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## *High energy high repetition rate diode pumped laser amplifier modules at 1064nm for space applications*

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# High energy high repetition rate diode pumped LASER amplifier modules at 1064nm for space applications

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**Abstract**—Quantel has developed, in the frame of ALADIN and ATLID projects, diode pumped amplifier modules for space application. Design, laser and environmental performances will be presented. High energy output of 480mJ at 100Hz, amplification starting with 7mJ input, has been demonstrated at 1064 nm. Laser performances as beam pointing stability, shot to shot energy stability,  $M^2$  have been demonstrated. Environmental qualification of this amplifier pump module has been successfully performed.

**Index Terms**—Laser, Amplifier, Space application

## I. AMPLIFIER DESIGN

### A. Design drivers

The main design drivers were the following:

- Ensuring the stiffness of the assembly in order to be compliant with the environmental conditions.
- Cooling the pumping head on one side by conduction.
- Ensuring a fast establishment of the steady state temperature gradient in the slab.
- Ensuring the symmetry of the heat extraction from the diode on both sides of the pumping chamber.
- Ensuring the symmetry as far as possible of the heat extraction from the slab.
- Sustain the wide range of storage temperature (-40°C to 50°C).
- Withstand a radiation exposure of 10 krad.
- Extracting a maximum of stored energy
- Optimization of electro-optical efficiency
- Ensuring a low  $M^2$  at the amplifier output
- Minimizing the depolarization at the amplifier output

### B. Amplification section Design

In order to be able to obtain 480 mJ at amplifier output, two diode pumped slab amplifier pump units (with slab shaped Nd:YAG) are used.

A double pass amplification in Nd : YAG slab is done for preamplifier, followed by a single pass amplification in Nd : YAG slab for the power amplifier.

A polarizer and quarter wave-plate are used for double pass amplification section input/output.

Cylindrical compensating lenses are used at input and output of each amplifier for the compensation of the thermal lens in the slabs.

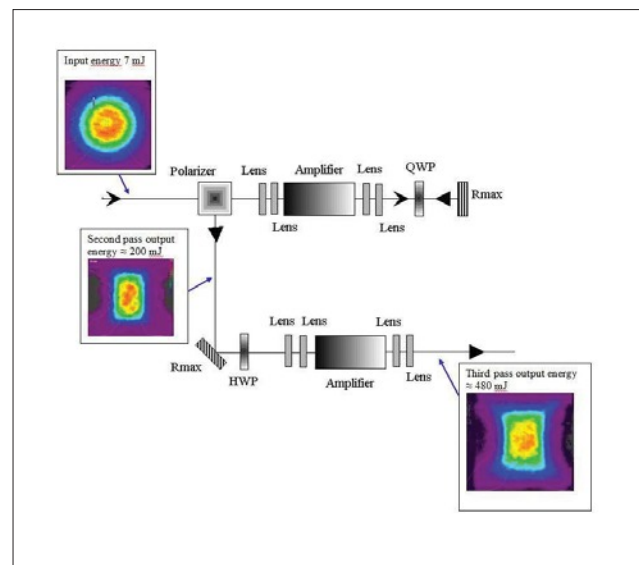


Fig. 1. Amplification section design

### C. Pump Unit Design

Taking into account the environmental and output energy requirement for such amplifiers, the pump unit designs is as follows:

- Each pump unit requires 1 Nd : YAG Slab (6x8x110 mm<sup>3</sup>) and 8x1000W laser diode stacked array for the pumping. The geometry of the slab with parallel input and output faces and zig zag beam propagation have been chosen.
- The slab is held and cooled through the same interfaces, and the cooling direction perpendicular to the pumping direction.

- The cooling is performed for the diodes and the slab through the same interface at the bottom of the PU (single cold plate).
- Filling material is used for all the mechanical interfaces to reduce the thermal resistance and air-vacuum transition effect.
- Several thermal sensors are implemented in the pump unit for temperature monitoring during operation.
- The Size of each pump unit is  $166 \times 77 \times 61 \text{ mm}^3$ , and it weights  $< 4 \text{ kg}$ .

Due to the cooling configuration (one heat sink for a pumping chamber) and in order to obtain the same operating temperature for all the stacks, a symmetrical configuration versus the cooling side was necessary. Diodes are located on the two opposite sides of the pumping chamber, and the thermo-mechanical architecture has been chosen as presented in the figure below.

This architecture has been chosen to reduce the warm up time of the amplifier.

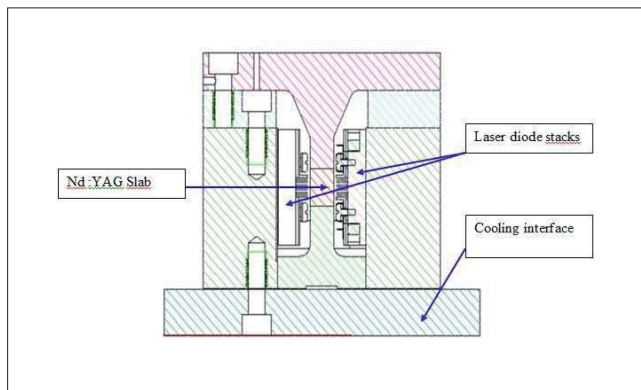


Fig. 2. Pump Unit architecture (cut view)

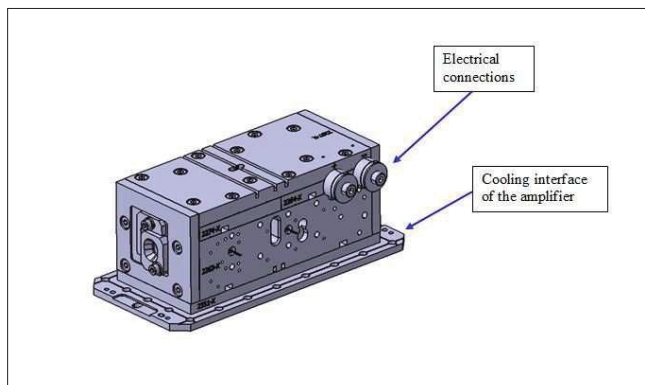


Fig. 3. Pump Unit (external view)

## II. PERFORMANCES

Operations in burst mode at 100 Hz and 50Hz continuous mode have been demonstrated with the same performance.

### A. Output Energy

#### 1) Double pass amplification

At the output of the double pass preamplifier, we measured, 195 mJ output energy for 7 mJ input energy (1.1 J pump energy) and 210 mJ output energy for 10 mJ input energy.

#### 2) Third pass output energy

At the output of the power amplifier, operation up to 480 mJ has been demonstrated (for 210 mJ at power amplifier input and 1.1 J pump energy).

#### 3) Shot to shot energy stability

The shot to shot energy stability was measured to be 0.65% RMS and 1.6% peak-to-peak and 423 mJ operation.

TABLE I. MEASURED ENERGY STABILITY

Energy Stability		
Average Energy (mJ)	Peak-to-peak variation (%)	RMS variation (%)
423	1.6	0.65

### B. Beam Pointing stability

The beam pointing stability was measured at  $2.5 \mu\text{rad}$  rms in the pumping plane and  $7.6 \mu\text{rad}$  rms in the cooling plane at the third pass output.

TABLE II. MEASURED BEAM POINTING STABILITY

Third pass Beam Pointing Stability		
	Along X axis ( $\mu\text{rad}$ )	Along Z axis ( $\mu\text{rad}$ )
RMS ( $\mu\text{rad}$ )	2.5	7.6
Peak-to-Peak ( $\mu\text{rad}$ )	8.8	42.7

### C. Beam Quality

$M^2$  have been demonstrated to be

- in the pumping plane:  $M^2_x = 1.4 \pm 0.4$
- and in the cooling plane:  $M^2_z = 3.3 \pm 0.6$

The typical third pass output beam energy distribution is given in the figure below.

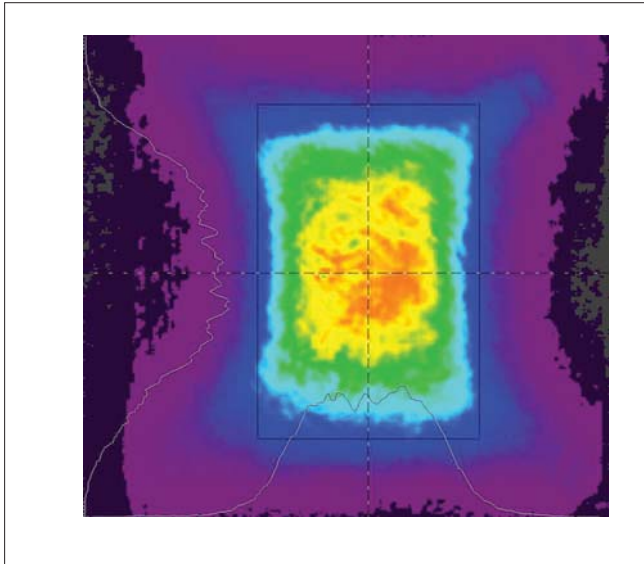


Fig. 4. Output beam energy distribution

*D. Polarisation*

The polarization ratio is measured to be >96% at amplifier output.

III. ENVIRONMENTAL PERFORMANCES

Environmental qualification of this amplifier pump module has been successfully performed.

*A. Thermal Environment*

Thermal cycles representative of non-operating temperature range: -40°C / +50°C were applied, with no impact on the amplifier performances.

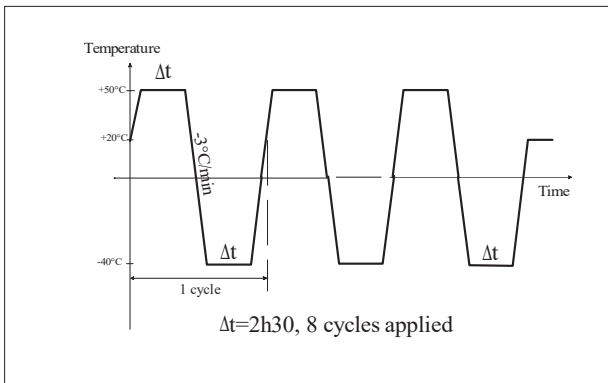


Fig. 5. Non-operative thermal cycling description

*B. Mechanical Environment*

*1) Random Vibrations*

Qualification was successfully passed using nominal rms acceleration of 30 grms along 3 orthogonal axes.

*2) Shocks*

The maximum value applied without consequence on the optical components was a half sine input of 175 g amplitude during 0.5 ms (for Ox axis). (We have observed no displacement of the slab after the shocks along Y and Z axes at 300g amplitude, 0.5 ms duration, 1/2 sinus)

*3) Pressure*

The pump unit performance is not sensitive to operation in air or in vacuum.

IV. CONCLUSION

We have shown diode pumped amplifier modules developed for space application. High energy output of 480mJ at 100Hz, amplification starting with 7mJ input, has been obtained at 1064 nm.

Mechanical, thermal, and pressure environment qualification were performed.

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