ADVANCES IN LASER DIODES
FOR
PYROTECHNIC APPLICATIONS

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OUTLINE

BACKGROUND ON LASER DIODES
  DAMAGE LIMITS
  TEMPERATURE STABILITY
  FIBER COUPLING ISSUES

SMALL FIBER RESULTS (100 MICRON)
  PACKAGE GEOMETRY
  ELECTRO-OPTICAL PROPERTIES
  TEMPERATURE STABILITY

LARGE FIBER RESULTS (400 MICRON)
  LASER BAR PERFORMANCE
  PACKAGE GEOMETRY
  ELECTRO-OPTICAL PROPERTIES
POWER LIMITS FOR LASER DIODES

FOR OPTICAL PULSES LONGER THAN 1 MICROSECOND FACET DAMAGE DEPENDS ON OPTICAL POWER NOT OPTICAL ENERGY.

FOR WELL "PASSIVATED" LASERS DAMAGE LIMIT APPROXIMATELY 10 MW/cm².

WELL "PASSIVATED" AlGaAs LASERS HAVE SAME DAMAGE LIMIT AS InGaAs LASERS.

LOW EFFICIENCY OR POOR HEATSINKING CAN CAUSE LASER TO "ROLL-OVER" BEFORE DAMAGE LIMIT IS REACHED.
Pulsed Laser

Catastrophic Degradation Output Power Limit (arbitrary units)

[Pulse Width]^{1/2} Slope (short pulse)

CW Limit (quasi-cw)

Pulse Width (μsec)
Short Pulse Power Curve

- 9.5 ns Pulse Width
- 1 kHz
- 100 μm Aperture

\[ \eta_D = 1.15 \text{ W/A} \]
High Brightness Multimode Lasers


0.5 W

100 µm

FWHM
40° x 10°

1 W

200 µm

FWHM
40° x 10°

1991 New Technology

1 - 1.5 W

100 µm

FWHM
30° x 10°

2 W

200 µm

FWHM
30° x 10°
AlGaAs SQW Characteristics (795 - 860 nm)

100 μm Aperture

Long Pulse (ms)

\[ \eta_D = 1 \text{ W/A} \]
\[ I_{th} \leq 0.5 \text{ A} \]
\[ \eta_T \geq 40\% \]

Optical Power (W) vs. Drive Current (A)

200 μm Aperture

\[ \eta_D = 1 \text{ W/A} \]
\[ I_{th} \leq 1 \text{ A} \]
\[ \eta_T \geq 40\% \]

Optical Power (W) vs. Drive Current (A)
Damage Limits of Diode Lasers

AlGaAs vs. InGaAs
(Both are single mode lasers of similar structure)

Aluminum-Gallium-Arsenide

Indium-Gallium-Arsenide

Damage > 10 MW/cm²

DAMAGE LEVEL NOT SIGNIFICANTLY DIFFERENT
High \( T_0 \) Quasi-cw 200 \( \mu \text{m} \) Aperture Laser

- C620S
- 1 msec
- 10 Hz
- \( T_0 = 160^\circ \text{C} \)

**Temperature Dependence of Laser Threshold:**

\[
\frac{I_{TH_1}}{I_{TH_2}} = e^{(T_1 - T_2)/T_0}
\]
Temperature Variations

Modeled 100 µm Aperture Laser

\[ \Delta P = 0.25 \text{ W} \]

\[ T_0 = 180 \]

\[ -55^\circ \text{C}, +75^\circ \text{C} \]

Drive Current (A)

Optical Power (W)

Modeled 200 µm Aperture Laser

\[ \Delta P = 0.7 \text{ W} \]

\[ \Delta P = 0.4 \text{ W} \]

\[ +75^\circ \text{C}, T_0 = 180 \]

\[ +75^\circ \text{C}, T_0 = 120 \]

1 W Required

Drive Current (A)

Optical Power (W)
FIBER COUPLING OF LASER DIODES

In simple coupling schemes the laser aperture is smaller than the fiber diameter.

Tapered fibers or other lens approaches can achieve coupling of lasers with apertures greater than twice the fiber diameter.

Common basis for comparison of laser system can be brightness from the fiber

\[ \text{Brightness} = \frac{\text{Power}}{\text{Area} \times \text{Solid Angle}} \]

Relaxing brightness requirement can reduce manufacturing costs.
Tapered Fiber Couple
50 μm Diameter, 0.4 NA

![Graph showing the relationship between CW output power (W) and current (A).](image)

- Laser Diode Output
- Fiber Output

Current (A) vs. CW Output Power (W) graph.
2 Watt Quasi-cw (10 msec) Fiber Coupled to 100 μm Fiber

1 Watt Quasi-cw from 100 μm Fiber Meets Present Sandia Detonator Requirements
S9140 SOT-148 Fiber Pigtail Package

Pin 1: Laser Cathode (-)
Pin 2: Laser Anode, MPO Cathode & Case Ground
Pin 3: Monitor Photodiode Anode (+)
### 100 µm Fiber Results

**SPECTRA DIODE LABS, INC.**

**DEVICE TYPE:** SDL-9141-G2  
**SERIAL NUMBER:** RL499  
**DATE:** 1 APRIL 92  
**TIME:** 13:56

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<th>PARAMETER</th>
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PULSE: WIDTH = 10000 usec, RATE = 10 Hz, TEST TEMP = 25°C

**MONITOR GAIN:** 0.6 mA/W

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**Graph:**

![Graph showing optical power and diode voltage against drive current.]

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**Shipment Checklist:**

- **LABELS:** SDL, S/N $-???? (??) 2064, $-3138
- **SERIAL NUMBERS MATCH**
- **WAVELENGTH MATCHES ORDER**

**Checked by:**

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Power Characteristics of S9140

![Graph showing optical power vs. injection current at different temperatures.](image-url)
- 2 °C
- 7200 μm Total Aperture

S.E. = 1.05 W/A
Conv. Eff. = 33% (@ 122W)
- Diamond Heatsink
- 4800 μm Total Aperture
20 W CW (4800 μm Total Aperture)

Projected Lives of 4,000, 7000, and 15,000 hours @ 25 °C
(3 bars, 20% increase in operating current)
High Heat Load Fiber Coupled Package (P5)

PACKAGE IS ANODE
SDL-3450-P5
Light vs. Current

![Graph showing light vs. current for SDL-3450-P5 with laser diode and 400 μm fiber output, and efficiency η_D = 80%]

Current (A) vs. CW Output Power (W) graph
High Power Fiber Coupled Laser for Pyrotechnics

Test Conditions: 10 ms pulse, 10 Hz
20 °C

Fiber: 400 μm, 0.4 NA

Optical Power (W)

η_D = 0.67 W/A

Drive Current (A)