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Laser Diode Ignition Characteristics of Zirconium Potassium Perchlorate (ZPP)

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ABSTRACT

Hi-Shear Technology, Corp. (HSTC) has designed and built a Laser equivalent NASA Standard Initiator (LNSI). Langlie tests with a laser diode output initiating ZPP have been conducted as a part of this effort. The test parameters include time to first pressure, laser power density requirements and ignition time. The data from these laser tests on ZPP are presented.

INTRODUCTION

This paper describes a part of an effort conducted by HSTC to design and build a Laser equivalent NASA Standard Initiator (LNSI). There is a need to establish a data base on the interaction between laser energy and pyrotechnic mixtures commonly used in aerospace applications. One of the standard pyrotechnic mixtures being initiated via a laser system is ZPP. The ZPP used in this study has been manufactured by HSTC (HSTC P/N 939321-003) since 1964 for use in the NSI.

There have been many efforts and studies using solid-state laser systems (Nd:glass, Nd:YAG, RUBY and others) as initiation sources. A steady increase in technology relating to high power laser diodes has resulted in the production of laser diodes with sufficient output power for initiation of explosive materials. One drawback in the technology of laser initiation is the lack of published data regarding experimental procedures and test results. Publication of this type of information in proper format would greatly help designers of new and existing systems in the selection and incorporation of lasers as an initiation source.

Laser initiation systems offer many desirable features not found in current ordnance systems. These features include the virtual elimination of inadvertent initiation by stray voltages, electromagnetic radiation (EMR) and electrostatic discharge (ESD). The inherent safety of a laser initiation system allows for the installation of the ordnance during the assembly of ordnance functioned devices resulting in less time required during installation or integration of the final assembly.

This paper will describe the experimental procedure used to obtain specific statistical data on laser diode initiation of ZPP. This testing was performed under laboratory conditions at HSTC and was funded under IR&D program number 970011.

EXPERIMENTAL PROCEDURE

The laser diode used for these tests was manufactured by Laser Diode, Inc. This diode operates at 820nm nominal and has an output of 750mW into a 0.29 Numerical Aperture (NA), 100 micron core fiber optic. This fiber optic cable is a hermetic integral pigtail installed by the manufacturer. The fiber optic cable was terminated at HSTC with an ST-type connector. The laser diode output was controlled by a Spectra Diode Lab Model 822 laser diode driver. The test setup is shown in Figure 1.

As the primary objective of this testing is to provide specific data on the initiation of ZPP with a laser diode, the spot size must be a constant. This was accomplished by pressing the ZPP directly on the fiber optic which holds the spot size constant at 100 microns. This test method also allows for the energy output to be measured directly at the pyrotechnic interface. To preserve the laser diode pigtail from damage when the ZPP initiated and allow for easy loading of the test initiators, an interface fiber optic cable assembly was used. This interface cable was terminated on one end with an ST-type connector for mating with the laser diode and an SMA connector for attaching the test cartridge on the other. The test initiator is shown in Figure 2.

The ST-type connector is a precision fiber optic connector which minimizes the interconnect losses. Both the test initiator and the energy meter accept the SMA connector. An O-ring is included in the SMA to provide a pressure seal when the test initiator is functioned. The interface cables were labeled and calibrated before the Langlie was begun to insure the repeatability of the interconnect loss through several mate/de-mate cycles. The actual loss due to this interconnect was not a concern for this series of tests. The calibration of the interface cables was to insure the losses were repeatable (within measurement error) over multiple mate/de-mates with the laser diode pigtail.

As stated above, the ZPP was consolidated directly onto the fiber optic face. A nominal 120 milligrams of pyrotechnic was loaded into the cartridge in two equal increments. After several pre-test firings it was found the cartridge function characteristics were not affected by the deletion of a closure. The omission of the closure during loading allowed for quicker testing.

The energy levels were monitored by a Photodyne Model 66XLA optical power/energy meter with a Model 350 integrating detector head. This detector head has adapters to allow any style of fiber optic connector to be accurately placed into the head, including a bare, unterminated fiber optic. The values calculated during the Langlie testing were measured at the SMA connector before installation into the test initiator. The various output values were obtained by varying the current supplied to the laser diode. The test initiator was then attached to the SMA connector and the ZPP loaded.

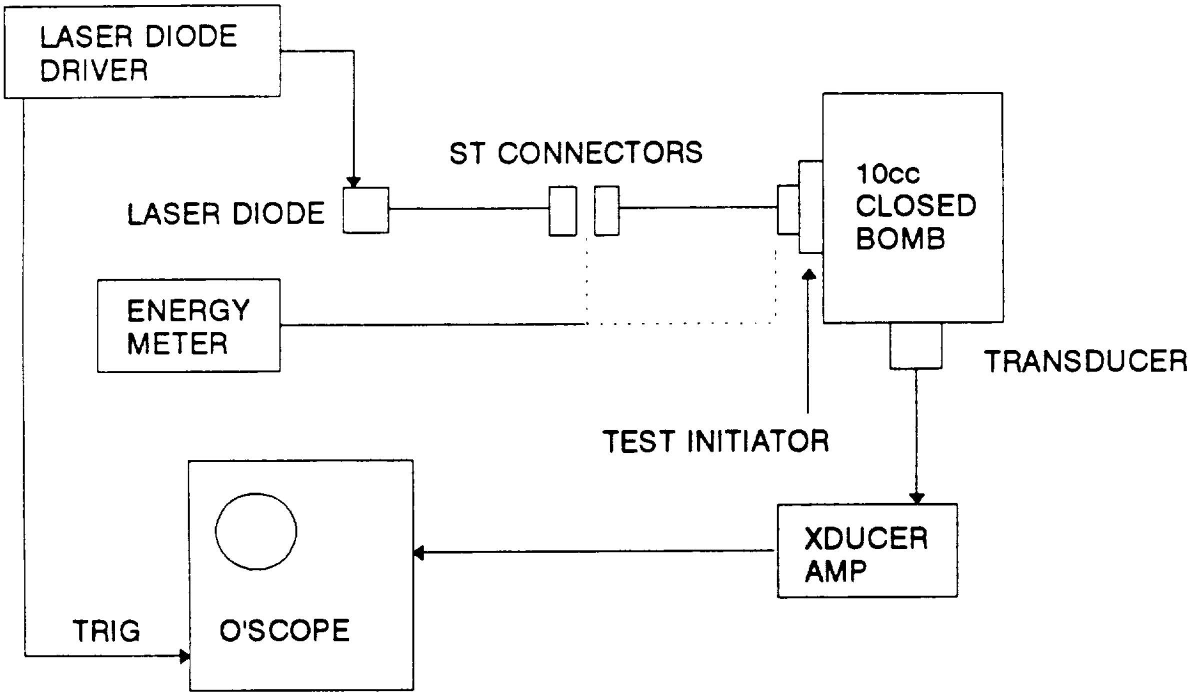


Figure 1
Test Set-up

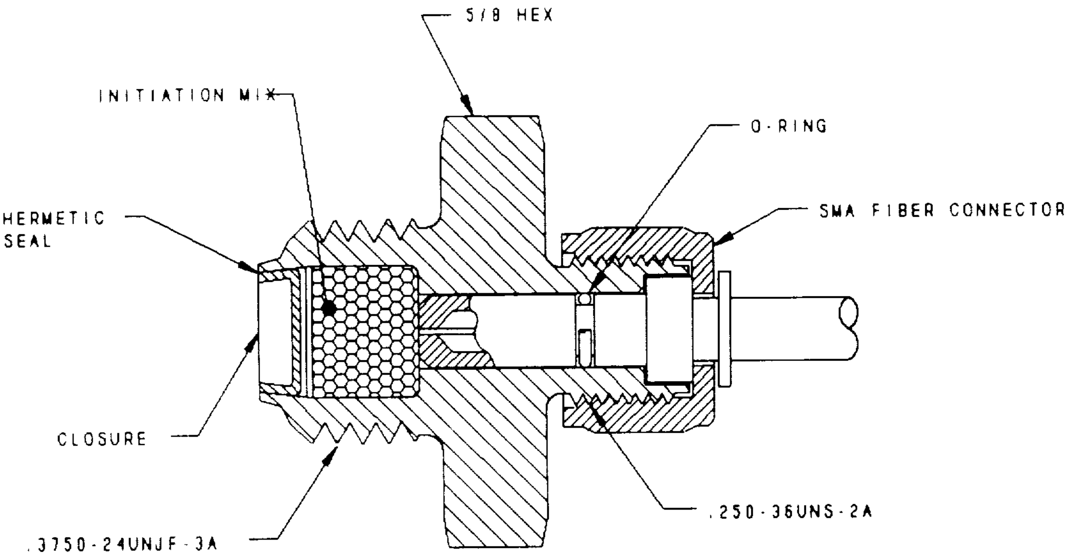


Figure 2

Laser Test Initiator

The test initiator was installed into a 10cc test bomb equipped with a pressure transducer to monitor pressure and function time. All tests were performed at room ambient temperature and humidity. A total of 30 trials were used in the test series. Of these 30 devices a total of 14 devices functioned. This even split between fire and no-fire indicates proper bracketing of the energy. A typical pressure verses time curve is shown in Figure 3. A typical NSI output is shown in Figure 4. The output monitor from the laser diode driver was used to trigger the O'scope and is used to find the function time.

TEST RESULTS

The Langlie statistical approach has an advantage over other test methods used in determining the function characteristics of ordnance devices. The Langlie method finds both the mean and standard deviation efficiently without requiring a detailed test procedure as does a Bruceton. An upper and lower limit of the mean firing point are chosen and the Langlie testing begins halfway between these two points. As the test continues the next level selected is calculated on the response of the previous firings - fire or no-fire. The statistical results from the Langlie test are shown in Table 1.

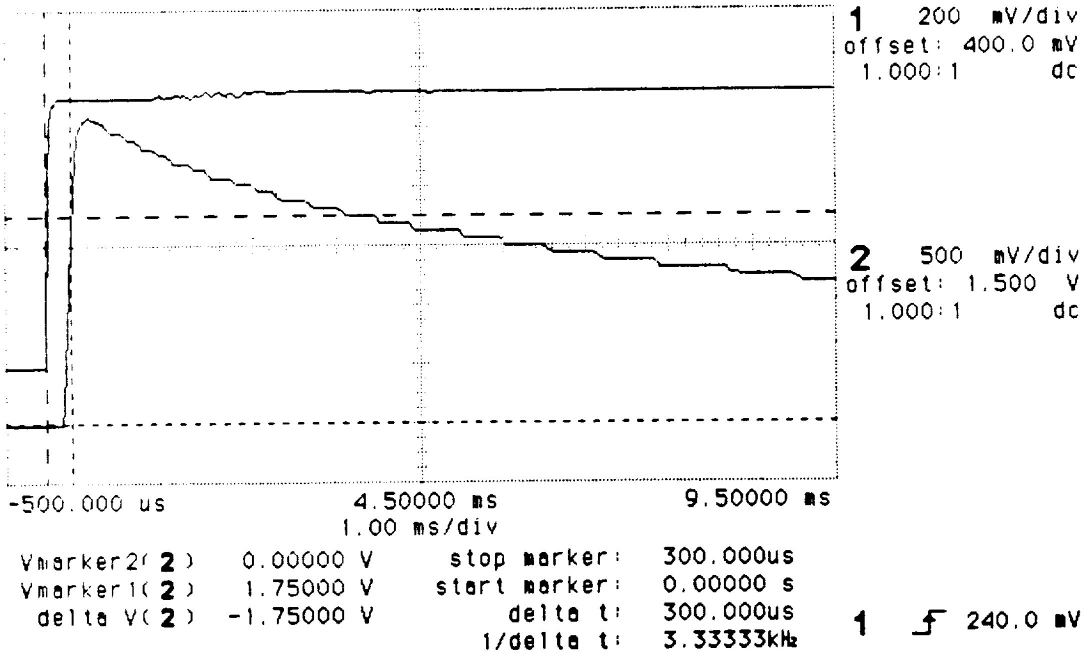
For information purposes the test initiators that did not function at the Langlie stimulus were fired at the calculated 99.9% at 95% confidence point. All 16 test initiators functioned.

The function time of an NSI when fired with 3.5 Amps constant current is 1.0 mSecond minimum and 6.0 mSeconds maximum. The maximum jitter in a test series is 3.5 mSeconds. The 1.0 mSecond minimum time is based on a NASA study which followed the function times of NSI lots over several years. No NSI's were found to function less than 1.0 mSecond when fired with 3.5 Amps. The LNSI function times ranged from 0.39 mSeconds to 2.5 mSeconds. This discrepancy in the minimum function time is not a true comparison to the NSI as the LNSI does not have a bridgewire.

CONCLUSIONS

The use of laser diodes as the ignition source of ZPP is a viable approach. Conventional testing of these devices produces repeatable results. The current laser diode technology can supply twice the all-fire energy into a 100 micron core fiber optic cable.

Additional studies planned by HSTC include the environmental dependance (temperature, shock and vibration) on the all-fire energy level. Other analysis includes a Taguchi test on the assembly process/procedures involved in the manufacture of the LNSI. Testing is planned on other pyrotechnic materials as well as secondary explosive materials.



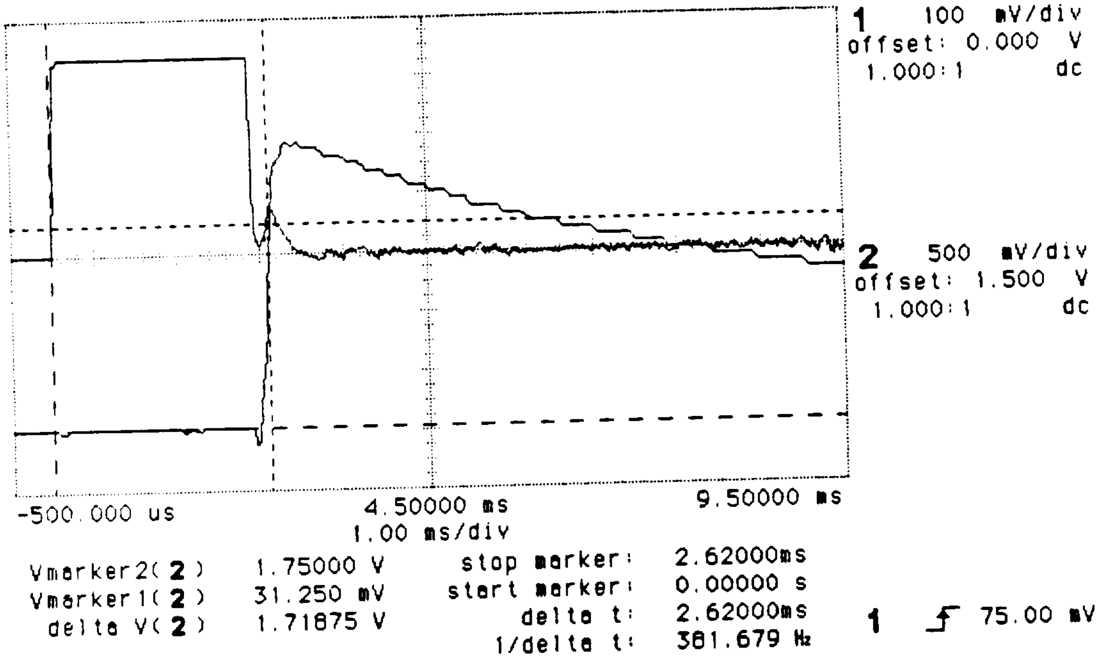
```
1     200  mV/div
offset: 400.0 mV
 1.000:1      dc

2     500  mV/div
offset: 1.500  V
 1.000:1      dc

Vmarker2( 2 )   0.00000 V    stop marker:   300.000us
Vmarker1( 2 )   1.75000 V   start marker:   0.00000 s
 delta V( 2 )  -1.75000 V        delta t:   300.000us
                               1/delta t:   3.33333kHz     1  _f 240.0 mV
```

Figure 3
Typical LNSI Pressure Curve

Channel 2 Calibration 300 psig/Volt



```
Vmarker2(2)   1.75000 V    stop marker:   2.62000ms
Vmarker1(2)   31.250 mV    start marker:  0.00000 s
 delta V(2)   1.71875 V         delta t:  2.62000ms
                              1/delta t:  381.679 Hz
```

Figure 4
Typical NSI Pressure Curve

Channel 2 Calibration 300 psig/Volt

TABLE 1
LANGLIE TEST RESULTS

MEAN FIRE (50%)	1.24 mJoules
SIGMA	0.12mJoules
ENERGY DENSITY	15.75 J/CM2

NO-FIRE POINT	CONFIDENCE	ENERGY
0.1%	90%	0.27 mJoules
0.1%	95%	0.23 mJoules
0.1%	99%	0.18 mJoules

ALL-FIRE POINT	CONFIDENCE	ENERGY
99.9%	90%	5.65 mJoules
99.9%	95%	6.56 mJoules
99.9%	99%	8.65 mJoules