Optical Instruments
Space for your Vision

AEOLUS ALADIN Performance status after almost 5 years of operation

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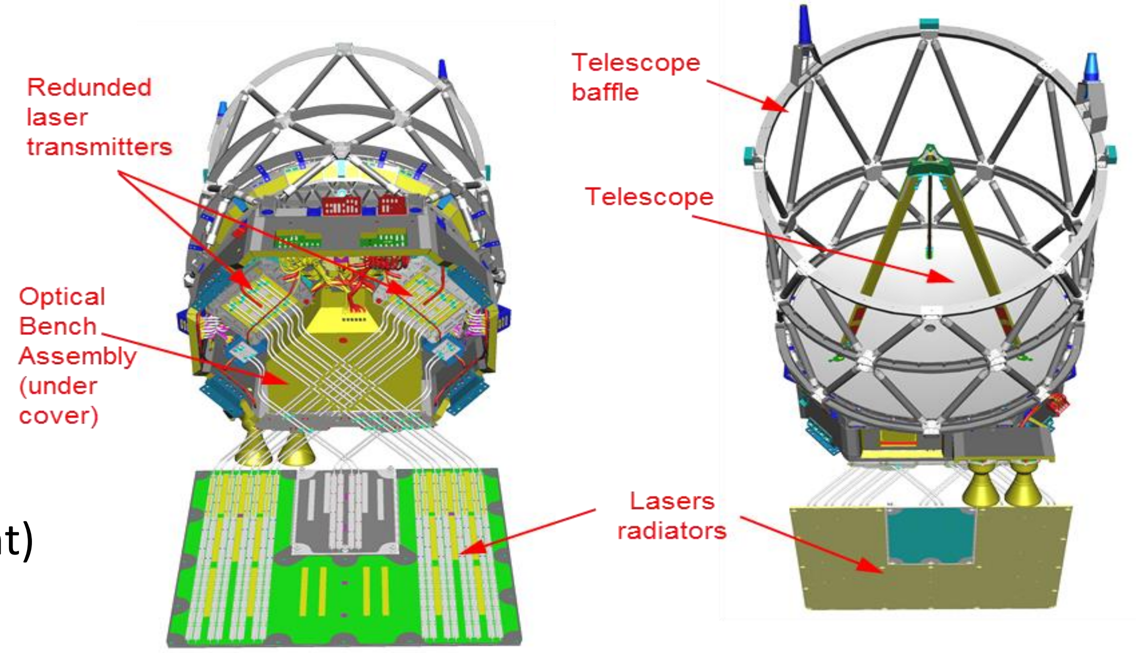
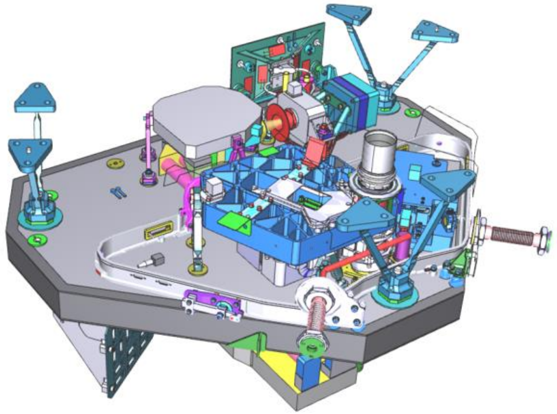
AEOLUS ALADIN Performance status after almost 5 years of operation

ALADIN instrument description
ALADIN measurement principle
Laser energy evolution
Atmospheric return signal
Laser Beam Monitoring
Mie fringe noise evolution
Conclusion

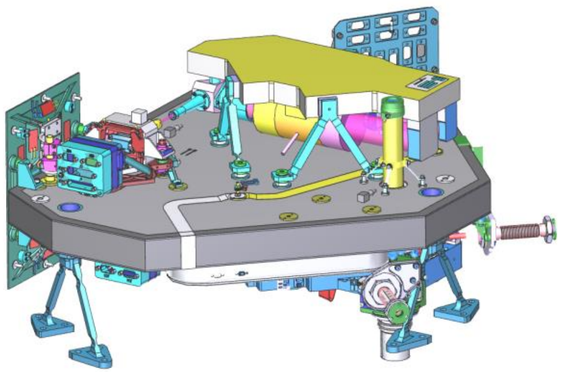
- ESA Aeolus' instrument is a **Doppler Wind Lidar** based on a **monostatic optical architecture** : the same Telescope is used in emission and reception
- Two Laser sources **~80 mJ/ 50 Hz** : **Laser A** (nominal) and **Laser B** (redundant)
- The cooling of the laser heat dissipation is done using a **radiator with heat pipes** for heat transport.
- The Telescope is a **full SiC structure** with a primary **mirror 1.5 m diameter**
- The receiver is based on **direct detection** using two spectrometers to separately filter the Mie and Rayleigh spectra



RSP
Rayleigh spectrometer



MSP
Mie spectrometer

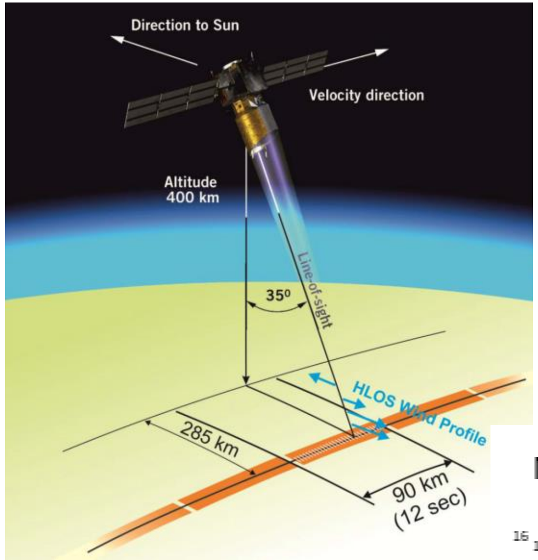


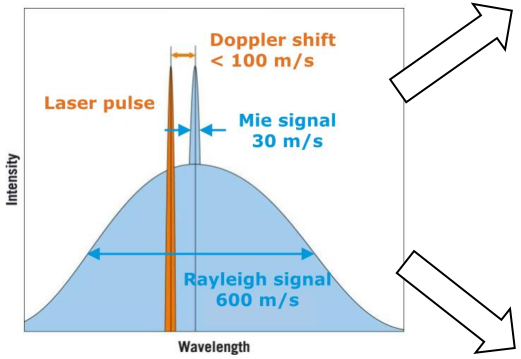
- The instrument Line-of-Sight is tilted to 35° off-track
  - ✓ The laser pulse is emitted
  - ✓ **The frequency of the back-scattered radiation is shifted due to Doppler effect of winds** (horizontal component)
  - ✓ Nadir pointing is used for zero-wind calibrations

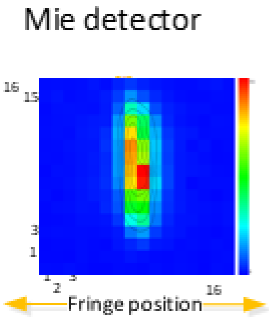
- The Mie spectrum from **aerosols** and Rayleigh spectrum from **molecules** are collected by the telescope

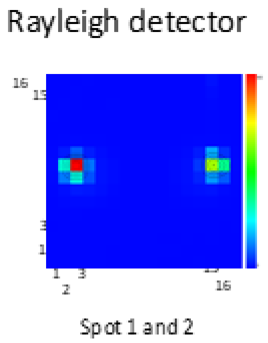
- The Doppler effect is measured by the spectrometers as the wavelength shift between transmitted and received spectrum centres
  - Mie signal is a **near field image** converted in fringe pattern at the output of a Fizeau interferometer
  - Rayleigh signal is a **far field image** converted in 2 spots at the output of a Fabry-Perot interferometer

- Wind profiles are calculated as a function of the emission, so of the altitude









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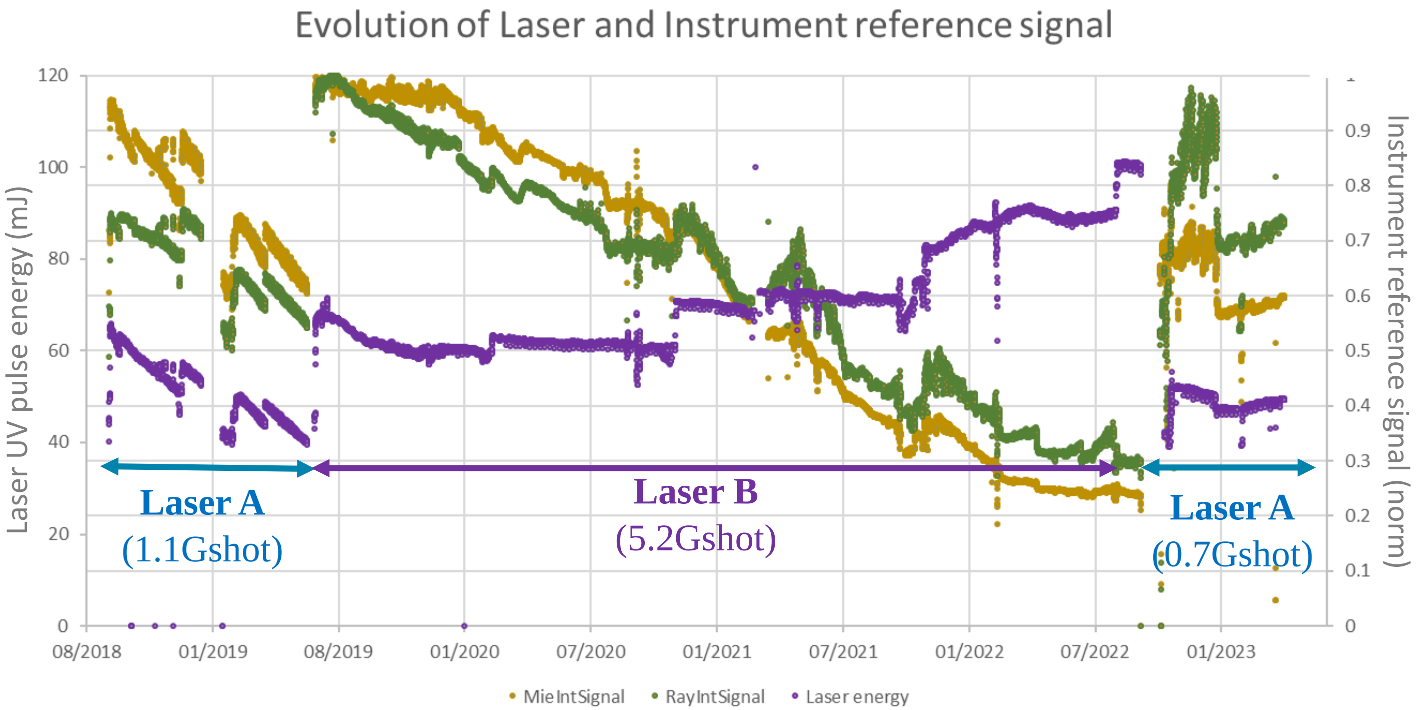

Internal laser energy evolution

- **Laser A** operation: energy reduction due to **ageing**, slight misalignment and set point detuning
- **Laser B** operation: energy roughly constant, several set point variations were implemented to **increase energy**
  - ✓ Finally up to more than 100mJ
- **Laser A** return: energy is constant due to a **much better set point tuning**

Internal instrument signal evolution

- **Rayleigh** spectrometer:
  - ✓ Decreased with both **Laser A and B** up to end of 2022: attenuation in the optical path
  - ✓ Return on **Laser A** is comparable to the first operation but with **a more stable trend**
- **Mie** spectrometer signal evolved similarly

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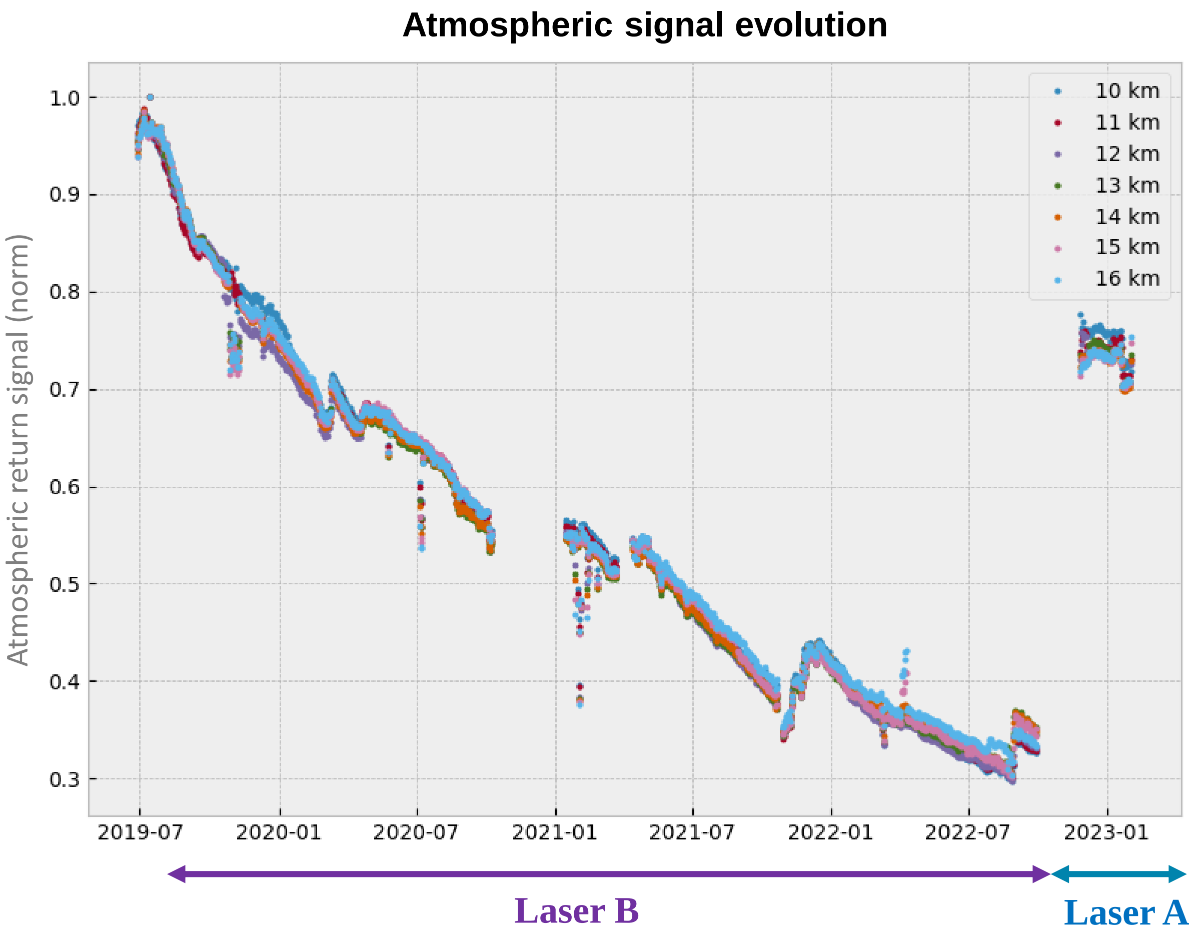

- The evolution of the Atmospheric return signal intensity **is similar to the internal instrument signal**
- Laser A performance is **much higher** than last Laser B performance

➢ <u>The attenuation is in the emission path of the specific path of Laser B</u>

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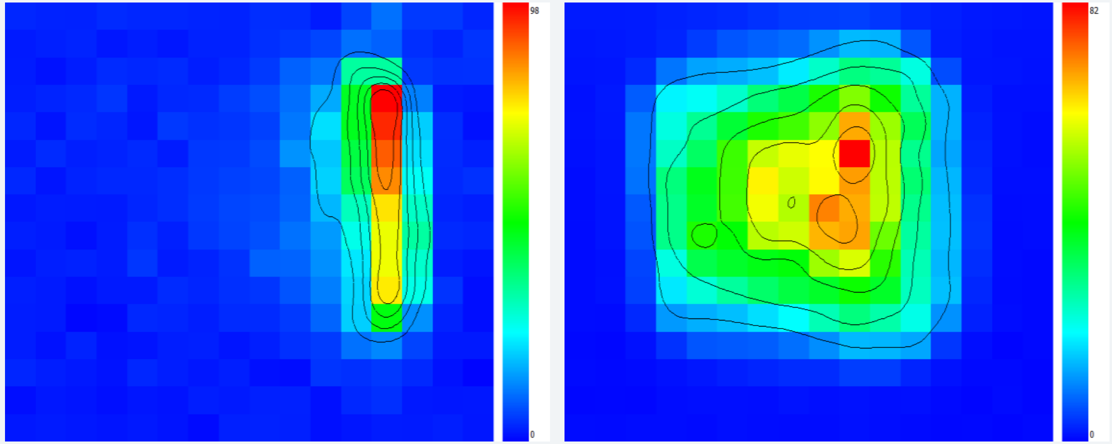
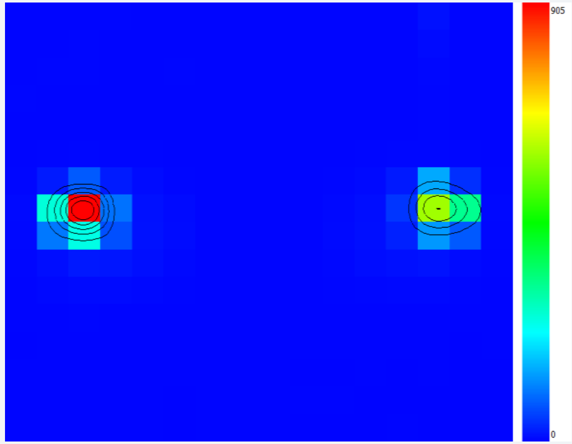
Goal: Allow to **estimate the laser beam profile and correlating it with the laser intensity per area (Fluence)** ➔ Important for securing no damage on the optics, and for monitoring the beam pointing (LoS) and the divergence

- ❑ LBM are weekly performed as part of instrument **calibrations**
- ❑ Spectrometer sensors set to imaging mode (**no pixel summation** as during wind measurement)
- ❑ **Laser frequency is swept** and sensor data and TMs acquired
- ❑ The laser beam is **imaged** on the Mie and Rayleigh detectors, via the **internal reference path:**
  - ✓ **Near Field** image reconstructed on Mie ACCD during a **laser frequency sweep**
  - ✓ **Far Field** image **averaged** on Rayleigh ACCD

Mie sensor (16x16 pixels)



Rayleigh sensor (16x16 pixels)



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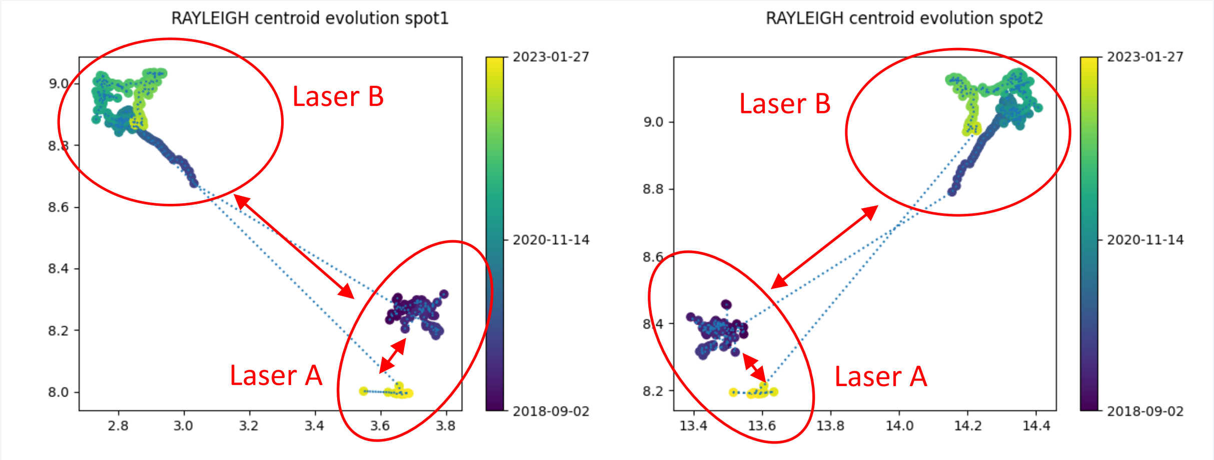
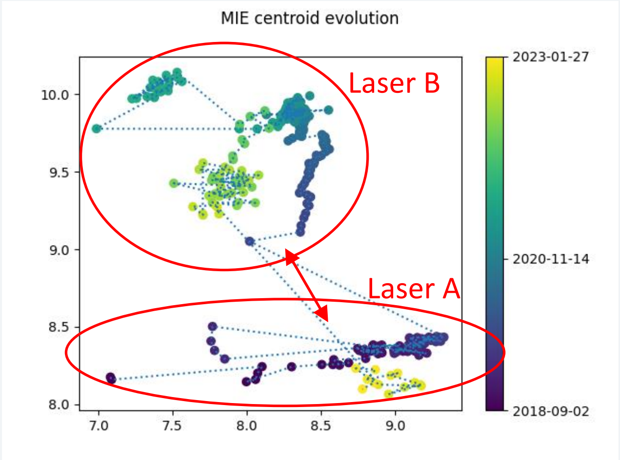
Monitoring of the beam pointing



X and Y axis in pixel



Rayleigh spectrometer

- On **Laser B**, after observing a drift evolution at the beginning of its operation, the centroid ended up to be rather stable
  - ➢ This could be correlated with the asymptotic trend observed on the energy degradation
- Between **Laser A and B**, the centroids are clearly separated : ~1.3 pixel => 0.9 mrad at laser output
- On **Laser A**, discrepancy observable between the first operation and new operation: ~0.3 pixel => 0.2 mrad at laser output (within the specification)
  - ➢ This demonstrates a **very good instrument stability**
- Periods of centroid stability seems to be correlated with transmitted and received energy stability

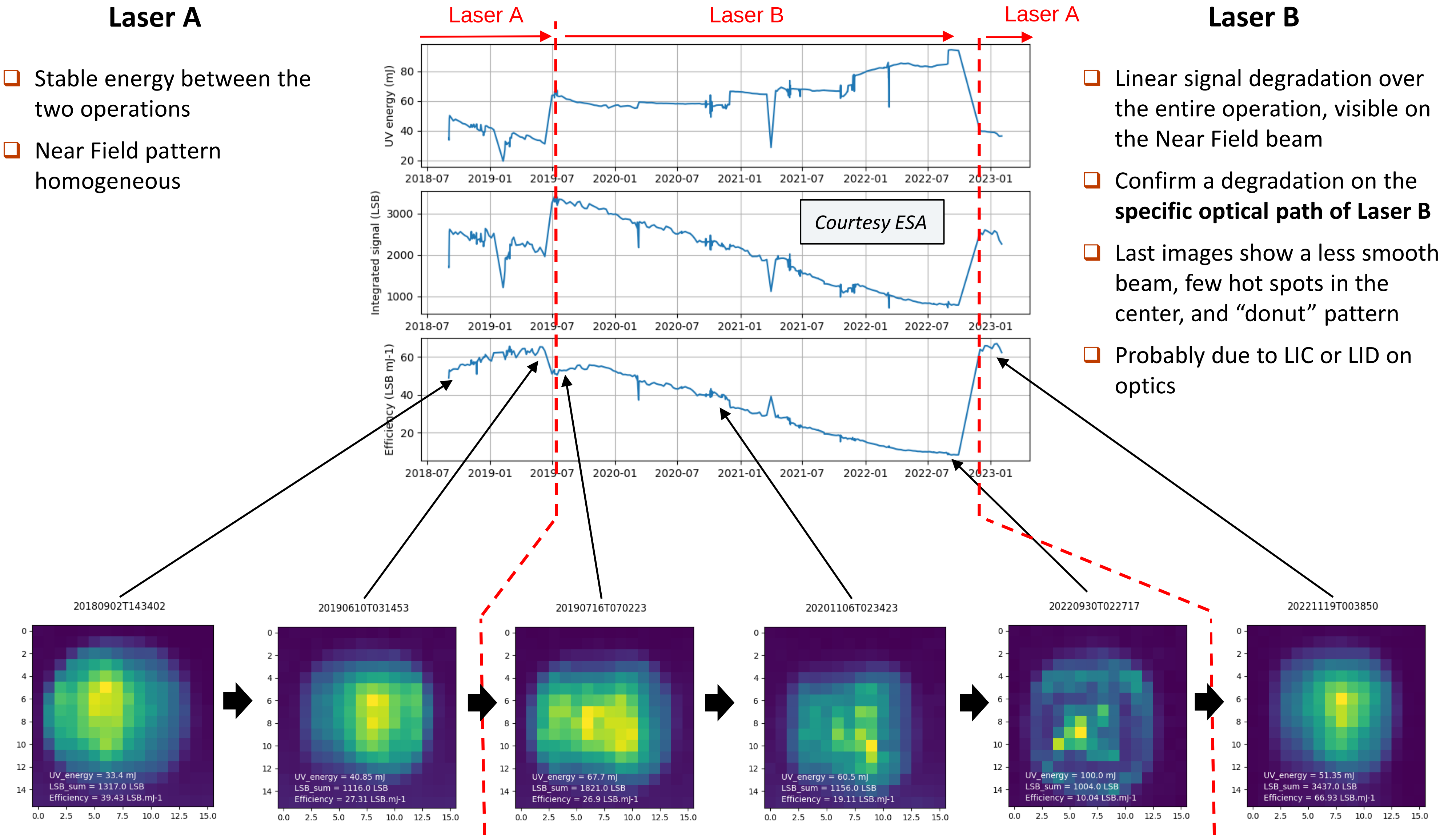
Mie spectrometer

- On **Laser B**, the centroid ended up to be rather stable as for the Rayleigh spectrometer
- Between **Laser A and B,** the centroids are separated : ~1.4 pixel far from FMB centroid positions => 700µm at laser output (10% of beam size Ø6.1mm)
- On **Laser A**, a small discrepancy is also observable between the first operation and the new one, with high fluctuations along columns at the first one

Mie fluence evolution

Laser A

- Stable energy between the two operations
- Near Field pattern homogeneous



Laser B

- Linear signal degradation over the entire operation, visible on the Near Field beam
- Confirm a degradation on the **specific optical path of Laser B**
- Last images show a less smooth beam, few hot spots in the center, and “donut” pattern
- Probably due to LIC or LID on optics

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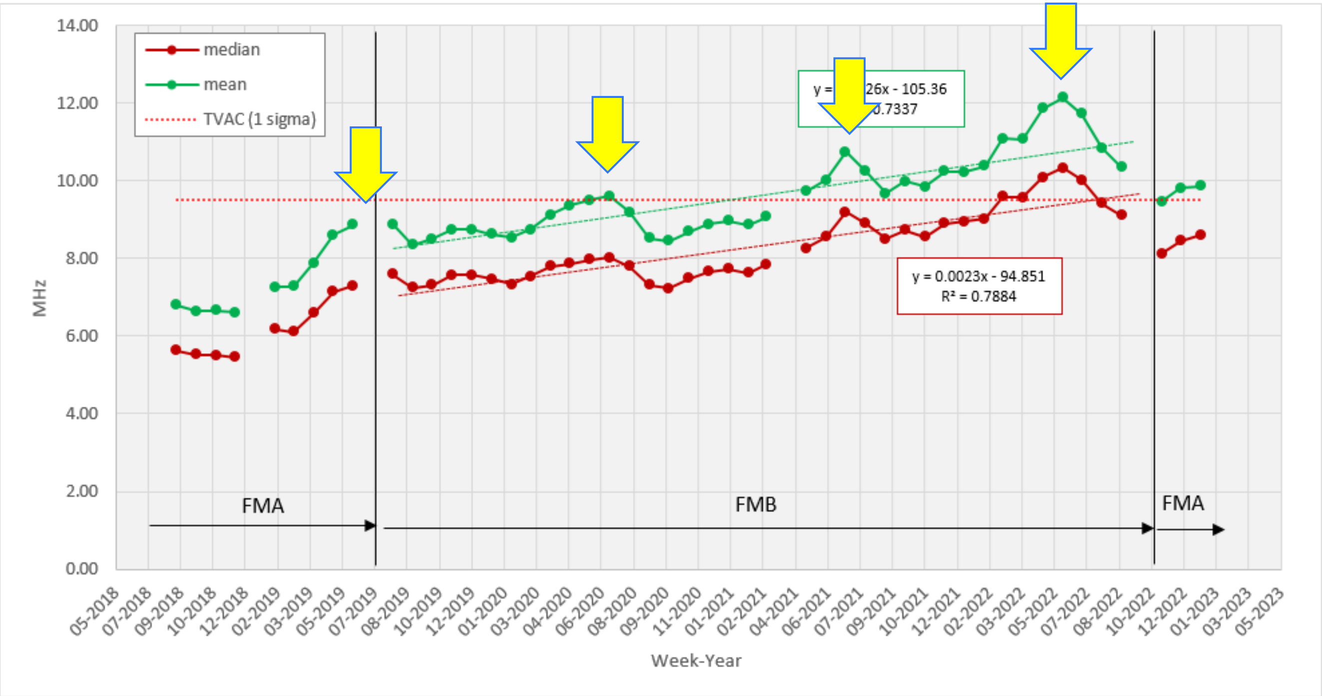
Mie fringe noise evolution



- On **Laser B**: the mean & median values were increasing over time (75 kHz/month), going above the expected 9.5 MHz value in flight
  - This is **coherent with the decrease of internal signal** and the relatively higher impact of the photon noise
- A likely **seasonal effect** is visible during the summers. At the **end of Laser B operation**, the noise was decreasing but an inversion of trend could have been observed in the following months
- On **Laser A new operation**, the trend is probably in the continuity of the seasonal effect even if we can observe that the noise is lower and around the 9.5 MHz expected (maybe also explained by higher internal signal)

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ALADIN has demonstrated exceptional performances

- **After almost 5 years** of operation in flight, both Lasers have generated more than **7 billion shots**
- By optimizing operation between Laser A and B: mission lifetime extended by more than 50%, leading to an **end of mission operation on 30 April 2023**, due to onboard propellant limit and not by instrument or laser cause

AIRBUS DS involved in the in-orbit performance monitoring

- Our expertise was necessary to **better understand the instrument**
- This **gives key information** for future development paving the way for AEOLUS-2