Aladin Laser almost 5 years in Space

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Aeolus Science Conference 2023

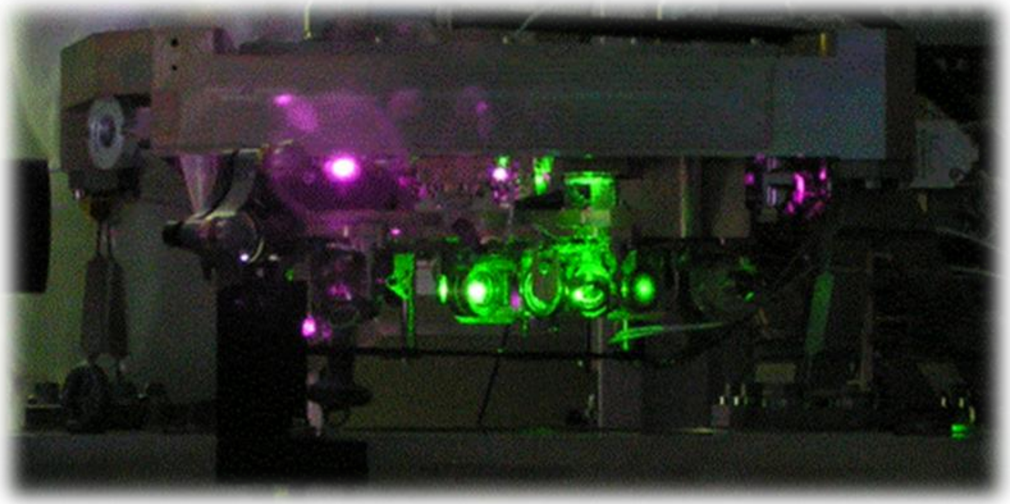
22–26 May 2023 | Rodos Palace Hotel | Rhodes Island, Greece

The people who made the success of the Aladin Laser possible

- From Leonardo:
  - Michele Balbi, Massimo Belardi, Ida Bellucci, Luigi Bracaccia, Fabio Brandani, Paolo Bravetti, Mauro Brotini, Annalisa Capanni, Pasquale Carpentiero, Samuele Colzi, Alberto Cosentino, Alessandro D’Ottavi, Michele De Maria, Fabio Era, Daniele Fabrizi, Pasquale Ferrara, Alessio Galeotti, Silvia Giordano, Gianna Gironi, Luca Mastrangelo, Massimo Marinai, Alessia Mondello, Gianfranco Morelli, Paolo Mosciarello, Stefano Naldoni, Stefano Nencioni, Antonio Padelli, Enrico Pasqualini, Stefano Perferi, Alessandro Perna, Giuseppe Pulella, Barbara Ricciarelli, Fausto Rosadi, Valentina Sacchieri, Adalberto Sapia, Virginia Schinaia, Carlo Simoncelli, Enrico Suetta, Mario Tamburrini, Claudio Tredici.
- From ESA, DISC and Industry:
  - Emilio Alvarez, Sebastian Thomas Andersnen, Elfving Anders, Gabriela Ansteeg, Sylvan Arnaud, Jean-Claude Barthes, Anna Baselga Mateo, Didier Bon, John Brewster, Trismono Candra Krisna, Martin Caspers, Irene Cerre Errero, Philippe Cervantes, Elena Checa Cortes, Alessandra Ciapponi, Guido Colangeli, Alain Couloma, Andriew Davies, Frank De Bruin, Frederic Fabre, James Harkins, Tim Harries, Sophie Jallade, Thomas Kanitz, Isabel Krish, Jille Labruier, Alessandro Latino, Olivier Lecrenier, Chistian Lemmerz, Jeremie Lochard, Emanuele Lovera, Oliver Lux, Jonathan Marshall, Didier Morancais, Michaël Olivier, Antonio Padelli, Tommaso Parrinello, David Patterson, Juan Piñeiro, Oliver Reitebuch, Mike Rennie, Massimo Romanazzo, Aditi Sathe, Marc Shillinger, Philippe Tatry, Dominique Thibault, Viet Duc Tran, Vittorio Trivigno, Pierre Vogel, Jonas Von Bismarck, Christoph Voland, Denny Wernham
- And surely many others, not mentioned here. I apologize for this.

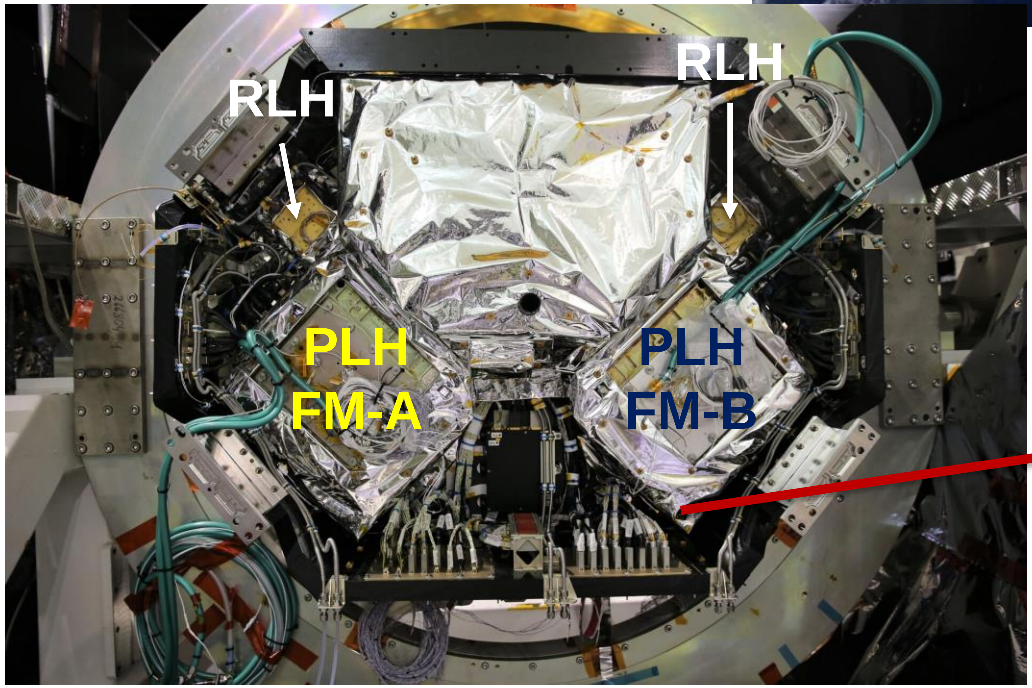
SUMMARY

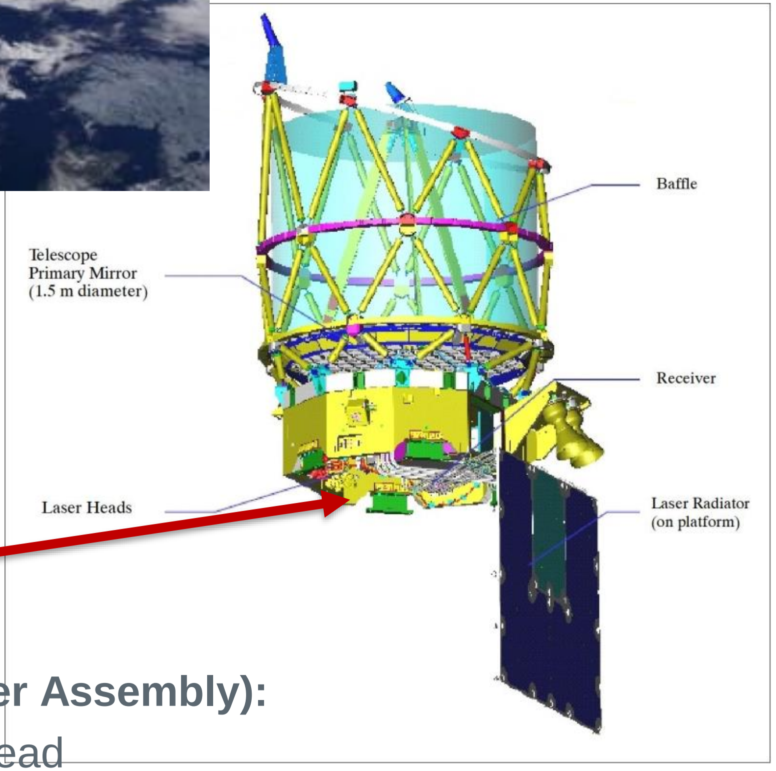
- ALADIN – Laser Transmitter (TXA) overview
- ALADIN Laser – More than 7 Gshots over 55 months of operation in space!
- ALADIN – Laser Transmitter B: 3 years of operation in space
- ALADIN – Laser Transmitter’s real potential
- ALADIN – Laser: improvement in ability and rapidity in the operations
- ALADIN – ALADIN – Switch-over to FMA in October 2022
- AEOLUS – Mission Extension



Aeolus Spacecraft – Laser Transmitter inside the Aladin instrument

Aeolus Platform
and
Aladin Instrument
designed and developed
by
Airbus Defence and Space





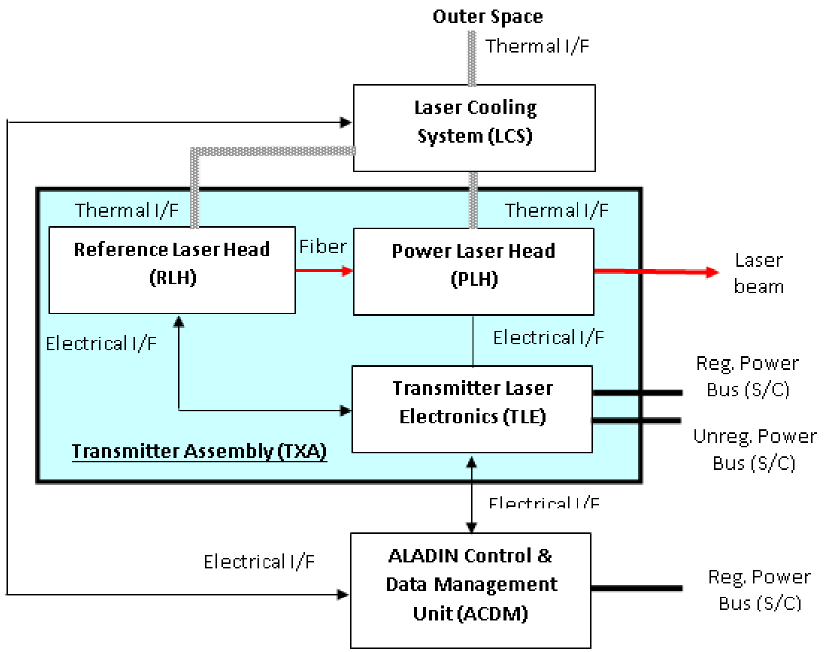
Aladin TxA (Transmitter Assembly):

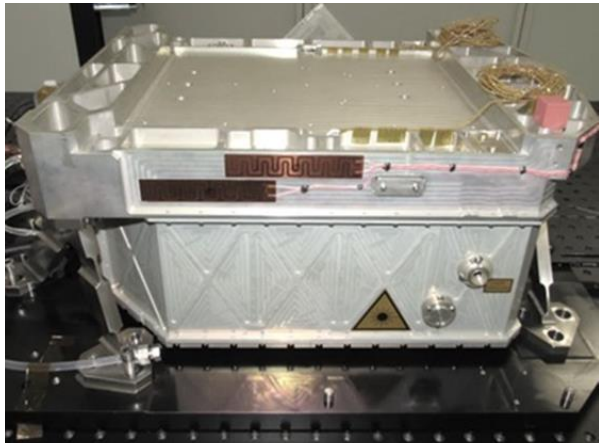
- PLH: Power Laser Head
- RLH: Reference Laser Head

ALADIN – Laser Transmitter (TXA)

- Power Laser Head (PLH)
- Reference Laser Head (RLH)
- Transmitter Laser Electronics (TLE)

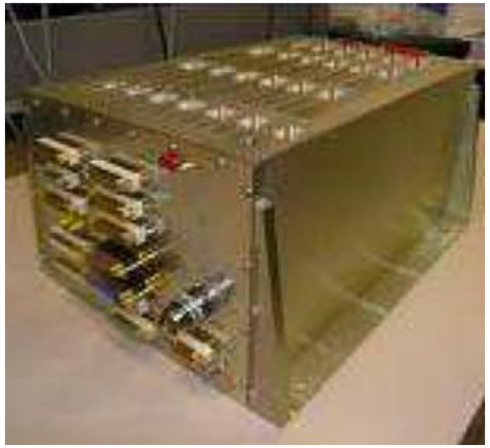
Aladin TXA Functional Block Diagram





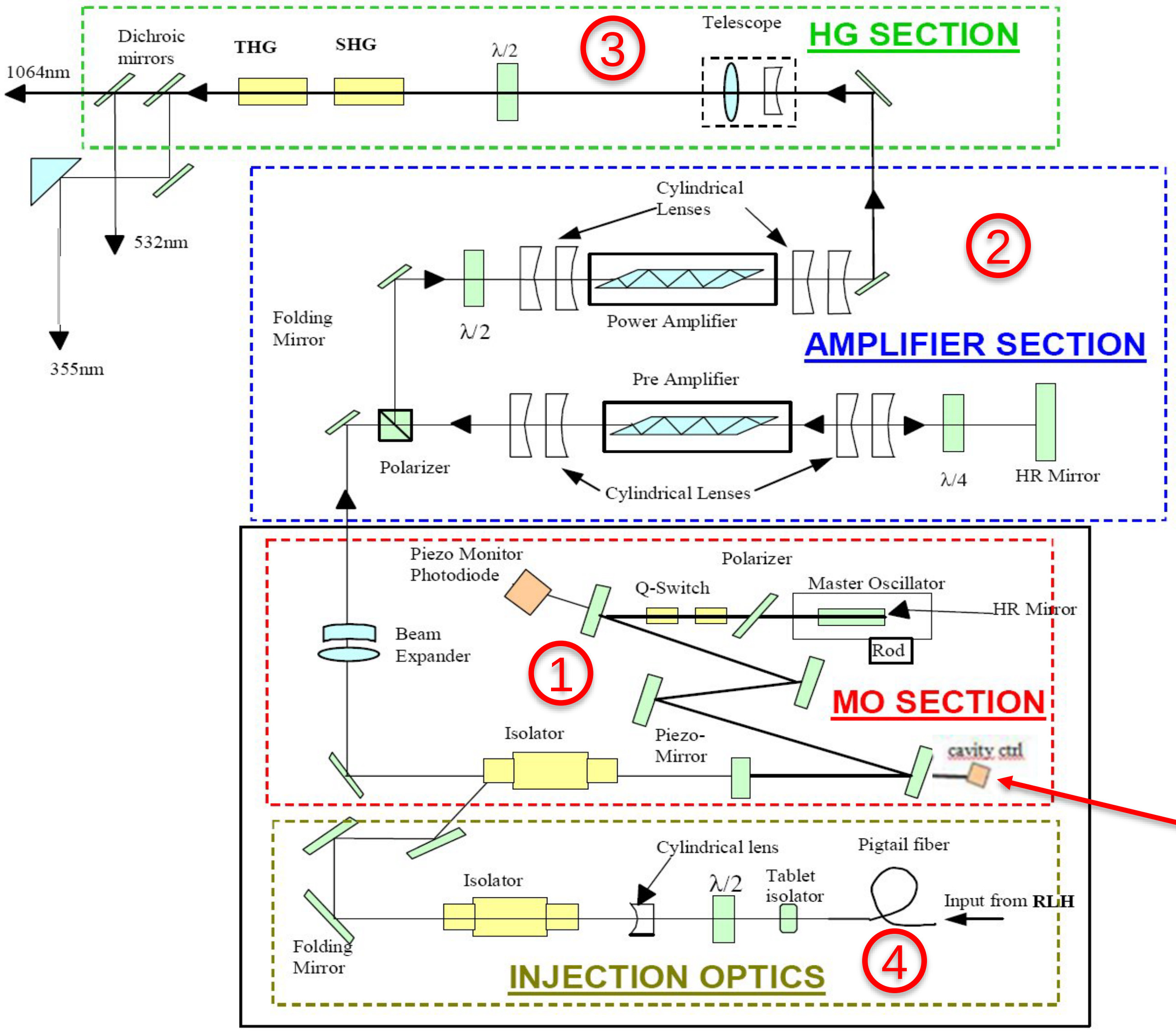
PLH

RLH



TLE

ALADIN – TxA Architecture

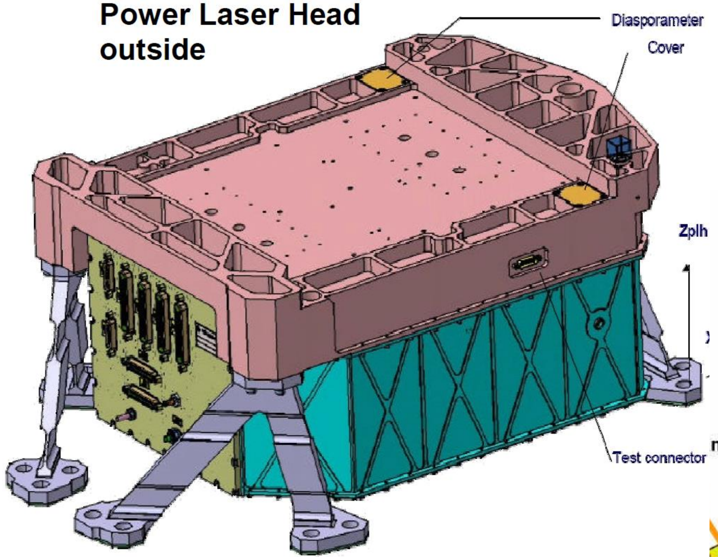


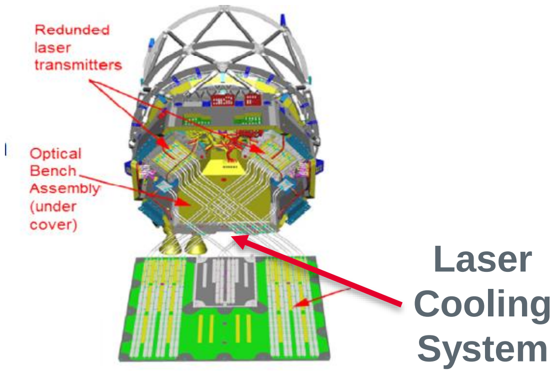
MOPA DPSS Laser:

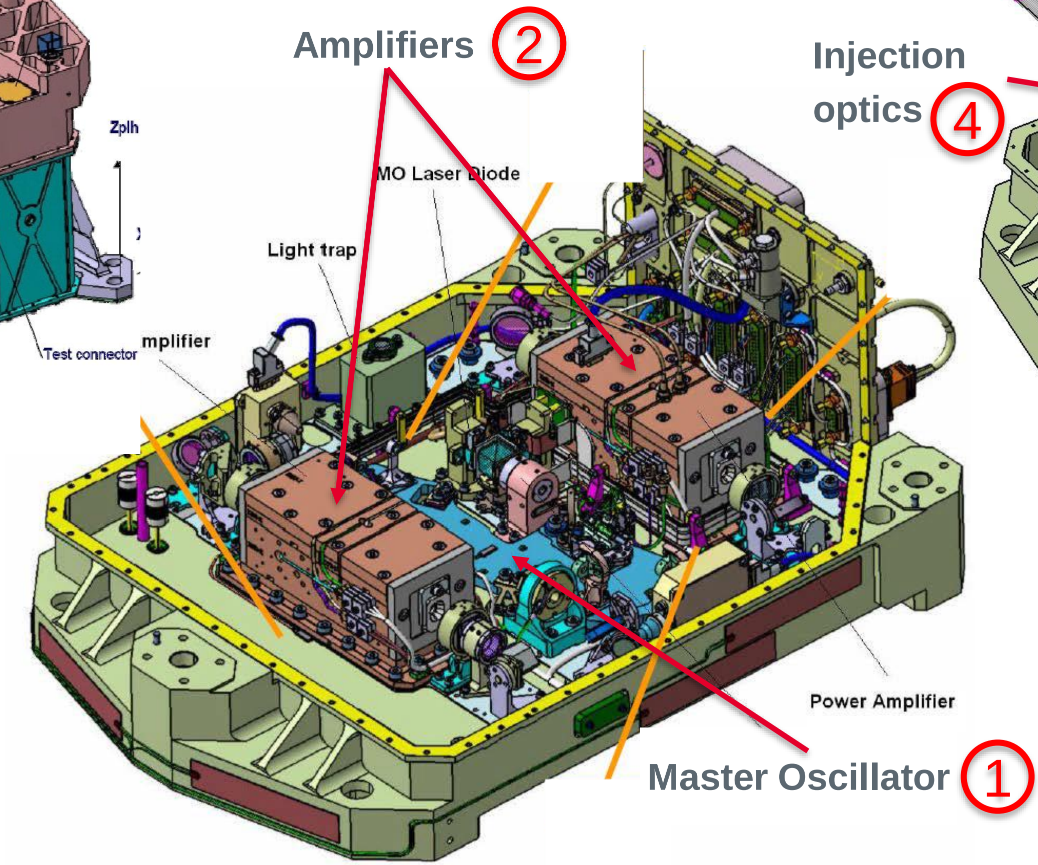
The Transmitter is a diode-pumped, Q-switched, Nd:YAG Laser frequency tripled

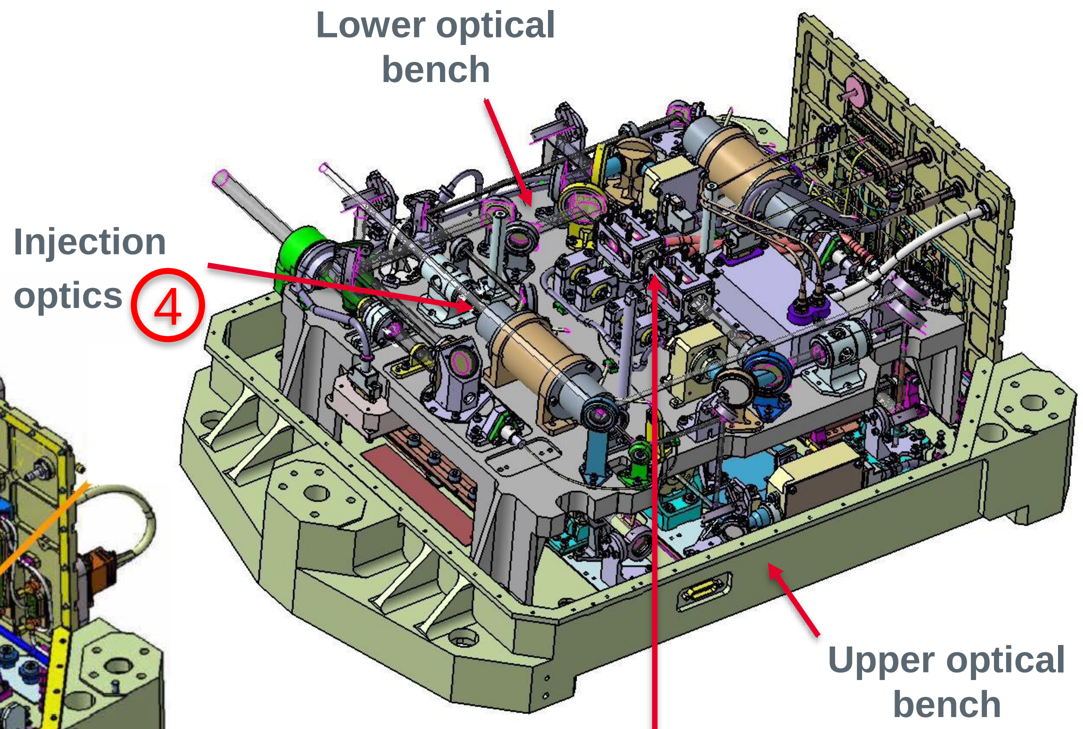
- **Sections**:
  - Master Oscillator (1)
  - Amplification (2)
  - Wavelength conversion (3)
- **Features**:
  - Seeder injection locking (4)
  - Oscillator cavity control loop

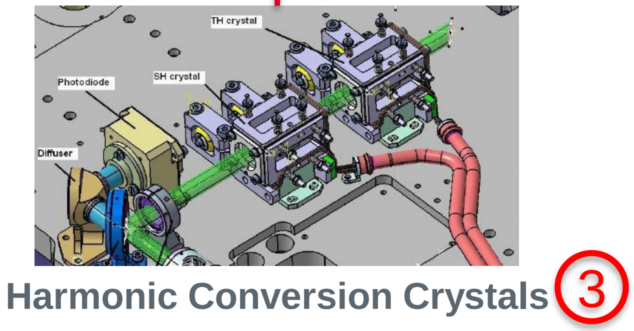
ALADIN – PLH Optical Layout











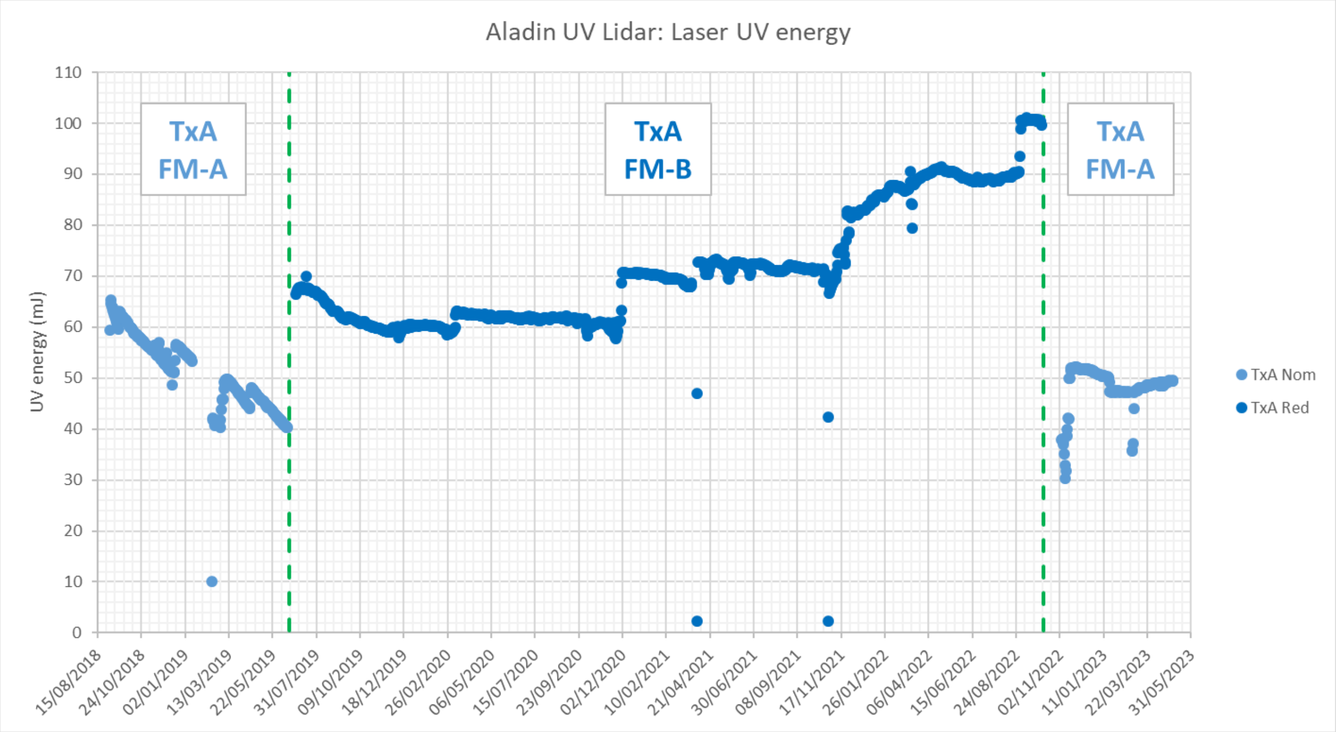
The Power Laser Head is composed by an Upper Optical Bench in direct contact with the thermal interface plate, which carries all the active (dissipating components) Passive components are located on a separated Lower Optical Bench

ALADIN Laser – More than 7 Billion shots over 55 months of operation in space!

- The first UV high power laser in space proved to be a remarkably reliable and robust laser
- The UV energy was set to about 70 mJ during Commissioning, to limit the fluence on the UV optics along the transmitter optical path, but the energy was increased along time until 100mJ.
- The first laser (A) was switched on after a few days from launch and was operated for about 8 months
- In June 2019, the second Aladin laser (B) was switched on and was operated until October 2022, emitting 5.2 Billion shots of almost continuous operation
- A single laser has covered more than the initially planned mission lifetime, i.e. 3 years, 3 months and 1 week
- In November 2022 the Aladin laser A was switched on again, to improve wind measurements, and worked until the end of official mission on 30th of April 2023.

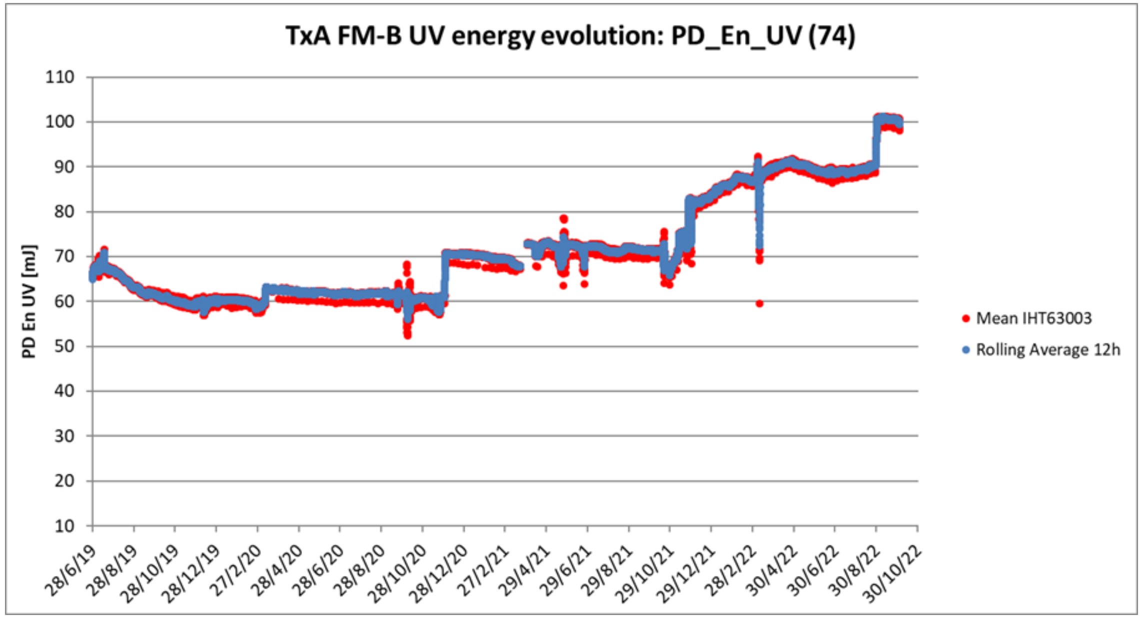
<u>7 UV Gshots emitted in space, overall</u>:

- **1.11 Gshots emitted by TxA FM-A**
- **5.21 Gshots emitted by TxA FM-B**
- **0.78 Gshots emitted by TxA FM-A**



ALADIN – TxA FM-B evolution

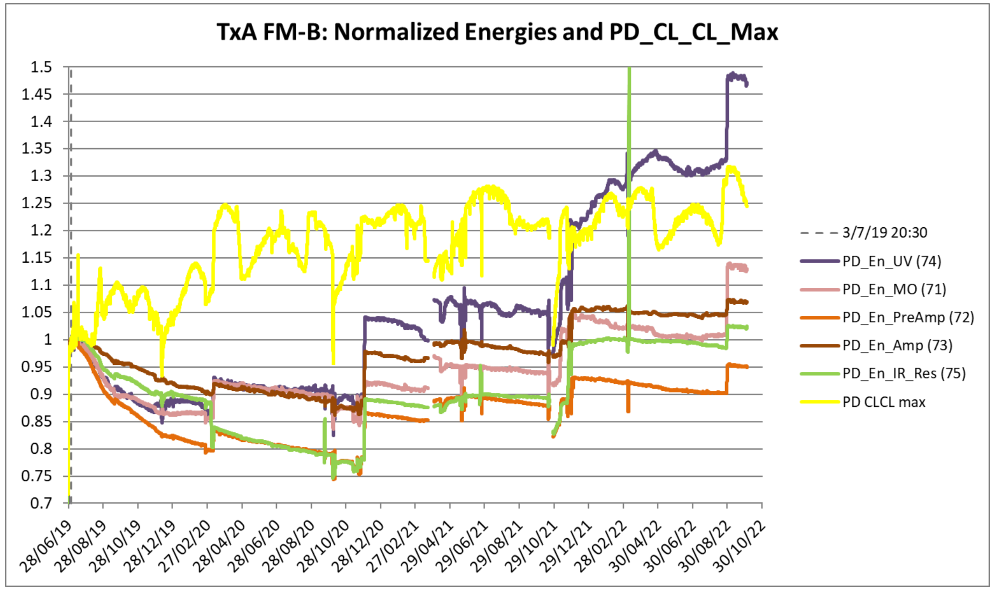
- Laser B energy showed a much smoother decreasing trend during time, in line with the best lifetime degradation expectations (degradation of semiconductor laser diodes).
- This degradation was compensated during lifetime by modification/tuning of laser parameters.
- Not considering all the intentional set point variations and the events that have influenced the energy, the loss would be only about 22% in more than 3 years of operation.
- Despite a non-decreasing laser energy, to compensate the signal loss, the laser energy was increased above 100 mJ at the end of laser B operations, after more than 5 billion shots, and additional margin is available in the laser.

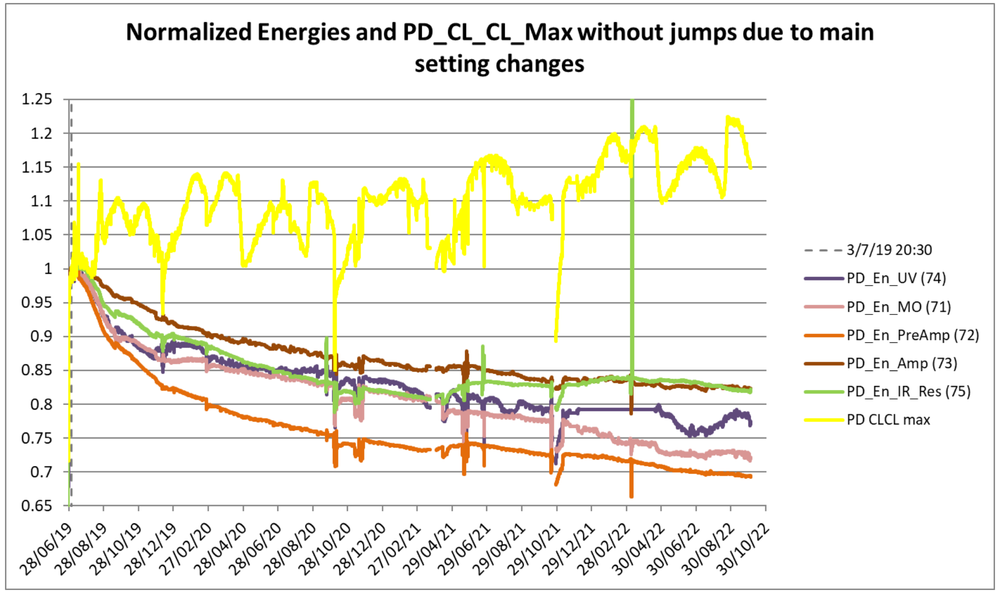


Aladin - Laser Transmitter B: 5.2 Billions of shots at high UV energy in space

Entire mission period covered with TxA FMB: 3 years, 3 months and 1 week of operations until last 4/10/22

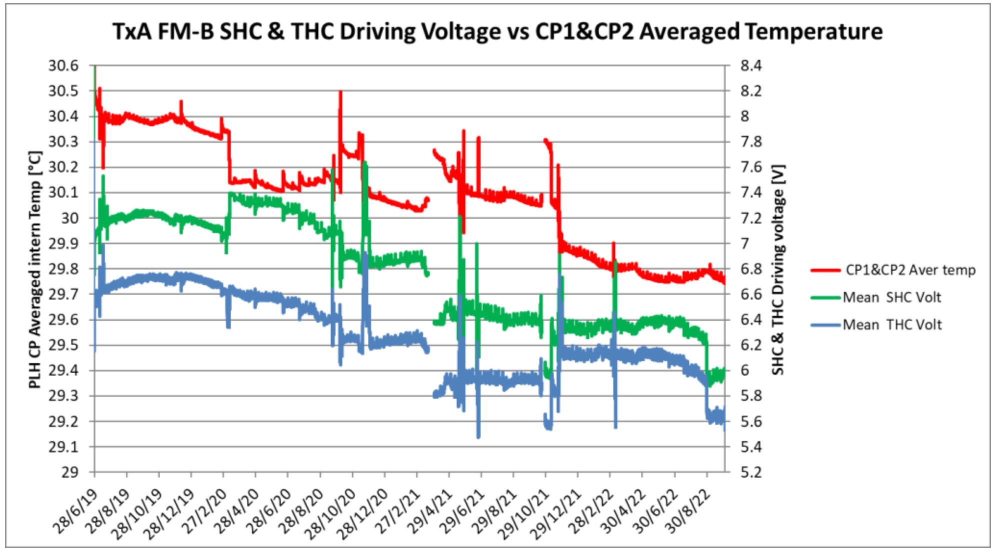
- **Last month of operations at more than 100mJ in UV in space**
- Every photodiodes measure at the end an energy higer wrt the beginning
- The UV energy showed a smooth decreasing trend during time, as expected for ageing, not considering all the intentional set point variations.
- **The best case lifetime degradation expectations**: every photodiodes losses around 22% +/-5% after more of 3-year operation
- MO good alignment confirmed by CLCL max signal over time and by the MO threshold measurement in flight

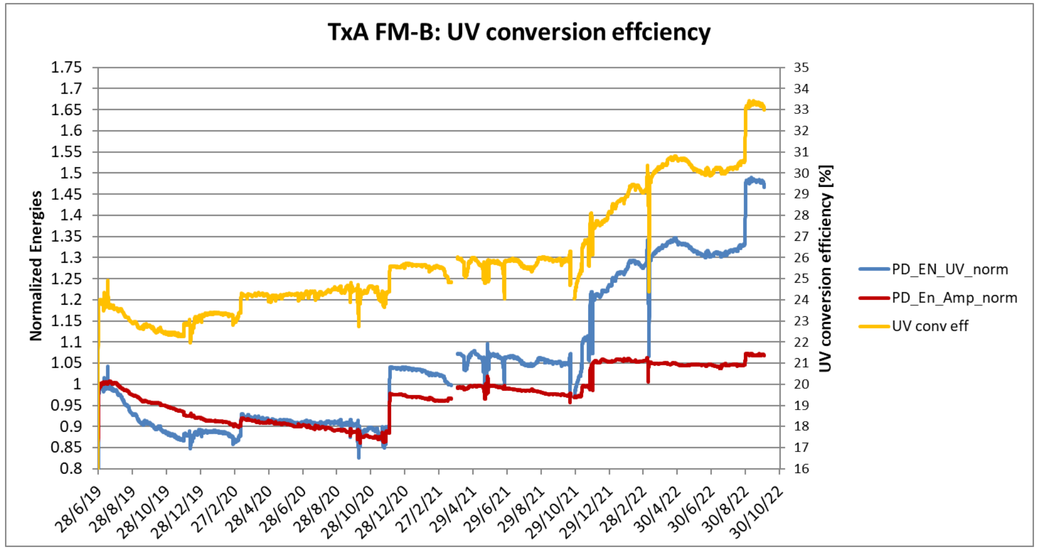


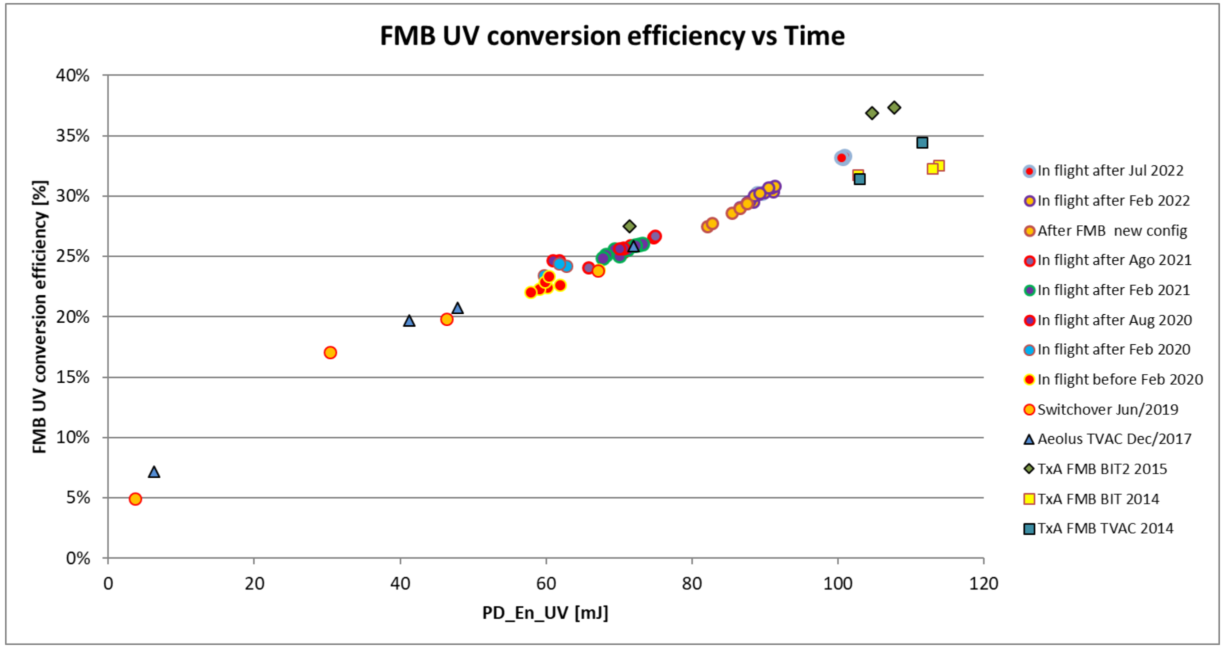


Aladin - Laser Transmitter B: 5.2 Billions of shots at high UV energy in space

No evidence of LIC during time, neither from HCs driving voltages nor from UV conversion efficiency







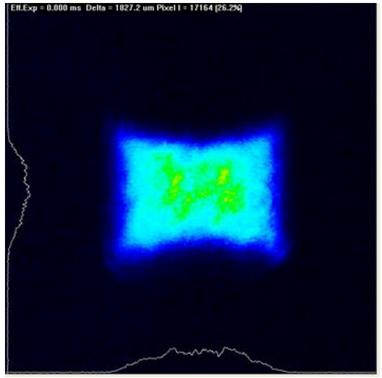
TxA FM-B UV Conversion Efficiency in vacuum versus UV energy, starting from TxA test campaign to Oct 2022 in-flight

ALADIN – Laser Transmitter real potential: TxA designed for 130mJ of UV Energy

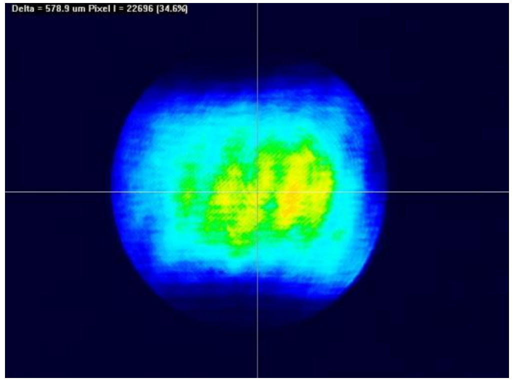
- **The 2 Flight Models were qualified on ground at an UV energy of 110mJ and a fluence < 1.3 J/cm2**
- In flight it was preferred to limit the UV emitted energy to 70mJ to keep the fluence low to prevent damage of UV optics

Max UV energy reached during the alignment

TxA	UV energy	Fluence	Conversion Efficiency
FM-A	162 mJ	1.25 J/cm^2	43.5%
FM-B	190 mJ	1.12 J/cm^2	50%

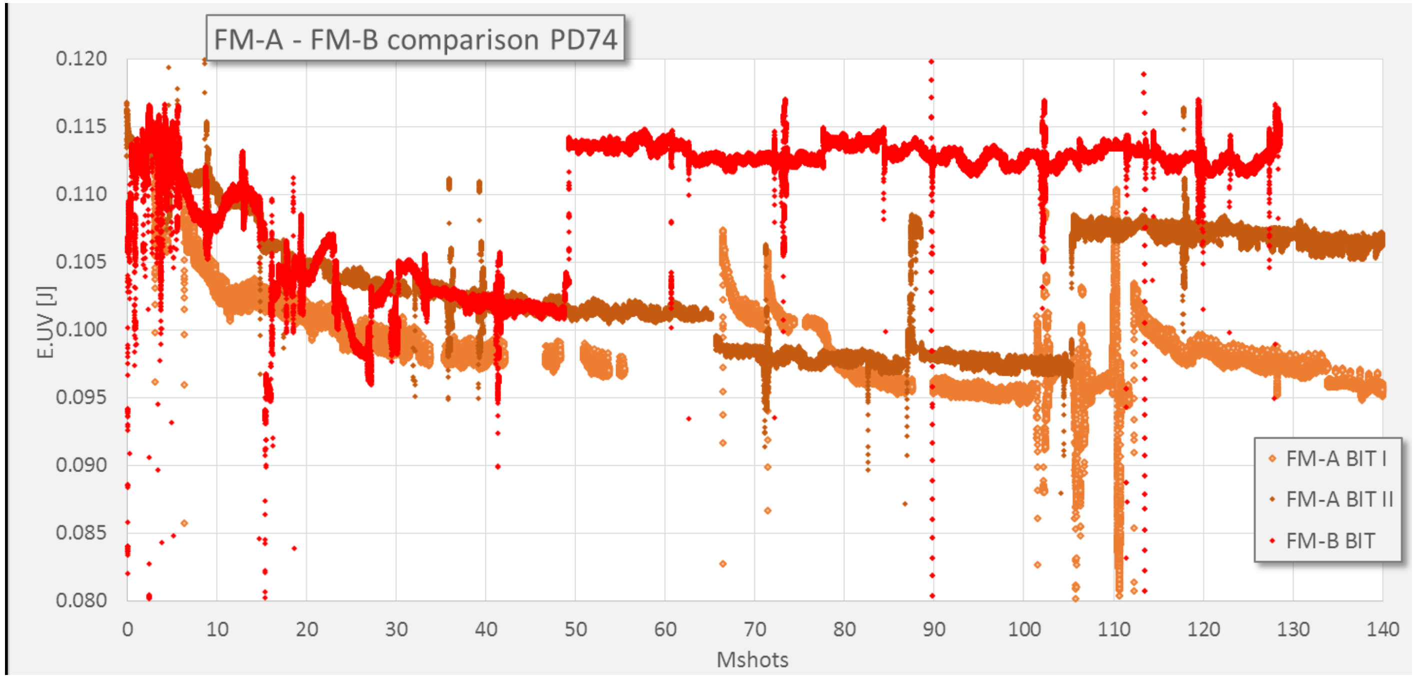


FM-B UV beam during alignment at 190mJ



FM-B UV beam at the end of BIT in vaccum 114mJ

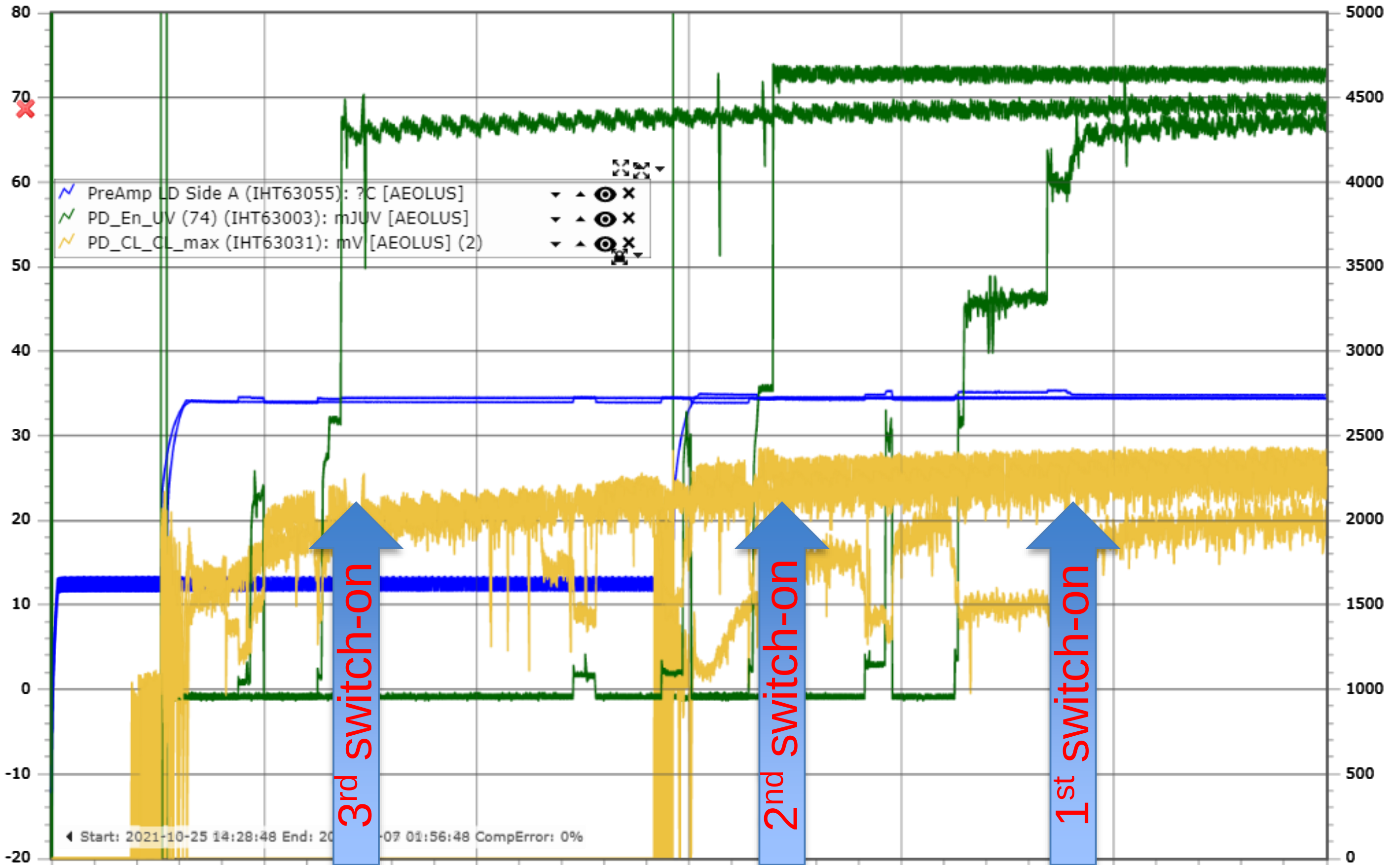
UV energy from FM-B TVBIT (red) and FM-A BIT II (brown) and FM-A BIT I (orange) in the range from 80 to 120 mJ



ALADIN – Laser: improvement in ability and rapidity in the operations

- Laser operations were considered one of the most critical limit of Lidar operability in space.
- During the Aeolus mission it was recorded a significant improvement in terms of ability and rapidity to command the laser thanks to:
  - methods applied for an active instrument
  - the very good communication between the many involved parties
  - development of complicated remote operations due to the Covid Pandemic Scenario
  - increase in the confidence acquired with time in terms of reproducibility and robustness of the Aladin laser

Comparison of 3 switch-on sequences from Stand-by to 70mJ



- **Only 4 days for last switch-on thanks to FOS dedication and TxA's repeatibily**
  - Almost 10 days for first switch-on and 8 days for the second one

ALADIN – Switch-over to FMA in October 2022

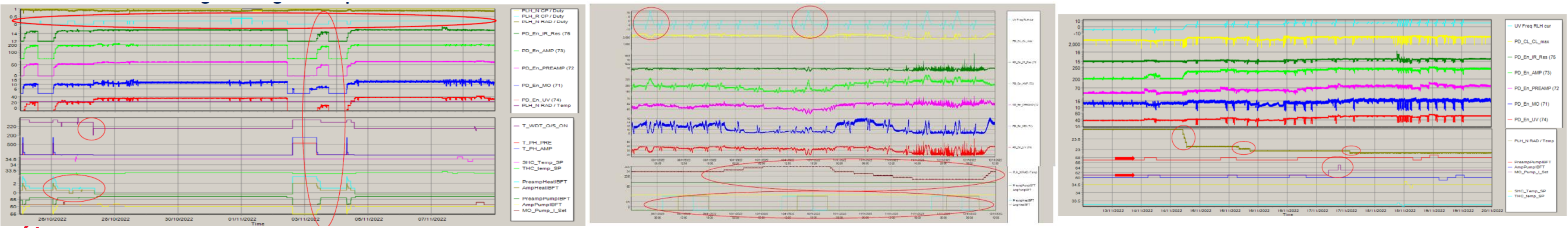
To improve wind measurement

- The laser A was switched back on starting in October 2022.
- During the switch-over, **<u>the probably most complex laser operation ever performed in space was realized to better tune the laser A and increase the performance</u>**.
- The return signal has improved with respect to the end of laser B operation despite laser A emitting only half the UV energy.
- Attenuation of the emitted signal with laser B was most probably mainly induced by an optical element of its path, not common with laser A.
- This and the new laser A UV energy trend allow to extend the mission lifetime until nearly 1.5 years beyond the mission lifetime, i.e. till the end of the platform propellant reserve.

A so complex activity needed the contribute of all involved parties :

ESA PLSO/FOS/MMPF (ESTEC/ESOC/ESRIN) + DISC/DLR + INDUSTRY

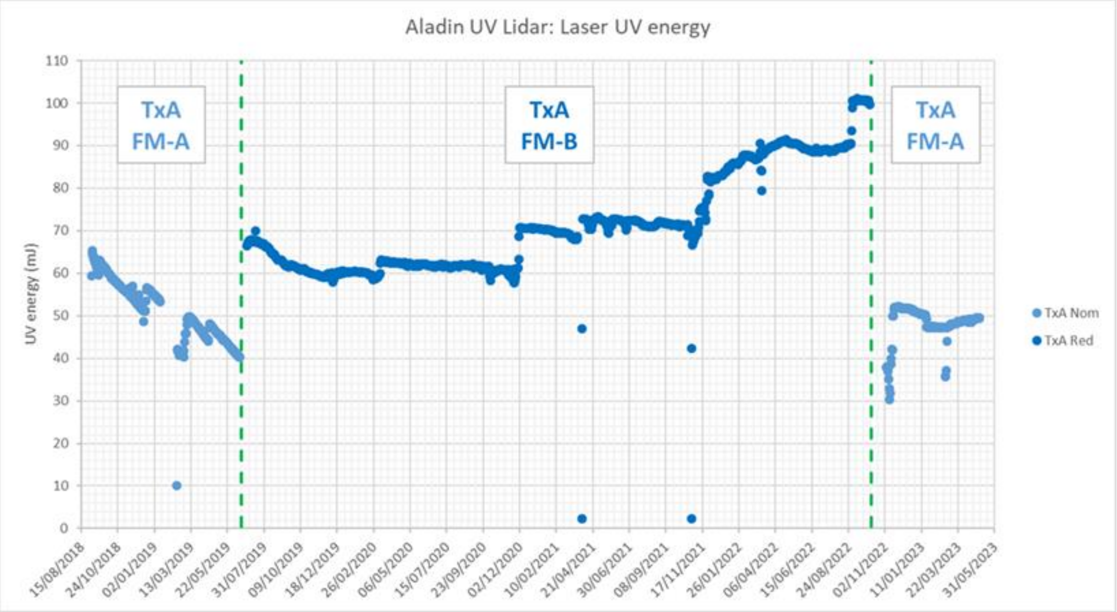
➢ **The achieved return signal increase allows extending the mission lifetime**



AEOLUS – Mission Extension

- The Aeolus lifetime extension has allowed:
  - Extending the availability of data for NWP models
  - Better characterizing the instrument and the laser, to better understand the processes that limit the lifetime and the performance
  - Gathering additional knowledge, which will be extremely important for the follow-on mission

- Thanks to the experience we collected and the robustness of the laser the mission was extended until 18 months
- Switch to TxA F-MA with the aim of:
  - Reducing the number of compromised optics in the instrument transmission path:
    - 5 optics used for the FM-B laser are not on the FM-A optical path
  - Improve the TxA FM-A performances by acting on its set point
  - Find a more stable laser operating point to prevent the laser energy fast decay observed at the beginning of the mission also on the basis of FM-B lessons learnt and….
  - **we succeded thanks to the big effort of the whole wonderful and unique Aeolus Team!**



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