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CONDUCTION COOLED COMPACT LASER FOR CHEMCAM INSTRUMENT

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ABSTRACT

A new conduction cooled compact laser for Laser Induced Breakdown Spectroscopy (LIBS) on Mars is presented. The laser provides pulses with energy higher than 30mJ at 1µm of wavelength with a good spatial quality. Three development prototypes of this laser have been built and functional and environmental tests have been done. Then, the Qualification and Flight models have been developed and delivered. A spare model is now developed.

This laser will be mounted on the ChemCam Instrument of the NASA mission MSL 2009. ChemCam Instrument is developed in collaboration between France (CESR and CNES) and USA (LANL). The goal of this Instrument is to study the chemical composition of Martian rocks. A laser source (subject of this presentation) emits a pulse which is focused by a telescope. It creates a luminous plasma on the rock; the light of this plasma is then analysed by three spectrometers to obtain information on the composition of the rock.

The laser source is developed by the French company Thales Laser, with a technical support from CNES and CESR. This development is funded by CNES. The laser is compact, designed to work in burst mode. It doesn't require any active cooling.

PRESENTATION OF CHEMCAM INSTRUMENT

ChemCam Instrument (subject of another dedicated presentation in this conference) is composed of two parts: "Mast Unit" (MU) and "Body Unit" (BU). MU corresponds to the French part of the project, and BU to the American part. MU contains the laser source, a Cassegrain telescope, a camera, and the electronics driving the laser. The laser emits a short and energetic pulse. The laser beam is then focused by the telescope to increase the optical intensity of the pulse. The goal is to obtain, on the Martian rock, an irradiance superior to 1GW/cm2. Thanks to this high optical intensity on the rock, a luminous plasma is created. The light emitted by the plasma is then collected by the telescope and sent to BU via optical fibers. Then, the spectrometers situated inside BU analyze the light (on the range 240-800 nm). Thanks to the spectra recorded by BU, we obtain information on the chemical composition of the rock studied.

Fig.1 gives a view of the MSL Rover and shows the position of ChemCam Instrument :

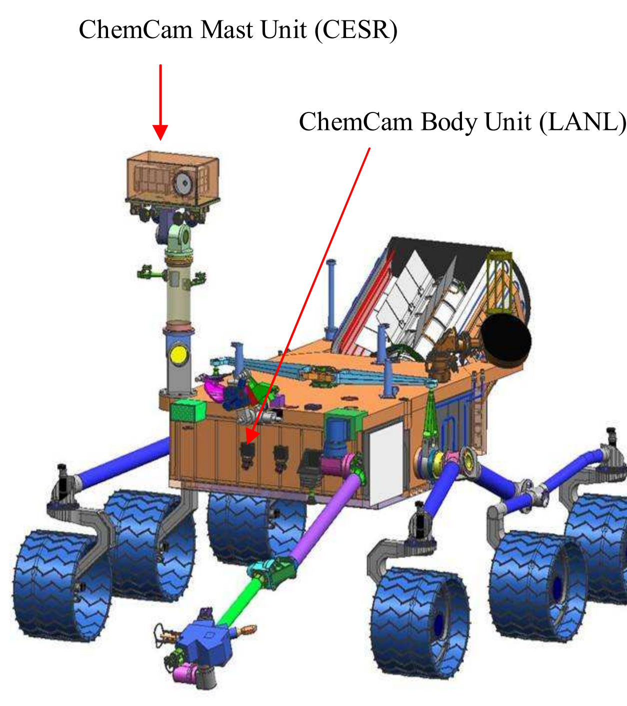

Fig.1. View of MSL Rover and situation of ChemCam (copyright NASA)

REQUIREMENTS

During the mission, the laser will have to run in harsh environmental conditions. In particular, thermal

environments are very severe: the laser will be exposed to daily thermal cycles on the range -40°/+35°C.
It must work within the full -30°/+30°C range, with nominal performance obtained over the -20°/+20°C range (performance can be lower outside).
The optical beam emitted by the laser source must be sufficiently energetic and short to obtain a high optical density on the rock.

The main optical specifications of the laser are then, on the range -20°C/+20°C:

- energy of the pulses > 24mJ (with an optimum superior to 30mJ)
- Pulse duration < 8ns,
- M2 < 3.

DESIGN

Due to the mission constraints, compactness and weight were also two driving factors of the mechanical design, having the necessary stiffness at the same time. The dimensions of the laser are about: diameter of 55 mm, length of 220 mm; the weight is about 550 g.

The laser runs in the nanosecond regime, at a nominal repetition rate of 10Hz. The number of shots expected on Mars during the mission is 3 millions minimum, during two years (1 Martian year). The laser will run in burst mode (100 shots @ 10 Hz, one burst every 5 minutes).

The architecture of the laser is based on an oscillator followed by two slab amplifiers. The oscillator is designed to provide a high beam quality. The output energy is enhanced in the amplifiers while keeping good spatial beam characteristics.

The design is made to insure a good mechanical and thermal stability under the severe conditions to which the laser will be exposed during launch, cruise, descent, landing and operation on Mars.

Indeed the laser has to survive to and to operate in a wide range of temperature, and during a large number of thermal cycles on Mars (around 670 minimum). It also has to survive to high vibration levels during rover tests and launch, and of high pyroshock levels during descent and landing.

Oscillator is based on a Nd : KGW rod longitudinally pumped by a 700 W diode stack. The very wide spectral acceptance of the Nd : KGW rod provides very small absorption variations over wide temperature ranges. This allows both the pumping diode and the rod to be conductively cooled and to run on the large temperature ranges expected on Mars. Oscillator is Q-switched with a RTP pockels cell to produce the nanosecond pulses needed for LIBS. The laser cavity is linear, closed on one side by the rod and on the other side by the output coupler. Reflectivity of the output coupler is 60%. A polarizer, a wave-plate and a pockels cell constitute the Q-switch system of the cavity. The oscillator provides an output energy of about 10mJ with a pulse duration < 8 ns and a beam quality factor (M2) < 3.

Amplifiers are based on transversally diode pumped Nd : KGW slabs. Two identical amplifiers increase the energy at the oscillator output. Each amplifier is pumped by a 700W stack. An energy higher than 30 mJ is obtained at the laser output, with a M^2 factor < 3.

Fig.2 presents the optical design of the laser.

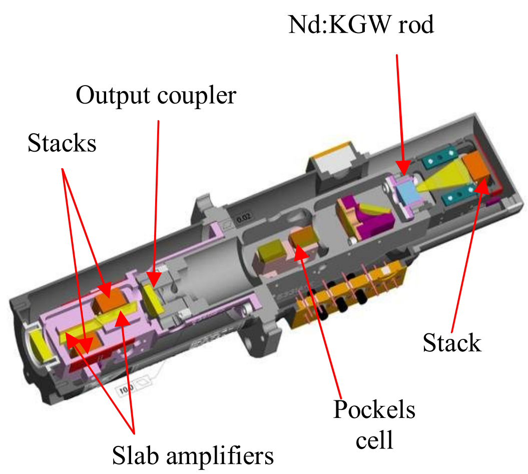

Fig.2. Optical design of the laser

To protect the optical components from the harsh environments of Mars, the laser is hermetically sealed by Titanium covers. This hermetic package is filled with dry air to avoid contamination problems.

Fig 3. shows an external view of the laser, with its covers:

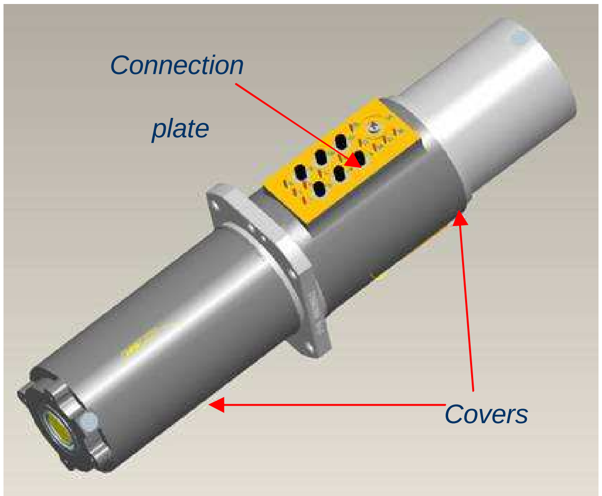

Fig.3. External view of the laser

VALIDATION STRATEGY

Before the Flight Model, 4 models of this laser have been developed in order to carefully define and validate its design. All the models of the laser have been deeply tested, in particular to measure their performance under thermal constraints. These tests showed that the laser pulses reach the optical specifications on the range -20°C/+20°C. The laser has also been qualified in space environments: thermal and mechanical tests (random vibrations and shocks).

Qualification tests have also been done at components level (on stacks, optics, glues, getters). For each critical component, radiation, thermal and mechanical tests have been done (including long term thermal cycling representing the daily Martian thermal cycles: up to 1000 cycles done for most of the validation tests).

The expected lifetime for the critical components has also been evaluated by test, taking the conditions of operation specific to CHEMCAM on MSL09 into account (including the long term thermal cycling).

RESULTS

Fig. 4 describes the main results obtained on the Flight Model (energy and pulse duration versus temperature).

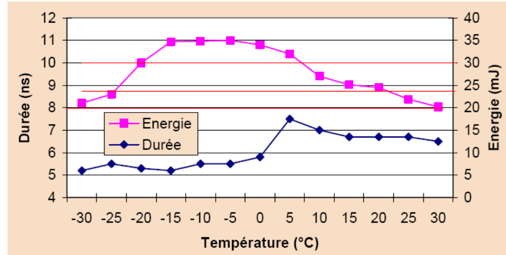

Fig. 4 : Energy and pulse duration versus temperature

We can see on this figure that the main optical characteristics of the flight model are within the specifications.

The main difficulties encountered during validation tests (at components and laser levels) are:

- ungluing of Pockels cell crystals during long term thermal cycling. This problem was solved by changing the procedure and the configuration of the gluing.
- bad adhesion of the coating on the Nd:KGW rod during long term thermal cycling. This problem was solved by changing the coating process (new manufacturer).
- ungluing of the Nd:KGW slabs on the laser structure during random vibrations. This problem was solved by changing the geometry of the gluing.

CONCLUSION

A complete set of test results show that the CHEMCAM laser, developed by Thales Laser with CNES and CESR technical support, is a new kind of pulsed solid-state laser source, compact and passively cooled, which is able to survive harsh environments like the ones to sustain during a mission to and on Mars : vibrations, shocks and wide temperature ranges.

The Flight Model of the CHEMCAM Laser has been delivered by Thales Laser to CNES in December 07. Its optical characteristics are above the specifications, and are not deteriorated after thermal and mechanical environments.

FM Laser has been then integrated by CNES/CESR in the ChemCam Mast Unit Flight Model, which has been delivered to Los Alamos National Laboratory (USA) in July 08. This Model works perfectly so far, like the Engineering and Qualification Models delivered before (respectively in June 2007 and March 2008).