# Long-duration Operation of Coherent Doppler Lidar in Space

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**NASA Langley Research Center**

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# Long-duration Operation of Coherent Doppler Lidar in Space

**Lifetime and reliability of a space-based coherent lidar will be influenced by**

***Reliability:*** **Possible Causes of Failure**

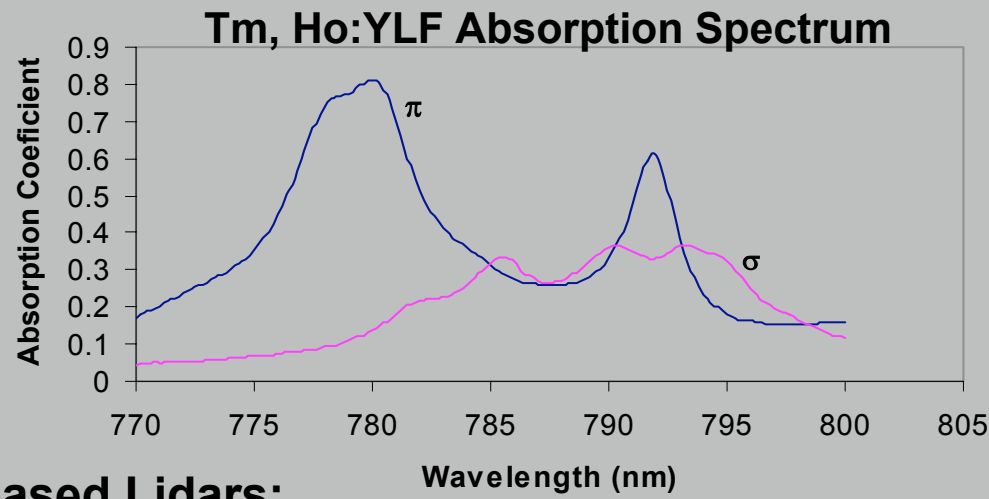
- **Electronics (EMI and cross talks)**
- **Electrical arcing and shorts (laser diode and Q-switch drivers)**
- **Thermal management and control operation**
- **Software anomalies**
- **Opto-mechanical misalignment**
- **Radiation darkening of laser crystals and optics**
- **Detectors failure**
- **Optical contamination**
- **Laser Diode Pump Array**

***Lifetime:*** **Essentially limited by Laser Diode Pump Array**

# Laser Diode Pump Arrays

## BACKGROUND

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

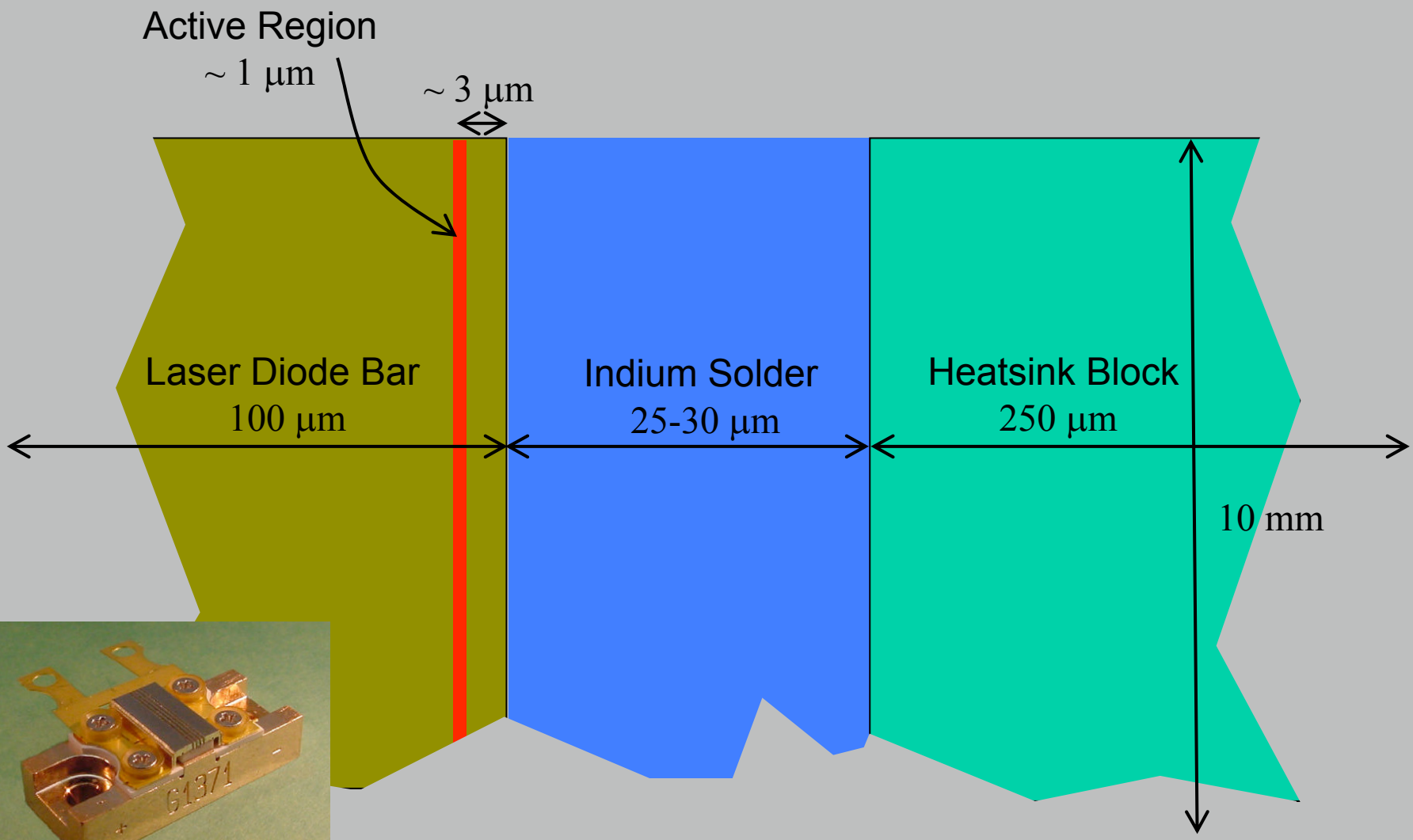



General Requirements for Space-based Lidars:

- Conductively-cooled
- Long lifetime > 2 x $10^9$ shots
- Reliability better than 300 FIT/6-bar device and 1000 FIT/bar
- Spectral width < 3 nm

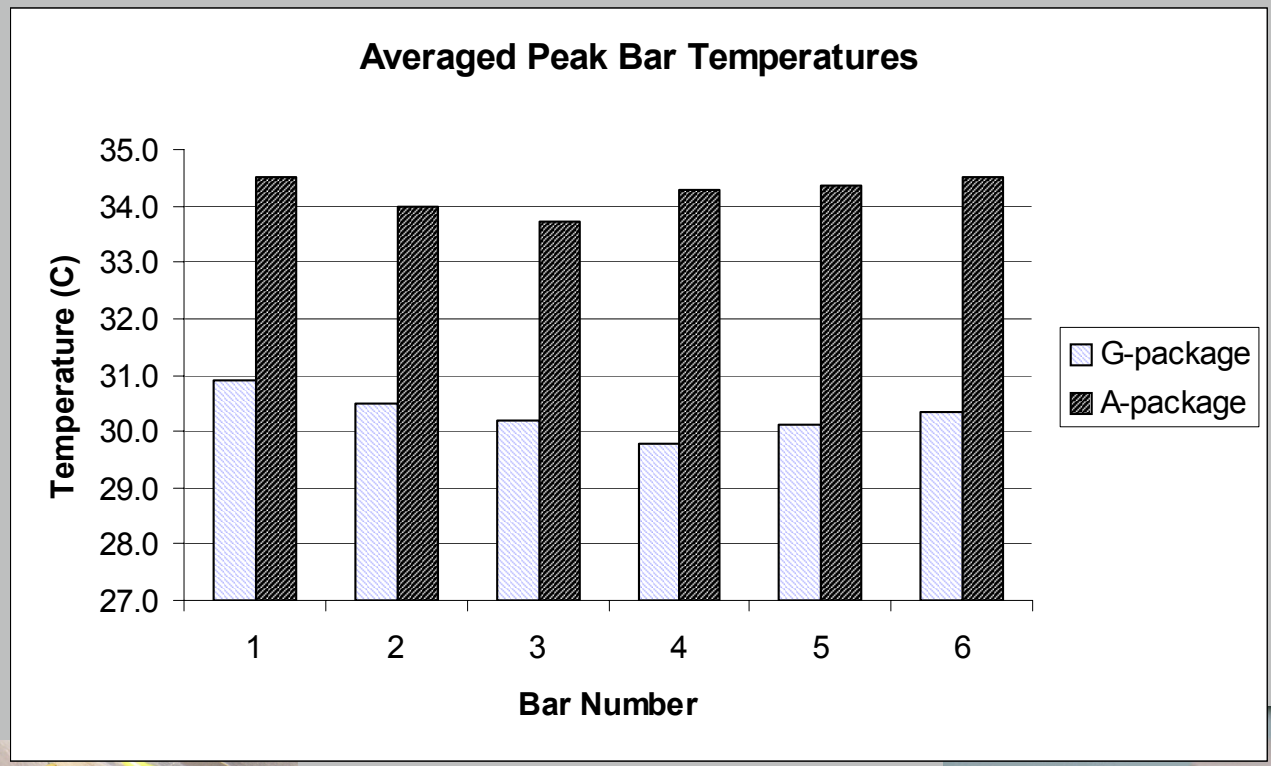
# Laser Diode Array Package

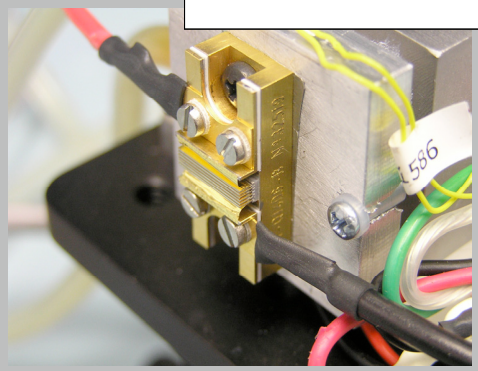
***Efficient heat extraction from the bar active region is the key***



# Comparison of Different LDAs

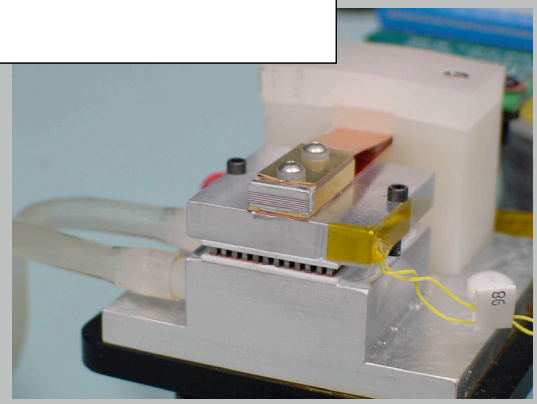
G-package bars run about 4 degrees cooler than A-package



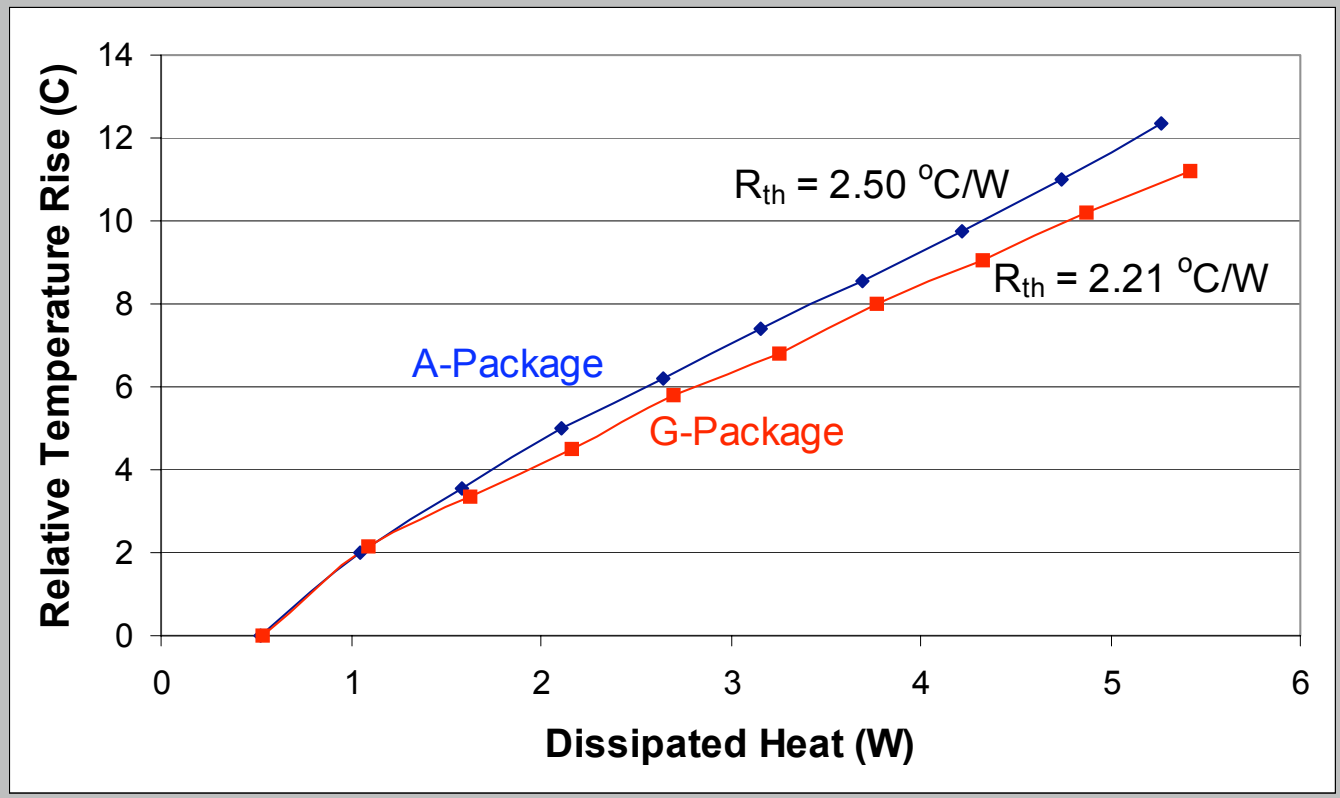
G-package

A-package

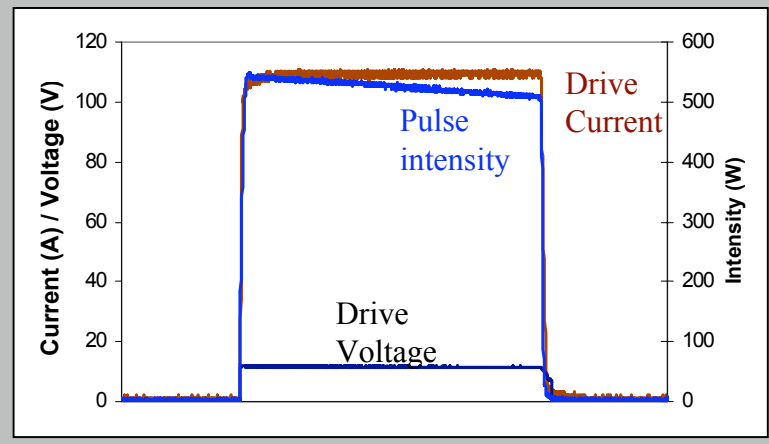


# Comparison of Different LDAs

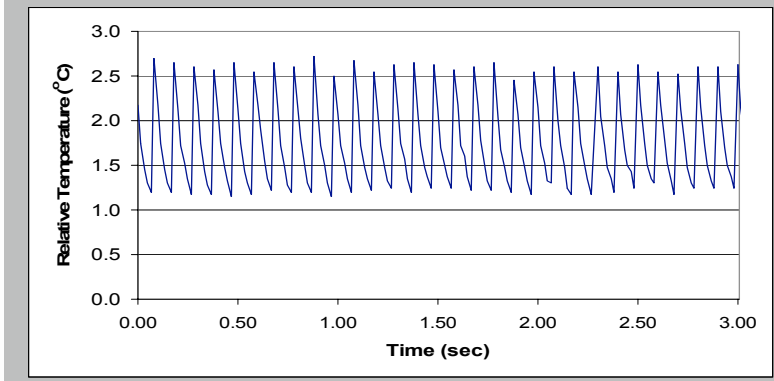
Thermal resistance of G-package is about 13% lower than A-package



# Thermal Cycling of Quasi-CW Laser Diode Array



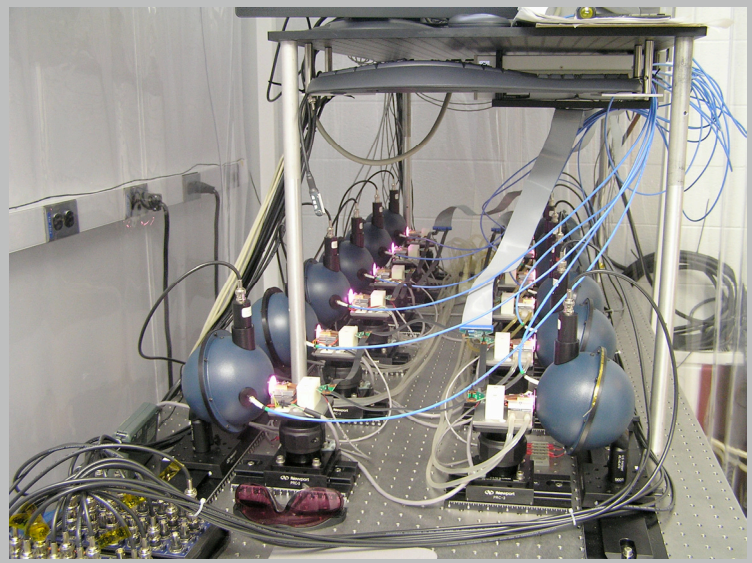


# Lifetime Testing of 792 nm LDAs

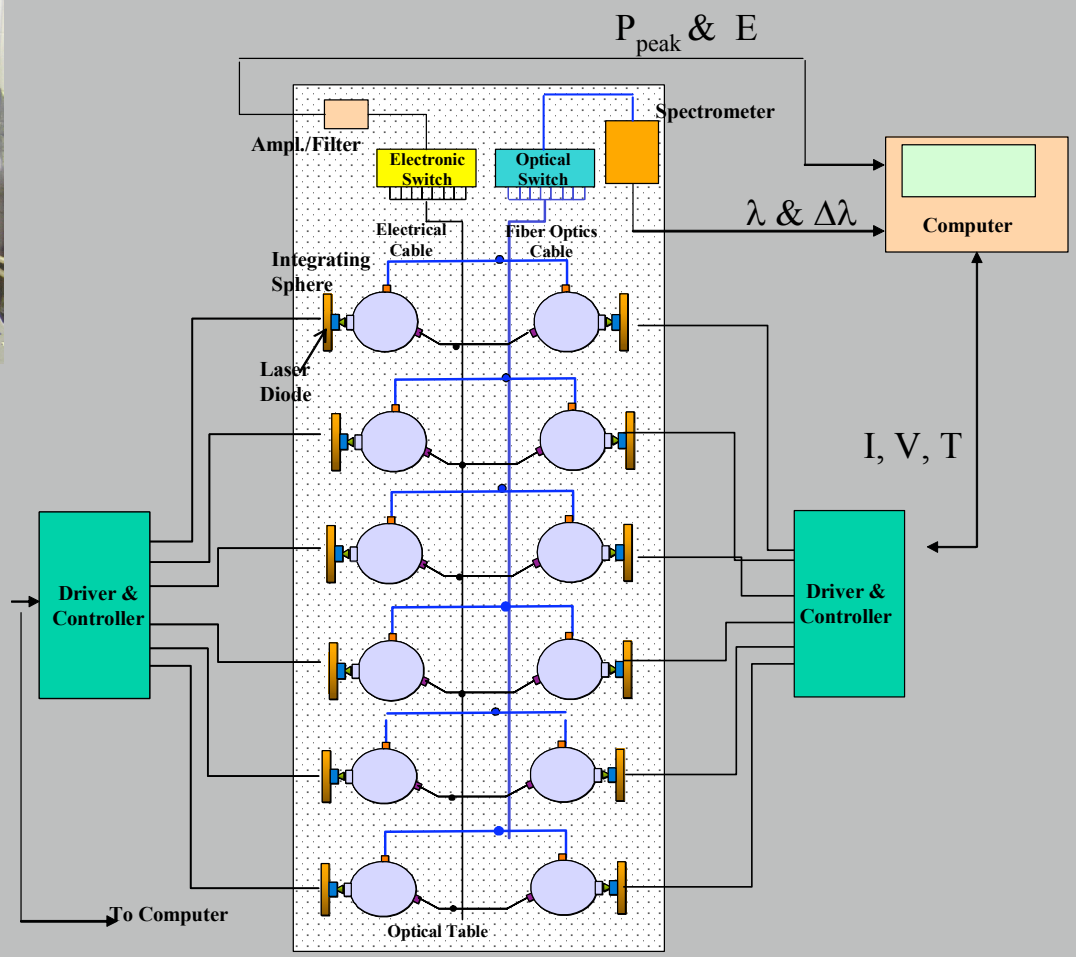
- Began lifetime testing of Standard "A" and "G" packages in February 2004
- LDAs from 2 major suppliers representing a sample of over 100 6-bar arrays characterized at Langley
- LDAs are being tested at full rated power and expected operational parameters for a space-based 2-micron lidar system
  - Drive current 100 A
  - Rep. rate 12 Hz
  - Pulse duration 1 msec
  - Operating temp. 25 deg. C

# Laser Diode Characterization/Lifetime Test Facility

## Lifetime Test Facility



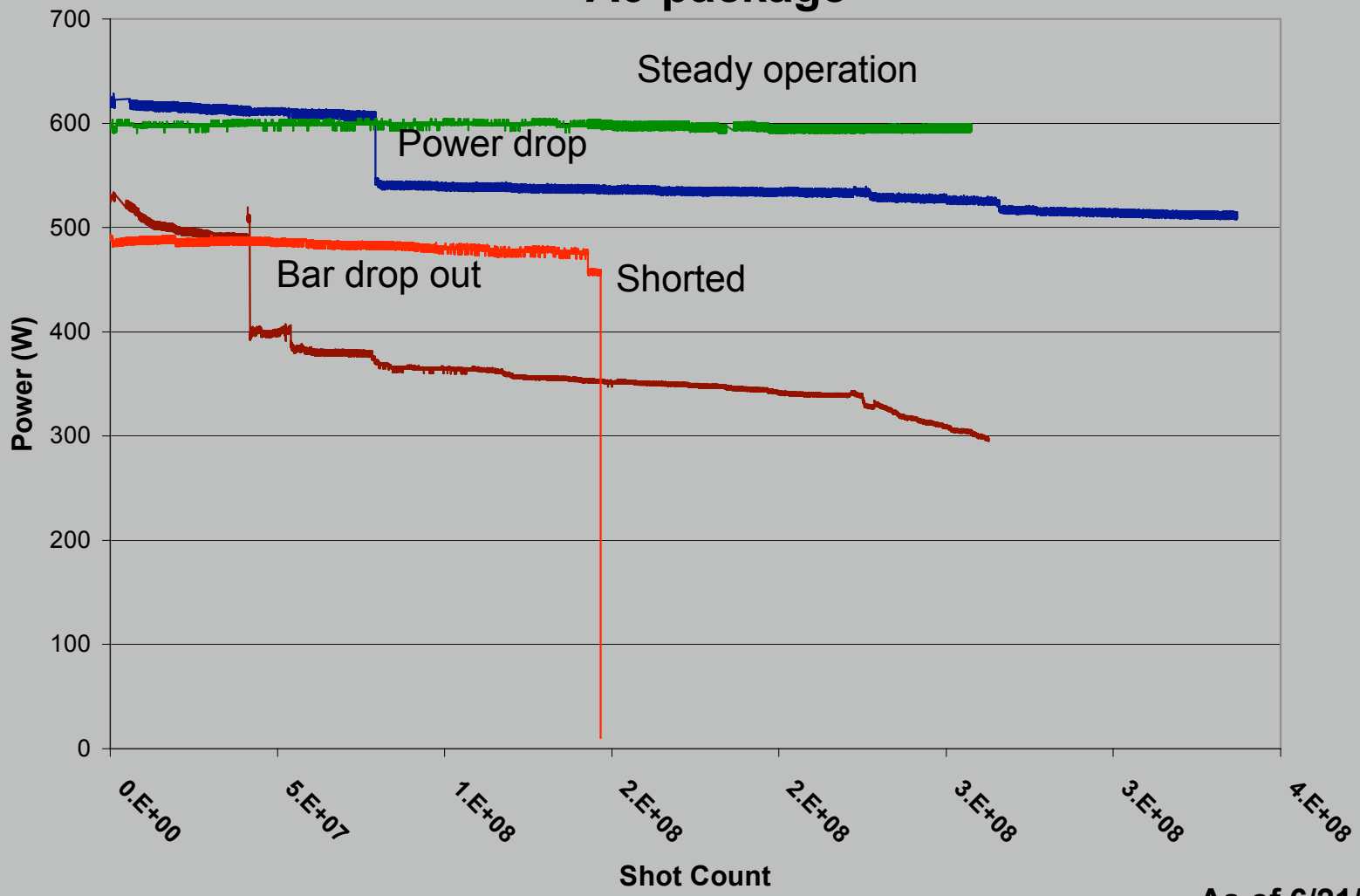
- Measures 12 LD Arrays Simultaneously - 24/7 operation. (Modularly expandable).
- Fully Automated
  - Control and Operation
  - Data Acquisition and Archive (Performance and all relevant environmental parameters)
  - Diagnosis and Alert
  - PC/Web-based



# Lifetime Testing of 792 nm LDAs

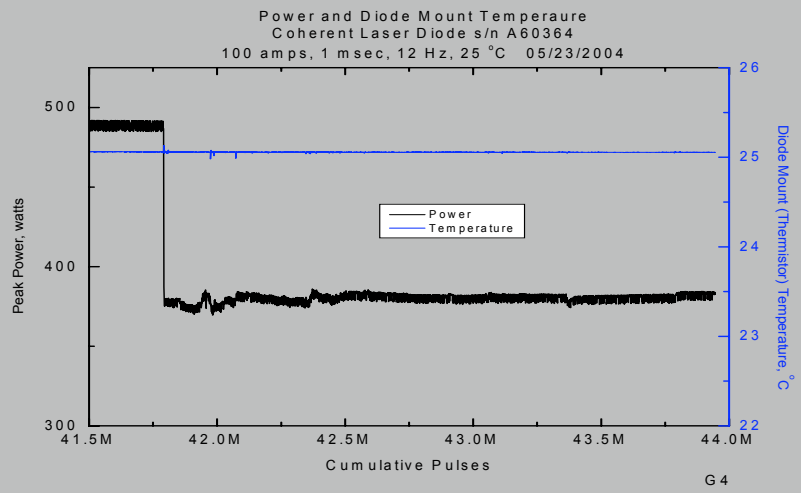
## Supplier A

### A6-package

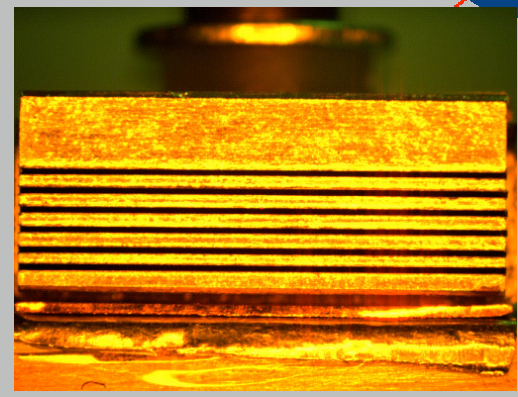



As of 6/21/2005

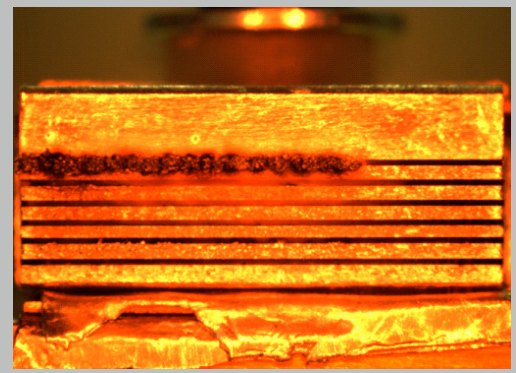
# Lifetime Testing

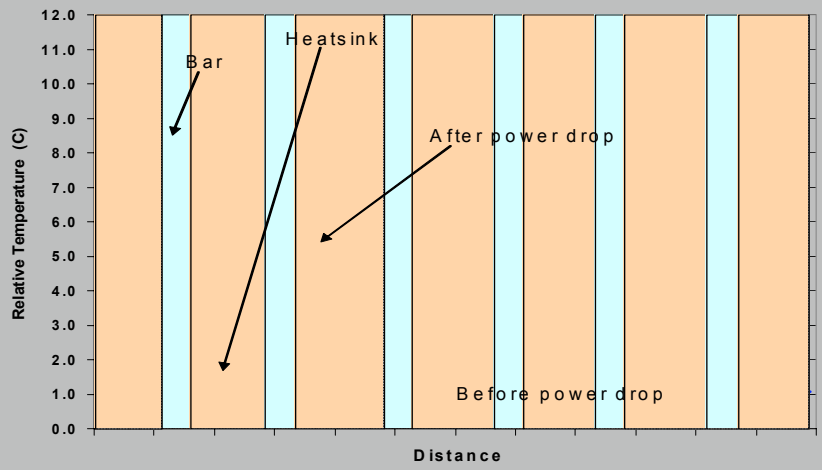



Before



After Bar Drop Out

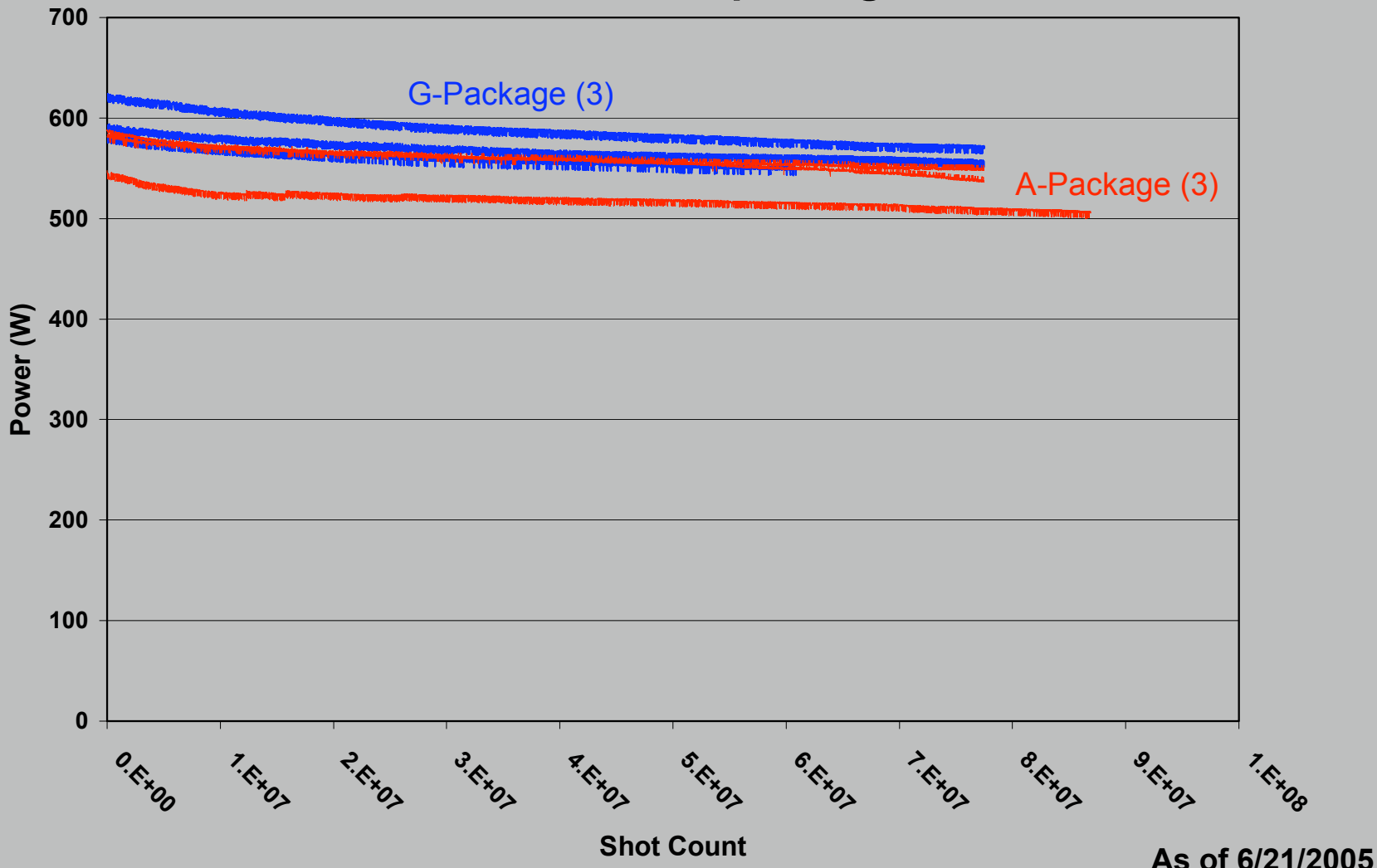





# Lifetime Testing of 792 nm LDAs

## Supplier B

### A6 and G6 packages




As of 6/21/2005

# Improving Lifetime and Reliability of Long Pulse Duration LDAs

## Using existing LDAs and current state of technology

| Plan and Recommendations | Lifetime | Reliability |
|---|---|---|
| Use G-package instead of A-package | X | X |
| Use 500μm pitch instead of 400μm | | X |
| Operate at a de-rated level (> 25%) | X | |
| Proven consistent fab/assembly processes | | X |
| Proper screening and testing procedures | | X |

# Improving Lifetime and Reliability of Long Pulse Duration LDAs

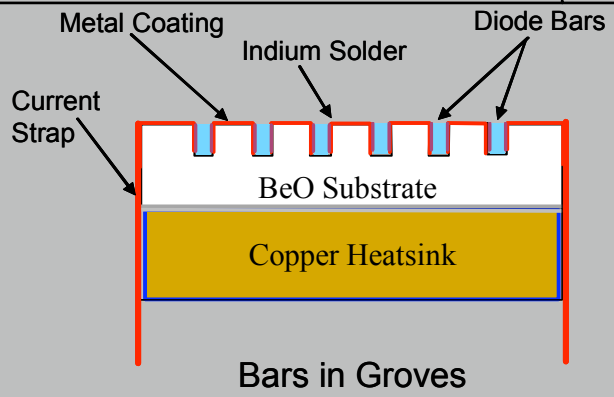
## Advancing Technology

| Promising Technologies Under Development | Lifetime | Reliability |
|---|---|---|
| Advanced package materials (Composites, CVD Diamond) | X | |
| Thin hard solder | X | X |
| Smart Driver | X | |
| Integrated fuse | | X |
| Efficiency | X | |

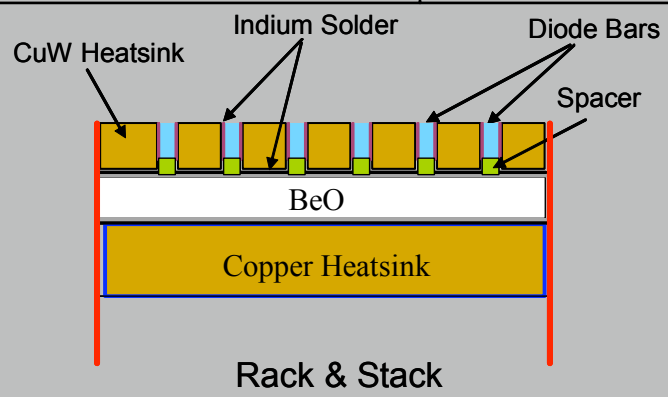
# Technology Advancement Addressing Reliability Issues

Thermal properties of package materials

| | Material | Coefficient of Thermal Expansion (m/m°C) | Thermal Conductivity (W/m·K) |
|---|---|---|---|
| Standard | GaAs (wafer material) | $6.8 \times 10^{-6}$ | 46-55 |
| | Indium Solder | $29 \times 10^{-6}$ | 86 |
| | BeO | $8 \times 10^{-6}$ | 260 |
| | Copper/CuW | $6 - 8 \times 10^{-6}$ | 200-250 |
| Advanced | Diamond | $1 \times 10^{-6}$ | 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 |



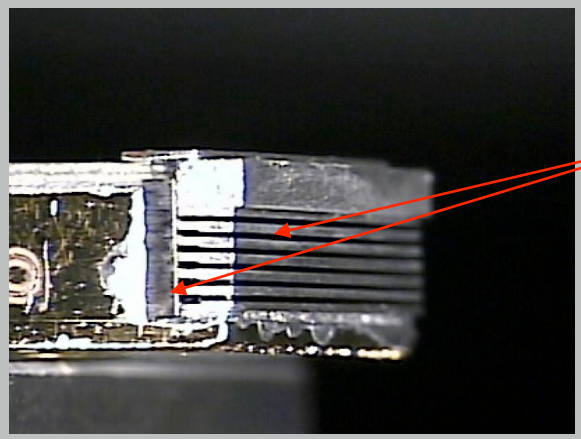
Bars in Groves

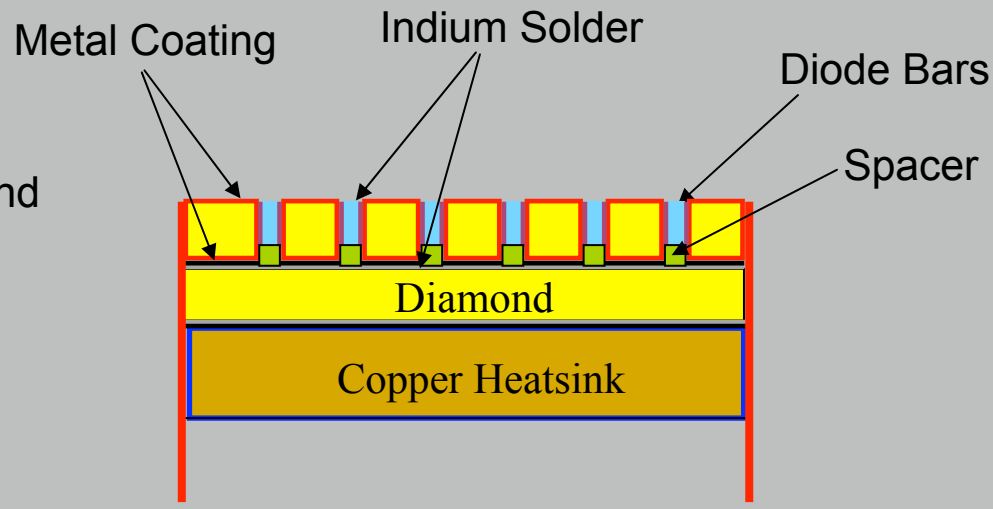


Rack & Stack

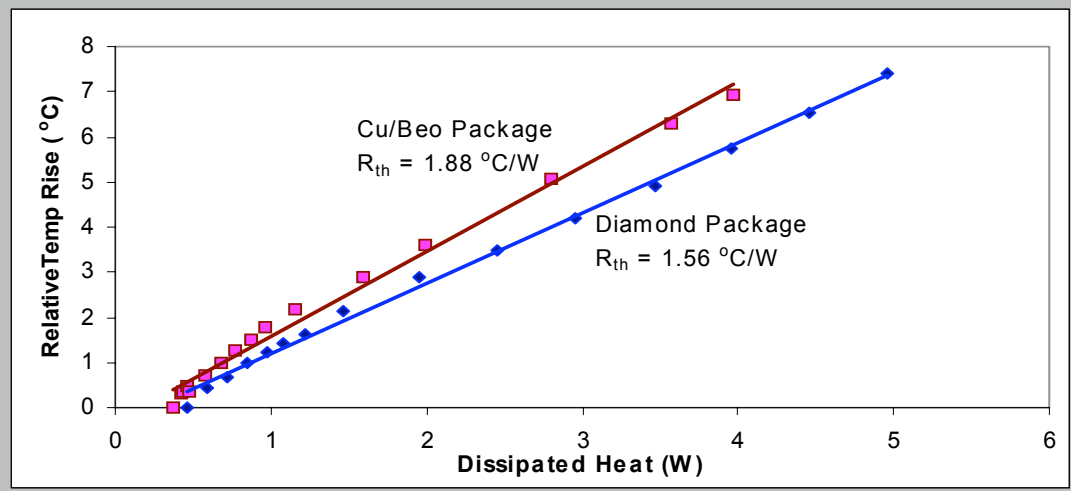
# Diamond Laser Diode Array

- *2 different experimental Diamond packages developed earlier showing substantial improvement in heat removal efficiency* (Joint effort with Northrop Grumman/CEO)




**Thermal resistance of diamond package is 17% lower than BeO/Cu package**

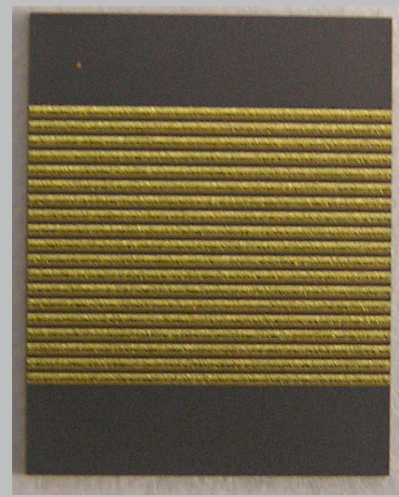


# Diamond Laser Diode Array
# Second Generation

Work on fabrication of a new set of Diamond packages is underway.

- A new set of Diamond submount parts, with even higher thermal conductivity, have been fabricated and delivered
- Single bar packages will soon be fabricated using 808 nm bars to investigate different soldering techniques and performing comparative analysis
- Several 6-bar packages using 792 nm bars from the same lot will be fabricated and tested

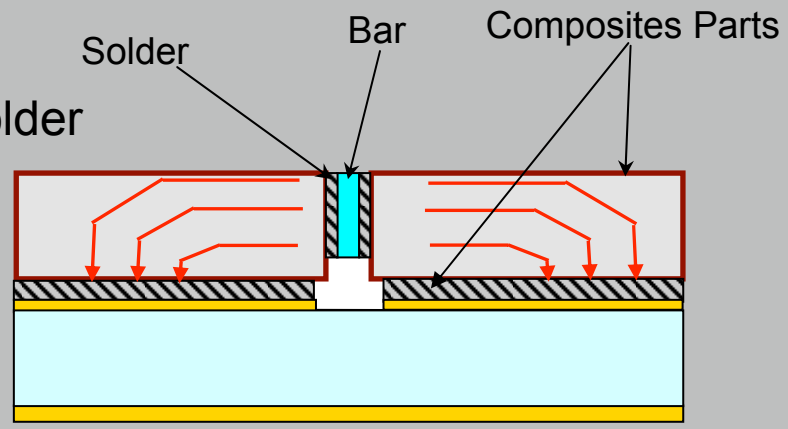
**Diamond heatsink parts**



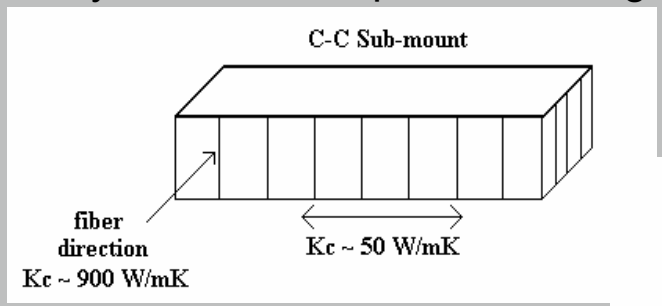
# Carbon Composites and Metal Matrix Composites Laser Diode Arrays

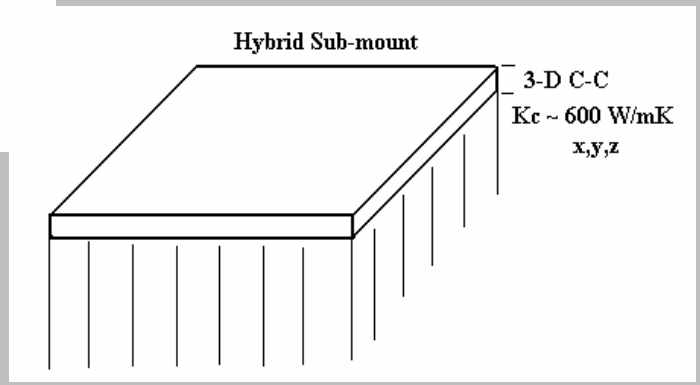
Carbon-Carbon and Metal Matrix Composites provide high thermal conductivity and matching CTE

- Reduce thermal resistance - Longer Lifetime
- Reduce solder thickness or allow use of hard solder - Lower Catastrophic Failure
- Dissipate heat from bars uniformly - Narrower Linewidth



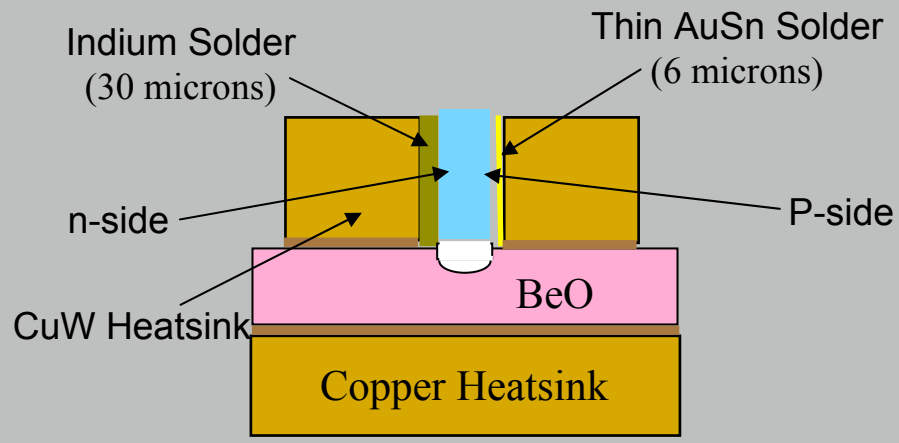

Hybrid C-C Composites / 3-D graphite foam LDA Submount



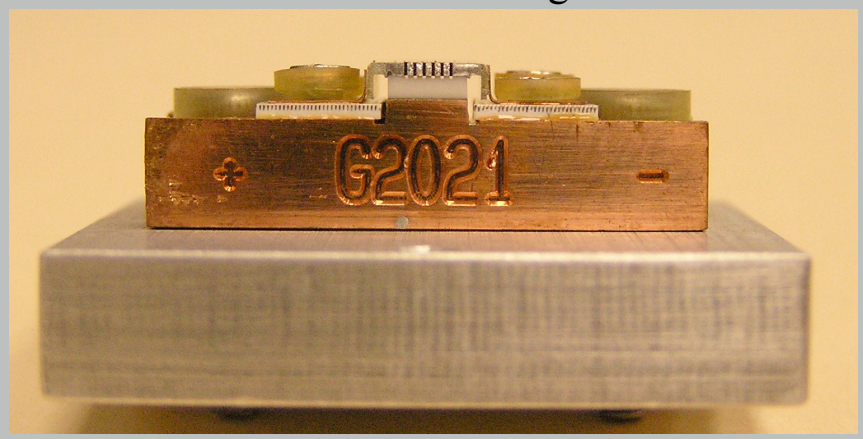



# Modified G-Package Laser Diode Array

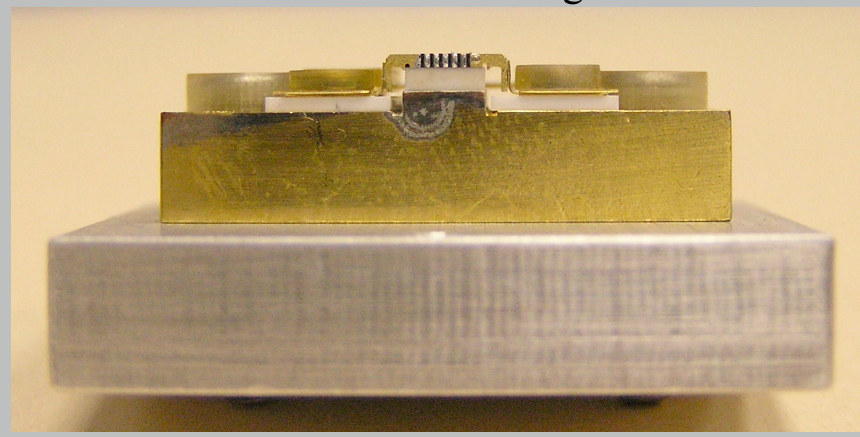
- Fabricated 3 experimental modified 6-bar G-package array and 2 standard packages for comparative measurements
- Thin AuSn hard solder on p-side of the bars and Indium solder on n-side




Standard G-Package




Modified G-Package



# Improving Reliability of Long Pulsewidth High Power Laser Diode Pump Arrays



## Near Term Plan

- Continue characterizing and lifetime testing of standard A and G packages from different vendors
- Develop a new setup for measuring thermal-induced mechanical stresses
- Expand lifetime test capability from 12 to 16 stations
- Continue experimenting with thin hard solder
- Complete fabrication of single-bar and 6-bar LDAs using advanced heatsink materials
  - CVD Diamond
  - Hybrid C-C Composites
  - Metal Matrix Composites
- Continue holding quarterly “Laser Diode Working Group” meetings (next meeting on August 16 at Langley)