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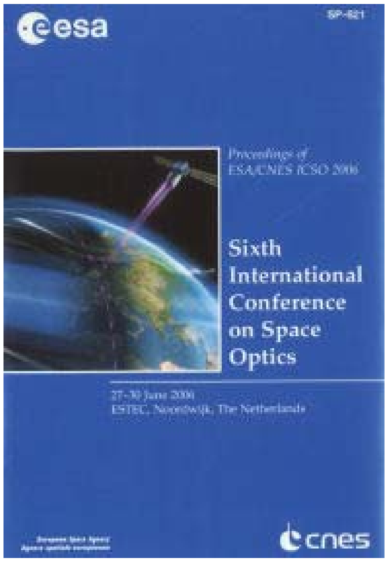

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# A NOVEL CAVITY CONTROL TECHNIQUE FOR THE STABILIZATION OF A BURST, PULSED LASER

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## ABSTRACT

This paper describes a novel technique used to get a high frequency stable pulsed laser used for spaceborn applications. The Laser assembly is based on a diode pumped tripled Nd:YAG laser, used to generate tunable laser pulses of 150 mJ at a nominal wavelength of 355 nm. This laser can operates in single mode at a pulse repetition rate of 100 Hz. A high frequency stability (< 4MHzrms @355nm) of the emitted laser pulse is maintained over several tens of seconds. A long time stability of 60MHz is also provided.

## 1. INTRODUCTION

An novel control technique used to get high optical frequency stability and to maintain single longitudinal mode operation of a burst pulsed laser is described. To increase the frequency stability the pulsed laser is seeded by a highly stable CW laser. In order to tune the laser cavity length to the seeding laser optical frequency, the cavity, between the laser pulses, is used as a Fabry Perot interferometer fed with the CW seeding laser.

A proper patented algorithm performs the scanning of the laser cavity to have the best cavity transmission. The cavity length is adjusted before each laser pulse. With this approach the pulse repetition rate is not affected by any jitter caused by the control algorithm operation, thus allowing a precise synchronization of each laser pulse with an external trigger signal. The control algorithm also analyzes the laser pulse shape by using a proper hardware/software subsystem. Such other algorithm compensates for any difference or drift occurring between the cavity length measured between the laser pulses and the actual cavity length present during the laser pulse.

## 2. FREQUENCY STABILIZATION

In order to get the necessary stability of the 355nm laser pulse a highly stable CW seeder laser at 1064nm is used to inject the pulsed laser assembly. A simple injection operation however cannot provide the necessary stability because of the mismatching between the injection seeder laser and the cavity length that can vary over the time. In fact if the cavity length is not controlled, the laser system, even if injected, can produce multimode pulses or pulses subjected to a high chirp frequency produced by the detuning existing between the injected frequency and the cavity resonant frequencies. For this reason the cavity length must stay well tuned to the CW laser frequency that is used to perform the injection.

The cavity length, is subjected to variation caused by thermal, mechanical and acoustic disturbances. To get the required 4MHz stability in the UV (that is 1.33MHz in the IR) the 80 cm cavity length must be controlled and kept stable within 4nm.

Since all the laser pulses must be within the specifications it is not possible to use/waste laser pulses to get information on the cavity tuning, like in the “build up time” method. Besides the laser pulses must be generated at a fixed pulse repetition rate, clocked by an external signal. The use of a pulsed laser prevents also the use of the Pound Drever technique [1] that is mainly conceived for CW lasers. For this reason a new stabilization method have been developed. This new technique is based on a rapid scanning of the cavity length performed by a piezo actuator before the laser pulse, in order to find the best cavity transmission, then the piezo actuator is repositioned to the maximum transmission position few tens of microseconds before the laser pulse takes place.

## 3. THE ALGORITHM

To perform this operation a dedicated control system, acting just before each laser pulse, have been developed. The optimal cavity length is determined by using the cavity as a Fabry Perot interferometer fed by the CW seeder laser. The cavity length is scanned with a piezoactuator over the entire Free Spectral Range in order to find the optimal cavity length for the single mode operation, that is the piezoactuator position where is found the Fabry Perot transmission peak. After finishing the scan, the piezoactuator is repositioned to the found optimal position so to make the cavity ready for the next 100Hz laser trigger. With this technique the laser pulse jitter can be strongly reduced. The drawback is the presence of a delay between the cavity length measurement and the laser pulse. Presently this delay is about 1ms, but it could be still reduced. A dedicated procedure and a proper driving signal for the control operations are used to reduce the effects generated by the piezoceramic actuator histeresys and non linearities.

Since such control only performs the adjustment of the “warm” cavity (the one without the laser pulse), a further correction procedure was implemented to periodically compensate for any long time drift occurring between the warm and the hot cavities. For this purpose several laser pulse shapes are periodically

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measured by a proper HW/SW system to provide a correction offset which is added to the optimal piezo position found with the Fabry Perot interferometer. This procedure also allows to check if the laser is operating in single mode.

Both the control procedures are independent on the seeder optical frequency which drives the laser oscillator frequency. The first procedure in fact uses the seeder laser to get the proper tuning between the cavity length and the seeder frequency. If the seeder frequency is varied also the cavity measurement will be automatically adjusted. The second procedure instead detects the presence of multimode pulses and defines the single mode operation region, in terms of cavity length, independently from the laser pulse absolute optical frequency.

A kind of noise the control algorithm cannot compensate comes from the delay time existing between the optimal cavity length measurement and the laser firing instant. By using a very small, high stiffness piezo actuator (shown in Fig. 1), it is possible to control and vary the cavity length in a few milliseconds, so the delay time between cavity measurement and piezo positioning can be kept as small as hundreds of microseconds.

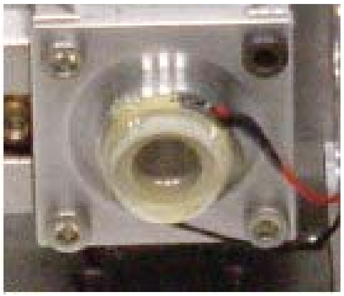

Fig. 1. High stiffness holed piezo actuator (the yellow item where wires are connected to) with the cavity mirror glued on it.

## 4. RESULTS

Fig. 2 shows the stabilization obtained over 1050 pulses by applying the described technique for the laser cavity control. As it can be noticed the fluctuations (red line) between the master oscillator optical frequency and seeder laser optical frequency, and the fluctuations (green line) between amplified IR pulse frequency and seeder laser frequency, are lower than 1MHzrms (right scale).

This means the length of the 80cm laser cavity is maintained tuned to seeder laser frequency within few nanometers.

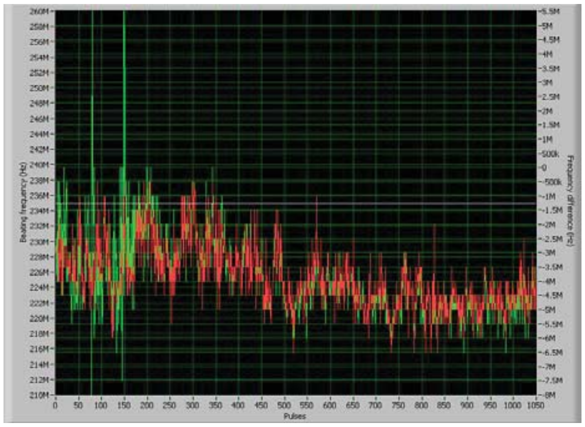

Fig. 2. Frequency stability of the laser pulses (master oscillator and amplifier) with respect to the seeder laser

## 5. CONCLUSIONS

The laser cavity control that has been described is capable of achieving a cavity control length better than few nanometers. The cavity length can be controlled in real time just before each laser pulse is generated. This technique allows also the possibility of having the laser pulse triggered by an external clock without generating any jitter on the pulse repetition rate.

## 6. ACKNOWLEDGMENTS

The control system and the related prototype have been used by CESI for a Galileo Avionica / ESA contract for the laser transmitter assembly used in the ALADIN instrument currently in C/D development phase for the ESA ADM-AEOLUS mission (EADS Astrium as prime contractor for the satellite and the instrument).

## REFERENCES

[1] Shoemaker , Brillet, Man, Cregut; “Frequency stabilized laser diode pumped Nd-Yag laser”; Optics letters, June 15 1989, Vol. 14, N°12; pp 609-611