LASER DIODE I GNITION ACTIVITIES
AT SANDIA NATIONAL LABORATORIES

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PRECEEDING PAGE BLANK NOT FILMED
IGNITION SUBSYSTEMS

ELECTRICAL

POWER SOURCE

EXPLOSIVE/PYROTECHNIC COMPONENT

BRIDGEWIRE

ENERGETIC POWDER

OPTICAL

POWER SOURCE

EXPLOSIVE/PYROTECHNIC COMPONENT

LASER ELECTRONICS DIODE LASER

OPTICAL FIBER
Optical Ordnance Power Densities in $W/cm^2$

<table>
<thead>
<tr>
<th></th>
<th>Laser Diode Ignition (LDI)</th>
<th>Pulsed Laser Ignition (PLI)</th>
<th>Direct Optical Initiation (DOI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>$10^3$</td>
<td>$10^5$</td>
<td>$10^9$</td>
</tr>
<tr>
<td>Operational</td>
<td>$10^4$</td>
<td>$10^6$</td>
<td>$10^{10}$</td>
</tr>
</tbody>
</table>

Thermal Ignition     Shock Initiation
LOW ENERGY OPTICAL ORDNANCE PROGRAM

OBJECTIVE: Develop optically ignited devices to replace low energy, hot wire igniters, detonators, and actuators.

CONCEPT: Transmit optical energy from a laser source to an explosive or pyrotechnic via a fiber optic. The fiber is coupled to the powder through a hermetically sealed window, fiber feedthrough or a reimaging lens window system.

ADVANTAGES: The absence of a bridgewire and electrical leads eliminates powder/bridgewire interface decoupling and corrosion concerns. No fire, CAF, ESD, EMR, and IR concerns are reduced.

Input energy required is comparable to hot wire devices.
OPTICAL IGNITION FACTORS

- Energetic Material Characteristics:
  - Optical Absorptance at Laser Wavelength
  - Ignition Temperature
  - Thermal Conductivity

- Laser Energy Delivery:
  - Pulse Width and Height
  - Spot Size
  - Wavelength

- Optical Header Properties:
  - Thermal Conductivity
  - Beam Divergence
  - Powder Confinement
The absorptance of CP near 800 nm can be enhanced by adding dopants.
## System Operational Electrical Requirements

<table>
<thead>
<tr>
<th>Device</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Pulse Width (ms)</th>
<th>Energy (mJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNL hot wire -- CP</td>
<td>3.5</td>
<td>3.5</td>
<td>1.75</td>
<td>21</td>
</tr>
<tr>
<td>SNL hot wire -- Ti/KClO₄</td>
<td>3.5</td>
<td>3.5</td>
<td>1.75</td>
<td>21</td>
</tr>
<tr>
<td>SNL hot wire -- Barium Styphnate</td>
<td>2.5</td>
<td>0.56</td>
<td>4</td>
<td>5.6</td>
</tr>
<tr>
<td>LDI -- CP (doped)</td>
<td>3.0</td>
<td>3.0</td>
<td>0.88</td>
<td>7.9</td>
</tr>
<tr>
<td>LDI -- Ti/KClO₄</td>
<td>3.0</td>
<td>3.0</td>
<td>1.76</td>
<td>16</td>
</tr>
</tbody>
</table>

a: wire burn out time
b: three times an ignition charge function time at 0.85 watts laser power
THE DDT EXPLOSIVE, CP

2-(5-cyanotetrazolato)pentaamminecobalt(III) perchlorate (CP)

Particle size:
production grade 15 μm
precipitated 4-6 μm
DOPANT CONCENTRATION EFFECTS FOR DIFFERENT CP PARTICLE SIZES

- Production Grade CP
- Precipitated CP
- Sterling R Carbon Black
- 100 Micron Diameter Spot
Zr/KClO₄ Optical Ignition Thresholds

<table>
<thead>
<tr>
<th>Thresholds</th>
<th>Ambient (20°C)</th>
<th>Liquid Nitrogen (-196°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest no-fire</td>
<td>3.0 mJ - 3.25 mJ</td>
<td>3.0 mJ - 5.0 mJ*</td>
</tr>
<tr>
<td>Lowest no-fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest fire</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Density = 2.7 g/cc (10 Kpsi loading pressure)

100 micron fiber

10 ms pulse width

* Limited number of units tested
# LDI Liquid Nitrogen Test Results

Units fired at 77 K or -196 C

<table>
<thead>
<tr>
<th>Header Type</th>
<th>Energy Levels</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sealed Fiber Header</td>
<td>1.8/3.0 mJ</td>
<td>No Fire/Fire</td>
</tr>
</tbody>
</table>

Powder--CP/1% Carbon Black

Typical Threshold at Ambient is 1.25 – 1.50 mJ
Electrostatic Discharge Testing

Both Header Types Survived The Sandia Severe Electrostatic Tester (Fischer Model)
With a 25 KV Input Pulse
SANDIA LOW ENERGY OPTICAL ORDNANCE PROGRAMS

MAST (Multiple Application Surety Technology)
Baseline LDI Subsystem

STEP (Stockpile Transistion Enablement Program)
Family of LDI Components for Future Applications

FOCAL POINT
Baseline LDI Subsystems as part of Other Adv. Dev. Projects

INTERNAL ADVANCED DEVELOPMENT

SANDIA NATIONAL LABORATORIES
Laser Diode Ignition of 3 ea. Devices

<table>
<thead>
<tr>
<th>Leg</th>
<th>Energy Level (mj)</th>
<th>Function Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.13</td>
<td>1.63</td>
</tr>
<tr>
<td>2</td>
<td>2.08</td>
<td>1.80</td>
</tr>
<tr>
<td>3</td>
<td>2.03</td>
<td>0.892</td>
</tr>
</tbody>
</table>

- 1 Watt, 10 ms pulse out of Diode Laser
Laser Diode Ignition of 7 ea. Devices

SDL Diode Array

Doped CP Devices

Fiber Bundle

<table>
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<tr>
<th>Leg</th>
<th>Energy Level (mj)</th>
<th>Function Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.74</td>
<td>3.00</td>
</tr>
<tr>
<td>2</td>
<td>3.16</td>
<td>2.10</td>
</tr>
<tr>
<td>3</td>
<td>2.79</td>
<td>2.40</td>
</tr>
<tr>
<td>4</td>
<td>2.59</td>
<td>3.26</td>
</tr>
<tr>
<td>5</td>
<td>3.10</td>
<td>1.81</td>
</tr>
<tr>
<td>6</td>
<td>3.80</td>
<td>1.73</td>
</tr>
<tr>
<td>7</td>
<td>2.85</td>
<td>2.11</td>
</tr>
</tbody>
</table>
SUMMARY

Low energy ignition represents an effective replacement for hotwire devices.

The removal of the bridgewire eliminates ESD and EMR concerns.

Multiple explosive functions have been demonstrated using both a single laser diode and a laser diode array.

Feasability of low energy optical ordnance has been demonstrated and the technology is now ready for full scale engineering development.