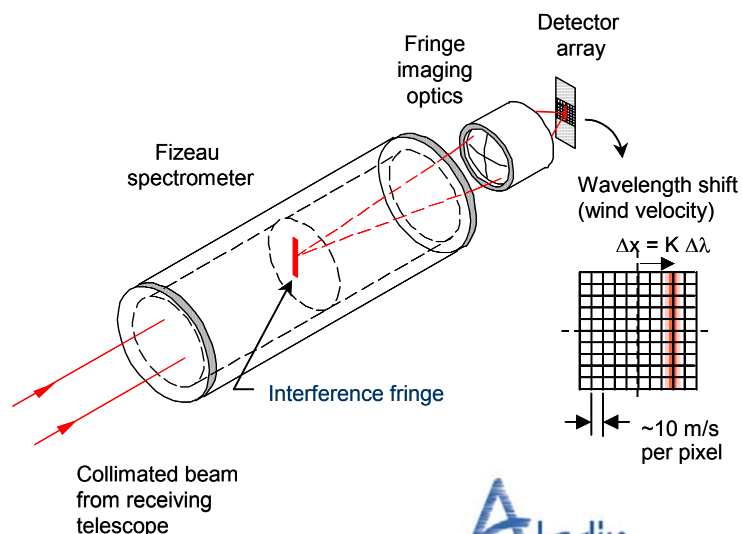
- **The Receiver is composed of two channels (Mie and Rayleigh) each composed by an etalon spectrometer and a CCD Front-End Unit.**
- **It also includes a polarisation diplexer to separate Transmit/Receive paths and a Chopper Mechanism to shut the receiver during laser firing**
- **The optical architecture allows to feed Mie and Rayleigh channels with maximum optical efficiency**
- **The spectral registration between the Mie and Rayleigh channels is performed with thermal tuning of the Rayleigh spectrometer :**
  - Thermal hood around the RSP
  - Tuning on a range of +/- 3 K
  - 1 mK accuracy
- **Detection modules are based on "Accumulation CCD" (Astrium patent) allowing quasi photon-counting performance with a Si-CDD**
  - Read-out noise < 4e- (equivalent to 0.5 e- noise per shot)

Mie Spectrometer

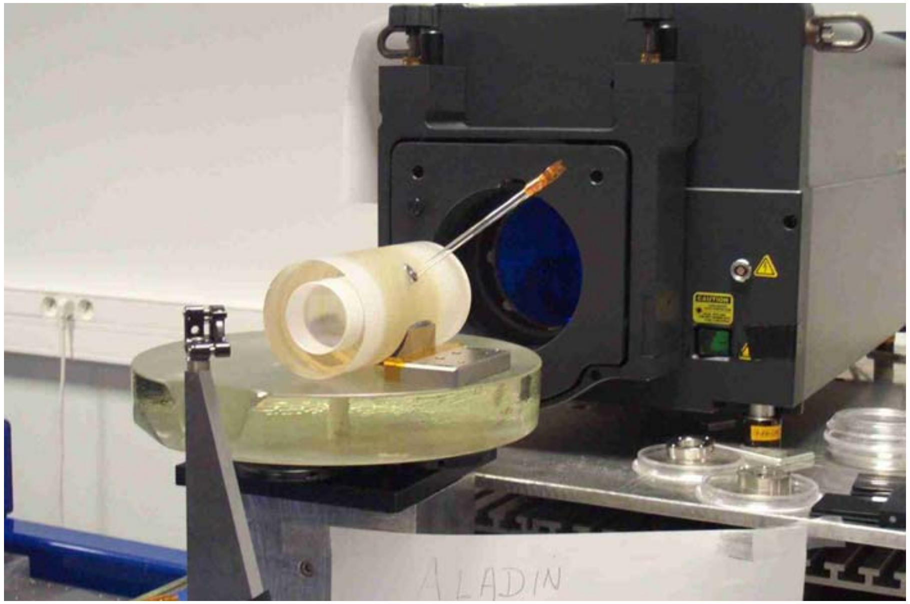
- **Fringe imaging technique**
  - An interferometer provides a fringe whose position is proportional with the spectral shift
  - The energetic distribution of the fringe is sampled (16 channels)
  - A specific processing allows sub-sample resolution to be achieved (e.g. centroiding)



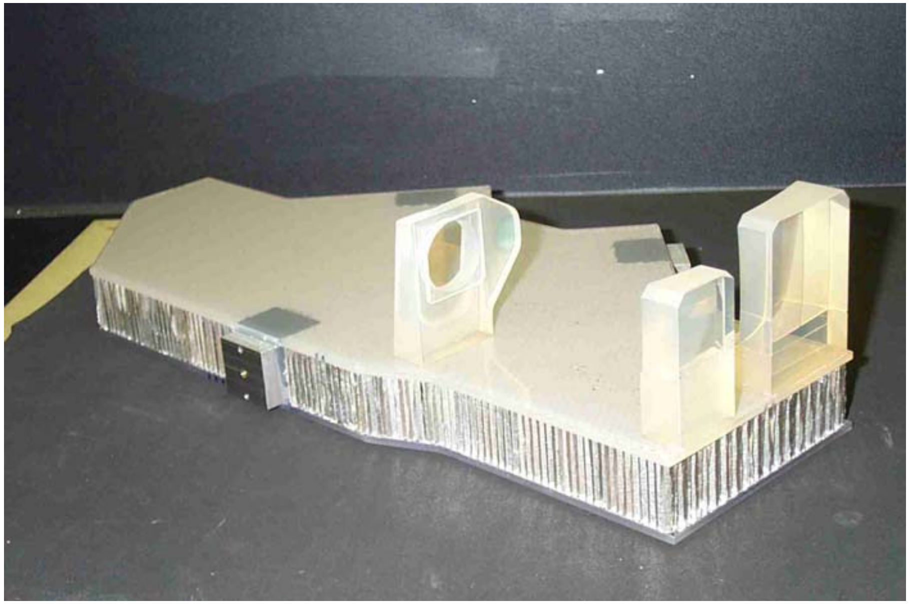
- **Physical implementation**
  - Fizeau spectrometer : multiple beam interferometer with a wedge which generates the fringe as output
  - Coupling optics
  - Detector: Accumulation CCD: quasi-photon counting with 80% quantum efficiency using on-chip shots accumulation



Mie Spectrometer



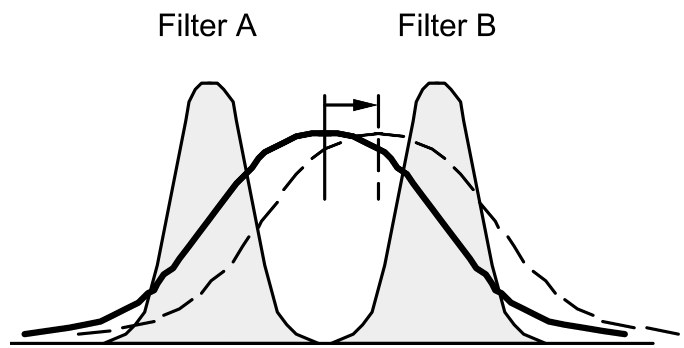
Fizeau etalon

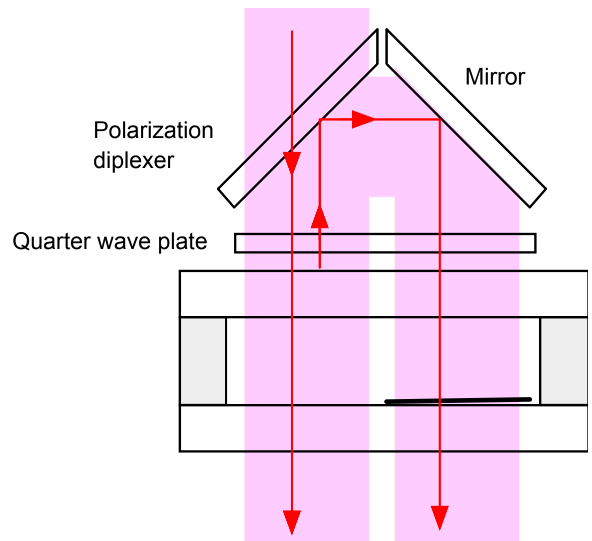


Mie Spectrometer during integration

Rayleigh Spectrometer

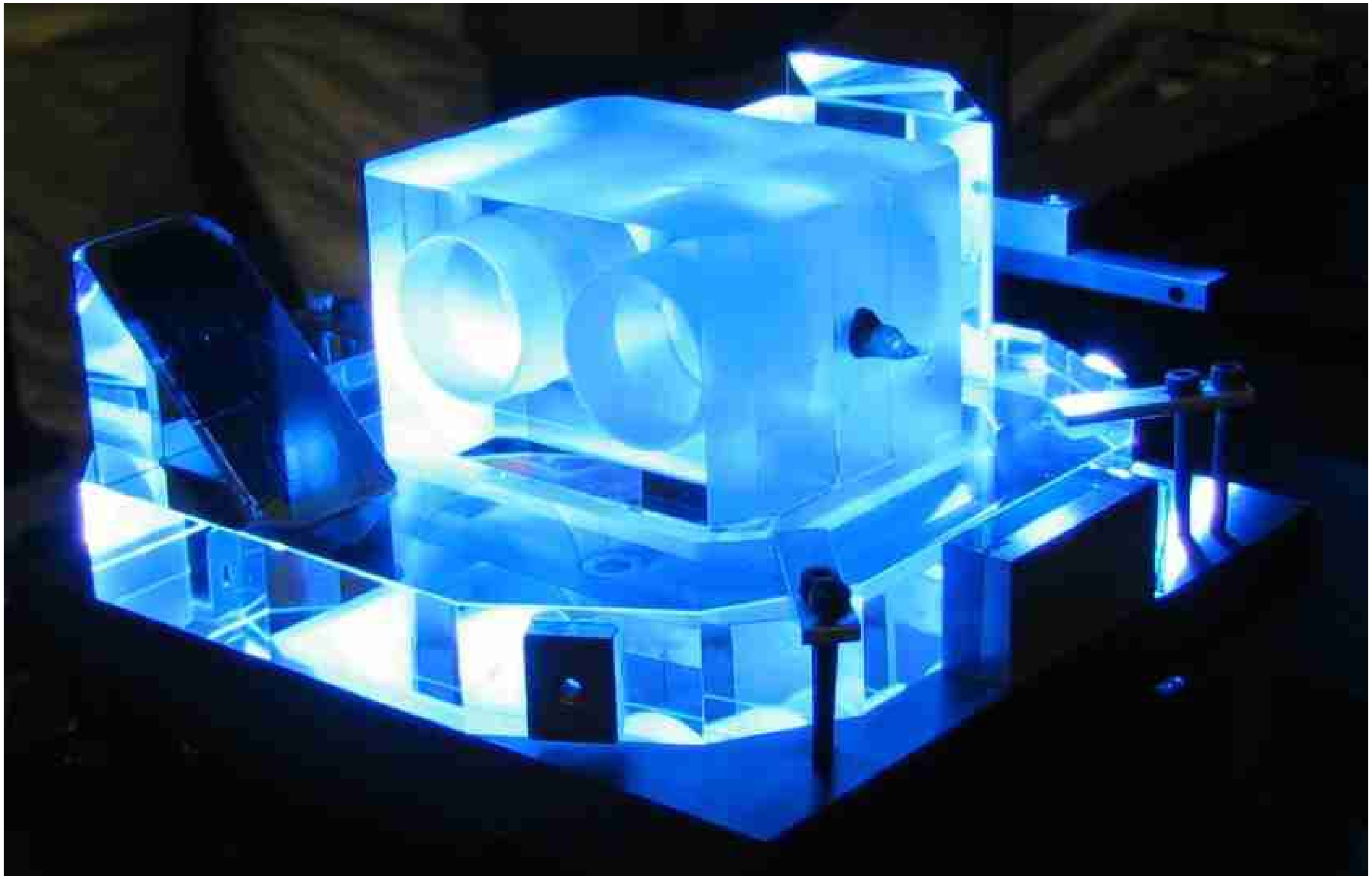
- **Double edge technique**
  - Two filters are implemented aside the Rayleigh spectrum.
  - The flux through each filter varies with the spectral shift
  - The detected flux is processed with an ecartometric-like function : (A-B)/(A+B)
- **Physical implementation**
  - Sequential Fabry-Perot cavity (Astrium patent)
  - Single detector in order to eliminate the errors due to the gain of the detection chains.
  - The detector is the same as for the Mie channel.



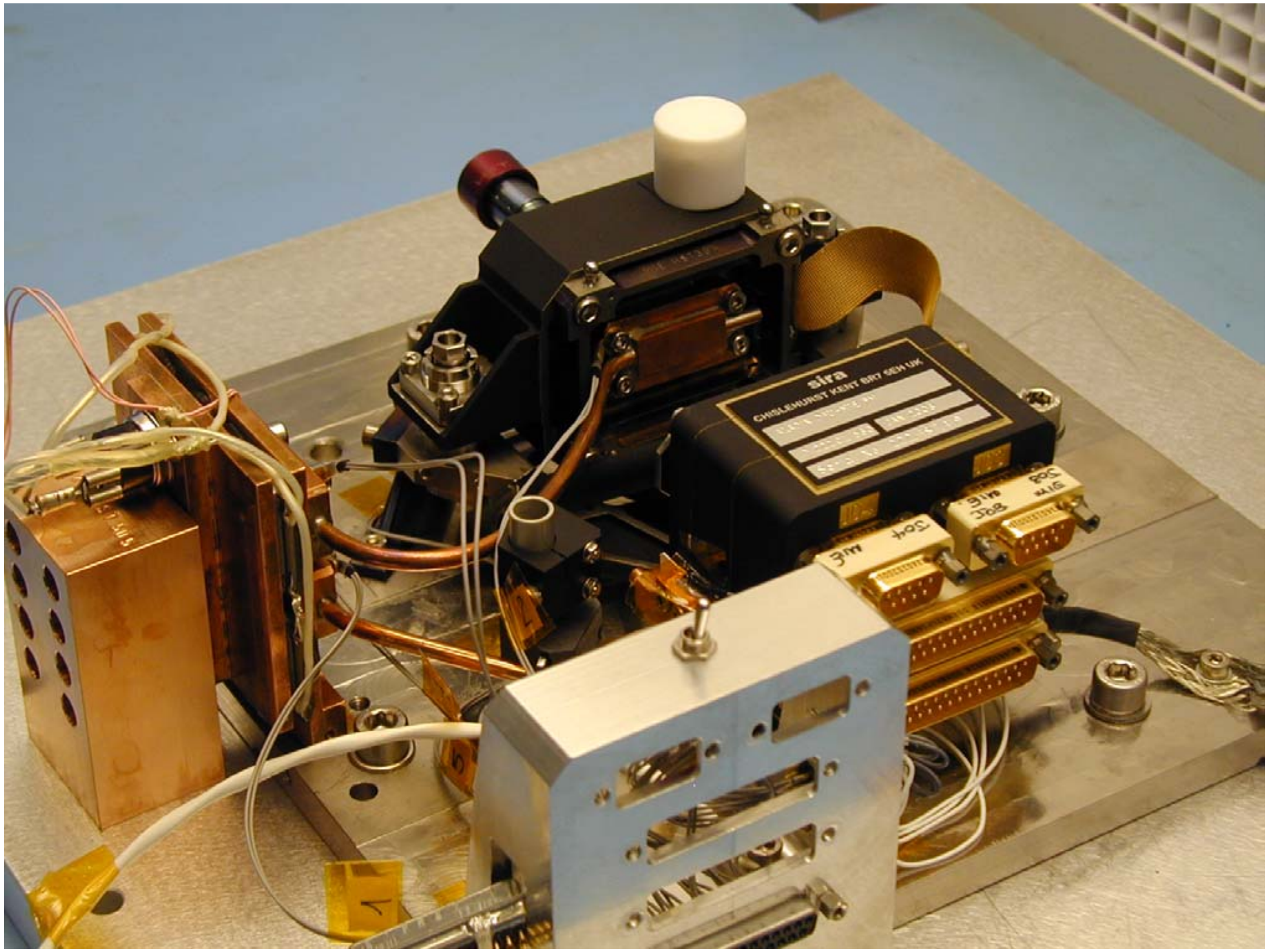


Full pupil sequential filter

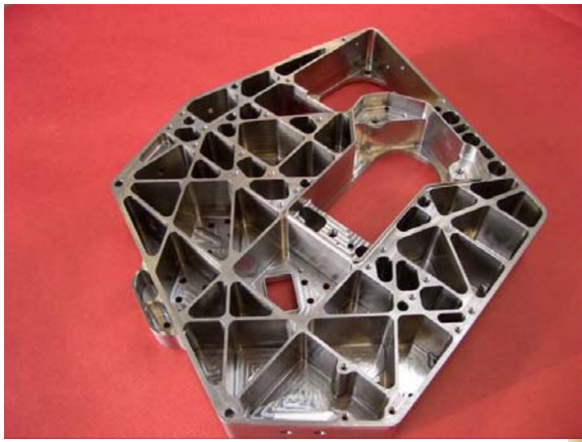
Rayleigh spectrometer

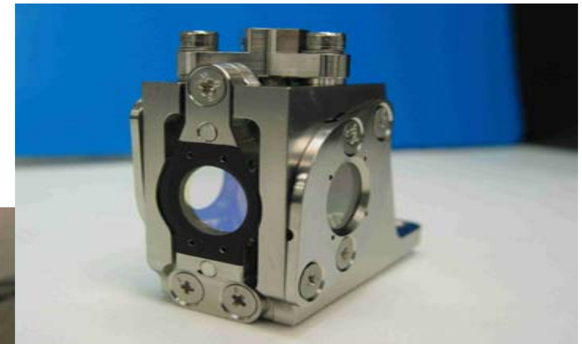


Detection Front-end Unit



Transmit/Receive Optics



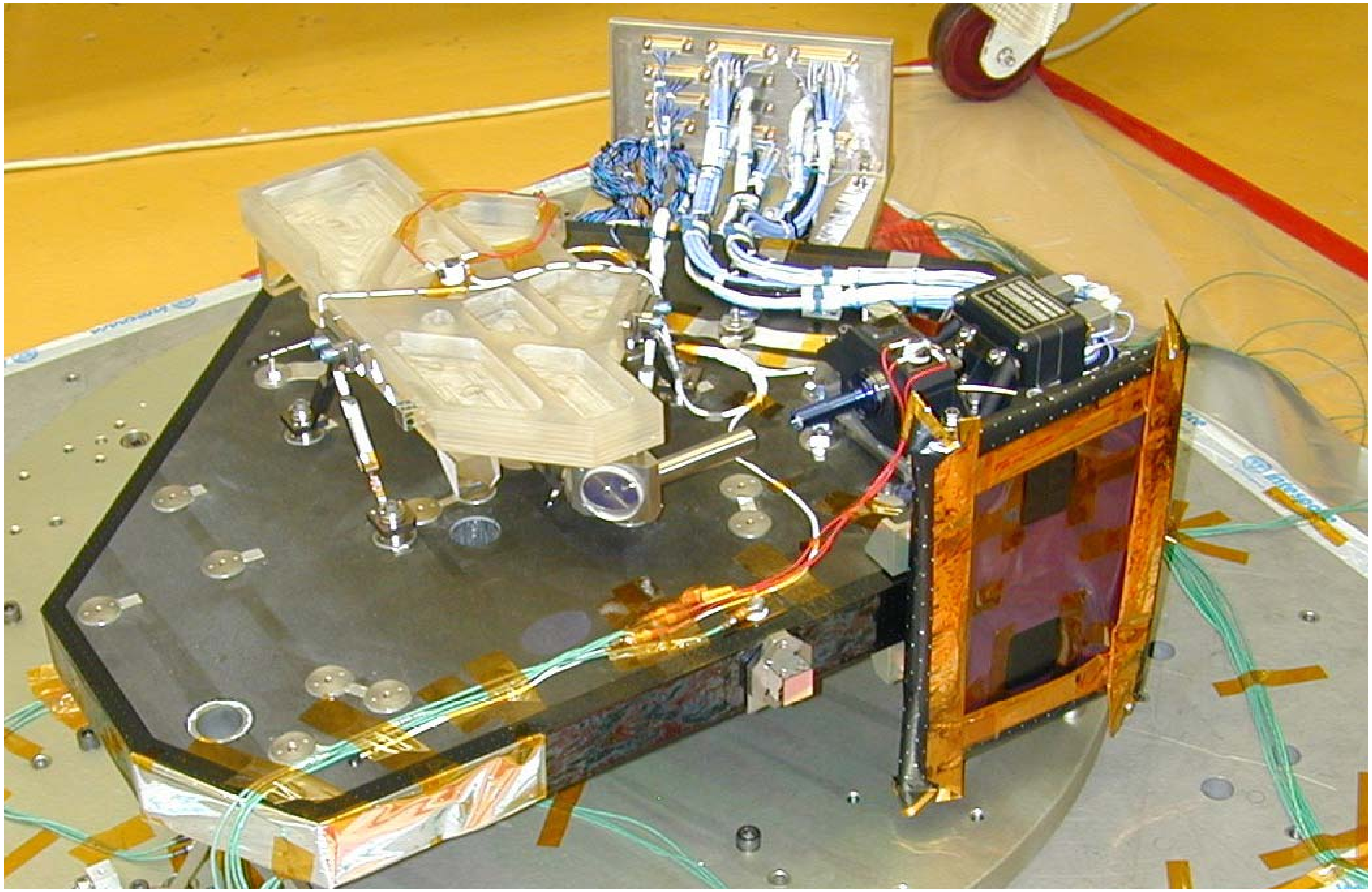


Left : Titanium bench

Right : Diplexer

Centre : TRO during integration

Receiver Engineering Model

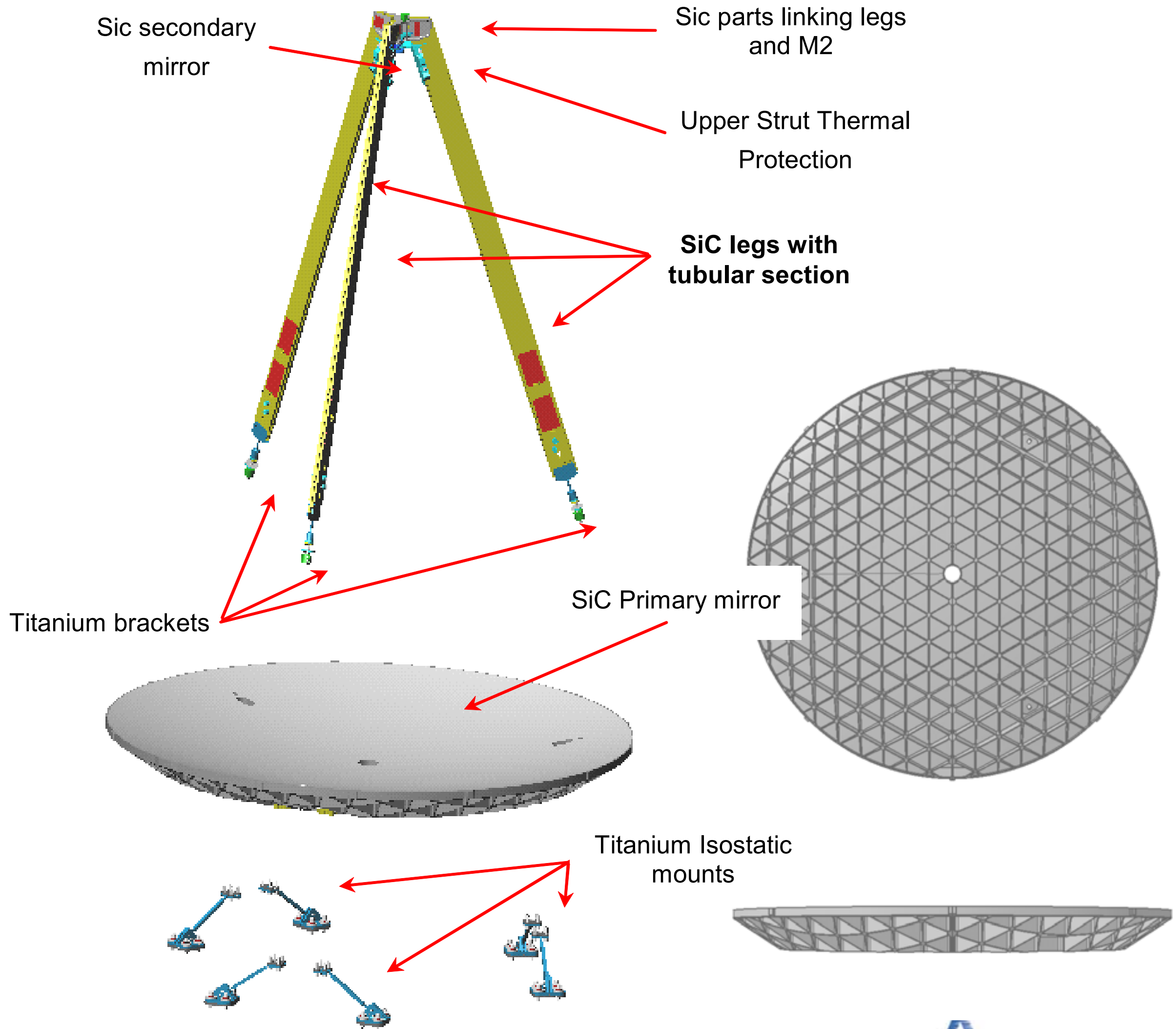


Key Issues on Receiver

- **High energy laser optics on Transmit/Receive Optics**
  - Same issues as for the Transmitter (Laser Induced Damage & Contamination)
- **Very high stability of Spectrometers**
  - Etalons assembled by optical contact and sealed under vacuum -> nm stability
  - Instrument calibration of spectral response -> allows to remove long term effects
- **Very low noise detection**
  - High optical isolation between transmit and receive path
  - Specific CCD architecture developed for lidar applications
  - Proton radiation effect on CCD noise verified to be acceptable
- **Complex alignment and integration**
  - High alignment accuracy (several 10 µrad per component)
  - Requires UV source

Telescope Design

- **<u>Ultra-lightweight Telescope all in silicon carbide (SiC)</u>**
- **Low mass / high stiffness**
- **Diameter: 1.5 m**
- **Afocal optics**
- **Mass: 75 Kg**
- **First frequency > 60 Hz**
- **Thermal re-focusing capability**



Telescope

M1 flight mirror

Tripod during vibration test

Key Issues on Telescope

- **High stiffness / high mechanical load**
  - Mechanical tests allowed to demonstrate compatibility to above 50 g level
- **High reflectivity**
  - Custom enhanced metallic coating at 355 nm developed for the mirrors
- **Good required optical quality**
  - Long polishing time (~1 year)
  - Requires mechanical decoupling from instrument / platform structure
  - Control of wavefront error at various steps of integration
- **Thermal control**
  - Use of a single material (SiC) with high conductivity to limit gradient
  - Thermal refocusing (avoids use of mechanism): 1 µm accuracy
  - Sun illumination: specific protections close to M1 focus

Conclusions

- ALADIN is the first space Lidar ever built in Europe
- Specific design solutions and integration methods have been developed with regards to laser aspects
- Qualification issues (e.g. optical materials, laser components) are discovered during the development phase and difficult decisions have to be taken
- Future R&D programs at Agency level should include qualification activities in order to secure future lidar programs