ICSO 2016

International Conference on Space Optics

Biarritz, France

18–21 October 2016

Edited by Bruno Cugny, Nikos Karafolas and Zoran Sodnik

Aladin performance validation

Frederic Fabre

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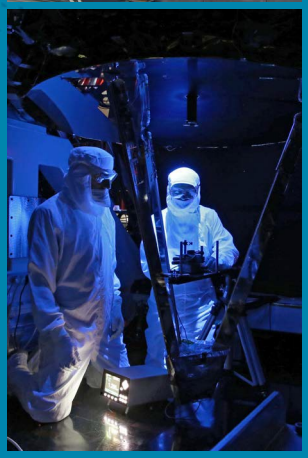

Aladin performance validation

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aeolus because wind matters

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Aeolus: ESA's Wind Lidar Mission

esa

Scientific objectives

- To improve the quality of weather forecasts;
- To advance our understanding of atmospheric dynamics and climate processes;

Explorer objectives

- Demonstrate space-based Doppler Wind LIDARs potential for operational use.

Observation means:

- Provide global measurements of horizontal wind profiles in the troposphere and lower stratosphere

Payload

- ALADIN: Atmospheric LAser Doppler INstrument

Recalls

Aladin is a Doppler wind Lidar based on direct detection (no heterodyne function)

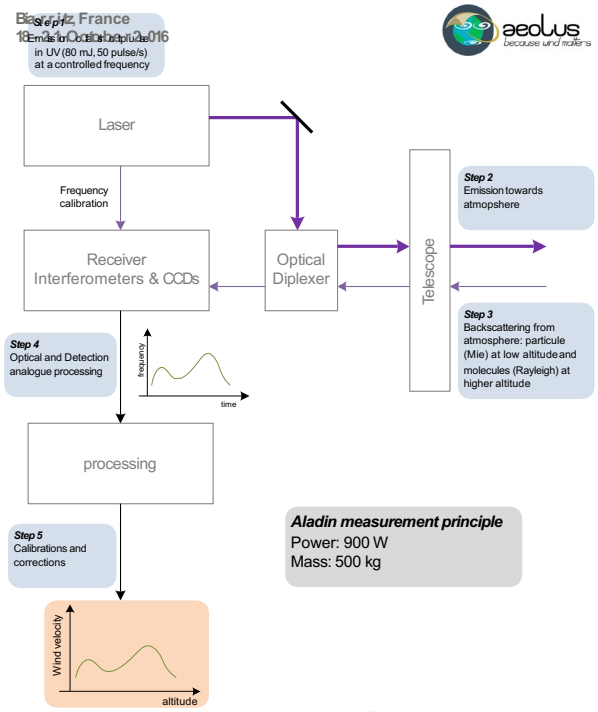
Aladin is self calibrated

- Emitted frequency measured at emission
- Absolute zero measured on ground echo
- Response independent from received amplitude
- Response slope calibrated in orbit

The receiver is closed during the laser emission in order to protect the receiver against straylight

The high energy laser sections are pressurised at ca. 0.6 mbar but the other units are operated in vacuum

The receiver is based on Fabry-Perot (Rayleigh) or Fizeau (Mie) interferometers



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Measurement principle

Doppler shift of backscattered light vs laser pulse

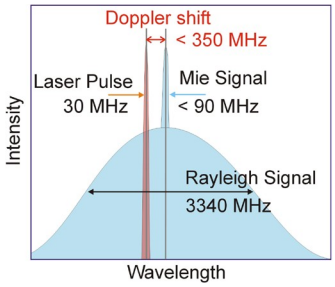
Aerosols signal (Mie)

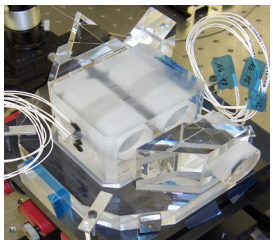
- Fringe imaging technique
- The frequency drift is proportional with fringe position

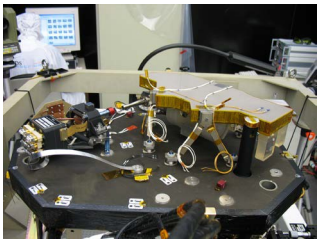
Molecular signal (Rayleigh)

- Ecartometric measurement: two high resolution filters are placed on the aisles of the Rayleigh spectrum
- Two optical signals are measured: A and B
- Response is defined as:

$$R = \frac{A - B}{A + B}$$







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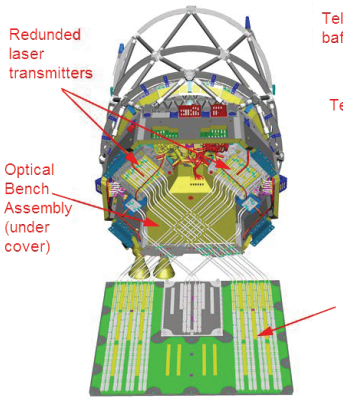
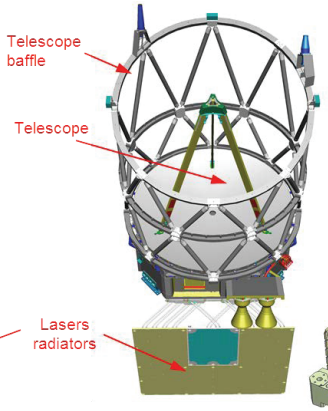
Overall architecture

ALADIN (Atmospheric LAser Doppler INstrument) will be the first European space-borne Lidar and the first space-borne Doppler Lidar in the world. It is developed by Airbus D&S for ESA.

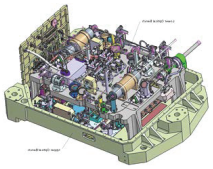
The ALADIN instrument is made of four main sub-assemblies: the opto-mechanical assembly essentially made of the structural parts the telescope and the thermal control H/W (also including components of the in-situ cleaning system and the Laser Cooling System), the optical bench assembly (OBA, including the sealed TRO), the lasers and finally the electrical units.



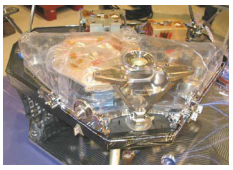


ALADIN:

- Direct detection Doppler Wind Lidar: Receiver based on HR interferometers (FWHM=50 fm)
- Mono-static concept -> transmit and receive beams propagate through the same path/telescope
- High energy UV laser -> typ. 80mJ @355nm
- Large telescope -> 1.5m diam.
- Overall mass=~500kg
- Power=~900W



Power Laser Head (PLH) (internal accommodation)



Optical bench

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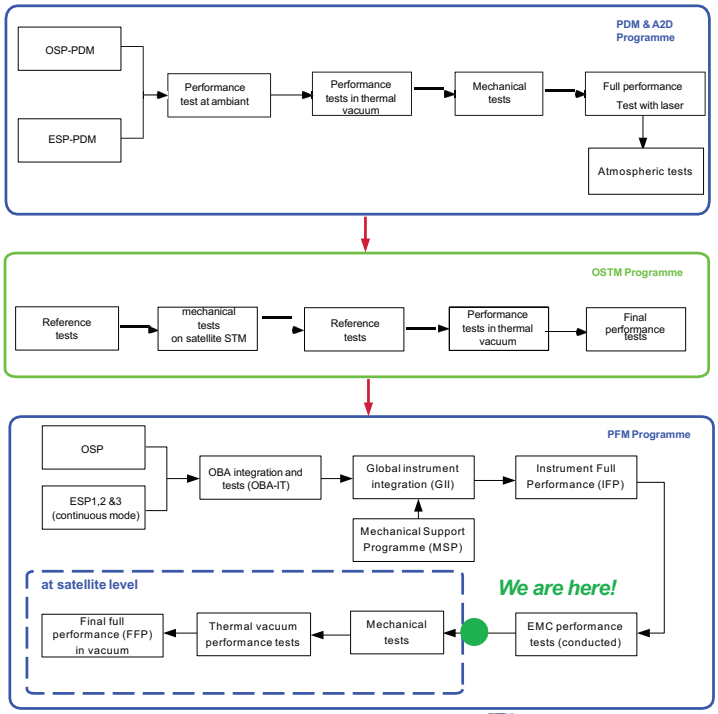
Development approach

Pre-development of the receiver and laser

Validation of the mechanical, thermal and optical model

Development and validation of the protoflight model



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Performance test overview

Instrument performance tests are:

- Performed at ambient pressure
- Intended to validate the random error and a part of the systematic errors
- Intended to be a rehearsal of the performance test to be performed in vacuum

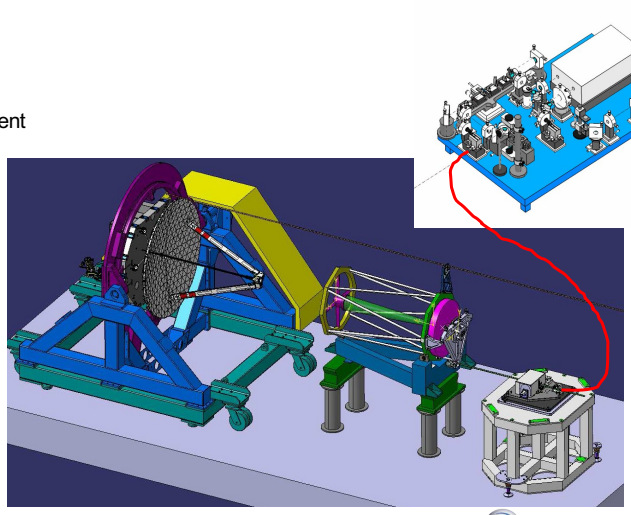
Main tests

	Radiometric and geometric	spectral
Low level test For characterisation and in-orbit performance consolidation	Peak transmission, noise in darkness, emitted energy, emission divergence, Rayleigh spot diameter	Mie channel resolution, fringe distortion
Higher level test Direct performance verification	Random error	Response calibration accuracy, response slope, residual error in response

Test set-up overview

The configuration is

- Instrument Flight model, except laser cooling system which is replaced by a chiller
- Thermal GSE
- Mechanical GSE
- Electrical GSE
  - Power supply
  - Digital interface to/from the instrument
- Optical GSE
  - –Generate a calibrated atmospheric Echo (frequency and amplitude)



All is set in an ISO5 clean room

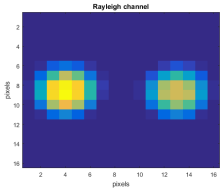
Operation in darkness

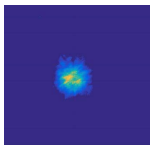
Operator protection (eye safety)

Radiometric and geometric tests

Test	Expected	Achieved	comment
Noise in darkness (Laser ON)	0,51 / 0,61 e-/pixel	0,56 / 0,66 e-/pixel	Mie/Rayleigh channel assuming accumulation over 50 returns. Design makes the detection noise insensitive to laser emission
Transmission (Tx)	0,80	0,69	Test result translated in flight configuration. Difference due to contamination
Transmission (Rx) Mie channel Rayleigh channel	 0,054 0,46	 0,048 0,46	Difference due to contamination
Emitted energy	62 mJ/shot	53 mJ/shot	Test result translated in flight configuration. Difference due to contamination
Emission divergence	<20 µrd	19 µrd	At instrument output
Rayleigh spot diameter	115 µm	113 µm	On detector

Rayleigh receiver spots



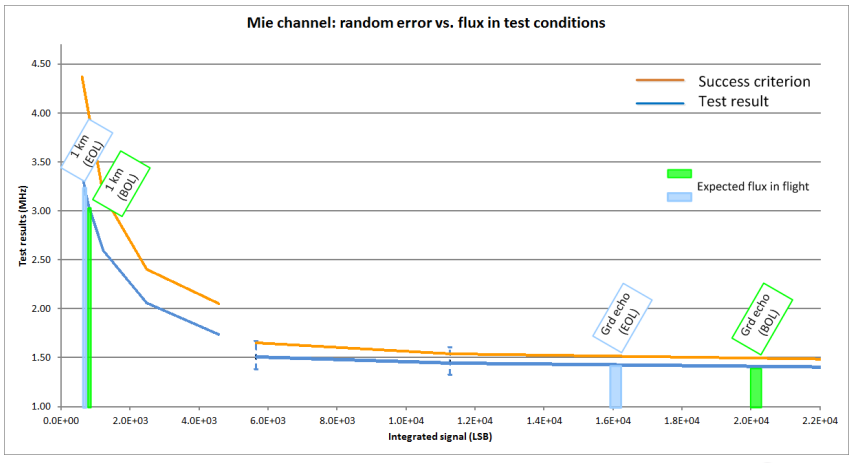


Instrument far field

Random error : Mie Channel (0-2 km alt.+ clouds)

The random error is the measurement noise (rms value).
For conversion into wind velocity: 1 m/s HLoS is equivalent to a frequency shift of 3.43 MHz

Test results are better than the success criterion and in line with expected values



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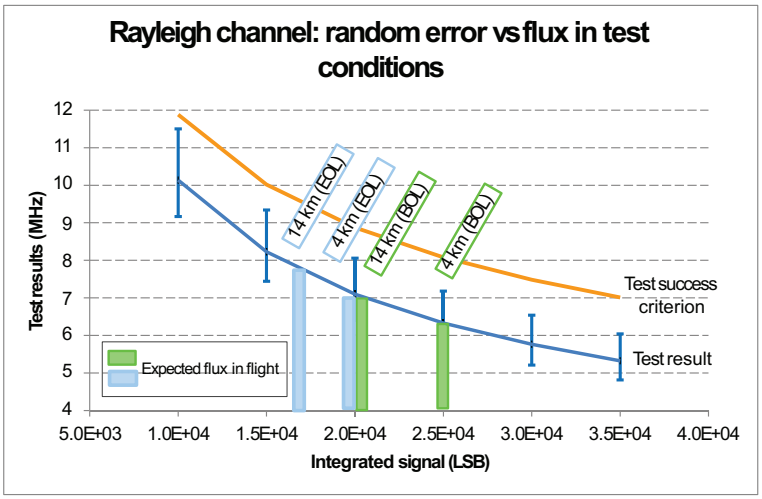
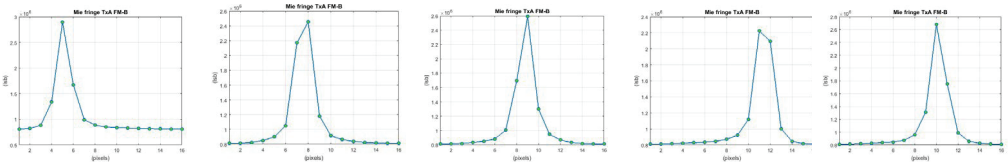
Random error: Rayleigh channel (2-20 km alt.)

Test results are better than the success criterion and in line with expected values



Spectral tests

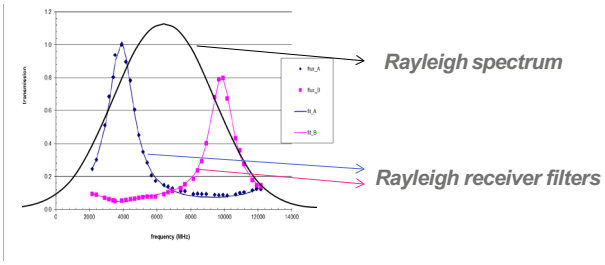
Test	Expected	Achieved	comment
Mie channel resolution	< 150 MHz	112 MHz	At FWHM on atmospheric path
Mie channel spectral range	>1550 MHz	1520 MHz	
Mie fringe distortion	< 25 MHz	+/-27 MHz	



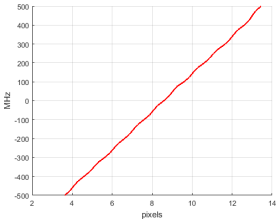
Mie channel fringe versus frequency drift (+/-340 MHz or +/- 100 m/s)

Spectral response

	Expected	Achieved	comment
Mie channel/CAL	111 MHz/p	99 MHz/p	Difference may be due to a variation of the Fizeau wedge under gravity. Weak impact on performance
Mie Channel/ATM	110 MHz/p	99 MHz/p	
Rayleigh channel/CAL	2083 MHz/resp	2127 MHz/resp	
Rayleigh channel/ATM With Rayleigh spectrum	1694 MHz/resp	1666 MHz/resp	
Rayleigh channel/ATM With Mie spectrum	2083 MHz/resp	2173 MHz/resp	



Rayleigh channel spectral response



Mie channel response

First conclusions and next steps

The measured performance is very close to the expected value. Especially the random error (high level test) is close to the predictions.

This test result allows the in-orbit performance to be consolidated (see graph: 1 m/s is 3.43 MHz)

The robustness of the UV coatings was tested over ca. 500 Mshots

Next steps:

✓ Integration of the instrument on the platform in Airbus D&S UK (done)
- Functional test at satellite level (up to December 2016)
- Satellite mechanical tests (Q1-2017)
- Satellite thermal vacuum tests (Q2-2017)