

High Power QCW Arrays for Harsh Environments

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

October 6, 2016

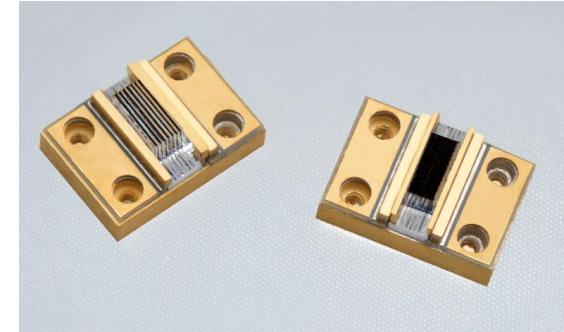
Jeremy Junghans and Ryan Feeler

Northrop Grumman Cutting Edge Optronics

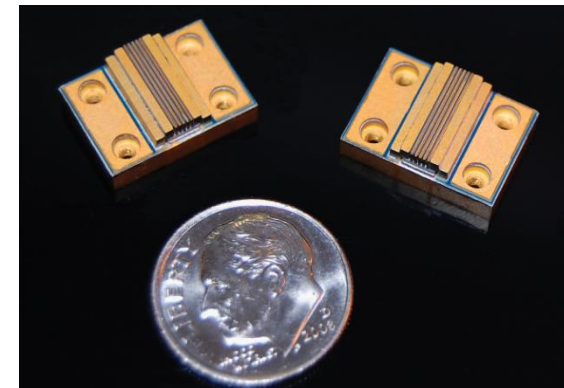
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Design and Test Overview

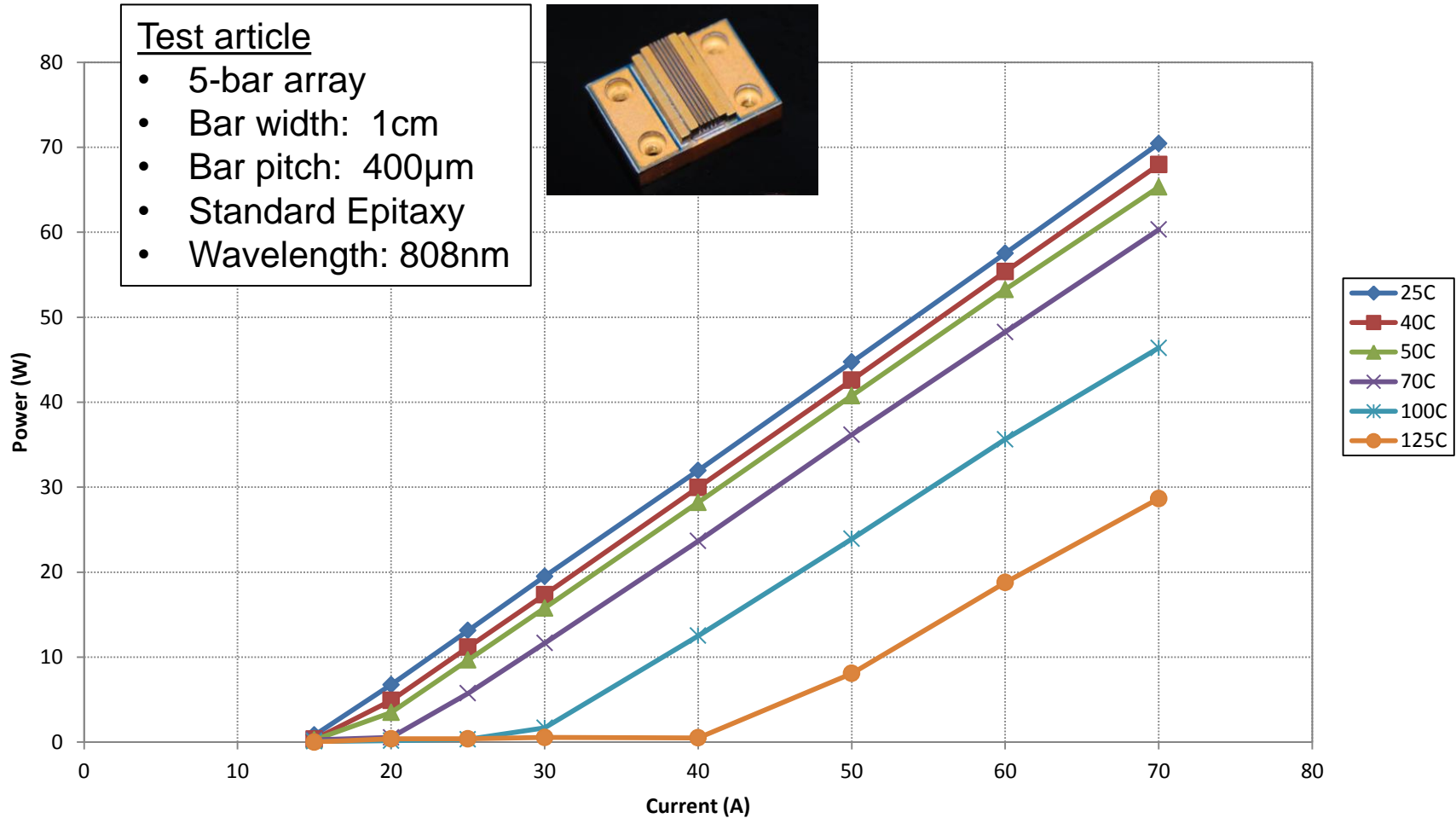
- CEO's diode bars are well suited for high temperature and high power operation
 - Standard epitaxial design maintains excellent slope and threshold values across a wide temperature range
 - Large optical cavity epitaxial material provides improved reliability at high powers
 - Bar geometries can be customized (cavity length, fill factor, bar width, etc.)
- High Power Harsh Environment Testing Completed
 - Arrays built from 150 μm stripe, 83% FF, 2 mm CL diode bars
 - Both full 1cm full-bars and 3.3mm mini-bars were tested
 - Three configurations of CTE-matched packages built
 - 5-bar (full 1cm-bar), 400 μm pitch Golden Bullets
 - 7-bar (mini-bar), 350 μm pitch Golden Bullets
 - 15-bar (mini-bar), 150 μm pitch High Density Stacks (HDS)
 - Arrays were then tested at a variety of pulse widths, duty factors and operating temperatures



Picture of arrays built for QCW experiments: 7-mini-bar, 350 μm pitch Golden Bullet (top-left), 15-mini-bar HDS (top-right) and 5-bar, 400 μm pitch Golden Bullet (bottom)

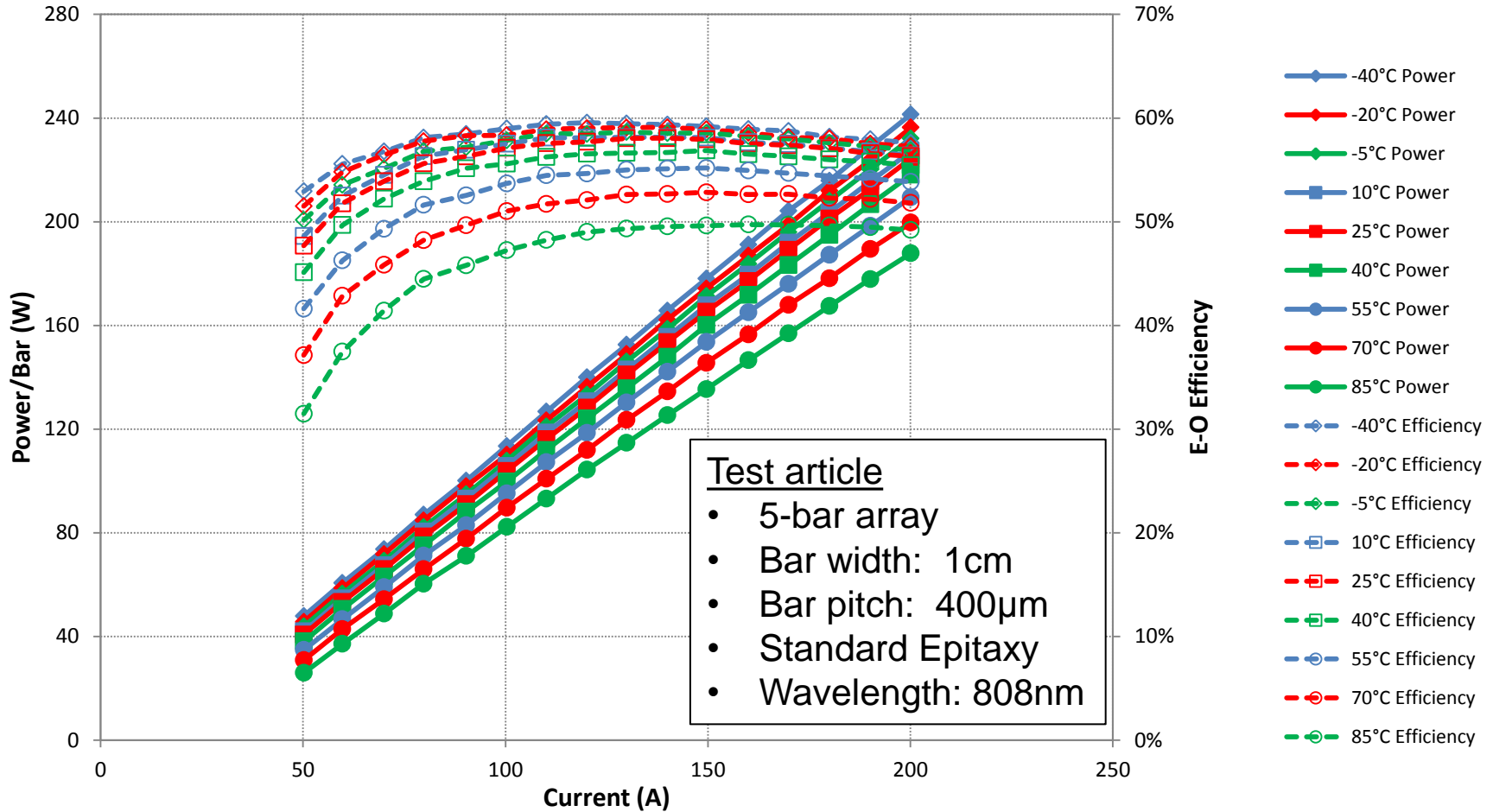


Output Power at Elevated Temperatures (Standard Epitaxy)



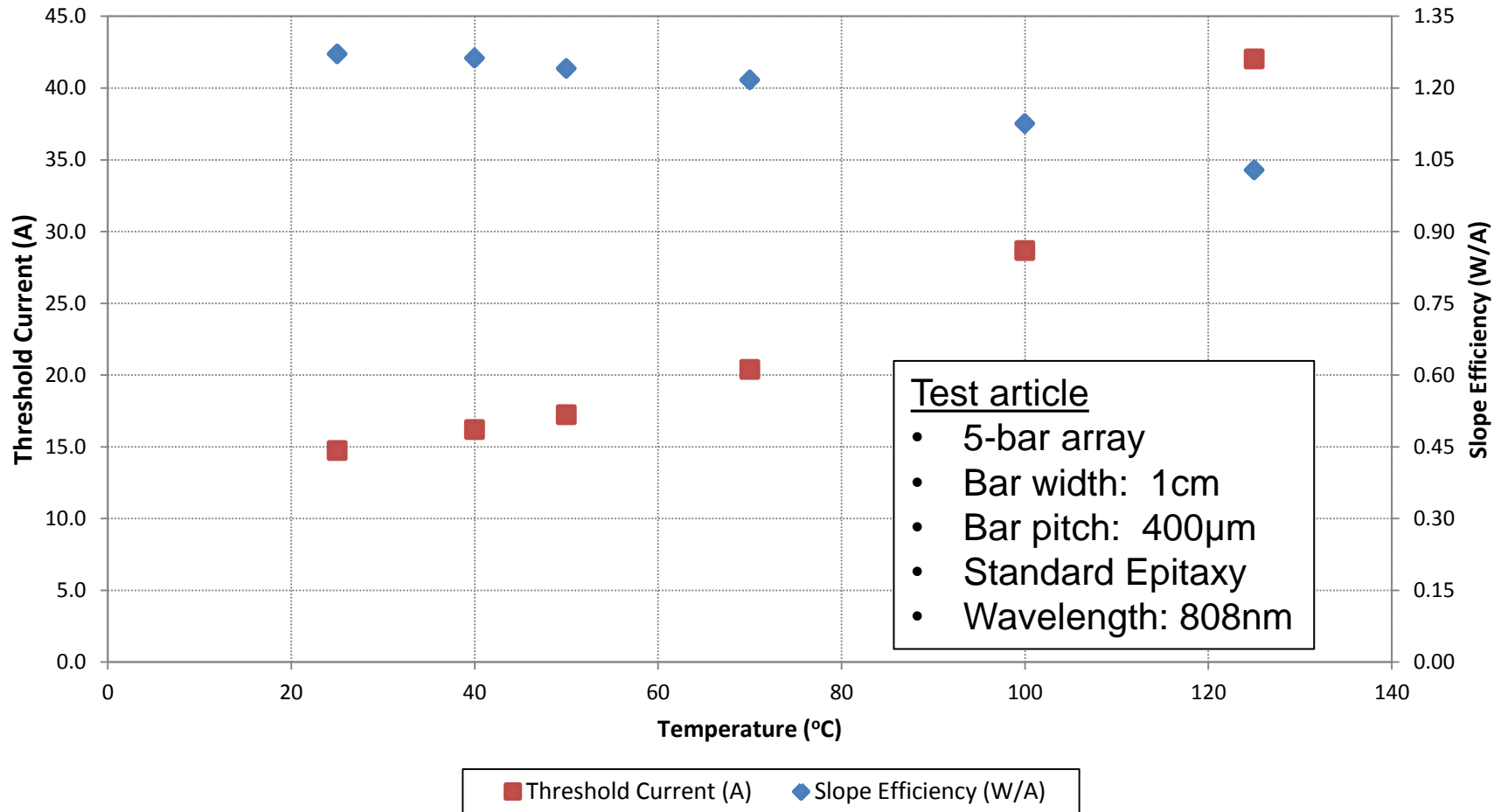
Diodes maintain excellent slope efficiency up to 125°C

E-O Efficiency and Output Power at Elevated Temperatures (Standard Epitaxy)



Standard epitaxy performed well across entire -40 to 85 °C range

Slope Efficiency and Threshold Current at Elevated Temperatures (Standard Epitaxy)

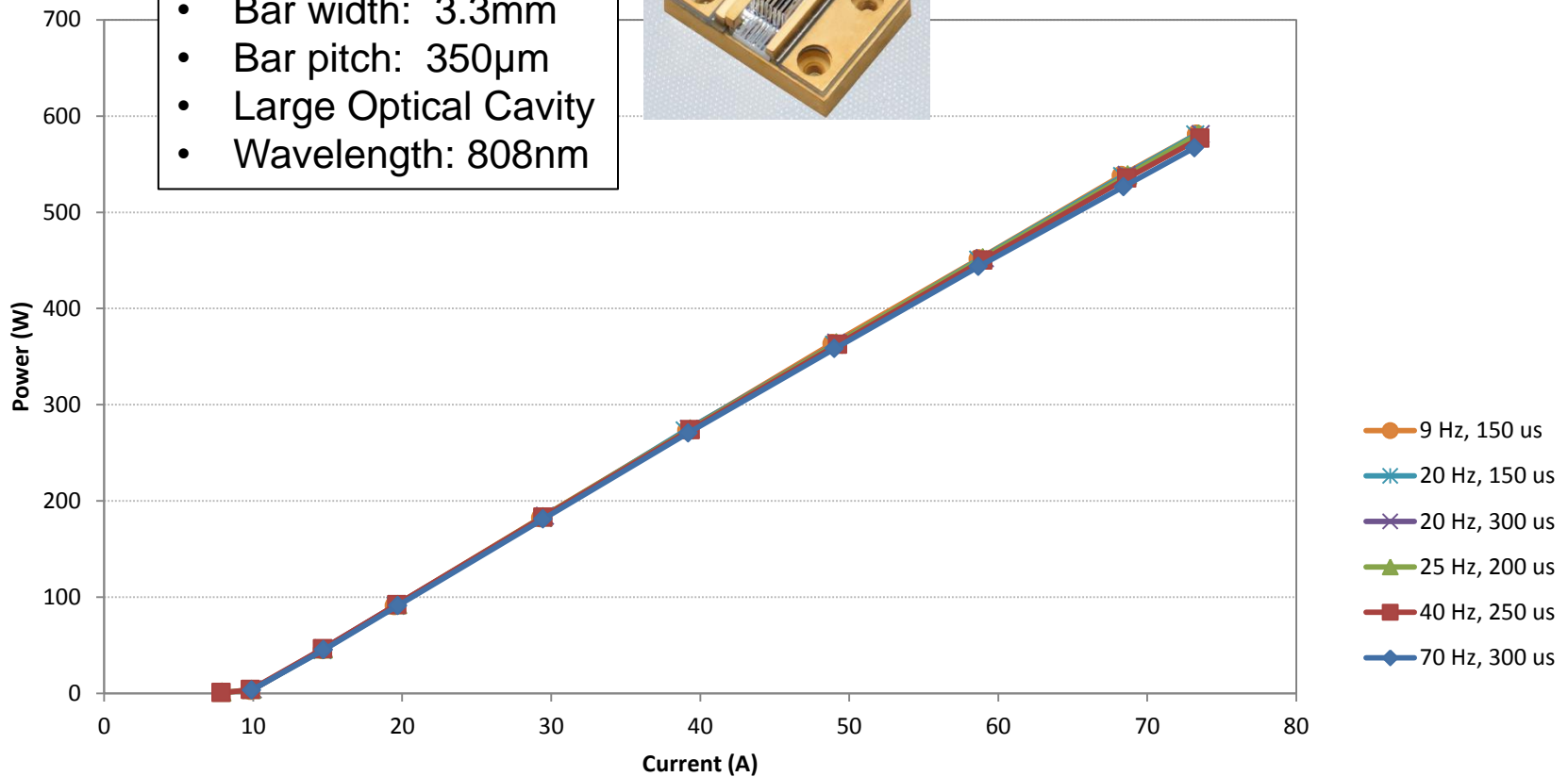
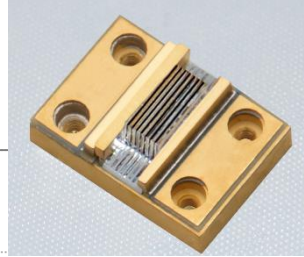


Minimal change in slope & threshold observed at elevated temperatures

P-I Curves at Various Duty Factors and Pulse Widths (Large Optical Cavity Epitaxy)

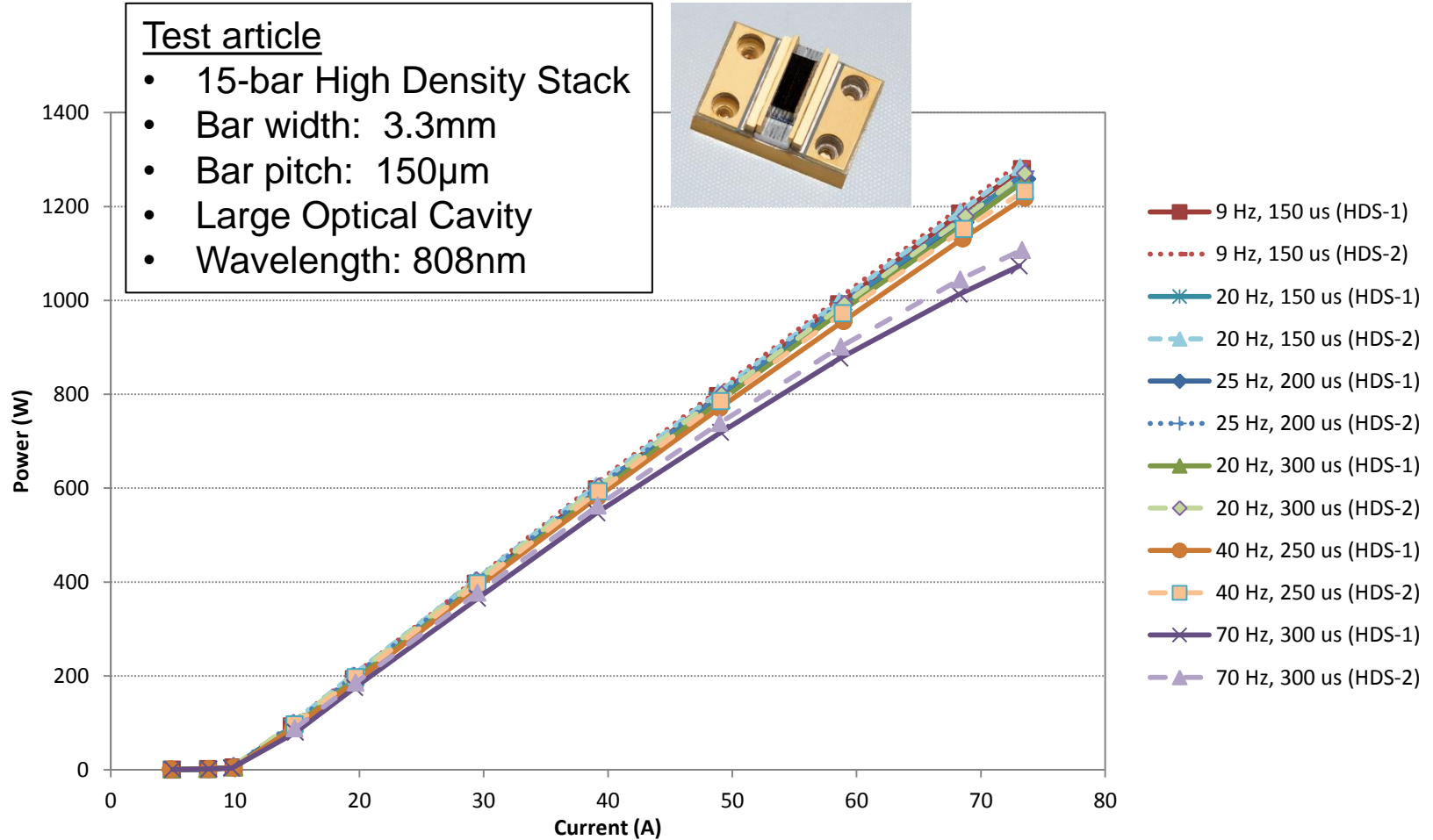
Test article

- 7-bar array
- Bar width: 3.3mm
- Bar pitch: 350 μ m
- Large Optical Cavity
- Wavelength: 808nm



Negligible change in slope efficiency for all tested drive conditions

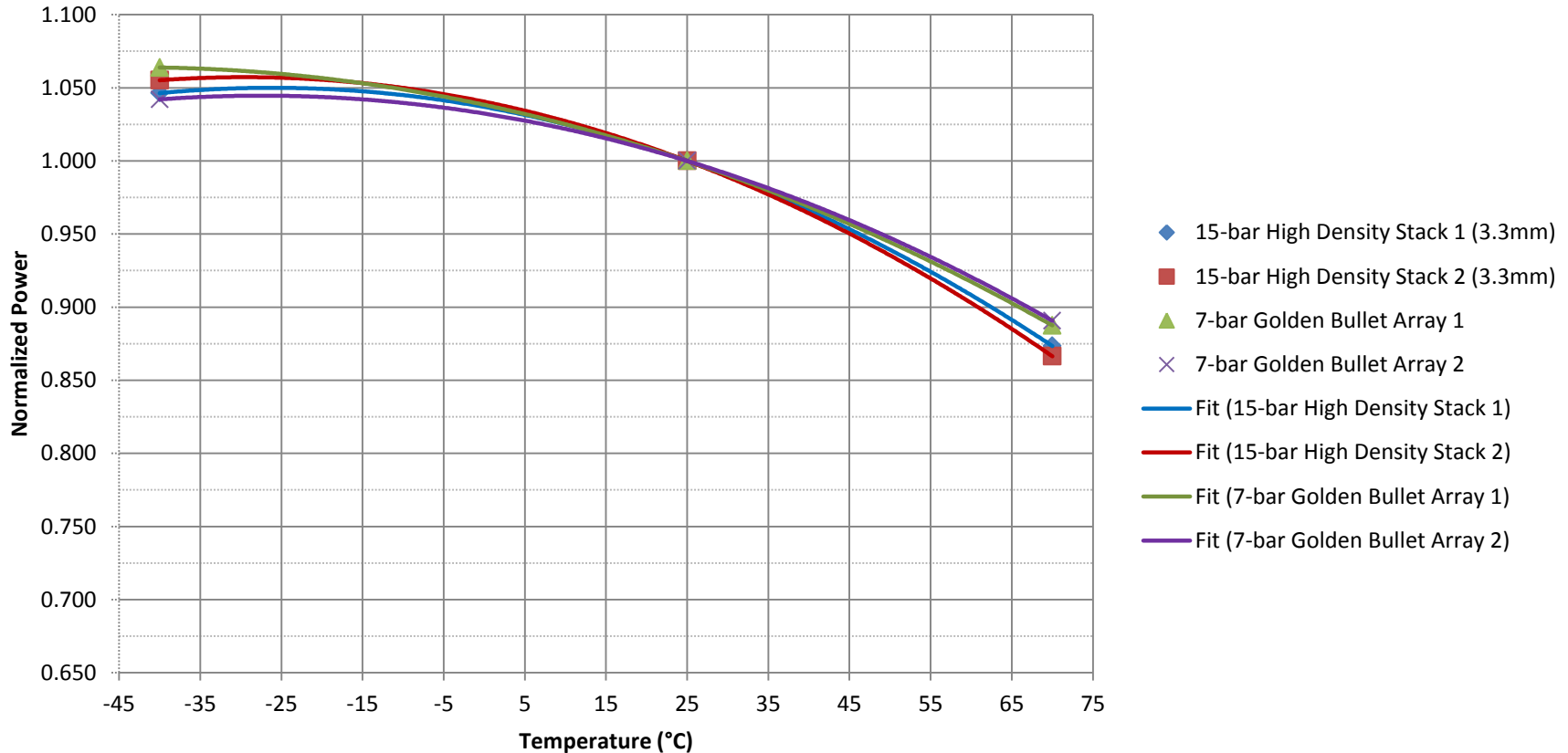
P-I Curves at Various Duty Factors and Pulse Widths (Large Optical Cavity Epitaxy)



High Density Stacks maintained slope up to 1% DF, slight decrease at 2.1% DF

Effect of Temperature on Output Power (Large Optical Cavity Epitaxy)

Performance of Mini-Bar Arrays (Large Optical Cavity 808nm Epi)

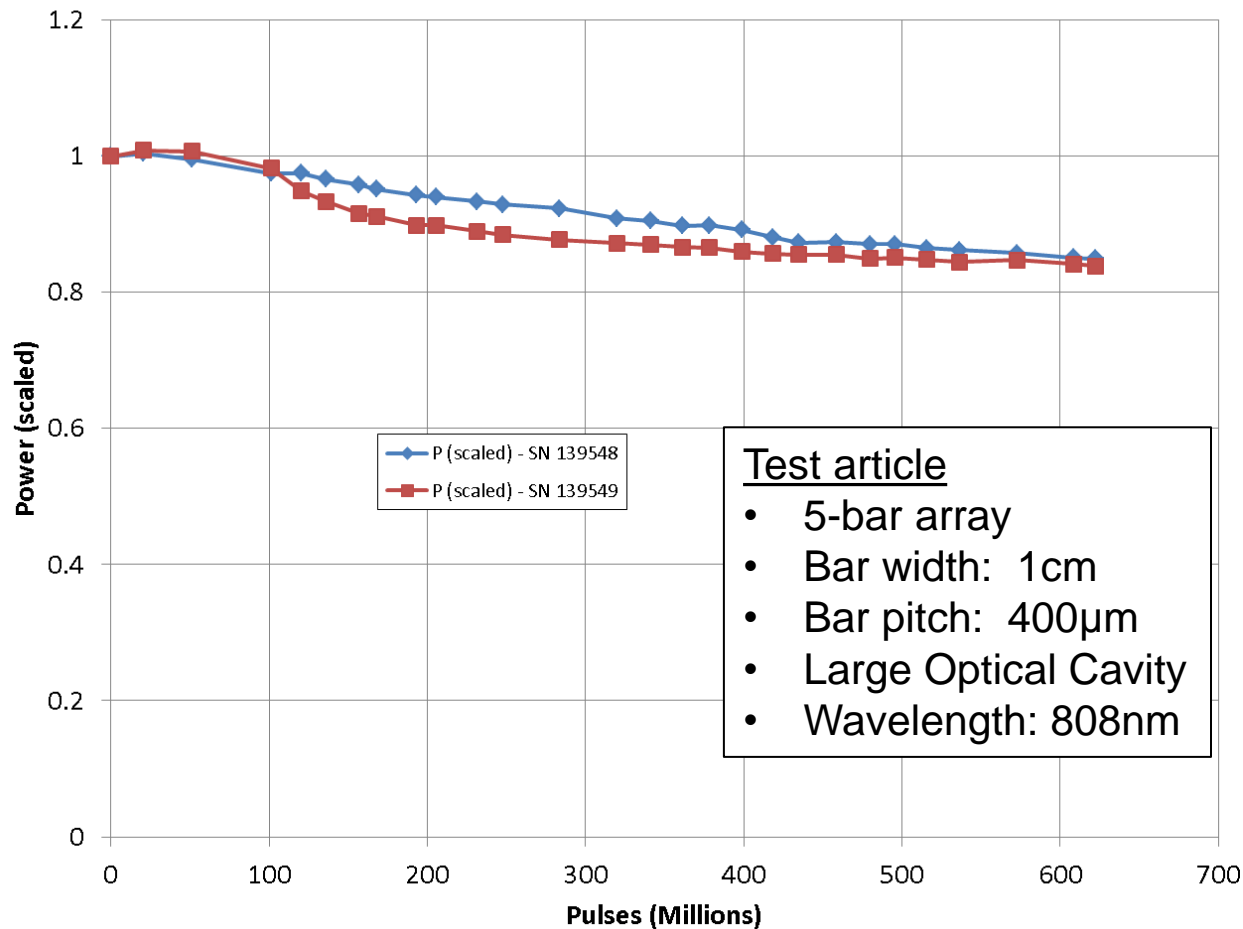


Large optical cavity epitaxy performed well across -35 to 70°C range

Life Test of Large Optical Cavity Epitaxial Material

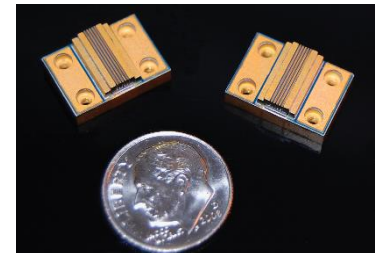
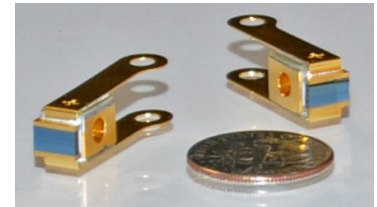
- CEO built (2) 5-bar arrays from large optical cavity epitaxial material
- These were built from 1cm bars and packaged into a standard CEO package
- The arrays were operated at 250A, 60Hz, 125 μ s, 80°C and were characterized periodically
 - 5-bar arrays produced approximately 940W at 80°C at beginning of life
- Arrays have accumulated ~ 622 million shots to date
 - ~ 16% total power loss
 - Excellent performance over lifetime for many applications requiring high-temperature operation:
 - Automotive
 - Hand-held range finders
 - Other military/aerospace

80°C Life Test



Arrays have accumulated >622 million shots at 250A, 60Hz, 125 μ s, 80°C

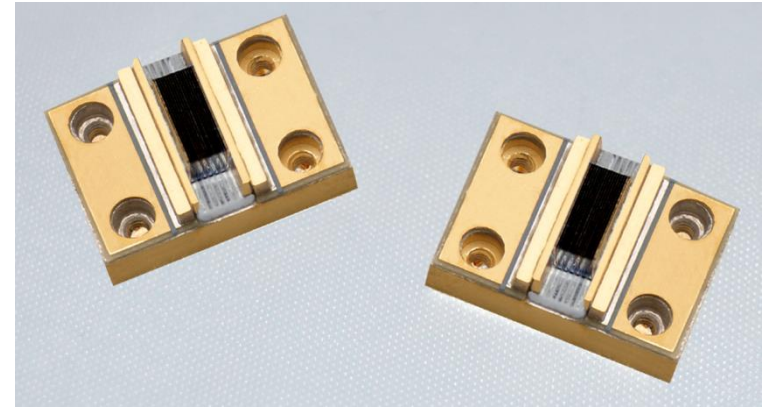
- NGCEO's laser diodes can be combined with hard soldered, CTE matched packaging to create high power arrays for harsh environments
- High Density Stack arrays provide a solution if extremely high power densities are required
 - Excellent performance at duty factors $\leq 2\%$
- All arrays maintained good slope, threshold and E-O efficiency at temperatures from -40°C to $+85^{\circ}\text{C}$
 - Array designs support operation at higher temperatures if desired
- 250A, 80°C life test results show that these arrays are well suited for high temperature operation
 - Less than 2.5% degradation observed per 100 Million shots at 80°C
 - Lower degradation expected at temperatures less than 80°C
 - Excellent candidate for automotive or military/aerospace applications



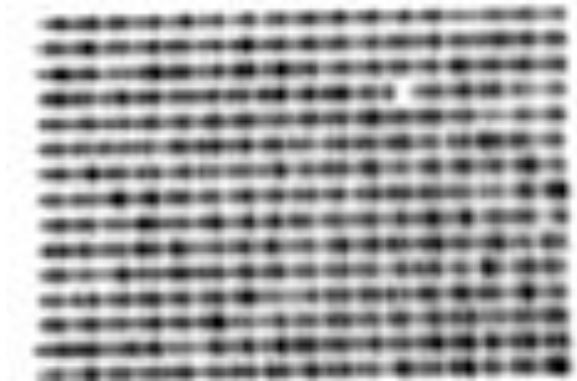
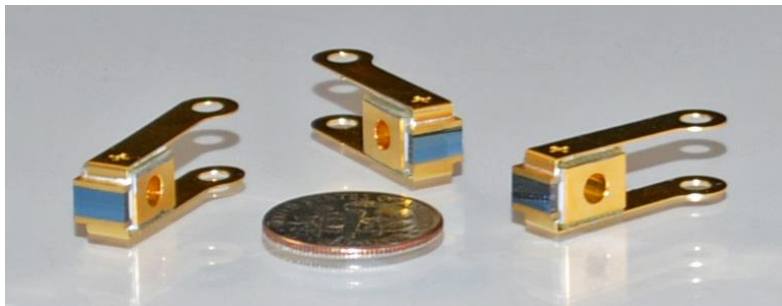
Advantages of High Density Stack Configuration

- Compact design

- Enables reduction in size and weight of QCW laser systems
- $<150 \mu\text{m}$ bar-to-bar pitch
- HDS at 150W/bar offers the same power density as 400 μm pitch array at 400W/bar
- Provides greater than $20\text{kW}/\text{cm}^2$ at 90A and greater than $26\text{kW}/\text{cm}^2$ at 120A



- All hard solder construction



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