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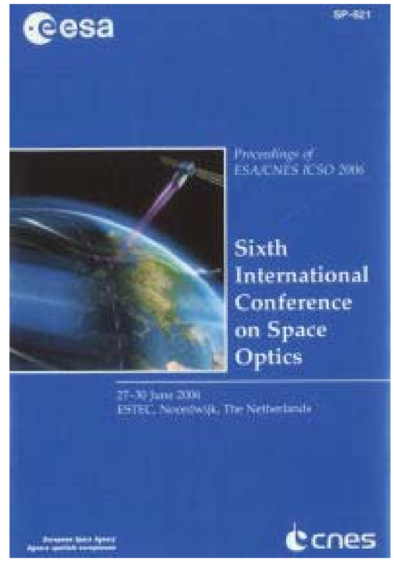

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HIGH STABILITY LASERS FOR LIDAR AND REMOTE SENSING

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ABSTRACT

Tesat-Spacecom is currently building a set flight models of frequency stabilized lasers for the ESA Missions AEOLUS and LTP. Lasers with low intensity noise in the kHz region and analogue tuning capabilities for frequency and output power are developed for the on board metrology of the LTP project, the precursor mission for LISA. This type of laser is internally stabilized by precise temperature control, approaching an ALLAN variance of 10^{-9} for 100 sec. It can be easily locked to external frequency references with >50kHz bandwidth. The Seed laser for the AEOLUS mission (wind LIDAR) is used as the master frequency reference and is stabilized internally by a optical cavity. It shows a 3* 10^{-11} Allan variance from time intervals 1 sec - 1000 sec. Furthermore it is step-tunable for calibration of the receiver instrument with a speed of GHz / sec by a digital command interface. Performance and environmental test results will be presented.

1. LASER HEAD AND PUMP MODULE

1.1 Laser Head

The laser source used for the LTP and ALADIN missions were developed for the German DLR-.LCT program. In this program, the lasers are used as transmitter and local oscillators of a coherent homodyne laser communication terminal, scheduled for launch on the TERRASAR mission this year. For coherent optical a single frequency laser source and a reliable pump laser are essential . Therefore Tesat has started dedicated developments on this strategic fields 8 years ago.
Fig. 1 shows the Tesat Laser Head, 50mW 30GHz continuous tuning version (20*25*18mm, weight 80 gr). The multi mode pump fiber (at front) delivers the light form the pump laser. A coupling optic focuses the 808nm light into the laser crystal. The 1064nm laser light aligned in polarization and coupled to the single mode polarization maintaining fiber assembly (on the right of fig.1). A Faraday isolator is also included in the package, together with temperature sensors, laser crystal heater and a monitor photo diode.

Fig. 1: Tesat single frequency laser head

This laser has successfully passed standard environmental tests including 200 thermal vacuum storage cycles between –40°C and + 65°C, launch vibration of 33 g rms, mechanical shock (1500 g), and gamma irradiation of 150 kRad. A life test of 2500 h with 60 mW output power and 45 °C housing temperature (laser crystal temperature of 93°C) was included into the test campaign also. Fig. 2 shows a summary of the frequency plots during the qualification test campaign.

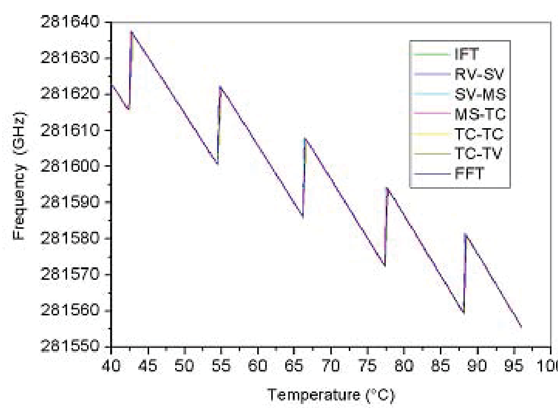

Fig. 2: Frequency – laser crystal temperature plots from the qualification campaign of the Laser Heads, showing no degradation in frequency tuning performance from initial functional test (IFT) to final functional test (FFT).

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1.2 PUMP LASER

Laser diodes at 808 nm for cw pumping were developed in a multiple redundant configuration. The designed mission life time (operational) is 10 years. Extensive life tests under accelerated conditions were performed an a continuous improvement in laser diode manufacturing process and packaging results in an > 5Mh MTTF (mean time to failure) reliability figure for a single emitter. Up to 8 emitters in a cold and hot redundancy arrangement are coupled into a 100µm multi mode fiber. The development was performed by Tesat, the Ferdinand-Braun-Institute in Berlin, Germany and the Fraunhofer Institut für Laser Technologie in Aachen, Germany. Fig. 3 shows the pump laser module.

Fig. 3: Tesat Pump Laser Head, 45*45*20 mm, 150 gr, hermetically sealed

2. LTP

The laser currently developed and tested for the ESA Lisa Test Package mission serves as a laser source pre-stabilized in frequency and amplitude. It will be locked and controlled by the payload in order to fulfill the demanding frequency and amplitude stability requirements of the experiment. The pre-stabilization is performed by using precise temperature control of the laser crystal (to ~ 100µK) and additional error compensation for the electronics. For the LTP mission frequency stability is of importance at long time intervals (1-10000 sec). The frequency stability approaches $1*10^{-9}$ for 100 sec. In addition to the temperature control of the laser crystal, Bragg stabilized pump lasers are used in order to give a well defined and temporal stable emission spectrum for the pump laser. This also supports the amplitude stabilization necessary for the LTP experiment. Relative intensity noise (RIN) levels of < 50 dB are required in the 500 to 2000 Hz spectral region. The LTP mission provides the Laser with a very stable thermal environment, however the absolute temperature in orbit is currently defined in a 6 K range , so the performance specification of the laser must be met in a temperature range of 23-29°C (at housing temperature reference point).

The LTP laser is based on the development of the NASA GIFTS mission reference laser (see fig. 4). A laser, a redundant pump laser and the control and driver electronics are combined into a 1 liter, 1 kg housing. Maximum power consumption is 12 W. The LTP lasers delivers up to 45 mW 1064nm light into a polarization maintaining single mode fiber

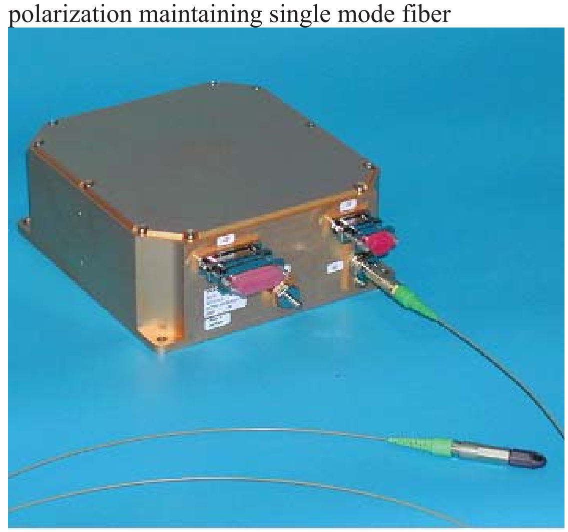

Fig. 4: FM of the GIFTS reference laser

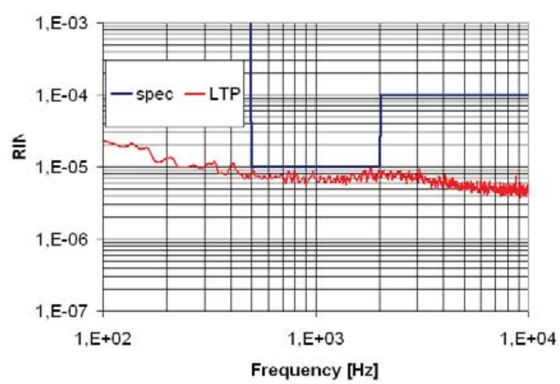

Fig. 5: Relative intensity noise spectrum of the LTP EM (red). Specification is shown in blue.

The relative intensity noise is suppressed by using a fast power control loop, measuring the output power of the laser crystal and acting onto the drive current of the laser diode, see fig. 5.

Fig. 6 shows a typical Allan variance plot of the frequency stability, approaching $1*10^{-9}$ for 100 sec. .

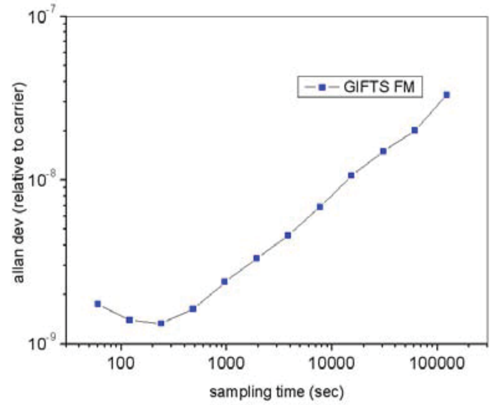

Fig.6: Allan variance plot of the frequency stability of a passively stabilized laser

3: ALADIN

The Reference Laser Head (RLH) of the ESA Aeolus mission is designed to act as a seed laser for a high power UV Doppler LIDAR. For this application, the laser has to emit frequency stable light (250 kHz / min) and it must be precisely tunable (for receiver calibration). These requirements (stability and tunabillity) are in contradiction, so the ALADIN design separates the functions into two design blocks, integrated into one housing

A frequency stable reference (a TESAT laser head locked to a high finesse optical cavity) and a seed laser, that is controlled by a digital phase locked loop (PLL, 12 GHz bw) for fast and precise frequency tuning. Both lasers are combined with the pump laser and the electronic onto one housing, see fig. 7.

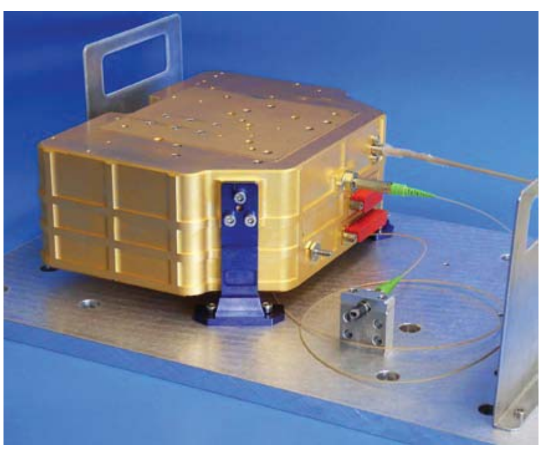

Fig.7: ALADIN BB on transport mount. Isostatically mounted, thermal interface is on top of the box.

The TM/TC (Telemeasurement /Telecommand) interface is digital, the size of the box is 2 liters in an isostatic design, power consumption is 20 W, weight 2 kg.

The frequency stability is dominated by the performance of the passive frequency reference resonator (made from ULE -Corning Ultra Low Expansion glass) and is approaching $2 *10^{-11}$ at 1000 sec, see fig. 8 .

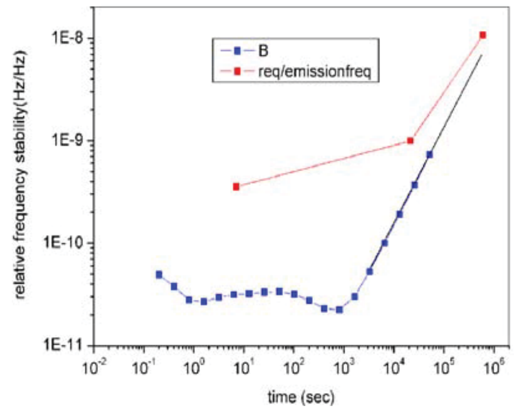

Fig. 8: Frequency performance of the ALADIN RLH compared with the specification.

The light of the frequency stable laser is combined with the light of the seed laser (that is coupled to the down streams laser and amplifier chains) onto a fast photo diode (from Discovery Semiconductors) and then locked and controlled via a digital PLL (Tesat development). This enables step tuning with a coarse (GHz / sec) rate and a fast fine tuning (8.3333MHz / 250 msec, 83.333 MHz / 950 msec), see figure 10. The PLL loop control enables a tuning speed of up to 400 MHz/sec without unlocking, 1-2 GHz / sec are possible with unlock and re lock, see fig. 9 and fig. 10.

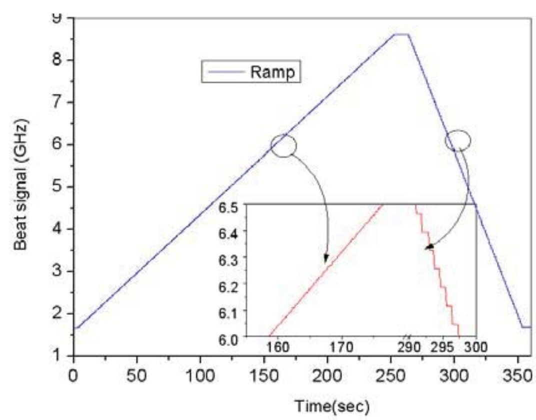

Fig. 9: ALADIN RLH step tuning performance, the upward ramp consist of 1000 steps with 8.3333 MHz each, the down ramp are 100 steps with 83.333 MHz. Jitter is induced by spectrum analyzer read out.

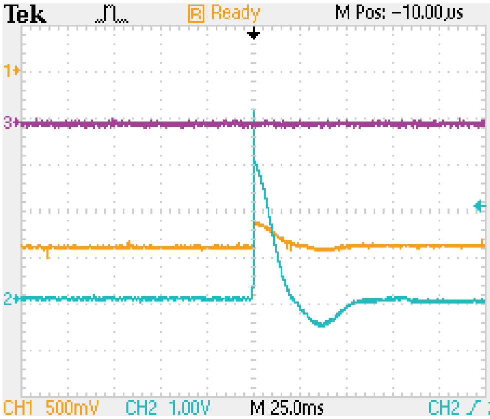

Fig. 10: Response of the ALADIN PLL loop for a 8.333 MHz frequency step. Blue is the Piezo voltage (the fast frequency actuator of the Laser Head, actuation range of ~ 40 MHz, bandwidth 80 kHz), yellow the crystal temperature control loop (actuation range 15 GHz, bandwidth 1 Hz). Scale is 25 msec/div.

4: Summary

Tesat-Spacecom has developed a set of frequency stable laser sources that serves as frequency stable lasers for missions as LTP and ALADIN. The lasers and pump modules were developed an qualified during the DLR LCTSX – program for Coherent Optical Inter Satellite Communication Terminals.