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# Robust DPSS Lasers for LIDAR Applications

**Photonics West 2018**

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# Outline



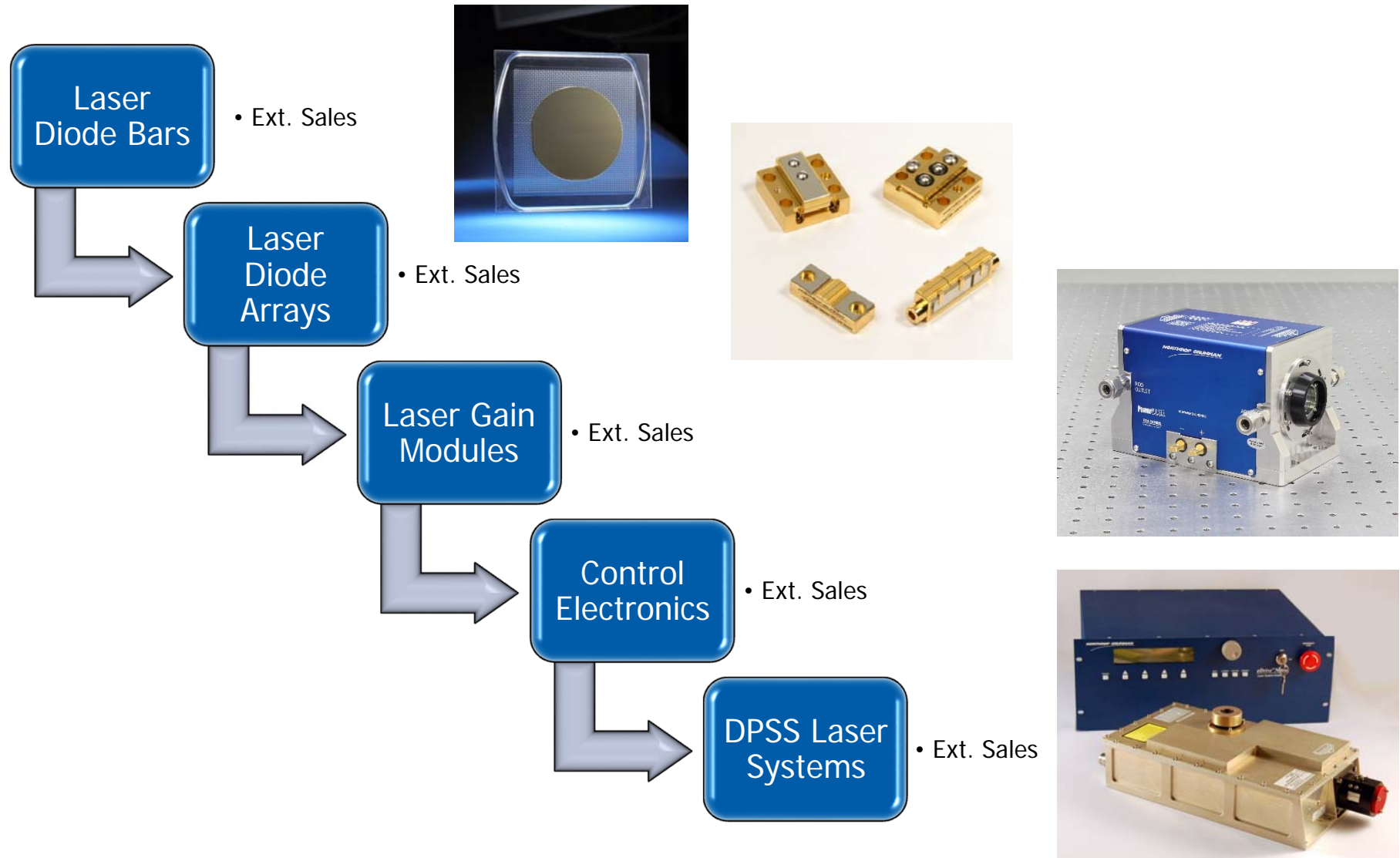
- 
- Introduction
  - Lasers for airborne LIDAR
  - Design challenges for airborne lasers
  - Detailed example of an airborne laser
  - Adapting ruggedized laser designs for ground based LIDAR
  - Conclusion

# Cutting Edge Optronics (CEO)

- Business unit of Northrop Grumman
- 25+ years in business
- Located in St. Charles, Missouri



# Vertically Integrated DPSS Laser Manufacturing



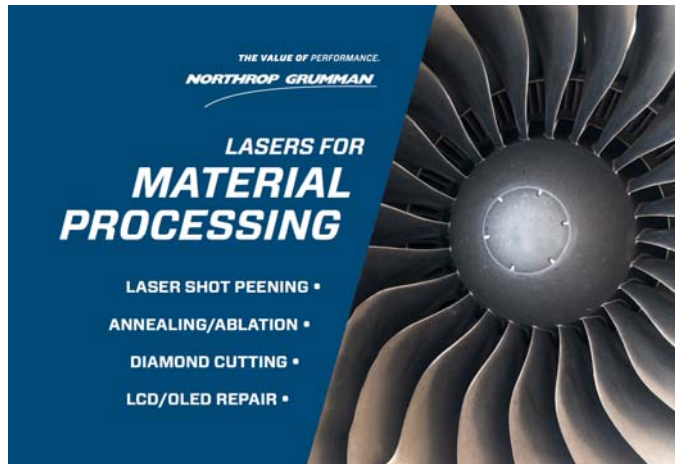
# Key Application Areas



**LASERS FOR  
Ti:SAPPHIRE  
PUMPING**

- EXCELLENT BEAM QUALITY
- ULTRA STABLE
- HIGH ENERGY
- LOW JITTER

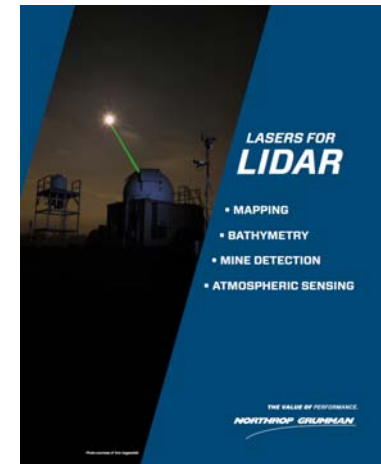
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**LASERS FOR  
MATERIAL  
PROCESSING**

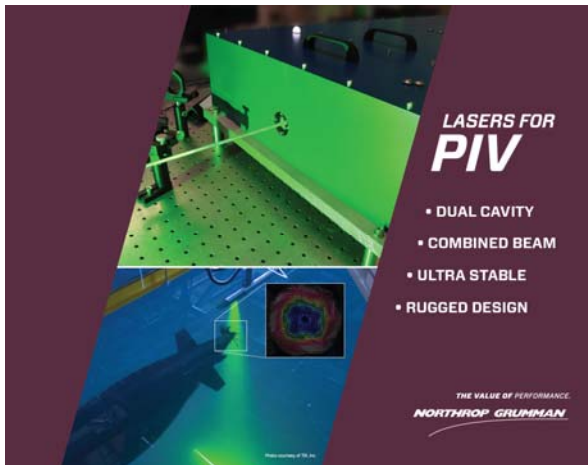
- LASER SHOT PEENING •
- ANNEALING/ABLATION •
- DIAMOND CUTTING •
- LCD/OLED REPAIR •



**LASERS FOR  
LIDAR**

- MAPPING
- BATHYMETRY
- MINE DETECTION
- ATMOSPHERIC SENSING

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**LASERS FOR  
PIV**

- DUAL CAVITY
- COMBINED BEAM
- ULTRA STABLE
- RUGGED DESIGN

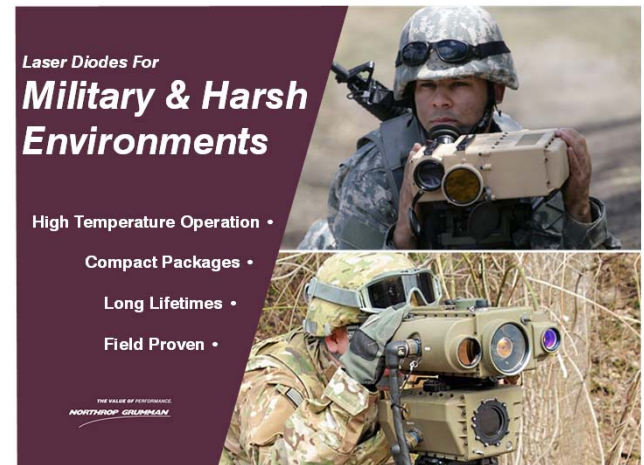
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**COMPONENTS FOR  
HIGH POWER LASERS**

- Diode Bars
- Diode Arrays
- Gain Modules
- Drive Electronics



**Laser Diodes For  
Military & Harsh  
Environments**

- High Temperature Operation •
- Compact Packages •
- Long Lifetimes •
- Field Proven •

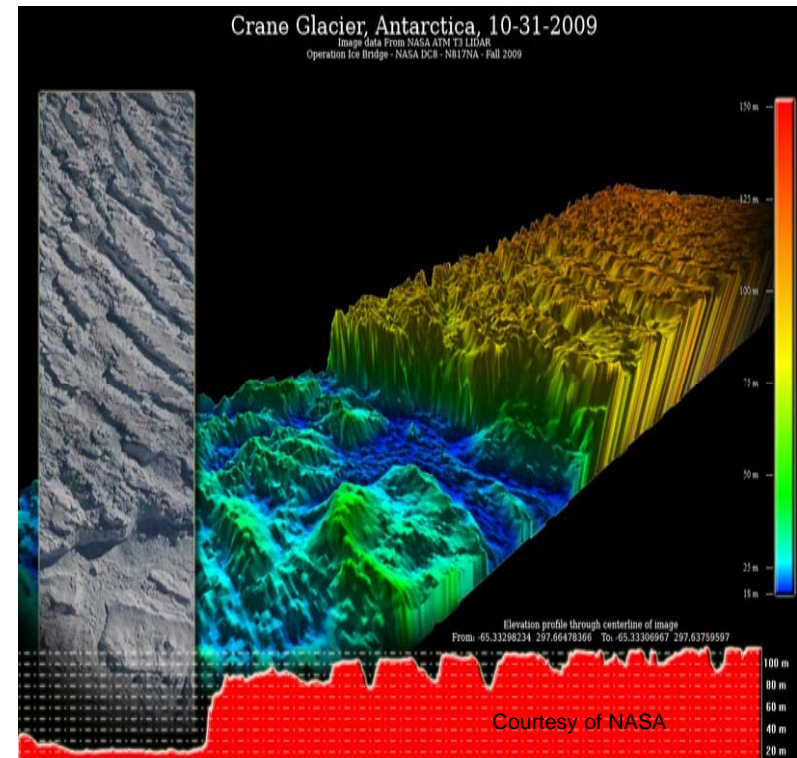
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Matching laser performance with applications

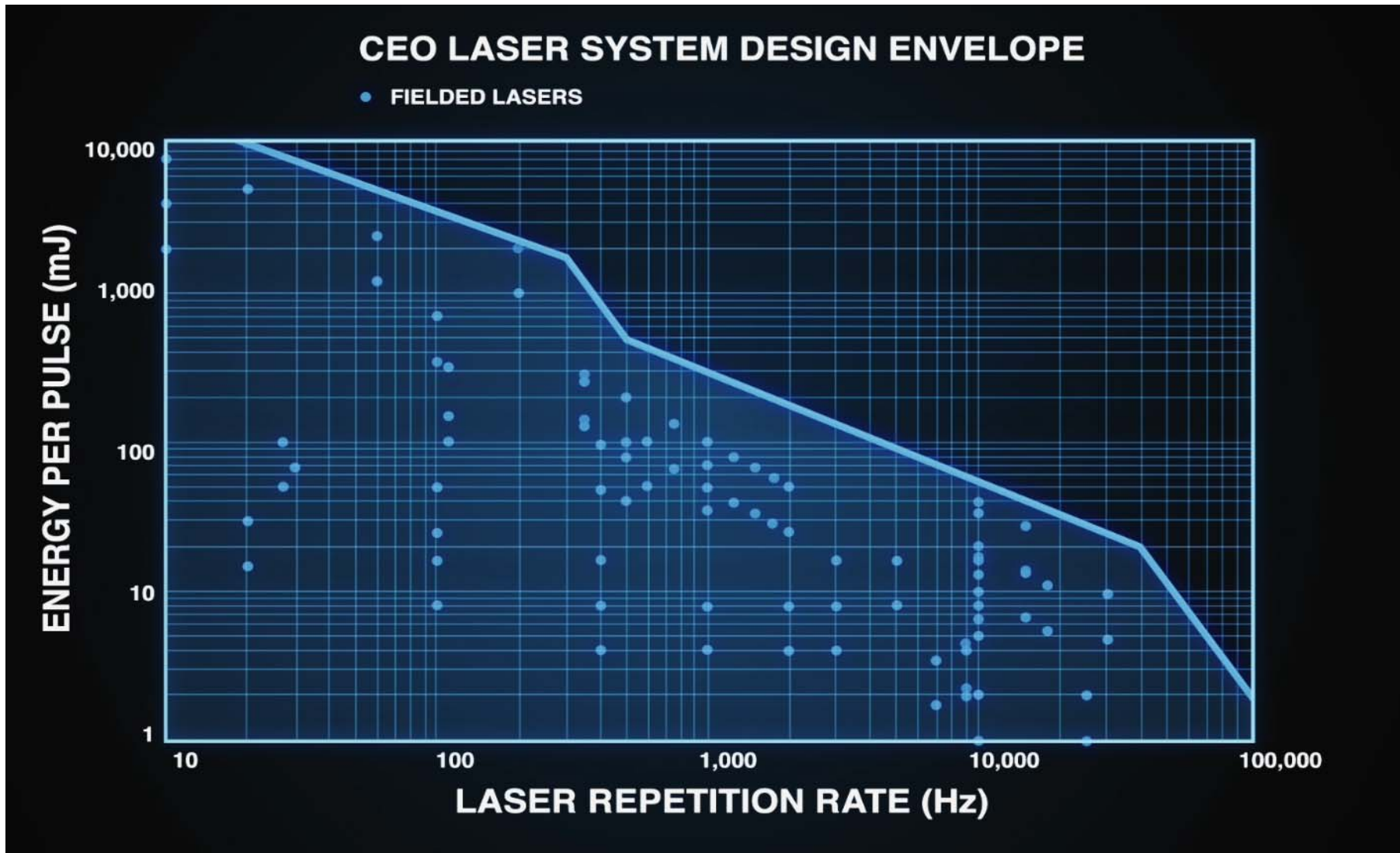
# Lasers for Airborne LIDAR Applications



- Mapping
  - Vegetation
  - Glaciers
  - Topographical
- Bathymetry
- Naval mine detection & classification
- Atmospheric sensing



# Laser Design Envelope



# Design Challenges for Airborne Lasers

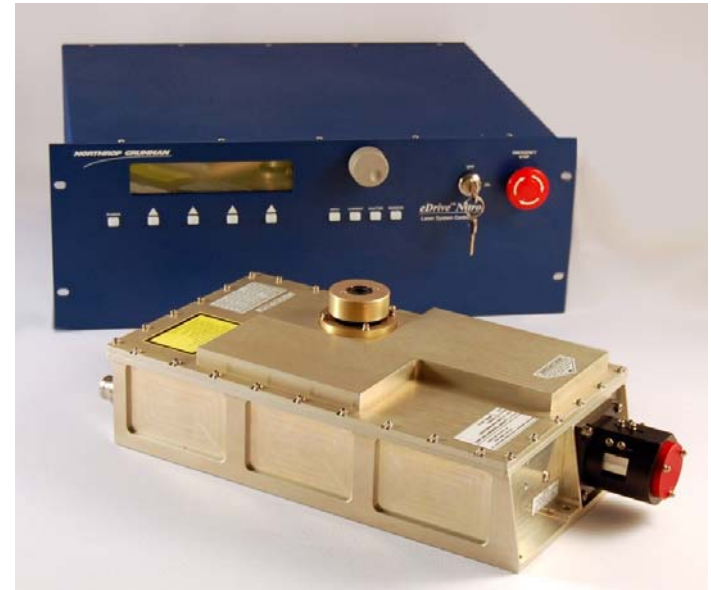


- Operation on helicopter & fixed wing aircraft
  - UH-1 helicopter to C-130 (and everything in between)
- High vibration environments
  - Take-off & landing shocks
  - Rotor & propeller beating
  - Turbulence during low altitude operation
- Significant thermal cycling
  - During flight (low altitude vs. high altitude)
  - On flight line
- Size, weight, and power (SWAP) constrained
  - Limited space
  - Dealing with aircraft electrical power (AC vs. DC)
  - Limited cooling options
- Meeting laser performance requirements in real world environment
- Requires high reliability
  - Lasers must perform during missions
  - Laser failures = lost time, lost data & significant lost \$



# Example Airborne Laser Design

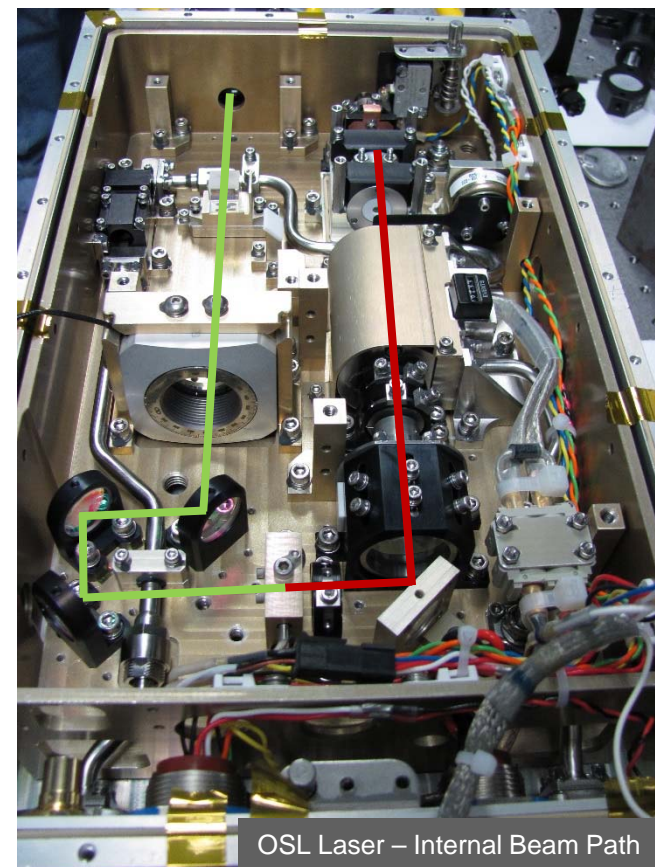
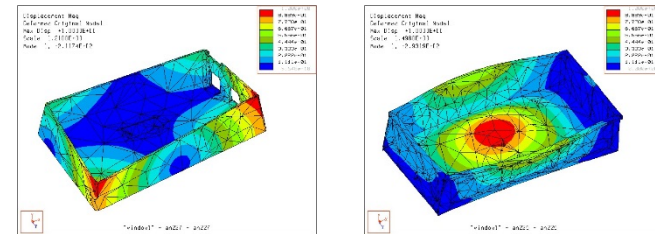
- OSL series laser
  - Repetition Rate: 1 - 3 kHz
  - Wavelength: 532 nm
  - Energy per Pulse: 2-4 mJ (depending on model)
  - Pulse Duration: < 6.5 nsec
  - Beam Diameter: < 6 mm
  - $M^2$ : < 5
  - Operating Temperature: +5 °C to +40 °C
  - Storage Temperature: -20 °C to + 60 °C
  - Shock, Vibration, EMI: RTCA/DO-160D
  - Diode Lifetime: 10 billion shots
  
- Laser optical design
  - Oscillator only
  - Linear cavity
  - 2 mm Nd:YAG rod (RB20 gain module)
  - EO Q-Switched
  - KTP second harmonic stage



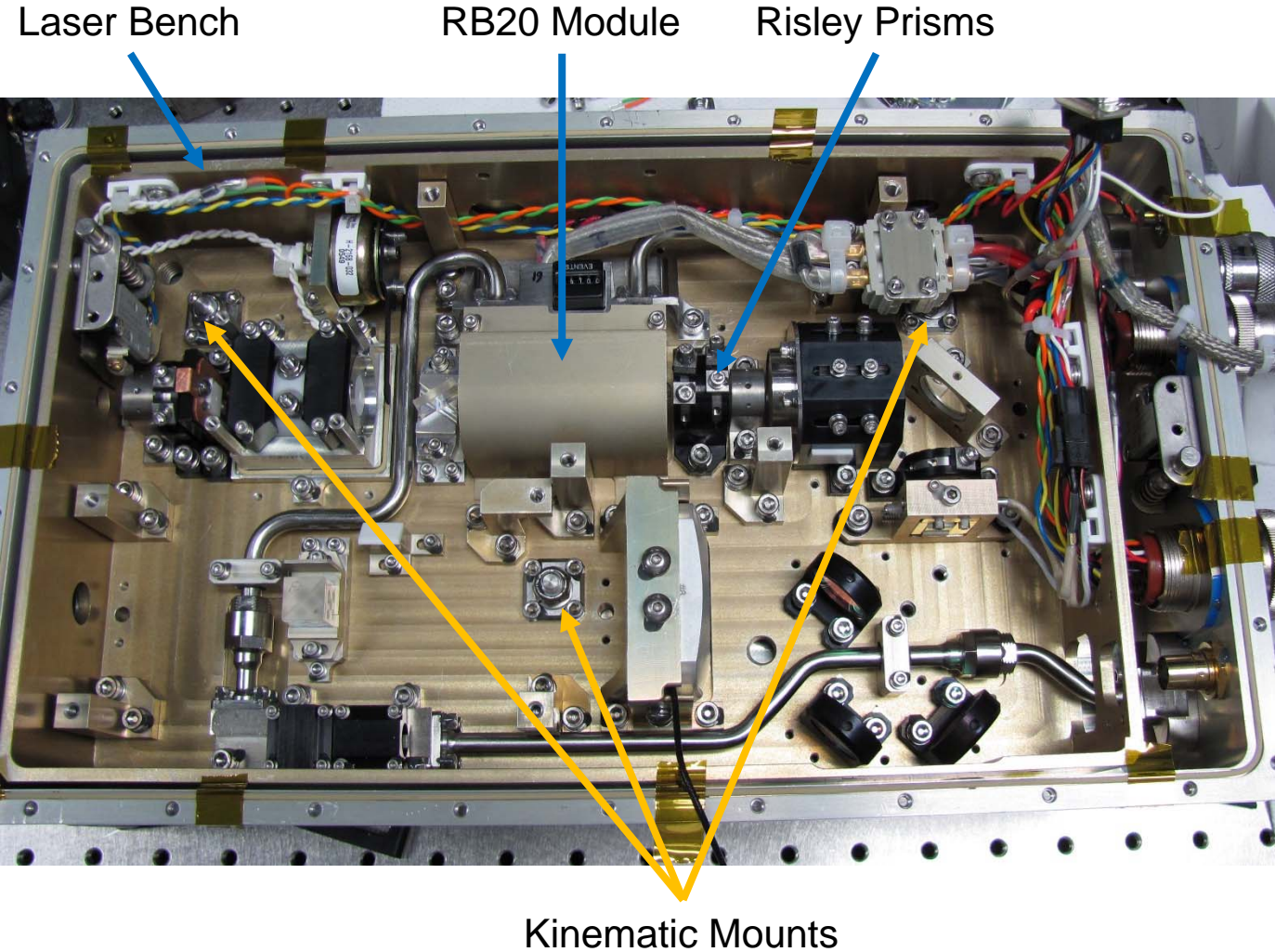
# Designing for Environmental Factors



- Optical bench & Housing
  - Stiff & stable (mechanical modeling and FEA)
  - Light weight
  - May require specialty materials
- High quality kinematic mounts
  - Allows for bench expansion & contraction
  - Helps isolate optical bench from housing
- Limit use of adjustable optical mounts
- Optical bonding
  - Use of techniques to reduce bonding stress
  - Factor in CTE of mount, optic and bonding agent
- Hard plumbing
  - Reduces moisture in housing
  - Reduces the potential for leaks inside the laser

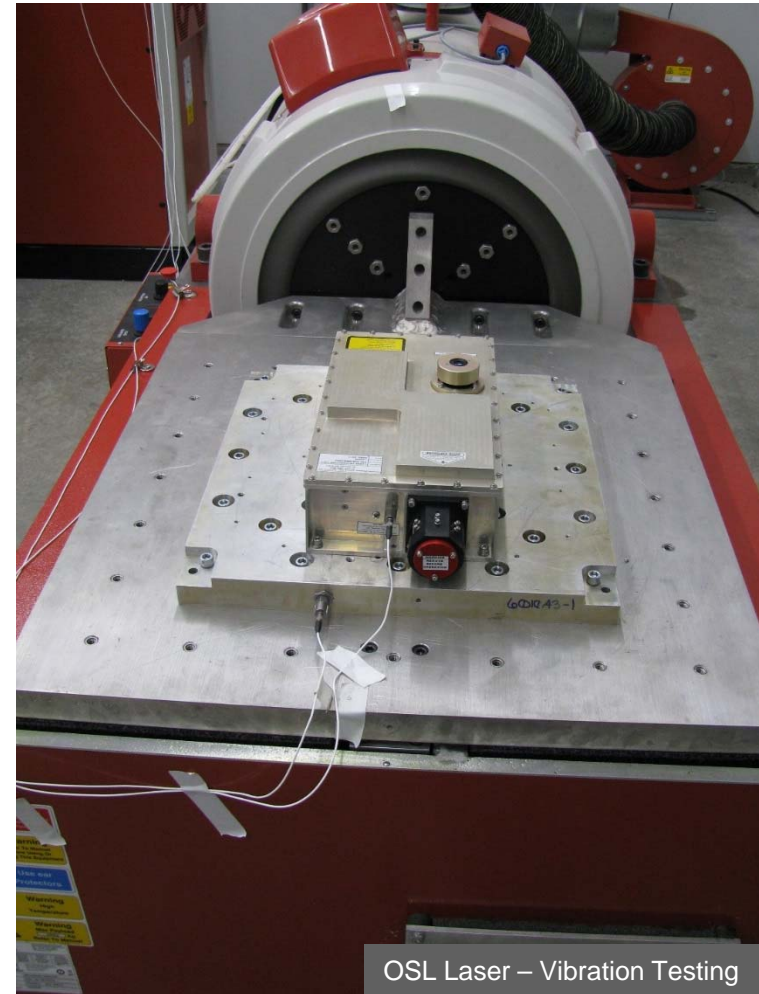
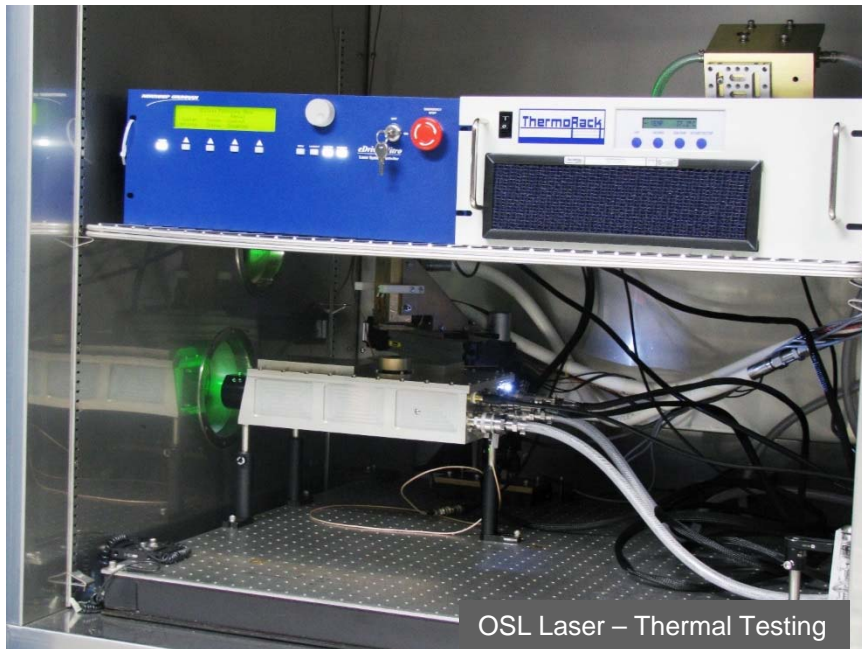


# OSL Series Laser – Inside View

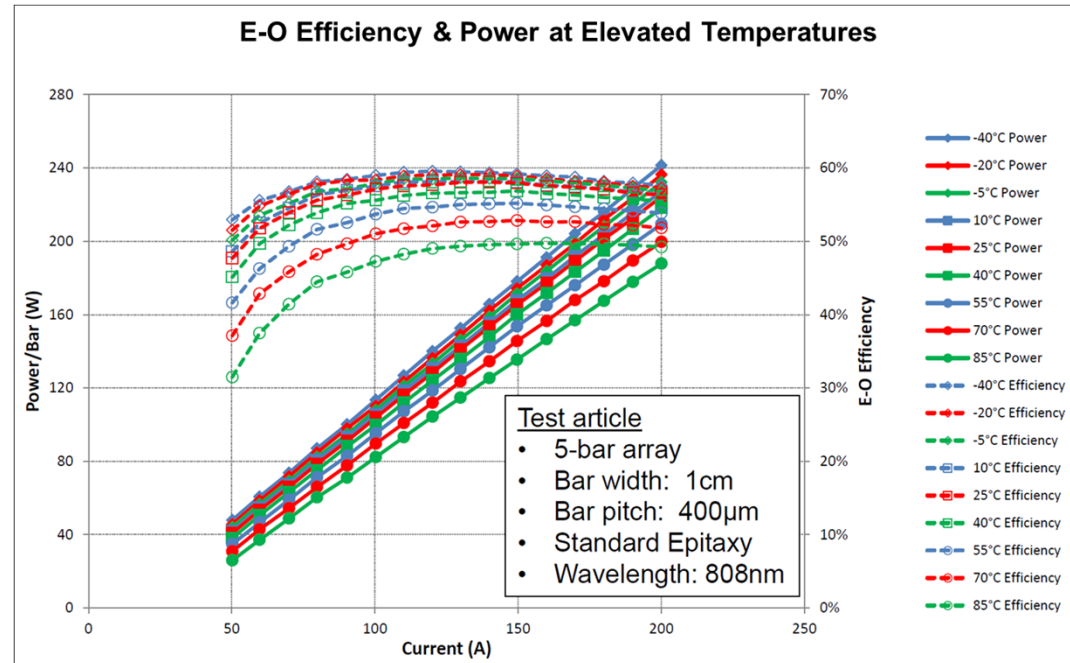


# Designing for Environmental Factors

- Verify design – test, test, test
  - Test over expected storage & operating environments
  - Test over expected shock & vibration spectrums



- Laser diodes are key
  - High efficiency
  - Able to operate at elevated temperatures
  - Long lifetime
    - CEO laser diodes
    - Standard lifetimes of 13-15 billion shots
    - > 1,200 hours at 3 kHz
    - > 3,600 hours at 1 kHz
- Optical design
  - Minimize sensitivity in opto-mechanical design
  - Keep fluence levels reasonable (~1.5-2 J/cm<sup>2</sup> @ 1064 nm)
  - High quality optics & coatings



Example Laser Diode Array Performance

# Adapting Airborne Laser Design Practices to Ground Based Lasers for LIDAR

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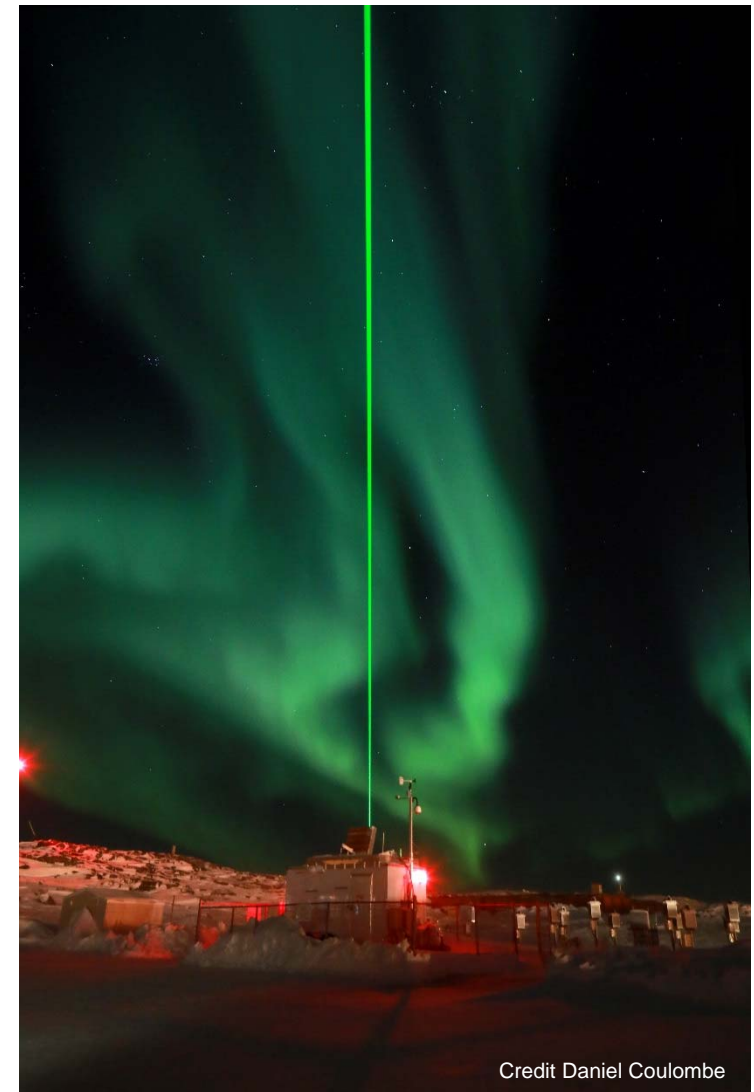
# Gigashot-L Series Laser for LIDAR



- New series DPSS lasers for LIDAR
  - Repetition Rate: 100 Hz
  - Energy per Pulse:
    - > 250 mJ @ 1064 nm
    - > 180 mJ @ 532 nm
    - > 125 mJ @ 355 nm



Credit Tom Zagwodzki

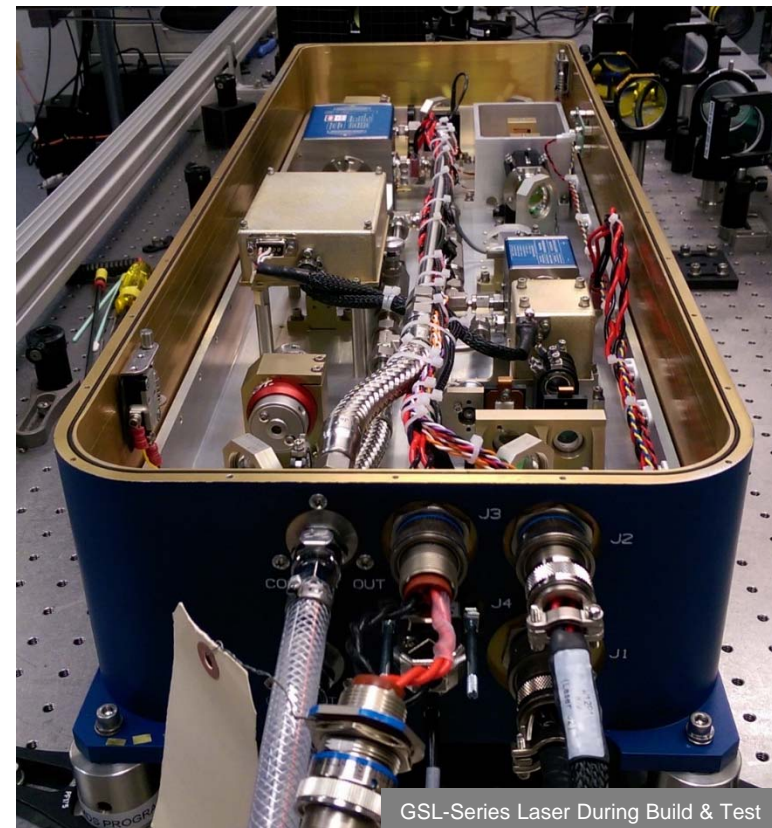


Credit Daniel Coulombe

# Gigashot-L Series Laser for LIDAR



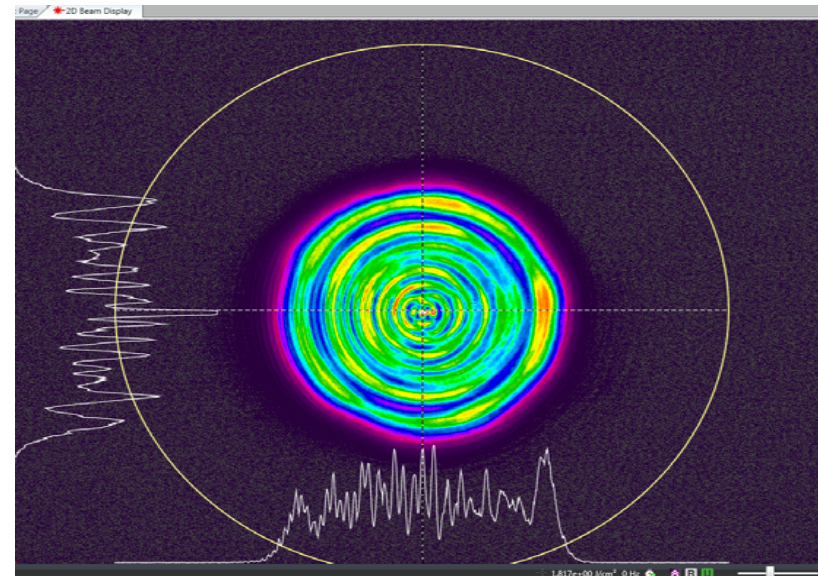
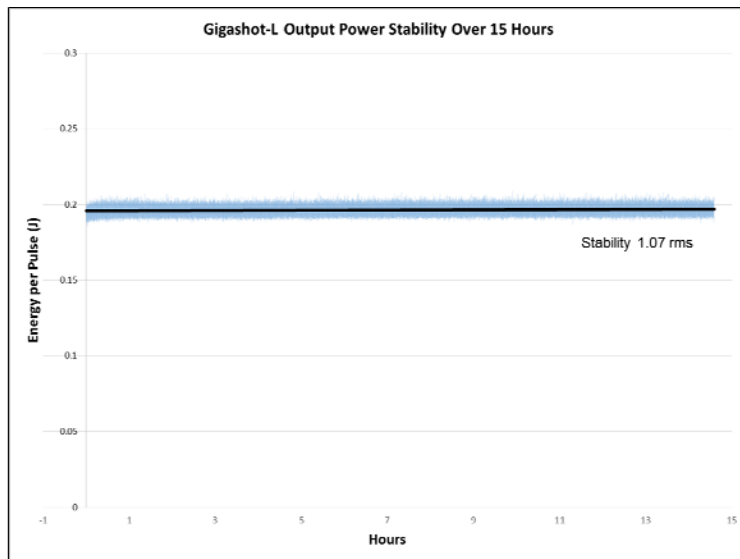
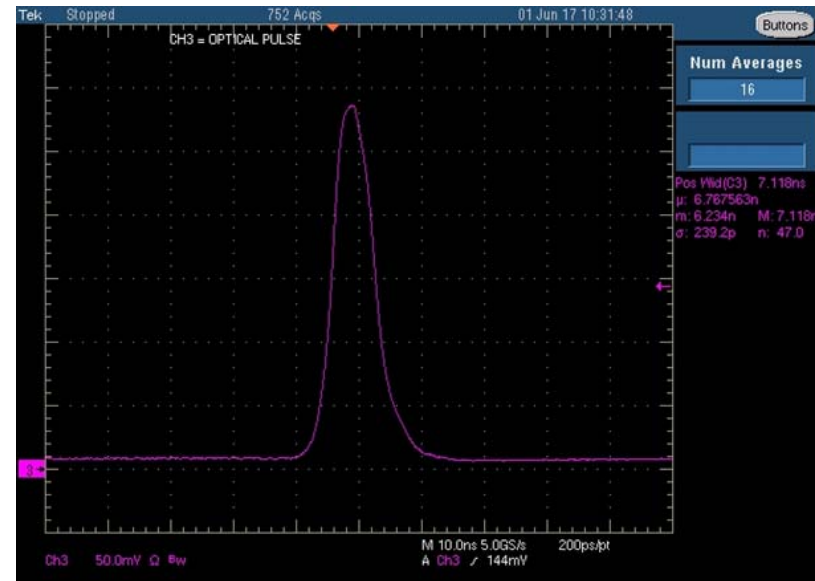
- Ruggedized & stable mechanical design
  - Stiff optical bench
  - Precision kinematic mounts
  - Non adjustable mounts
  - Stable opto-mechanical design
    - Highly resistant to misalignment
    - No user alignment required
- Long life laser diodes
  - Rated for 13-15 billion shots
  - 4+ years 24/7 operation (>36 kHrs)
- External communication (Ethernet)
  - Laser can be remotely controlled, monitored & adjusted (if required)
  - Ideal for remote locations



# Gigashot-L Series Laser for LIDAR

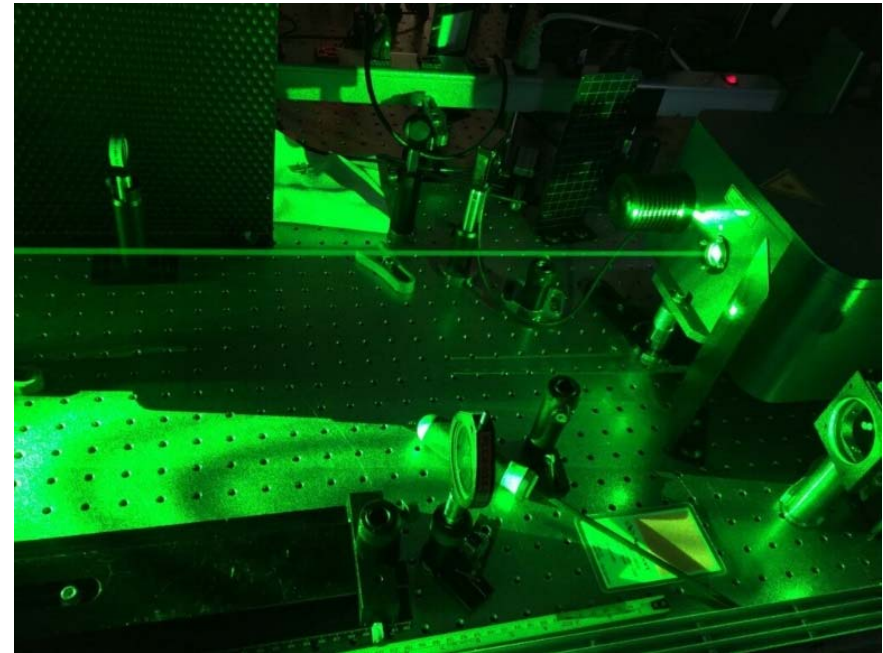


- Additional measured performance
  - Pulse duration: 6.7 nsec
  - $M^2 < 3.3$  (532 nm)
  - Beam diameter: 5.2 mm
  - Divergence:  $< .53$  mrad (full angle)
  - Stability  $< 1.07$  % rms
  - Beam pointing stability:  $35 \mu\text{rad}$
  - Injection seeded version in 2018



# Conclusion

- CEO has a long history of designing & building robust airborne laser systems
- CEO has adapted designs and practices used in those laser systems to develop a new ruggedized laser for ground based LIDAR (Gigashot-L)
- The Gigashot-L laser does not require user alignment and can be remotely operated via Ethernet
- This laser is ideal for operations in remote locations and/or in laboratory environments



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# Questions?



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