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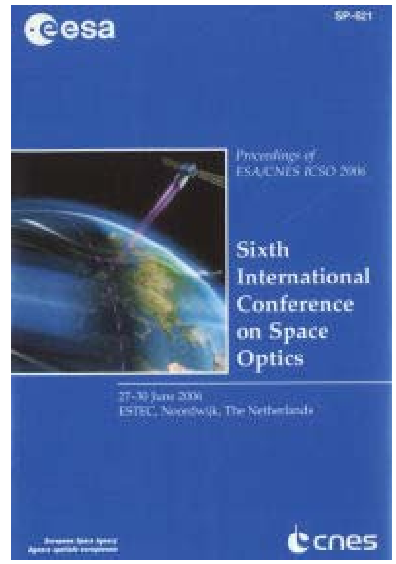

High energy, single frequency, tunable laser source operating in burst mode for space based lidar applications

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HIGH ENERGY, SINGLE FREQUENCY, TUNABLE LASER SOURCE OPERATING IN BURST MODE FOR SPACE BASED LIDAR APPLICATIONS

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ABSTRACT

This paper describes energetic, spatial, temporal and spectral characterization measurements of the Engineering Qualification Model (EQM) of the Laser Transmitter Assembly (TXA) used in the ALADIN instrument [1] currently under development for the ESA ADM-AEOLUS mission (EADS Astrium as prime contractor for the satellite and the instrument). The EQM is equivalent to the Flight Model, with the exception of some engineering grade components. The Laser Transmitter Assembly, based on a diode pumped tripled Nd:YAG laser, is used to generate laser pulses at a nominal wavelength of 355 nm. This laser is operated in burst mode, with a pulse repetition cycle of 100 Hz during bursts. It is capable to operate in Single Longitudinal Mode and to be tuned over 25 GHz range. An internal "network" of sensors has been implemented inside the laser architecture to allow "in flight" monitoring of transmitter. Energy in excess of 100 mJ, with a spatial beam quality factor (M^2) lower than 3, a spectral linewidth less than 50 MHz with a frequency stability better than 4 MHz on short term period have been measured on the EQM. Most of the obtained results are well within the expected values and match the Instrument requirements. They constitute an important achievement, showing the absence of major critical areas in terms of performance and the capability to obtain them in a rugged and compact structure suitable for space applications. The EQM will be submitted in the near future to an Environmental test campaign.

1 INTRODUCTION

The Aladin Laser Transmitter Assembly (TXA) is one of the most challenging laser transmitter for LIDAR spaceborne applications even if compared to the homologous devices employed in the last 5 years NASA missions [2] [3].

The ALADIN TXA [4], fully redundant in the instrument, is organised in 3 units:

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Reference Laser Head (RLH). The RLH is an ultrastable diode-pumped CW Nd:YAG Laser [5], used as injection seeder for the Power Laser Head (PLH). The output beam of the RLH is fed into PLH by means of an optical fibre.

Fig. 1. RLH Unit.

Power Laser Head (PLH). The PLH is a diode-pumped, Q-switched Nd:YAG Laser working in the third harmonic. A picture of the closed unit is reported in Fig. 2.

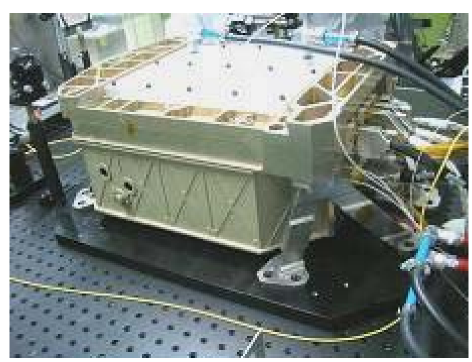

Fig.2. PLH Unit.

The optical lay-out of this unit is reported in Fig. 3.

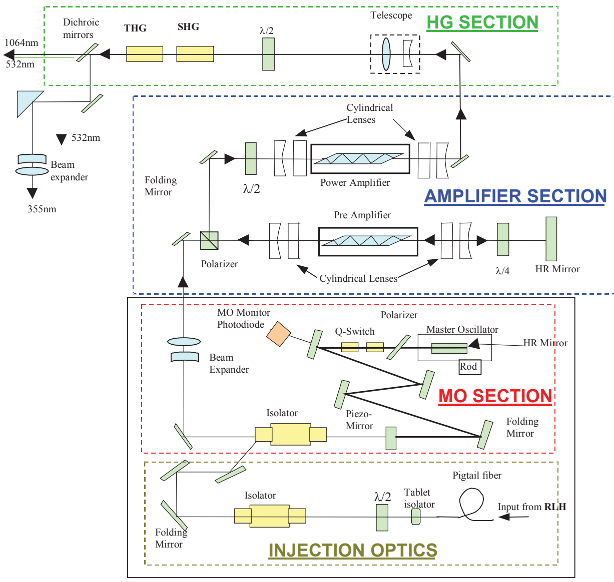

Fig. 3. PLH Optical Lay-Out.

The PLH is composed of 4 main subunits described and shown hereafter:

– A low energy injection seeded, Q-switched, longitudinally laser diode pumped Nd:YAG Master Oscillator (MO).

Fig. 4. MO Subunit.

– A first amplifier (PreA) in a double pass configuration (transversally pumped).
– A second power amplifier (PwA) in a single pass configuration (transversally pumped).

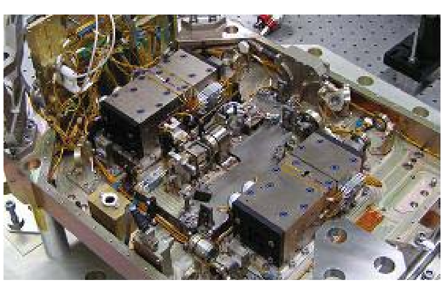

Fig. 5. Pre and Power Amplifier Subunits.

– A Harmonic Section (HS) employing two non-linear crystals.

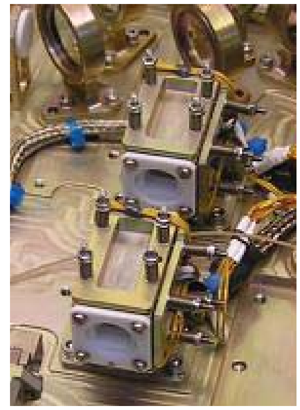

Fig. 6. HS Subunit.

The whole PLH operates in burst regime with a cycle of 12 s ON (7s useful) and 16 s OFF. An image of the open unit is reported in Fig. 7

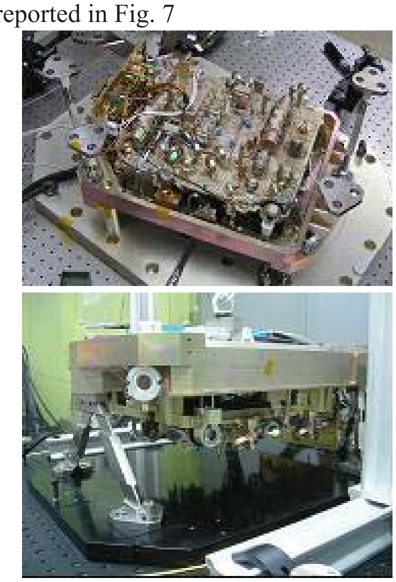

Fig. 7. PLH Unit: On-Ground integration configuration (upper), Testing/In-Flight configuration (lower) without cover.

Transmitter Laser Electronics (TLE). The TLE is organised in three main sections:

– Power Section, containing the Laser Diode Power Supplies for MO, PreA and PwA and High/Low voltage Power Supply;
– Interface & Control Section containing several boards dedicated to command and control PLH and RLH operations and to interface the Aladin Control and Data Management (ACDM).
– Cavity Length Control Loop (CLCL) section, dedicated to lock the MO to the RLH ensuring the PLH tunability and Single Longitudinal Mode operations.

Fig. 8. TLE Unit.

The TXA/PLH EQM model is equivalent to the Flight Model, with the exception of some engineering grade components. The RLH and the TLE are engineering level units.

The ALADIN Instrument and TXA will be respectively the first European spaceborne Wind Lidar, and All-Solid-State laser Transmitter to be launched in 2008 for a three-year mission in space.

2 TXA EQM EXPERIMENTAL RESULTS

The main experimental results obtained in air with the TXA EQM are reported in Table 1.

Table 1. Main UV Laser Output Performance

Parameter	EQM Measurement
Energy/pulse	107 mJ (mean during ON period)
M^2	≤ 3
Pulse duration	18.4 ns (FWHM)
Beam Angular Stability	24.4 µrad X (zig-zag plane) 28.7 µrad Y (orthogonal to zig-zag plane)
Spectral linewidth	40 MHz (FWHM)
Frequency stability	3.7 MHz (rms value)

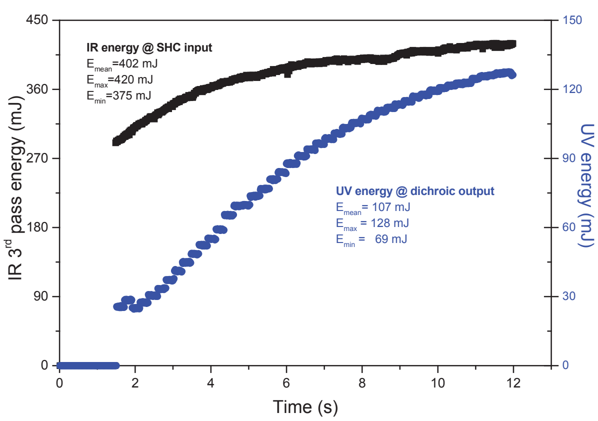

Fig.9: IR/UV Energy during 12 s. The reported values refer to last 7 s useful period.

Due to the transient thermal behaviour induced by the burst operations, the IR beam spatial profile and consequently the output energy vary during the useful ON period. Both causes make the UV conversion efficiency to increase from 18% to 31% from the beginning to the end of the burst.

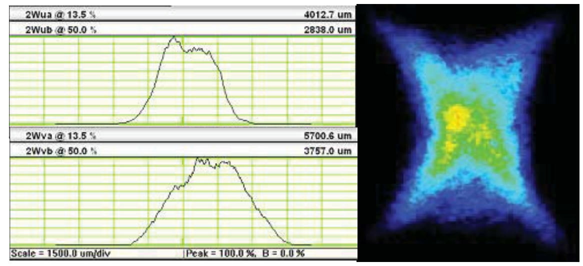

Fig.10: Typical UV Near Field profile.

A typical Near Field profile is shown in Fig. 10. Its dimensions at $1/e^2$ of the peak irradiance are 4 mm in one direction and 5.7 mm in the other one.

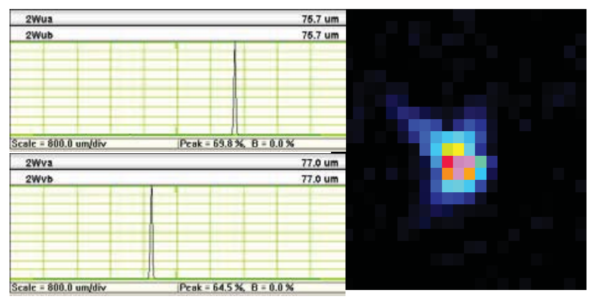

Fig.11: Typical UV Far Field profile.

The good quality of the beam ($M^2 \leq 3$) results in a typical Far Field profile measured at the focal plane of a 500 mm lens, as the one shown in Fig. 11. Its dimensions at $1/e^2$ of the peak irradiance are around 77 µm in both directions.

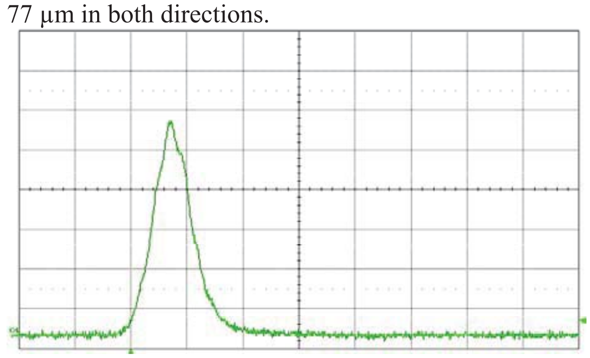

Fig.12: Typical UV pulse temporal profile.

The temporal profile width is of 18.4 ns (FWHM). It does not exhibit any temporal modulation when the

RLH is injected inside the MO, indicating that the laser is operating in Single Longitudinal Mode (SLM).

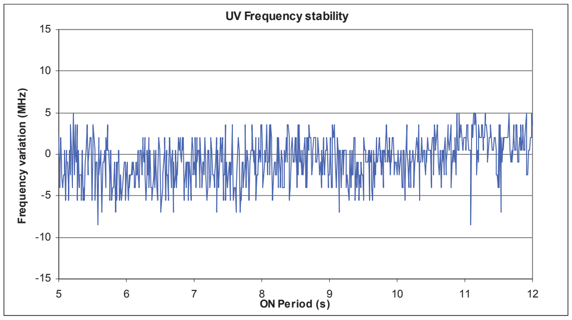

Fig. 13 Optical frequency stability.

The ultrastable RLH frequency characteristics guarantee a whole TXA frequency stability after harmonic conversion, as reported in the graph of Fig. 13.

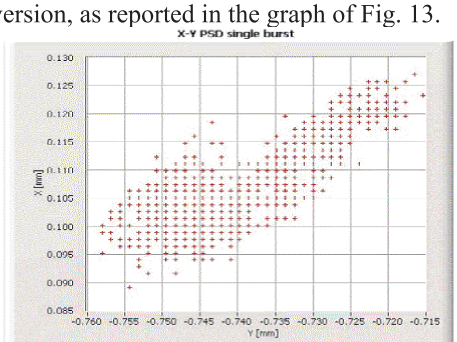

Fig.14: UV beam angular stability during a burst.

The X,Y centroid displacements reported in Fig. 14, have been measured at the focal plane of a 500 mm lens.

The main physical characteristics and budgets of the TXA EQM single units are reported in Table 2.

Table 2. Physical Data & Budgets

Parameter	EQM Measurement
Mass	PLH EQM = 27.3 kg RLH EM = 2.4 kg TLE EM < 22.2 kg
Volume	PLH = 450x350x215 mm^3 RLH < 150x120x75 mm^3 TLE < 450x345x230 mm^3
Stiffness	PLH Resonance frequency X axis 182 Hz Y axis 288 Hz Z axis 251 Hz RLH Resonance frequency X axis 347 Hz Y axis 342 Hz TLE Resonance frequency X axis 220 Hz Y axis 430 Hz Z axis 510 Hz
Cold Plate	24 ± 1 °C
Power consumption	440 W (measured average value)

The EQM will be submitted in the very near future to an environmental test campaign encompassing vibration and thermal vacuum tests. The flight TXA will operate in vacuum.

3 TXA SPECIFIC PROVISIONS

Several provisions have been adopted in the TXA design, development and test phases to guarantee a correct operability during the mission and improve the reliability.

Cleanliness/Contamination

A high level of cleanliness, supported by continuous environmental monitoring during assembly activities, is essential to minimize surface contamination levels and to maintain the contamination within values that do not affect the instrument performance and reliability. In this contest, particulate contamination (PAC) is directly correlated to the environmental cleanliness levels, the personnel activities inside the controlled area and the duration of the various operations. All the TXA EQM assembly, alignment and test activities have been performed in a class 100 ambient. A rough formula indicating the particle accumulation on horizontal surfaces as a function of the cleanliness level of the integration ambient, is reported hereafter

$$\mathbf{PFO} = 0.069 \times [\text{Cleanroom class}]^{0.72} \quad [\text{ppm./day}]$$

this implies, as rough assessment:

- CR, class 100.000 (M6.5) ⇒ ≈ 275 [ppm./day]
- CR, class 10.000 (M5.5) ⇒ ≈ 53 [ppm./day]
- CR, class 100 (M3.5) ⇒ ≈ 2 [ppm./day]

For what concerns the molecular contamination (MOC), due to a non linear relationship between the time and the amount of contaminants deposited on surfaces, an assessment can be done based on the acquisition of several typical values (on weekly and monthly basis), relevant for the specific AIT areas. An experimental graph showing the PLH EQM molecular particle accumulation during 300 days of integration activities, compared with the theoretical curve (green) and goal value (red) of 1.2 g/cm^2, is reported hereafter.

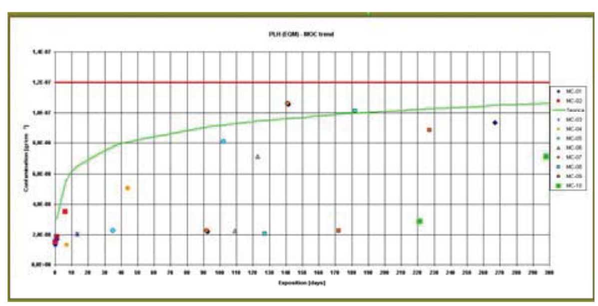

Fig. 15. MOC exposition PLH EQM curve.

It is worth noting that the contamination level remained below 1.2 g/cm^2, that is considered a reasonable level obtainable with suitable precautions.

In-Flight monitoring and control

Temperatures of the key components (laser diodes and active materials of the various unit sections, cold plate, optical benches, etc.) are continuously monitored to verify the "health" status of the laser and/or detect anomalous behaviours.

Fig. 16. Example of various PLH internal components temperature monitoring.

Laser energy at the output of the different PLH subunits are also monitored by means of sampling photodiodes. Cross correlating this information with the temperatures, it is possible to detect ageing effects and compensate them where possible. For example, the LD current can be increased compatibly with the allocated power budget and HW limitations. In fact together with the Tele Measurements (TM) cited above, the TXA has been conceived in order to accept several Tele Commands (TC), such as laser diode currents or pulse durations, that will enable "in flight" management of the laser.
Being Single Longitudinal Mode (SLM) operation crucial for the whole Aladin Instrument and Mission performance, a monitoring of the single frequency emission of the laser is operated periodically during mission.
Temperatures, energy and currents monitors are also used to consent to operate safe transitions among the different laser Tx operational modalities at switch ON/OFF.
A series of protections, at unit, subunit and modules levels have also been implemented. They take action when some critical parameter goes out of a predefined "hazard threshold limit", forcing the TXA in a safe operation mode (STAND-BY).

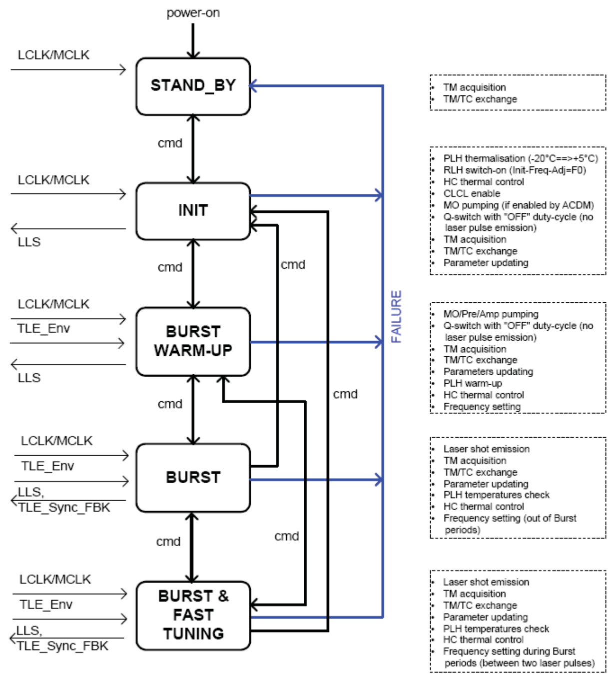

Fig. 17. TXA functional mode diagram and mode control parameters.

This should prevent catastrophic failures or damage of optical components and improve the success probability of the whole mission.

4 AKNOLEDGMENTS

We whish to thank Team people from Quantel, CESI, Tesat and Nuvonix for the strong contribution and technical support given in this program.

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