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CONSIDERATIONS FOR THE DESIGN AND IMPLEMENTATION OF THE GEOSCIENCE LASER ALTIMETER SYSTEM LASER TRANSMITTER

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Introduction

The Geoscience Laser Altimeter System (GLAS) is a NASA Earth Observing System (EOS) project[1]. GLAS will be a satellite laser altimeter whose primary mission is the global monitoring of the Earth's ice sheet mass balance. GLAS will also use a lidar for global monitoring of cirrus cloud heights. The GLAS science requirements drive the overall laser transmitter design. This paper will review some of the performance requirements, challenges and new technologies in the design of the laser transmitter in order to meet the mission objectives.

Requirements

The GLAS instrument is required to operate continuously for five years in a 705 km polar orbit and to give 10 cm height resolution over 3° slope. In order to accomplish this resolution over the ice sheets, the link analysis and altimetry simulations show that the laser transmitter must have the following performance characteristics: pulse energy - 100 mJ @ 1 µm, 50 mJ @ 0.5 µm, repetition rate - 40 Hz, pulse-width 4 - 6 ns, beam divergence - 95 µrad, beam profile - nominally Gaussian, 6% electrical efficiency, with a > 1 billion shot lifetime. In addition the laser components must be tolerant of the orbital radiation environment. Once completed the GLAS laser transmitter will be the most advanced space-based laser to date.

Design considerations

Presently the best laser architecture for a light weight, rugged, high peak power and efficient transmitter is a diode laser pumped Nd:YAG laser. Diode lasers can often obviate the need for water cooling, reduce the size and weight of the laser, increase the electrical to optical efficiency, system reliability, and lifetime. Nd:YAG has proven itself as a rugged and efficient diode pumpable material; also high quality Nd:YAG and especially Cr:Nd:YAG has been shown to be radiation tolerant[2]. Other materials such as Nd:YLF have a greater susceptibility to damage from gamma rays and high energy protons.

One of the more challenging aspects of the performance requirements is to simultaneously generate 4 ns, 150 mJ, near diffraction limited beam quality pulses efficiently with long-life using a rugged architecture. This performance regime is not easily accessible to the Q-switched laser due to gain and cavity-length constraints and Q-switched, cavity-dumped lasers typically require complex high-voltage switching stages which hold little promise in lasting the mission duration. Performance of high peak power lasers capable of generating 4 ns pulses are also typically limited by laser induced damage of the optical components. All these ramifications must be considered in the overall system design. We believe presently, that the development of a low energy, short pulse with high beam quality oscillator in conjunction with double-pass amplifier stages is the most promising technique for meeting the transmitter performance objectives.

System description

Our current efforts have concentrated on the development of a high performance master oscillator that meets all the GLAS requirements except for pulse energy. Then amplifier stages are used to bring the pulse energy to the desired mission requirements. Even though the pulse energy requirement is reduced in the oscillator, it is still a challenge to generate 4 - 6 ns pulses efficiently with high beam quality because high inversion densities with good modal overlap in short resonators are still required.

Longitudinal or end-pumping of solid state lasers has proven to be the most efficient technique used to date to generate efficient lasers with high beam quality. This is due primarily to the excellent ability to match the transverse mode of the pump source to the laser's fundamental transverse mode. Considerable effort has also been placed on using high power quasi-cw diode bars as the pump sources for end pumping. Unfortunately these bars do not lend themselves readily to ideal end-pumping. The extremely asymmetric beam emerging from a diode bar typically requires the use of two or more stages of beam shaping optics to collimate and circularize the beam. This reduces brightness, energy, and increases system complexity in an effort to select the fundamental transverse mode. We have developed a pumping technique[3] using high power, quasi-cw diode bars collimated with cylindrical micro-lenses[4] to efficiently side pump a laser crystal such that the fundamental transverse mode of the resonator is selected. This pumping scheme (stripe pumping) offers most of the advantages of end-pumping, including high modal overlap, high pumping densities, single transverse mode and operation of the laser without the disadvantage of complex coupling optics. A further advantage includes better thermal management due to the more uniform distribution of pump energy in the lasing crystal.

The technique of stripe pumping a crystal is to effectively deliver the pump energy to a specific volume to attain high inversion densities and automatically select the fundamental TEM_{00} mode (figure 1).

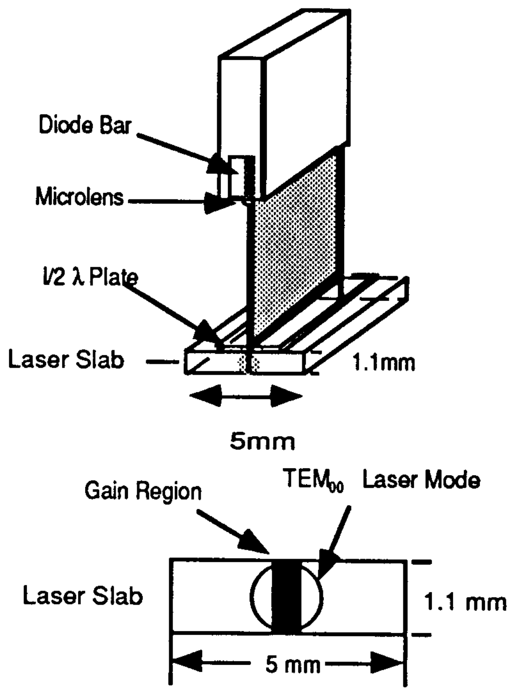
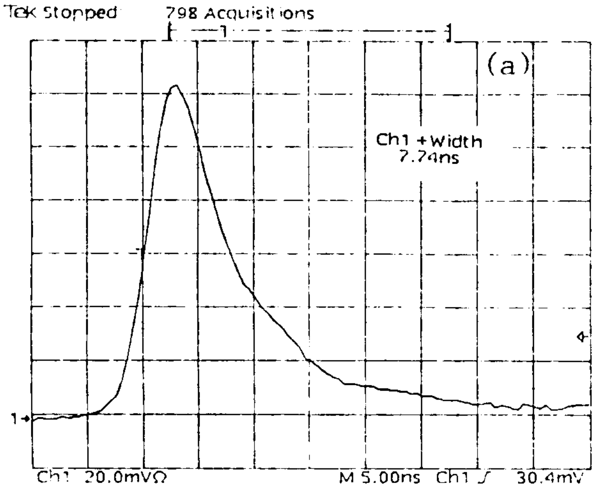


Figure 1 - Diagram of the stripe pumping scheme and expanded view of the crystal showing the pump region smaller than the laser mode in one axis.

In one axis the gain region was designed to be smaller than the fundamental transverse mode diameter so that operation could be biased in favor of the fundamental transverse mode of the resonator, as in longitudinal pumping. On the other axis, the top and bottom of the laser slab act as an aperture to ensure fundamental mode operation.

The diodes are collimated using cylindrical micro–lenses in order to produce the desired high brightness pump source. The collimated diode bars produced "stripes" of light slightly over 1 cm long with Gaussian intensity profiles. The $1/e^2$ widths are as small as 470 μm at a distance of 3.1 cm from the emitters. This allows for the deposition of the pump energy into a very prescise region of the laser medium producing high inversion densities. Generating short Q-switched pulses now depends on building a short resonator around the gain region.



(b)

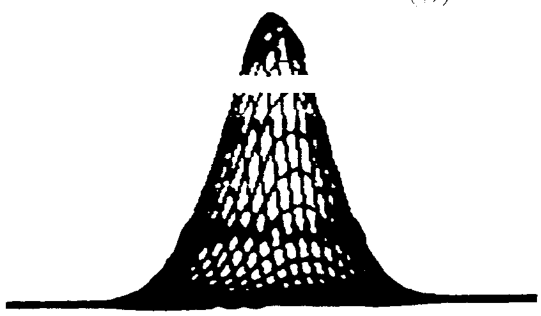


Figure 2 - (a) Temporal profile of a single Q-switched pulse. (b) View of the intensity distribution of the transvers mode profile. Fits to a Gaussian are better than 95 % in both axes.

Laser performance and potential design

We have presently demonstrated the stripe pumping technique in several laser systems[5,6] including a Q-switched Nd:YLF oscillator[7]. The Nd:YLF laser has demonstrated performance levels of 1.6 mJ, 8 ns, TEM_{00} operation at 40 Hz. Figure 2a and 2b show a temporal pulse shape and beam profile. These results are in close agreement with uur numerical simulations which predict an output of 1.6 mJ in 7 ns from the Nd:YLF laser. With Nd:YAG, the model predicts 1.6 mJ in 4.5 ns which meets the GLAS requirement for pulse width. Starting with a laser at the millijoule level standard double pass amplification techniques can be employed to generate the desired energy levels.

We are presently developing a configuration with a double pass zig-zag preamplifier to generate 12 - 15 mJ pulses and then a double pass zig-zag power amplifier stage to generate the desired 150 mJ (figure 3). To efficiently extract energy, the laser pulse must be close to the saturation fluence while simultaneously keeping the gain low enough to avoid amplified spontaneous emission (ASE). Our simulations show that keeping the gain-length product below 3 minimizes ASE while maintaining high extraction efficiency, and low system complexity. At this time we envision a final system which uses between 0.9 to 1 J of total pump energy and delivers > 150 mJ while maintaining the optical loading on the surfaces to under 3 J/cm^2. Using typical diode efficiency valuse that translates to ≈ 6% electrical efficiency to the diodes. We are in the process of building a 1/4 scale prototype breadboard to test system and hope to have system results by year's end

Long duration survivability issues are being addressed by investigating the effects of multi-billion shot exposures under accellerated conditions on the laser cavity optics, electronics and laser diode pump degredation. Test stations are in the process of definition and assembly.

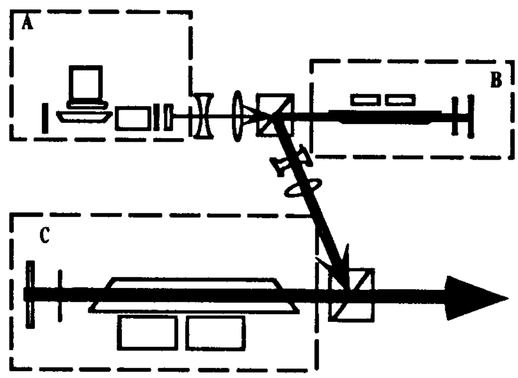


Figure 3 - Schematic of potential optical layout showing regions A) stripe pumped oscillator B) preamplifier and C) power amplifier.

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