Laser Trigger System for the Jupiter Module

Kansas City Division

Richard Paiva; Scott Sundvold;
Gregg Morelli; Curt Powell;
Roy Hamil, SNL/NM; John Corley, SNL/NM;
Peter Pankuch, SNL/NM; Kim Law, SNL/NM; and
Jeff Alexander, SNL/NM

RECEIVED

OCT 20 1995

OSTI

KCP-613-5671

Published October 1995

Approved for public release; distribution is unlimited.

Prepared Under Contract Number DE-ACO4-76-DP00613 for the
United States Department of Energy

MASTER

AlliedSignal
AEROSPACE

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade names, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Printed in the United States of America.

This report has been reproduced from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P. O. Box 62, Oak Ridge, Tennessee 37831; prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service, U. S. Department of Commerce, 5285 Port Royal Rd., Springfield, Virginia 22161.

Copyright © 1995 by AlliedSignal Inc. The Government is granted for itself and others acting on its behalf a paid-up, nonexclusive, irrevocable worldwide license in this data to reproduce, prepare derivative works, and perform publicly and display publicly.

A prime contractor with the United States
Department of Energy under Contract Number
DE-ACO4-76-DP00613.

**AlliedSignal Inc.
Kansas City Division
P. O. Box 419159
Kansas City, Missouri
64141-6159**

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Approved for public release; distribution is unlimited.

LASER TRIGGER SYSTEM FOR THE JUPITER MODULE

Richard Paiva; Scott Sundvold;
Gregg Morelli; Curt Powell;
Roy Hamil, SNL/NM; John Corley, SNL/NM;
Peter Pankuch, SNL/NM; Kim Law, SNL/NM; and
Jeff Alexander, SNL/NM

Published October 1995

Paper submitted to Tenth IEEE International Pulsed Power Conference
July 10-13, 1995
Albuquerque, NM

LASER TRIGGER SYSTEM FOR THE JUPITER MODULE

Richard Paiva, Scott Sundvold, Gregg Morelli, Curt Powell
AlliedSignal Aerospace Company
Kansas City Division*
PO Box 419159, Mail Stop MY40
Kansas City, Missouri 64141

Roy Hamil, John Corley, Peter Pankuch, Kim Law, Jeff Alexander
Sandia National Laboratories
PO Box 5800, Mail Stop 1178
Albuquerque, New Mexico 87185-1178

ABSTRACT

A UV laser trigger system has been designed to trigger the eight SF6 filled high voltage switches in the Jupiter module. The system is compact and modular, allowing for approximately thirty lasers to be triggered simultaneously in the full Jupiter design. The laser will be kinematically mounted near the high voltage section to minimize the path length to the high voltage switches and decrease the sensitivity to misalignment. The laser system is specifically built for the purpose of triggering the Jupiter module. It is a 265 nm UV laser system designed to generate eight simultaneous laser pulses of 10 mJ each with a 13 nsec pulsewidth. A 1061 nm solid-state Nd:Cr:GSGG laser is frequency quadrupled with a two stage doubling process. The 1061 nm fundamental laser energy is frequency doubled with a type II KTP crystal to generate 530 nm energy. The 530 nm output is frequency doubled with a type I KD*P crystal to generate 265 nm energy. The 265 nm pulse is split into eight parallel channels with a system of partially reflecting mirrors. Low timing jitter and a stable energy output level for the system were achieved. The entire optical system was packaged in a rugged, sealed aluminum structure 10" x 19" x 2.75". The size of the laser electronics unit is 7" x 8" x 8".

BACKGROUND

The goal for the project was to design a compact solid-state laser that could replace a KrF laser as a triggering source. Low timing jitter and a stable energy output level are considered extremely important factors. The approach taken for the project was to frequency quadruple a rugged, compact, 1061 nm solid-state laser to provide 265 nm pulses. Breadboard tests were performed early in the project to select nonlinear crystals and to develop the frequency doubling modules. A splitting module was designed to evenly split the UV pulse into eight parallel channels. In the Jupiter's design, the eight pulses would then be directed to the high voltage switches through laser delivery tubes. The laser pulses would be focussed into the laser triggered gap with a 1.0 meter focal length lens. Figure 1 shows one of the laser triggered gas switches and Figure 2 shows one of the Jupiter accelerator modules and the relative location of the laser system.

Figure 1. A laser triggered gas switch.

Figure 2. A Jupiter accelerator module.

THE 265 nm OPTICAL PULSE CHARACTERISTICS

Each laser optics module generates eight simultaneous 265 nm output pulses. The eight output pulses have an average energy of 11.5 mJ. The laser source and the doubling modules were designed to have a very stable output. The resulting shot-to-shot energy stability of the UV output is within $\pm 3\%$. The 265 nm pulses have a fwhm pulsewidth of 13.5 nsec. The output beam diameters are 10.0 mm and have a far-field, full angle divergence of 2.5 mrad.

The system was designed to have a very low timing jitter. This allows the use of a large number of the eight channel systems to be used with good timing simultaneity. The timing jitter of the output pulse to the electrical trigger signal is only ± 2 nsec (1 sigma) and the 3 sigma timing jitter is ± 5 nsec. There is no timing jitter between the eight output pulses. The maximum timing delay between any two of the eight optical pulses is < 1 ns. This could be eliminated by equalizing the path lengths in the splitting module. The 265 nm output pulses contain negligible amounts of residual 1061 nm and 530 nm energy. Figure 3 shows the far-field intensity profile of a UV pulse and Figure 4 shows the 265 nm optical pulse temporal profile.

Figure 3. The 265 nm far-field intensity profile.

Tek Run: 5.00GS/s

Figure 4. The 265 nm pulsewidth.

THE EIGHT CHANNEL SPLITTING MODULE

The eight output pulses are generated by passing the primary 265 nm pulse through a splitting module that uses a series of partially reflecting mirrors. The mirrors are UV grade fused silica and have dielectric coatings designed for the nominal split ratio for unpolarized light at a 45 degree angle of incidence. A waveplate adjusts the split ratio for each mirror by changing the amounts of 'S' and 'P' polarizations incident on the splitting mirrors to either raise or lower its reflectivity to the incident pulse. For this reason, the 265 nm output pulses from the system are not linearly polarized. The overall 265 nm energy transmission through the splitter module is 85%. The total energy output from the eight channels is 94 mJ. Channels 1 through 8 have an energy output of 11.8, 11.7, 11.5, 11.8, 11.8, 10.9, 12.2, and 12.2 mJ, respectively.

THE 1061 nm LASER SOURCE

The optical energy source for the system is a Q-switched, Nd:Cr:GSGG solid-state laser. The lasing wavelength for Nd:Cr:GSGG is 1061 nm. The efficiency of a flashlamp pumped Nd:Cr:GSGG laser is roughly twice as high as a comparable Nd:YAG laser. The laser utilizes a single laser rod with a 9.5 mm diameter and a length of 100 mm. A single Xenon flashlamp pumps the laser rod in a close-coupled, diffuse pump cavity. The optical output energy of the 1061 nm laser is 600 mJ with a 12 nsec pulsewidth at its maximum operating point. The near field spatial profile of the laser output is highly multimode with a relatively low peak-to-average variation across its diameter. The near field beam diameter was measured to be 9.0 mm (0.64 cm²). The full-angle divergence of the laser was measured to be 3.9 mrad at the 1/e² points. The laser output is linearly polarized.

The laser resonator configuration was chosen on the basis of providing maximum alignment stability. A polarization output coupled resonator with two porro prism reflectors was selected. Light incident on a porro prism returns parallel to its incident path even if the porro prism rotates about an axis parallel to its roof crest. This provides one axis of alignment stability. Orientating the porro prism roof crests at 90 degrees to each other achieves alignment stability about two axes. Output from the laser is achieved by depolarizing a portion of the circulating power and having the output energy reflect off a polarizer in the resonator. The laser head is assembled into a very stiff and rugged 3" x 6" x 1" housing machined from a single piece of 6061-T6 aluminum alloy. The laser head is o-ring sealed.

The flashlamp pulse forming network (PFN) utilizes a 20 μ F capacitor and a 36 μ H inductor to provide a critically damped pulse across the flashlamp. The nominal operating point is a PFN voltage of 1800 volts. The stored energy in the capacitor at this voltage is 32.4 J. This yields an efficiency of 1.85% for the 1061 nm output energy relative to the electrical stored energy in the PFN capacitor.

The laser resonator is Q-switched with a 12.7 mm x 12.7 mm x 35 mm lithium niobate crystal. The Q-switch PFN consists of a 3 mesh LC circuit, a pulse step-up transformer, and a krytron switch to produce a negative going high voltage (-3 kV) square pulse across the lithium niobate Q-switch crystal in the laser. The short pulse duration (100 - 200 nsec) and low switching current will allow the krytron to exceed a million shot lifetime. The Q-switch circuit utilizes a high krytron anode voltage and a tightly regulated 'keep-alive' current to obtain very low laser timing jitter.

THE 1061 nm TO 530 nm FREQUENCY DOUBLING ASSEMBLY

The 1061 nm laser output pulse passes through a wave plate to transform the linearly polarized pulse into two orthogonal polarizations for the type II doubling interaction. The 1061 nm laser pulse then passes through a 1.8x beam reducer to increase the power density on the potassium titanyl phosphate (KTP) doubling crystal (Figure 5). The divergence of the reduced 1061 nm output was measured as 6.4 mrad. Given the large divergence of the 1061 nm laser source, a type II KTP crystal was chosen because of its large angular acceptance bandwidth. A 7 mm x 7 mm x 5 mm crystal with dual band AR coatings was used. The KTP crystal was angle tuned to provide optimum conversion efficiency. As expected, the KTP crystal was not excessively sensitive to angular misalignment. Once the crystal was angle tuned and locked in place, additional realignments were not required.

Figure 5. The optical schematic for the laser system.

The energy incident on the KTP crystal was measured to be 540 mJ with a 12 nsec pulsewidth. The average power density incident on the KTP crystal is 225 MW/cm². The 530 nm energy output was measured to be 355 mJ with a pulsewidth of 12 nsec. A frequency conversion efficiency of 65% was obtained. Dielectric coated, harmonic laser mirrors separated the fundamental 1061 nm energy from the 530 nm harmonic energy generated in the KTP crystal.

THE 530 nm TO 265 nm FREQUENCY DOUBLING ASSEMBLY

After removing the residual 1061 nm energy, the linearly polarized 530 nm pulse passes through a potassium dideuterium phosphate (KD*P) crystal for the second doubling process. The 530 nm fluence incident upon the input face of the KD*P crystal is 150 MW/cm². A 7 mm x 7 mm x 25 mm Type I KD*P crystal with a deuteration level of 90 - 95% is used. The crystal is cut for noncritical phase matching and was temperature tuned with a thermo-electric cooler assembly to optimize the conversion efficiency.

The optimum phase match temperature was determined to be 17.95 degrees C. A temperature control feedback circuit controlled the crystal temperature. The temperature control electronics and crystal housing were capable of maintaining the correct phase match temperature and the 265 nm energy output was very stable. Again, dielectric coated mirrors separated the residual fundamental energy from the harmonic energy generated in the doubling crystal. The 265 nm output energy was measured as 110 mJ with a 13.5 nsec pulsewidth and was linearly polarized. The frequency conversion efficiency was 31% at the maximum operating point. There was some pulse lengthening in the conversion process from 530 nm to 265 nm.

OPTOMECHANICAL PACKAGING

The laser and optical systems were designed to be compact, rugged, and to not require any alignment maintenance. This enables the optical system to be mounted near the high voltage section of a Jupiter module to minimize the path length and alignment sensitivity. The entire optical system was packaged in a very stiff housing machined from a single piece of 6061-T6 aluminum alloy. Its dimensions are 10" x 19" x 2.75". The optical system is sealed by utilizing a cover o-ring, a bonded output window, hermetic electrical connectors, and o-ring sealed test ports. Figure 6 shows the size of the complete system. Figure 7 shows the optics module with the cover removed.

Figure 6. The laser optics module and electronics.

The component most sensitive to misalignments, the solid-state laser, is built in its own sealed housing and is subsequently bolted in place in the main housing. All of the optics are bonded into stainless steel mounts which are pinned and bolted to the individual plates. There are no tilting mirrors used for alignment purposes. All beam steering is done with rotating alignment wedges which are then bonded into stainless steel mounts. This method maintains maximum alignment stability for the system. The unit was shipped from the AlliedSignal manufacturing facility in Kansas City to Sandia National Labs in Albuquerque. The unit was set up and tested when it arrived. The system did not require any realignments or adjustments after shipping.