Lifetime Testing of Laser Diode Arrays

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Overview

- Introduction
- Motivation & Requirements
- Issues & Objectives
- Approach & Methodology
- Observations & Results
- Future Work
- Conclusion

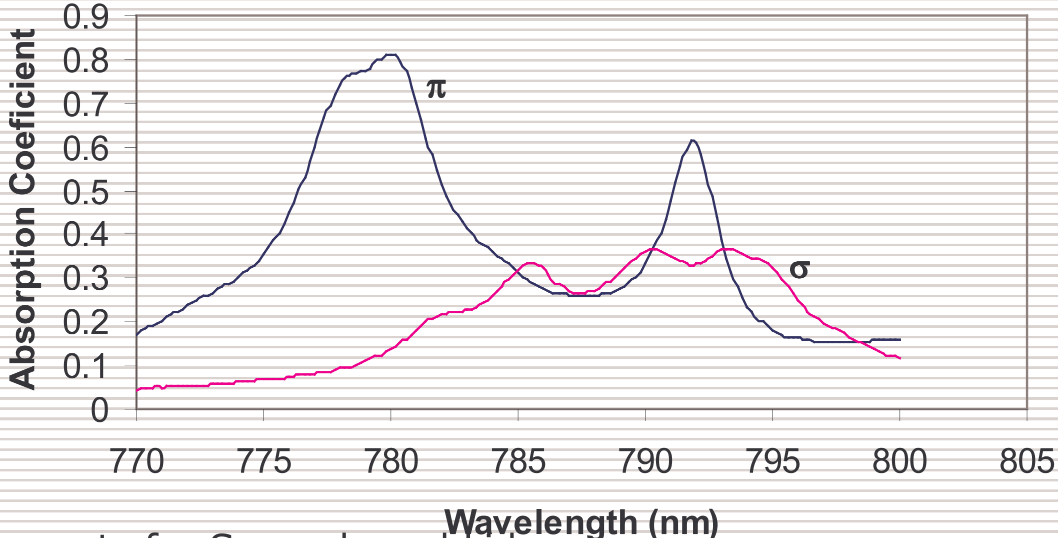
Motivation

Laser Diode Arrays are a critical component of and a major risk area for deploying Lidar instruments in space, defining their efficiency, lifetime, and reliability.

- ***Laser Diode Arrays Establish Instrument Lifetime***

Requirements

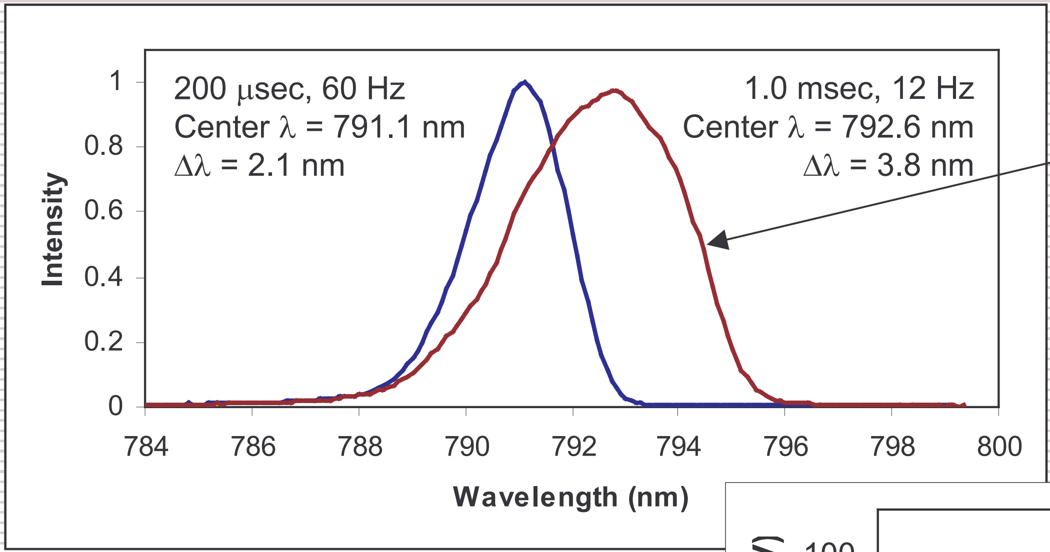
- Moderate and high pulse energy solid state lasers require High Power Quasi-CW 2-D Pump Arrays
  - 808 nm and 200 μsec for 1-micron lasers
  - 792 nm and 1000 μsec for 2-micron lasers



Tm, Ho:YLF Absorption Spectrum

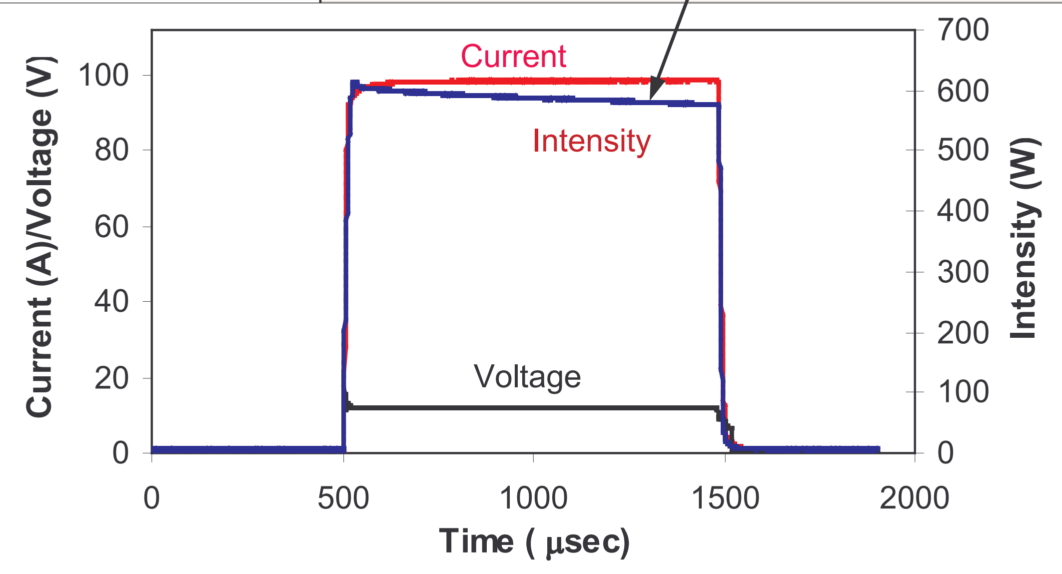
- General Requirements for Space-based Lidar:
  - Conductively-cooled
  - Long lifetime > 3 x 10^9 shots
  - Reliability better than 300 FIT/6-bar device and 1000 FIT/bar
  - Spectral width < 3 nm

Issues



Spectral shift and broadening due to thermal cycling

Intensity drops over 1.0 msec pulse duration due to temperature rise in diode active region



G6-Package
Current 100 A
Op Temp 25ºC

Issues

- Arrhenius indicates a highly reduced relative lifetime

Arrhenius equation:

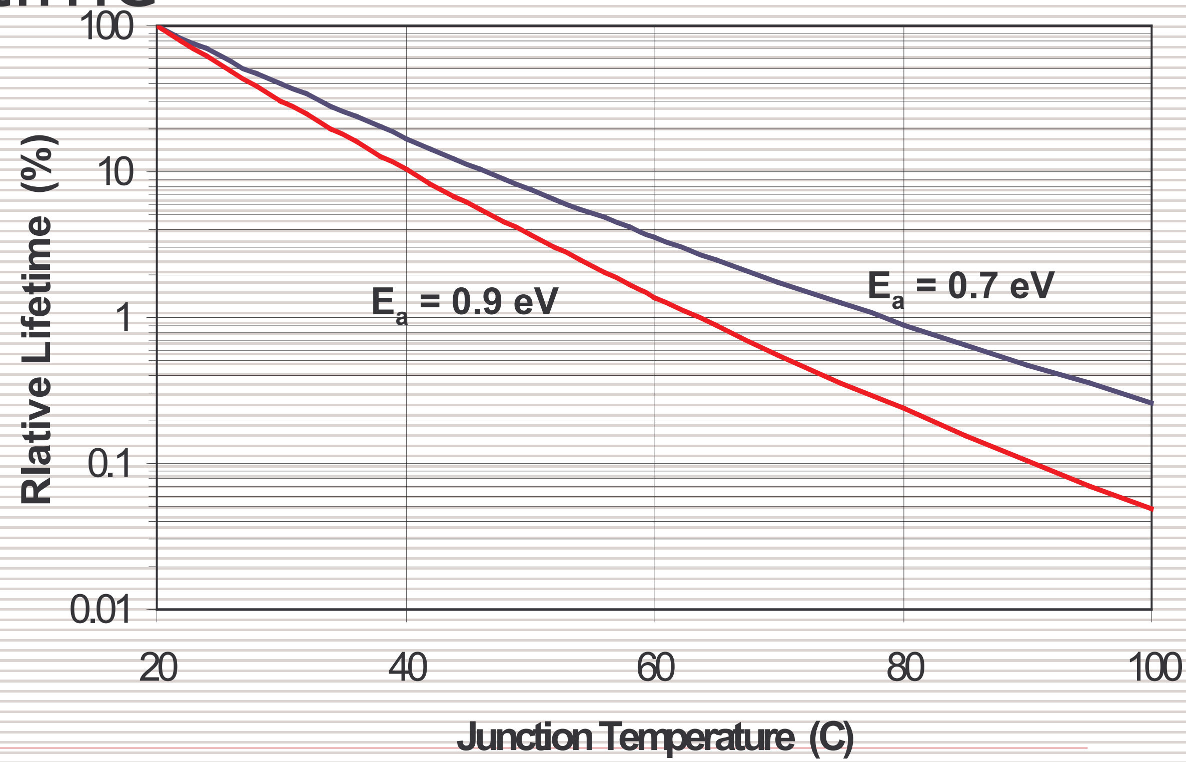
Lifetime $(\tau) \propto I^{-m} e^{(E_a/kT)}$

T Junction Temperature

I Drive Current

E_a Activation Energy

m Current Acceleration Factor



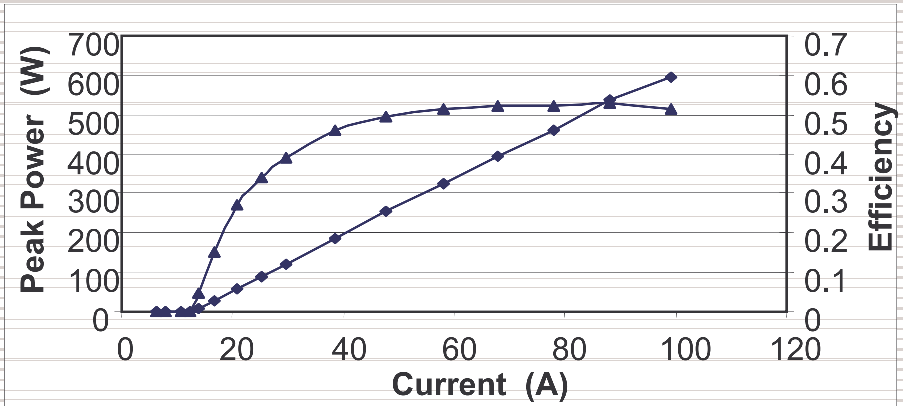
Issues & Objectives

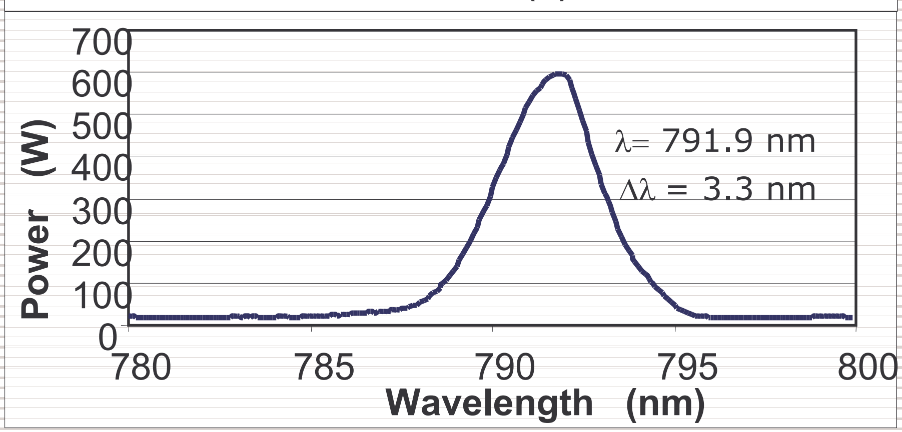
- Limited reliability and lifetime
- Lack of statistical and analytical bases for performance and lifetime prediction
- Limited commercial availability

- Improve understanding of Laser Diode Arrays
- Establish an independent lifetime and performance data base
- Investigate development of analytical models for predicting lifetime and performance, enabling end-to-end instrument trade analyses of E, PRF, τ_p, lifetime, …
- Support development of advanced Laser Diode Arrays
- Provide experimental and analytical results to Laser Diode manufacturers in order to improve fabrication process for higher reliability and consistency
- Develop qualification test procedures for space-based lidar instruments

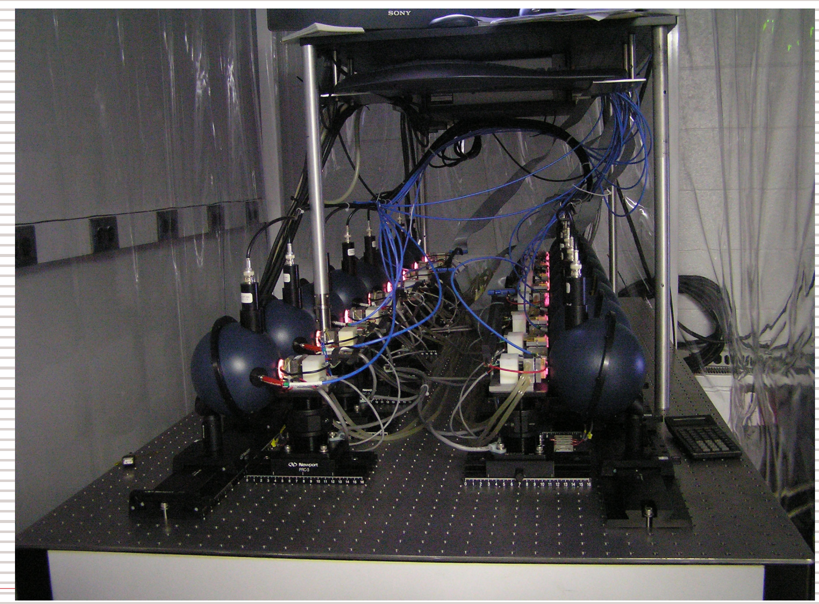
Approach & Methodology

- Characterization:
  - Visual, PIV, λ

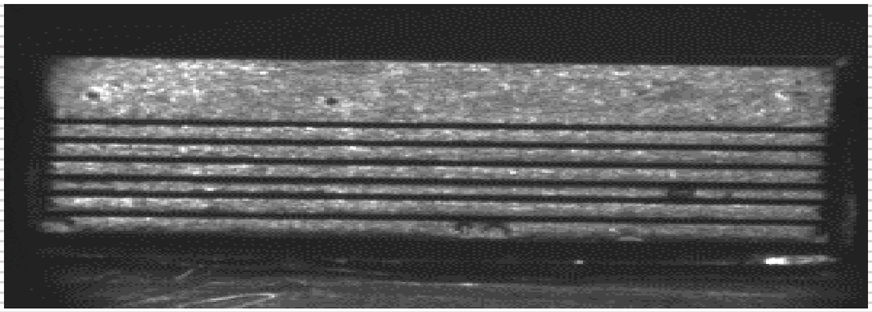


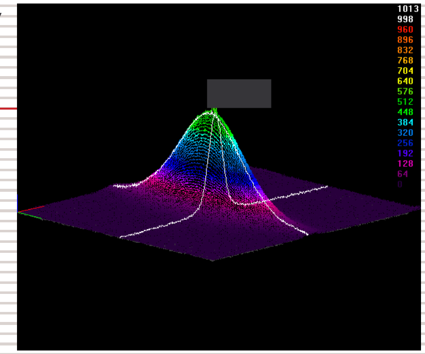


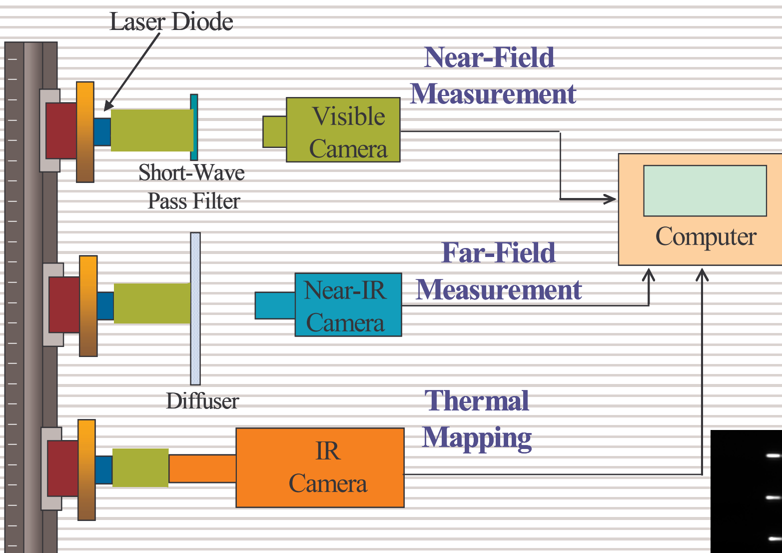
- Lifetesting:
  - 16 LD Arrays Simultaneously
  - 24/7 Fully Automated Control & Operation
  - Data Acquisition and Archive (Performance and all relevant environmental parameters)
  - Diagnosis and Alert
  - PC/Web-based

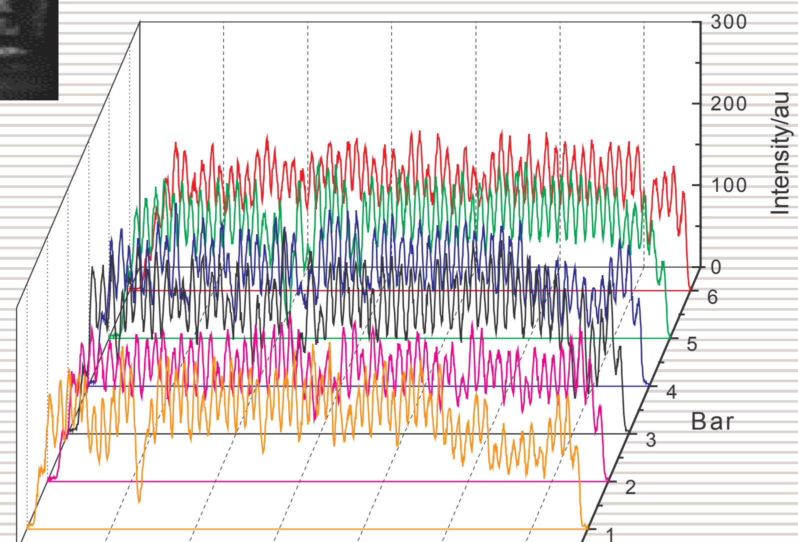


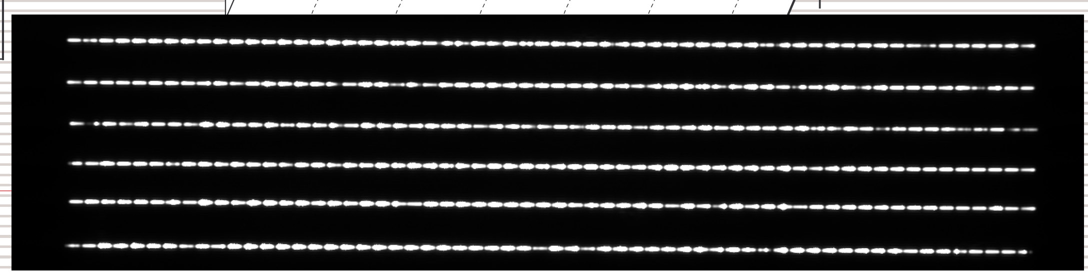
Approach & Methodology



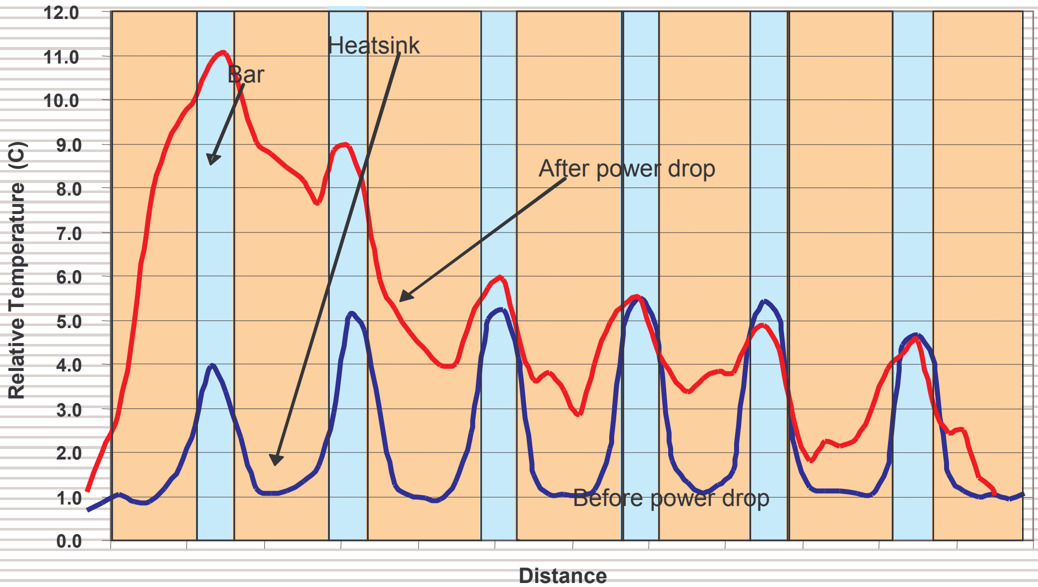


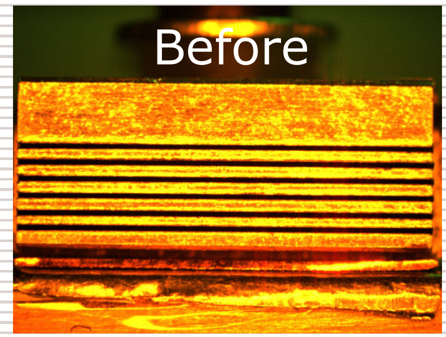


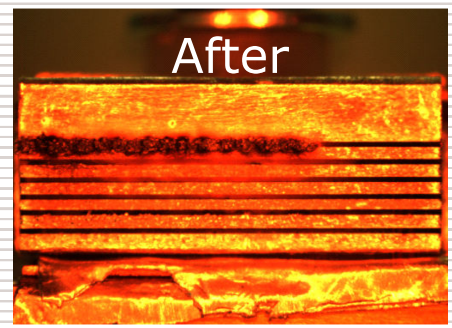


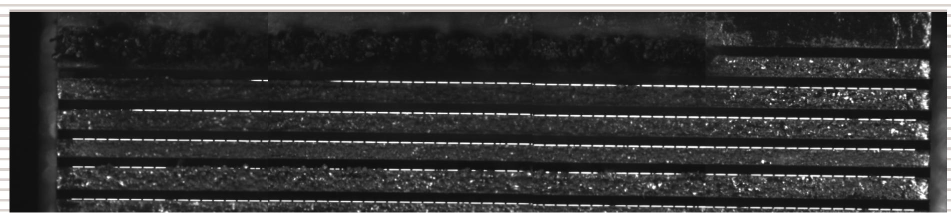


Methodology - IR Analysis









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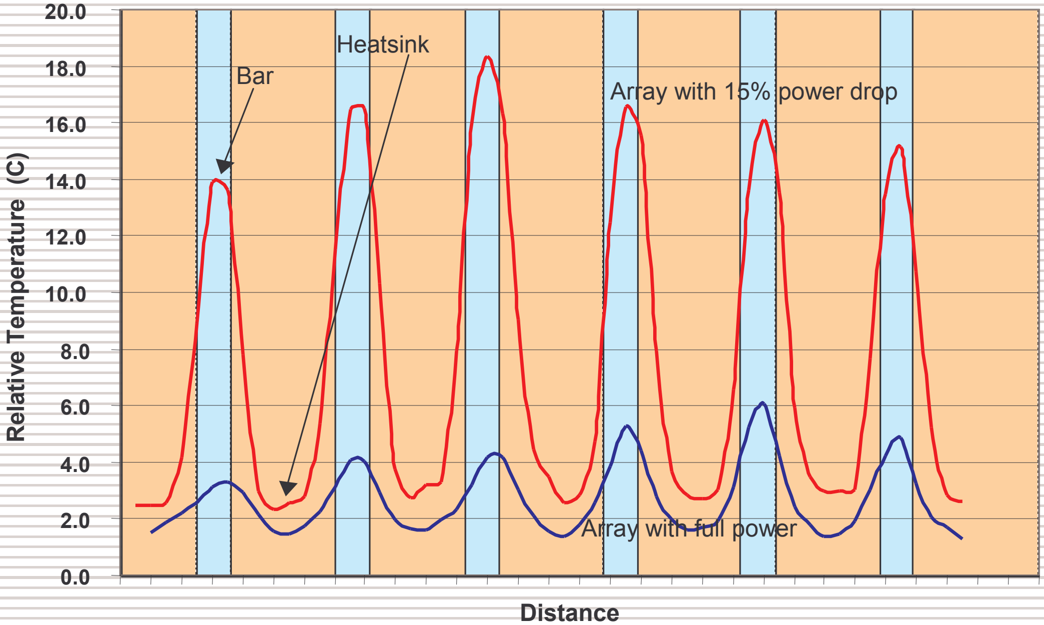
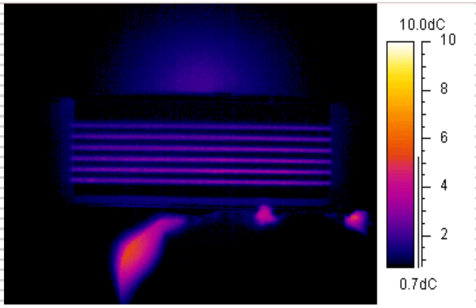
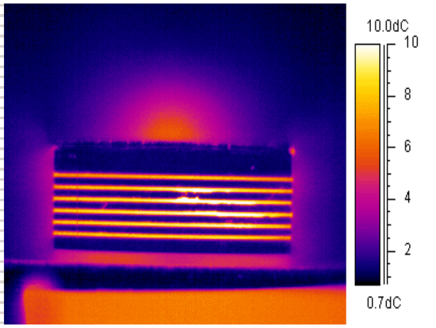


A-6 Array without any dark emitters



A-6 Array with some failing emitters (15% drop in power)



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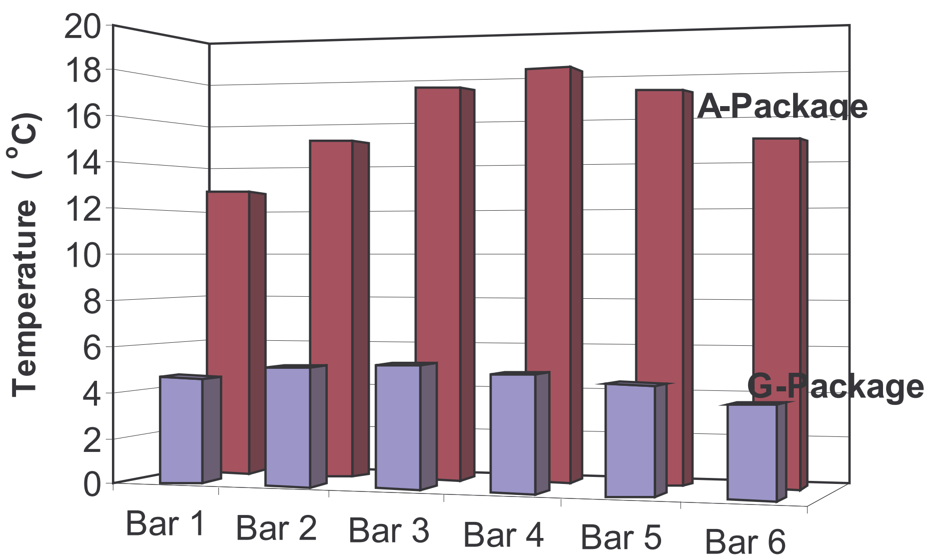
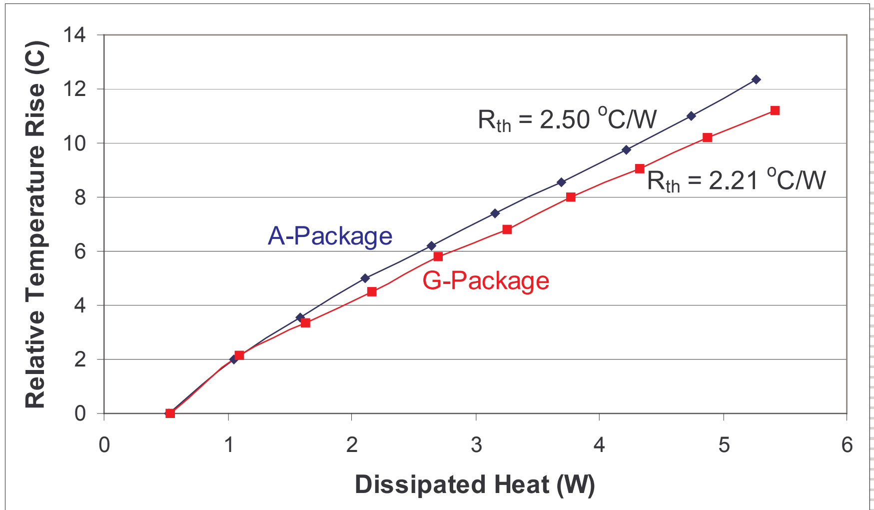
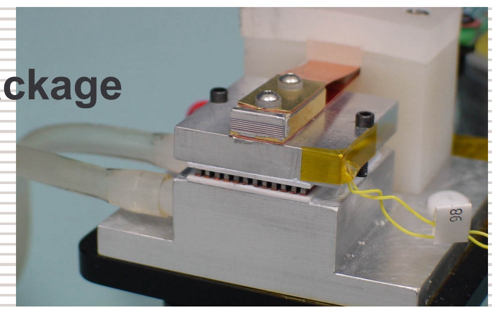
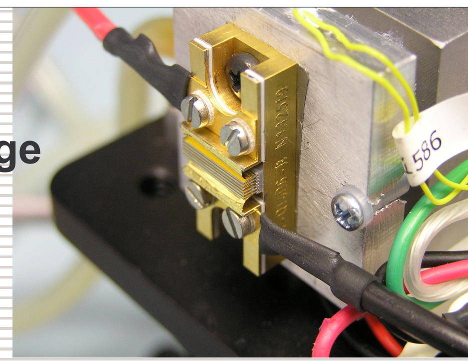




A-package

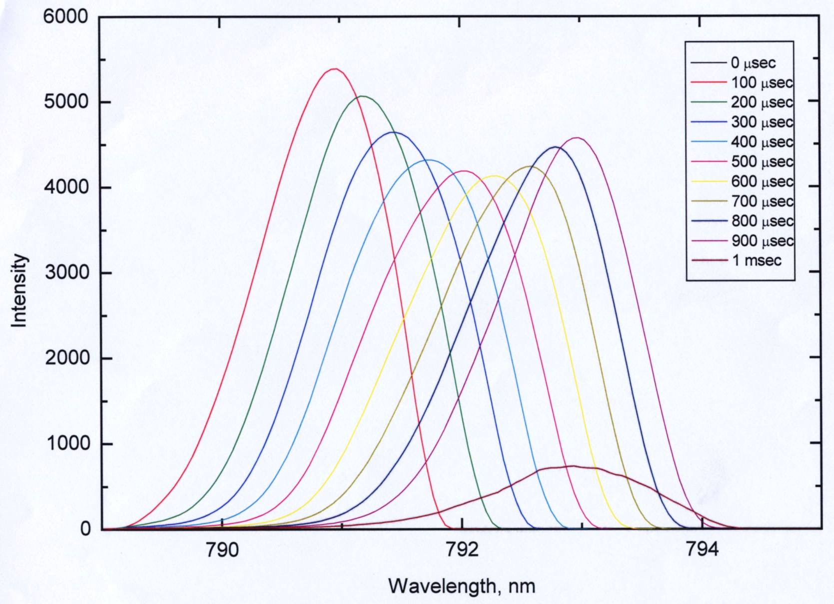


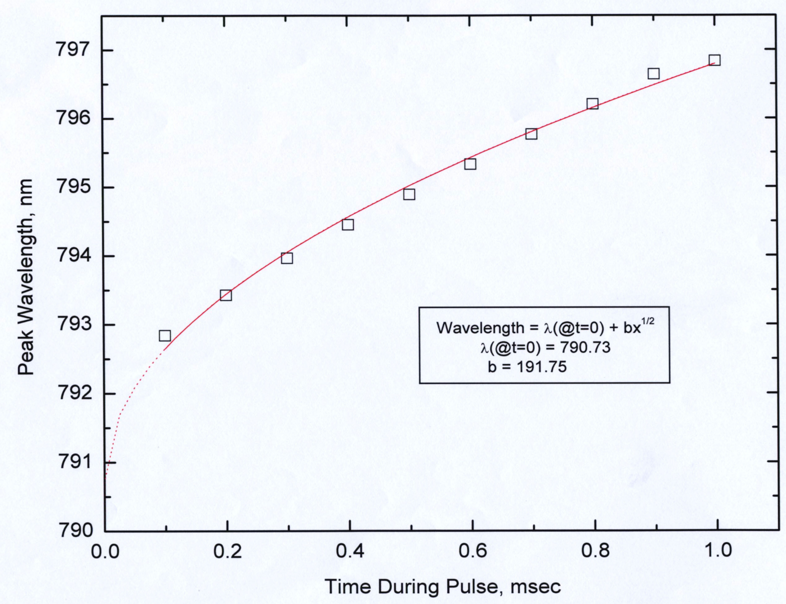
G-package



G-package bars run from 6 to 13 degrees cooler than A-package

Methodology –Temporally Resolved Spectral Measurements



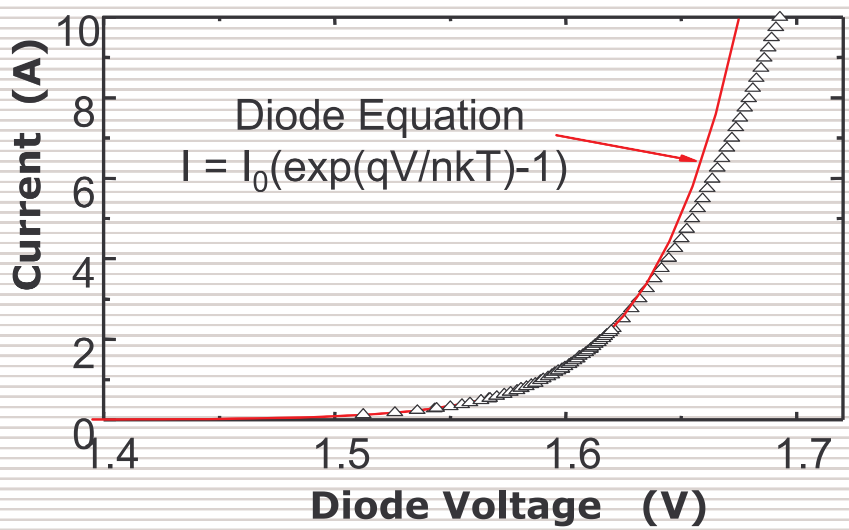


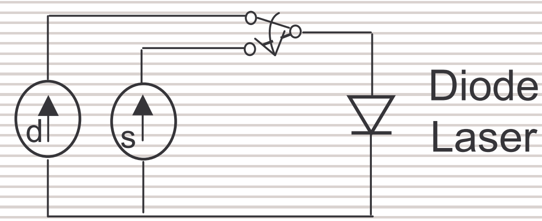
Spectral Shift during Pulse = 6 nm

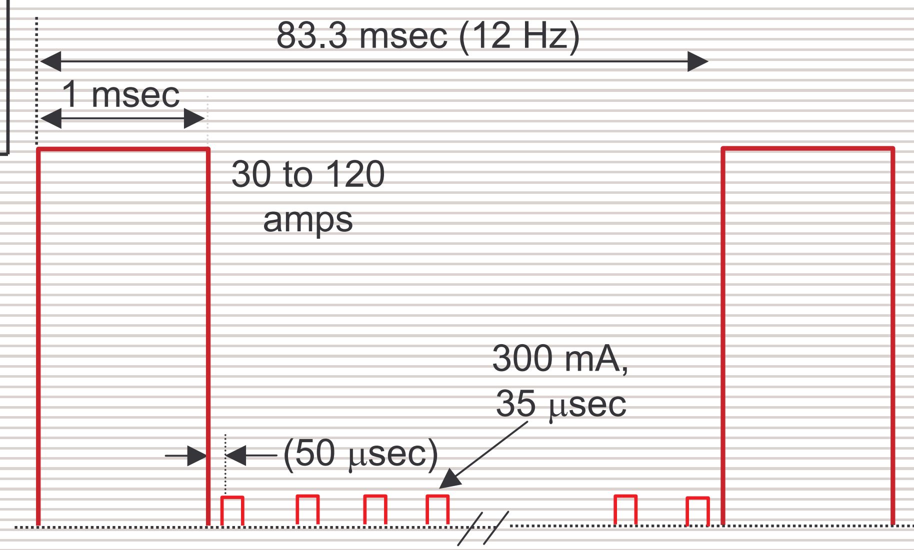
Temperature Rise during Pulse = 6 nm / 0.23 nm/^{o}C = 26 ^{o}C

Methodology – Forward Voltage Short Pulse (Junction Temperature)

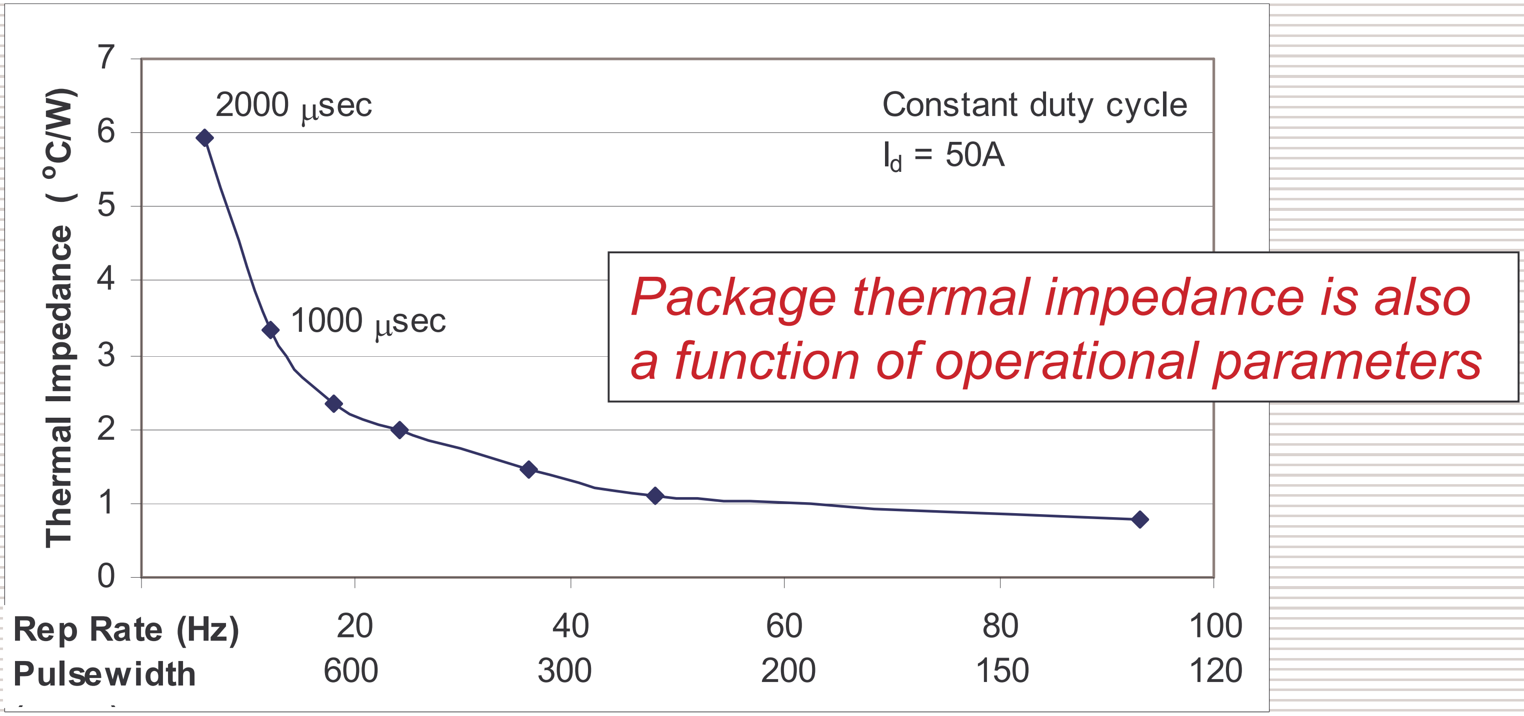
I-V characteristics of LDAs follows classical diode model up to 2.5A







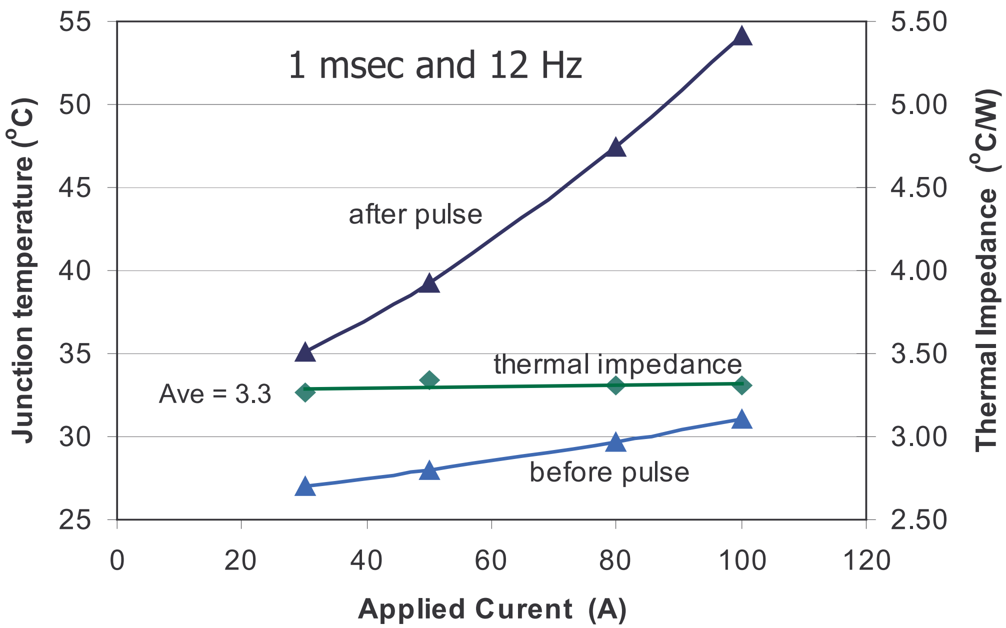
Methodology - FVSP

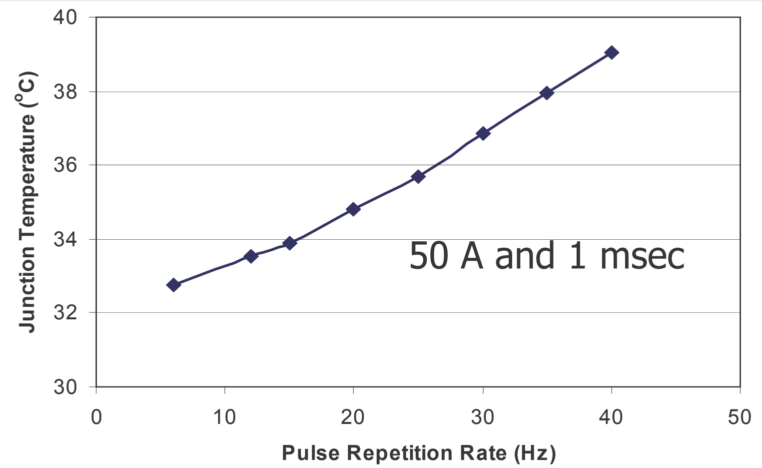


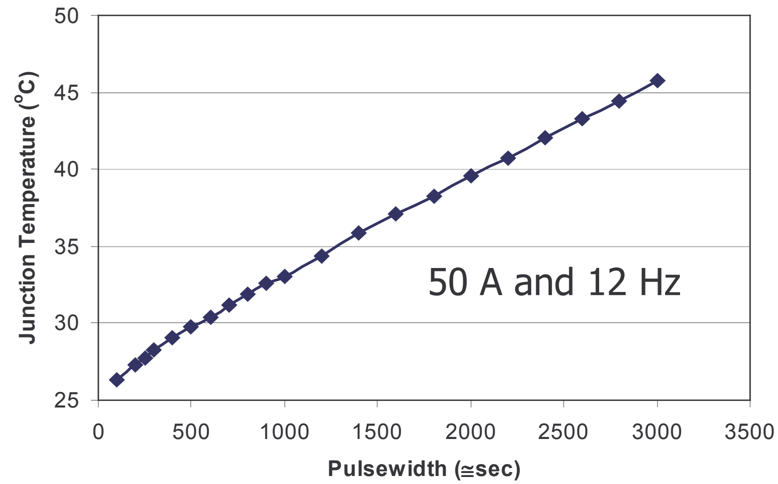
Varying pulsewidth (125 μsec to 2 msec) and repetition rate while keeping duty cycle constant at 1.2%

Average output power = 3.4 W

Methodology - FVSP

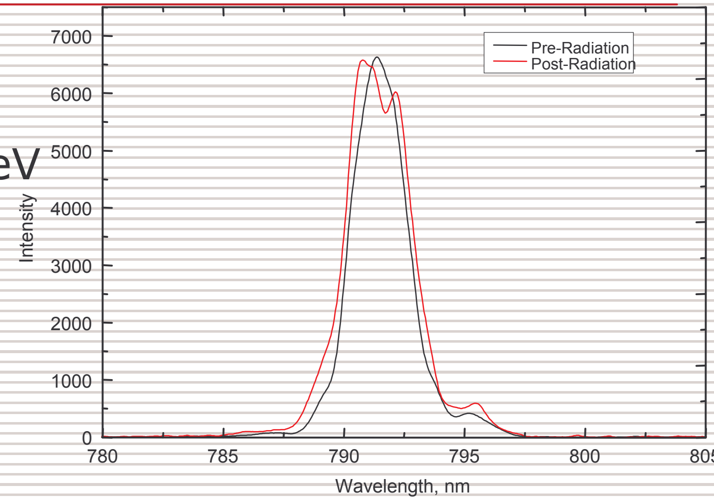


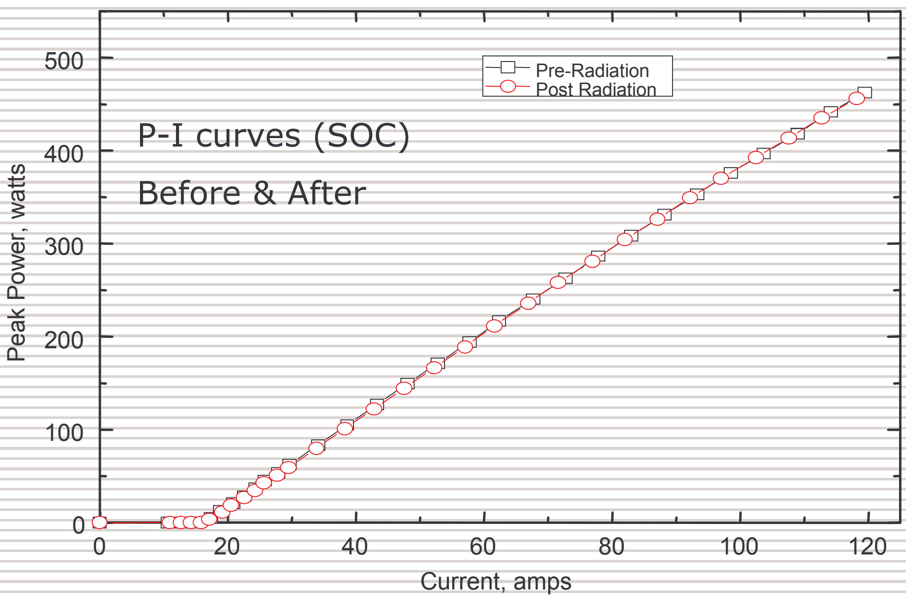


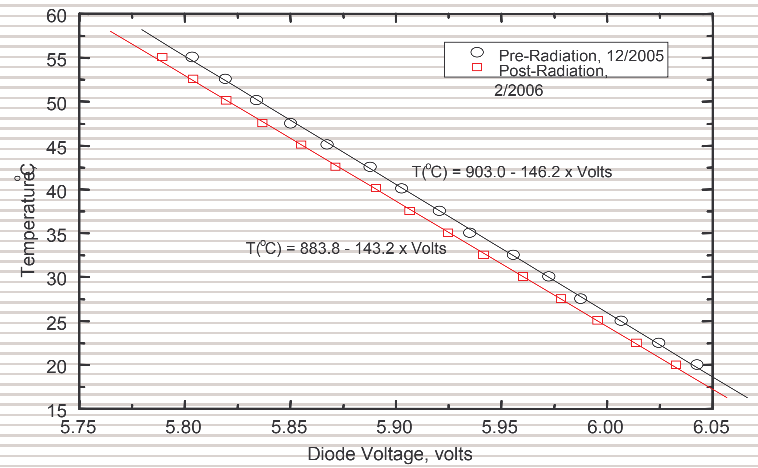


Methodology - Radiation

- Proton radiation testing in collaboration with JHU/APL and GSFC
- LDAs exposed to 2×10^{12} p/cm^2 at 200 meV
  - Slight change in junction temperature

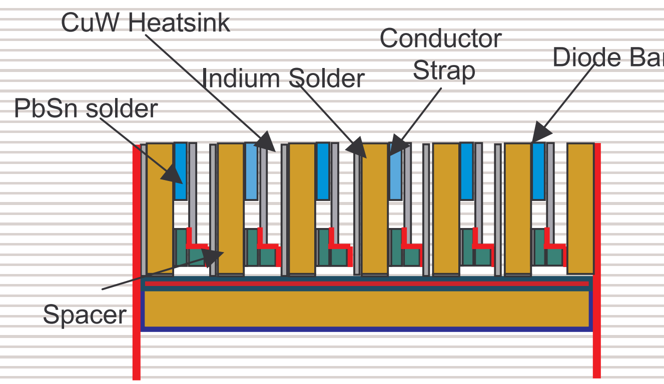




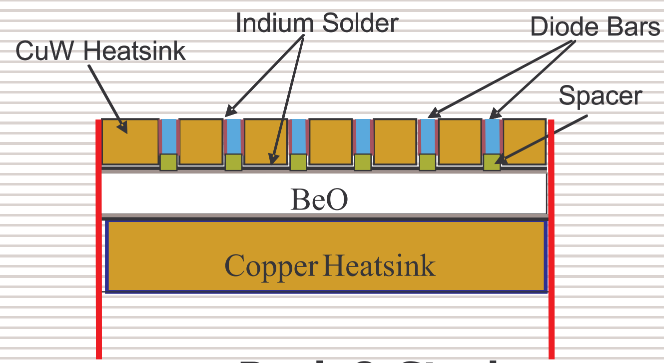


Methodology – Advanced Materials

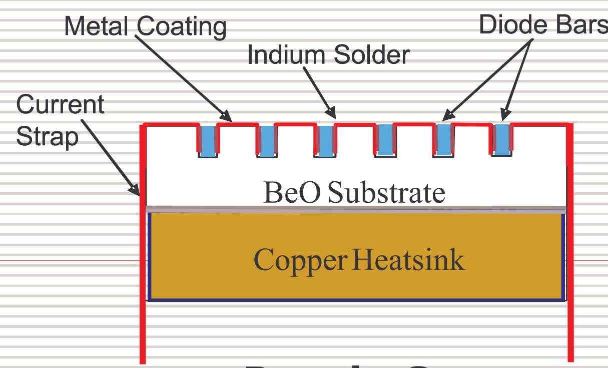
	Material	Coefficient of Thermal Expansion (m/m°C)	Thermal Conductivity (W/m·K)
Standard	GaAs (wafer material)	6.8×10^{-6}	46-55
	Indium Solder	29×10^{-6}	86
	BeO	8×10^{-6}	260
	Copper/CuW	$6 - 8 \times 10^{-6}$	200-250
Advanced	Diamond	1×10^{-6}	1100-1600
	Carbon-Carbon Composites	$1\text{-}6 \times 10^{-6}$	300-600
	Metal Matrix Composites	$6\text{-}16 \times 10^{-6}$	820-890
	AuSn Solder	16	58



Stacked Subassemblies



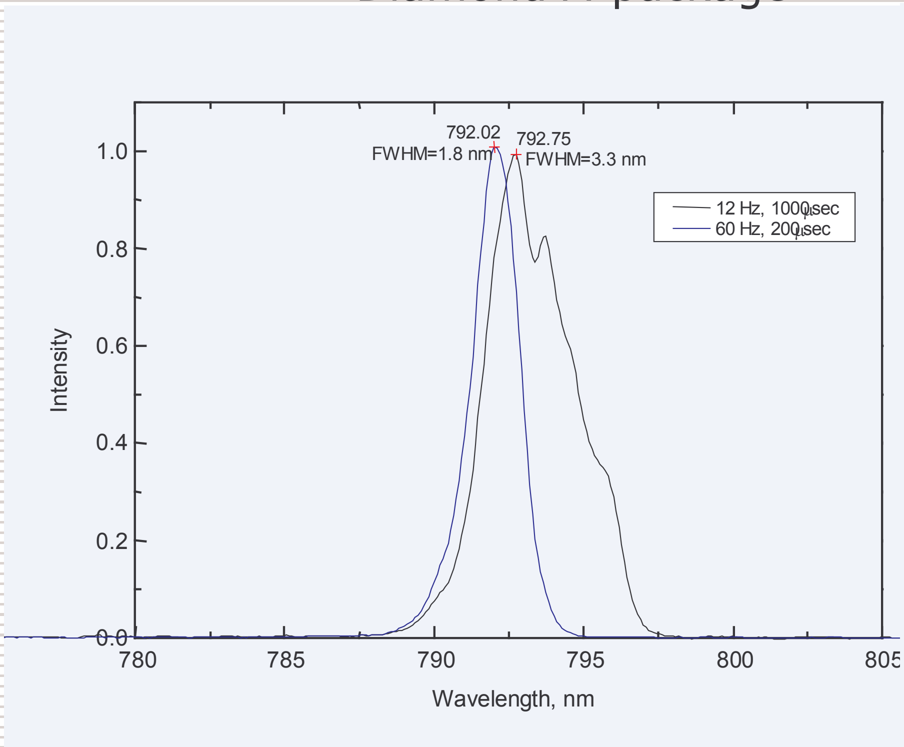
Rack & Stack



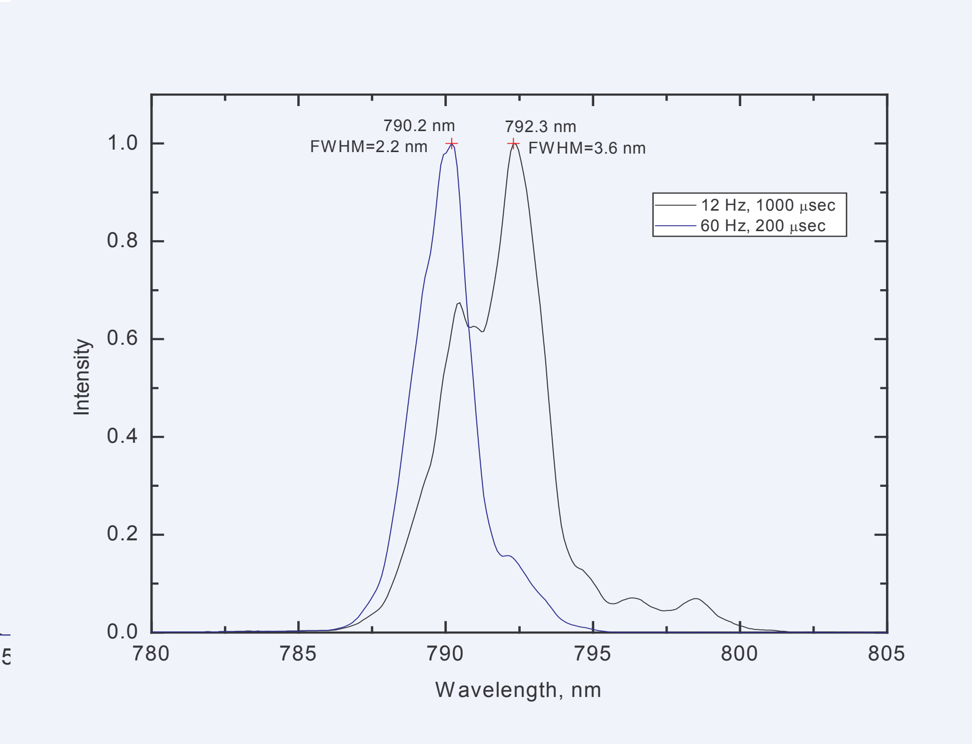
Bars in Groves

Methodology – Advanced Materials

Diamond A-package

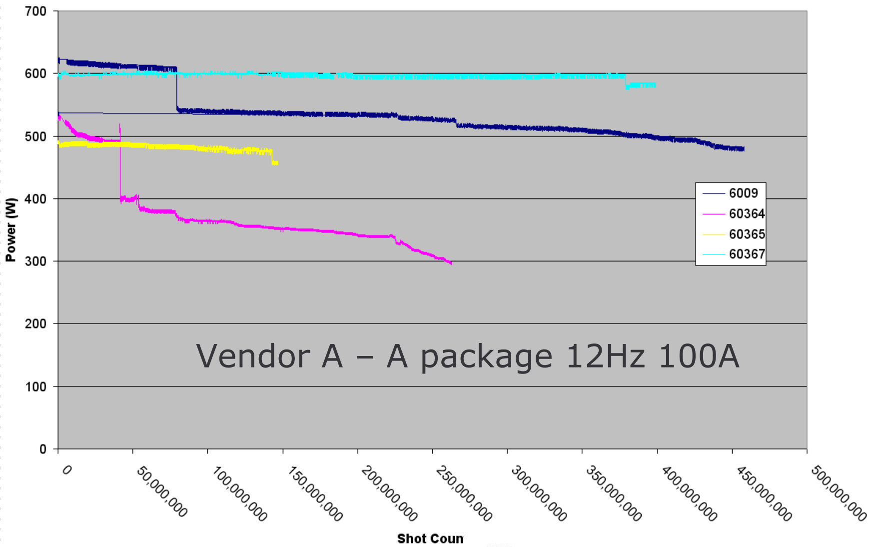


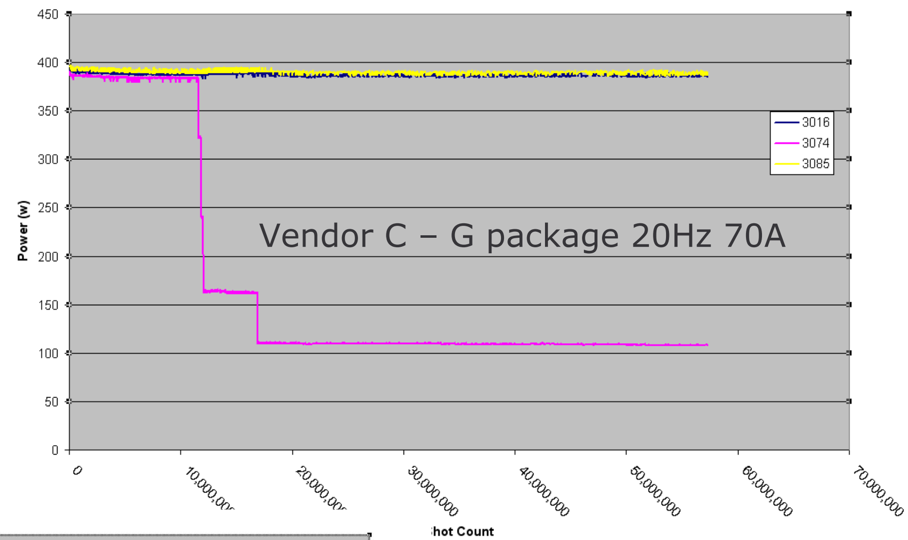
Standard G-package

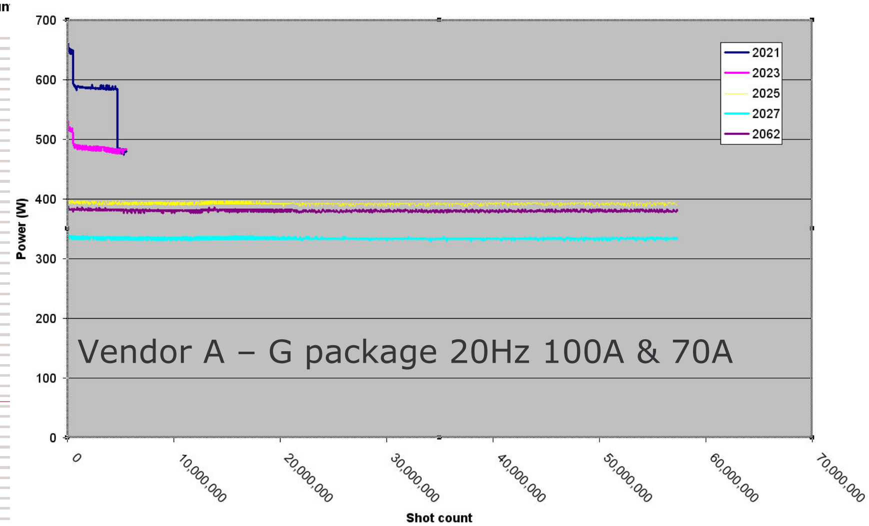


Spectral response at 200 μsec and 1 msec pulse durations

Results – Lifetime







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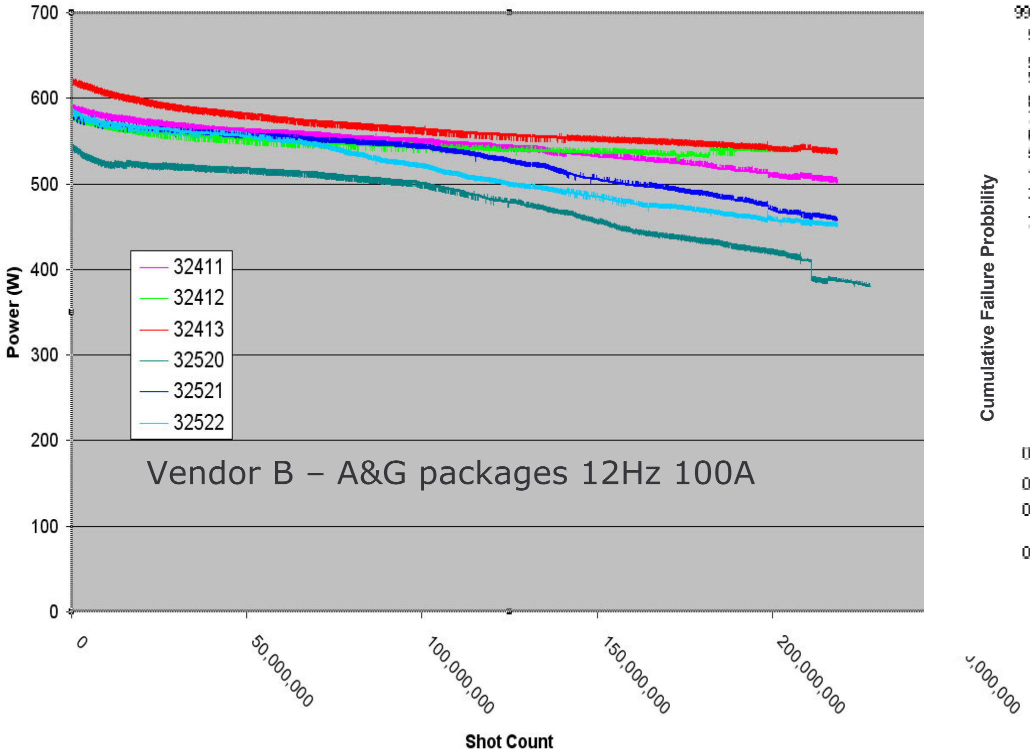

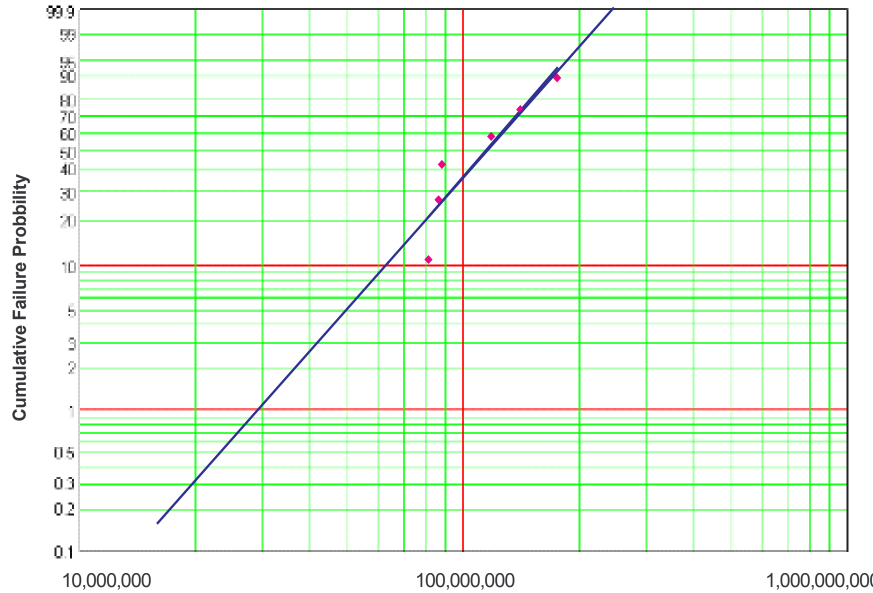

Lessons & Observations

- Trade space
  - Number of bars
  - Bar Pitch
  - Current derating
  - Pulsewidth & prf
  - Temperature
- Screening – FVSP
- Redundant systems

Future Work & Conclusion

- Spectral Mapping – in implementation
- Smart Drivers
- Additional Advanced Materials and Configurations
- Data Processing & Archive
- Continue lifetime testing & re-characterization