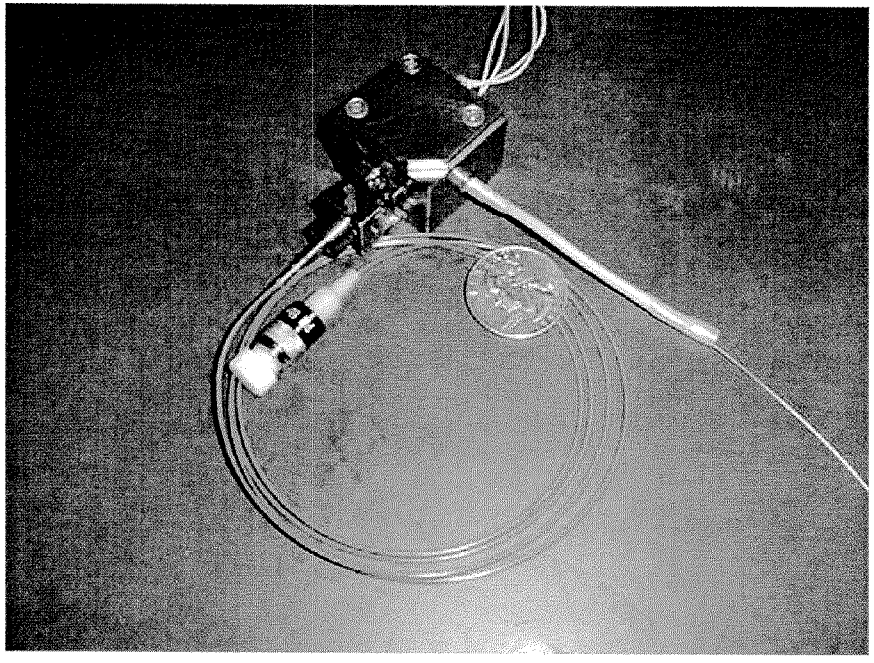
Reliable, Laser-welded Packaging of a Nd:YAG Laser for Spaceflight Application



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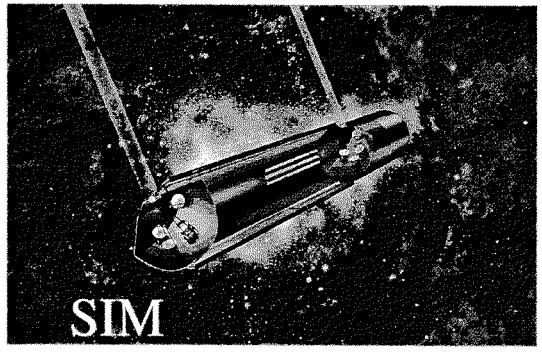
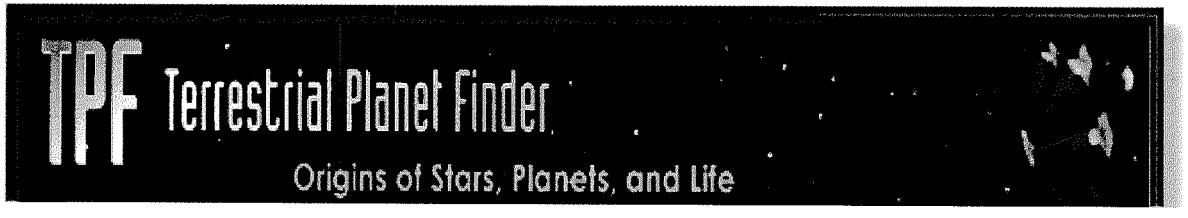
Overview

- Motivation and Background
- Brassboard Laser Design
- Test results and conclusions
- Novel redundant pump configuration
- Summary

Motivation

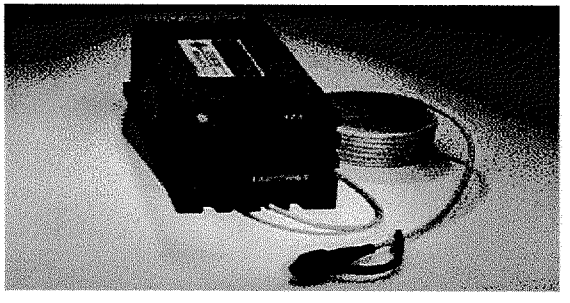
- Upcoming missions could benefit from a laser that is:
  - High-performance
  - Reliable
  - Designed to survive the rigors of space
- Laser packaging improvements can be applied to other optical systems for space





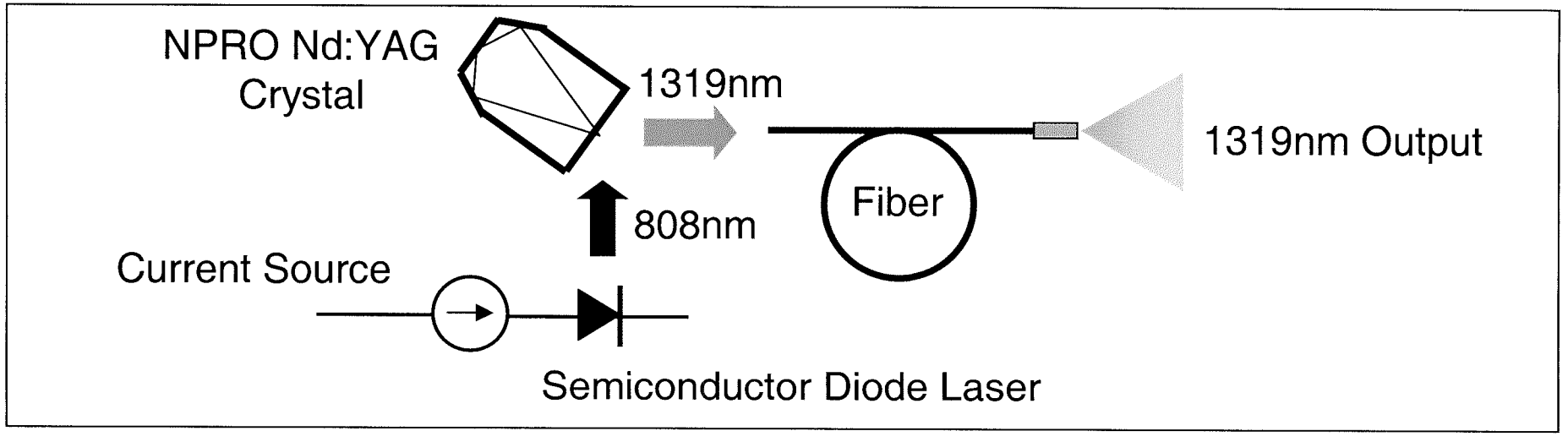
Background

- High-performance means:
  - Stable, single mode output (required for metrology)
  - Relatively high output power (~ 200 mW)
- Commercial laser from Lightwave Electronics Corporation meets these requirements
  - Monolithic resonator called an NPRO™ (Non-Planar Ring Oscillator) provides stable, single mode operation
  - Free-space or fiber-coupled output at 1319nm or 1064nm and requisite power



- Disadvantages:
  - Packaging not designed for harsh environments
  - Not intended for long-life missions in space

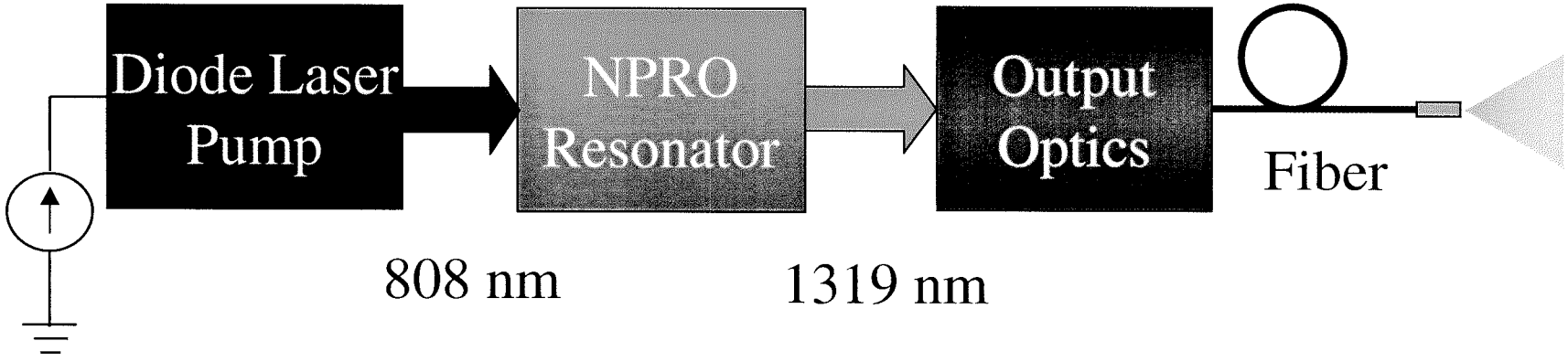
Laser Nomenclature



- Nd:YAG (Yttrium Aluminum Garnet crystal doped with Neodymium ions) – Solid-state lasing material
- NPRO™ (Non-Planar Ring Oscillator) – patented shape for Nd:YAG crystal that produces single-frequency output
- Metrology Laser – Solid-state laser consisting of an NPRO™ crystal, made of Nd:YAG, that is optically pumped by a semiconductor laser

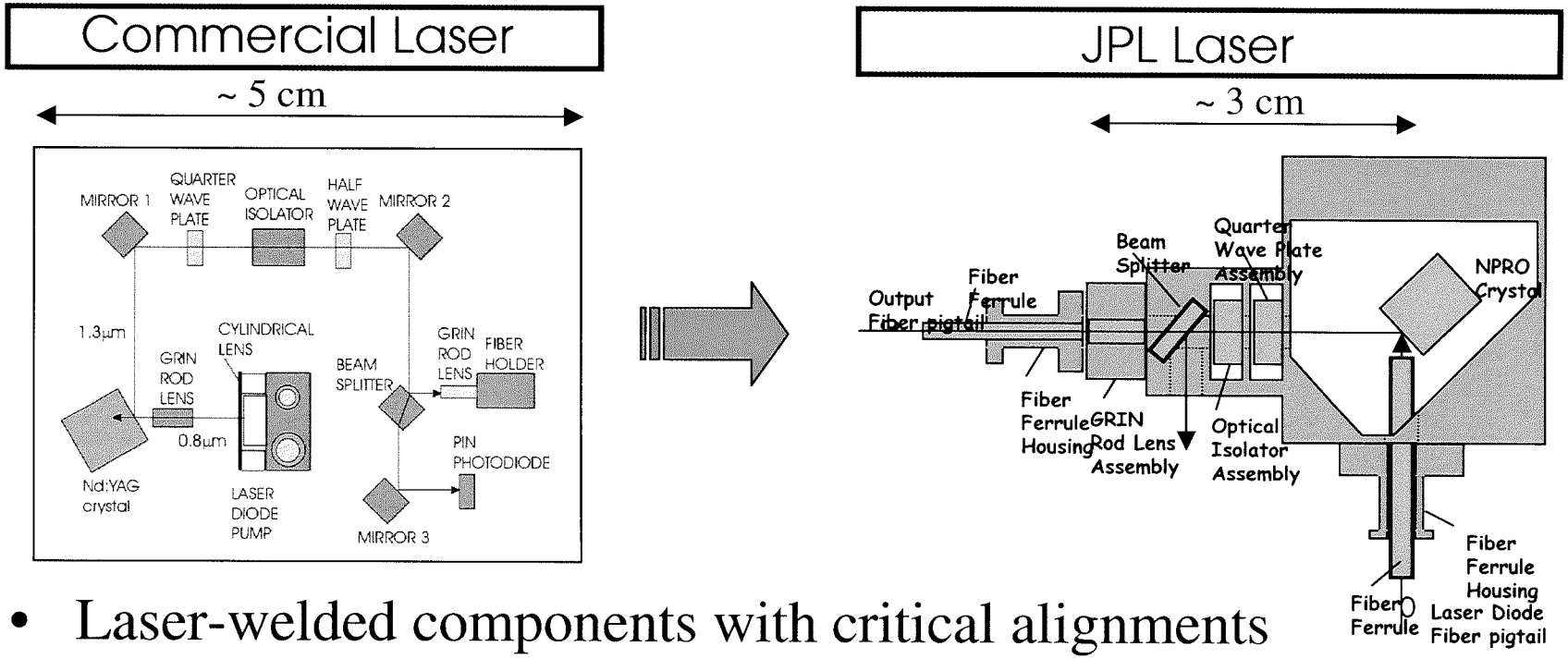
Reliability Concerns

LASER SYSTEM DIAGRAM



- Alignment stability between pump and NPRO™
- Alignment stability between NPRO™ and output optics
- Reliability of pump laser diode

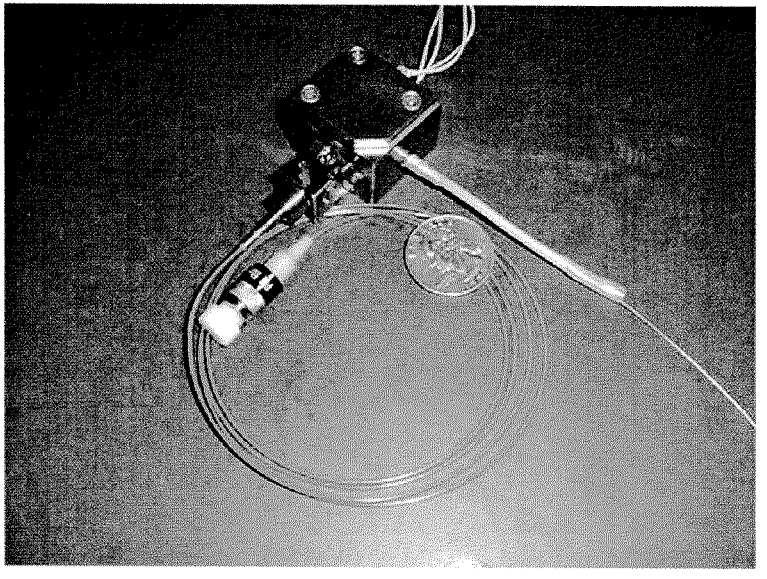
Brassboard Laser Design



- Laser-welded components with critical alignments (Input pump fiber, Output fiber, GRIN lens)
- Shortened optical path from ~ 8cm to ~ 3cm
- Pump light delivered via fiber
- Reduced number of component interfaces
- Replaced TEC under NPRO™ with alumina heater pad

Laser Performance

- Three Brassboard Lasers were built
- Identical assembly process except for high Tg adhesive under NPRO™ in BB 2C



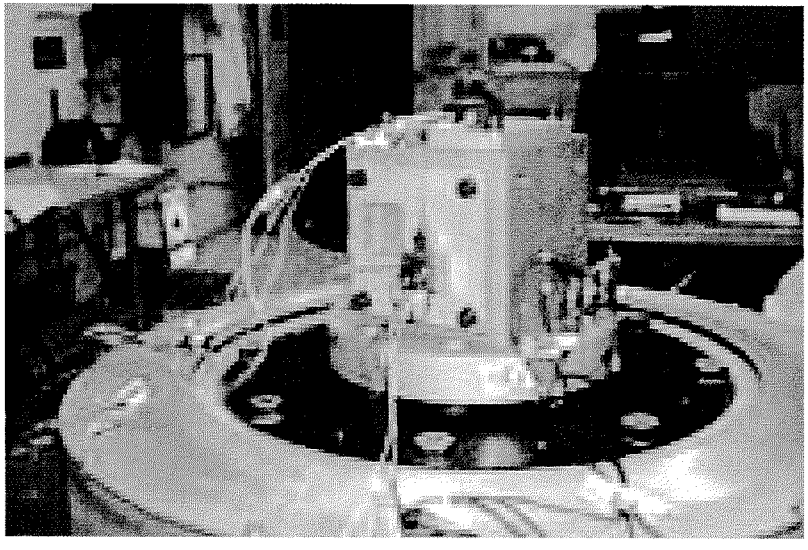
	BB 2A	BB 2B	BB 2C
Output Power (w/ 1W pump)	200 mW	198 mW	170 mW
Efficiency	20 %	19.8 %	17 %

Design Reliability Testing

- Long-term life test at room temperature (~ 1 year)
- Vibration
  - Laser BB 2B: Sine Survey, Sine Vibration and Random Vibration
  - Lasers BB 2A, BB 2C: Random Vibration only
  - Overall Random Vibration: 22 g-rms
- Thermal Cycles
  - Laser BB 2A, BB 2B:

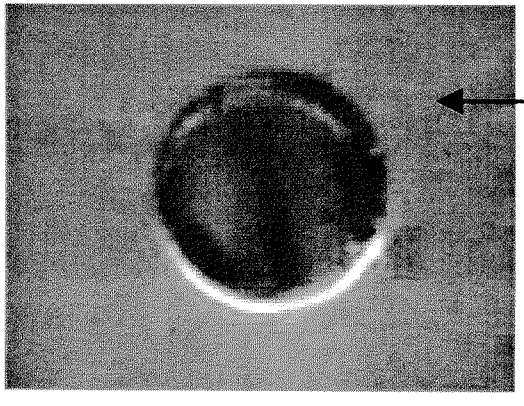
    range from –20°C to +55°C
  - Laser BB 2C:

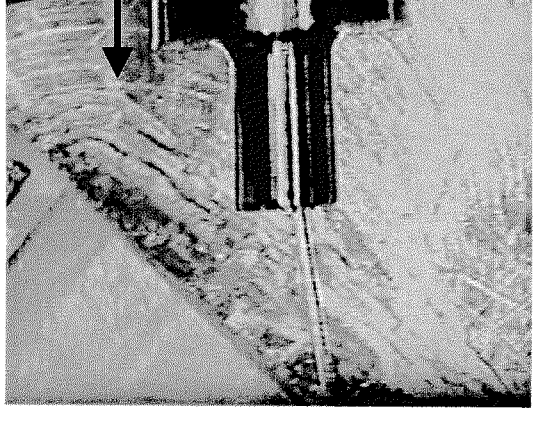
    range from –20°C to +70°C



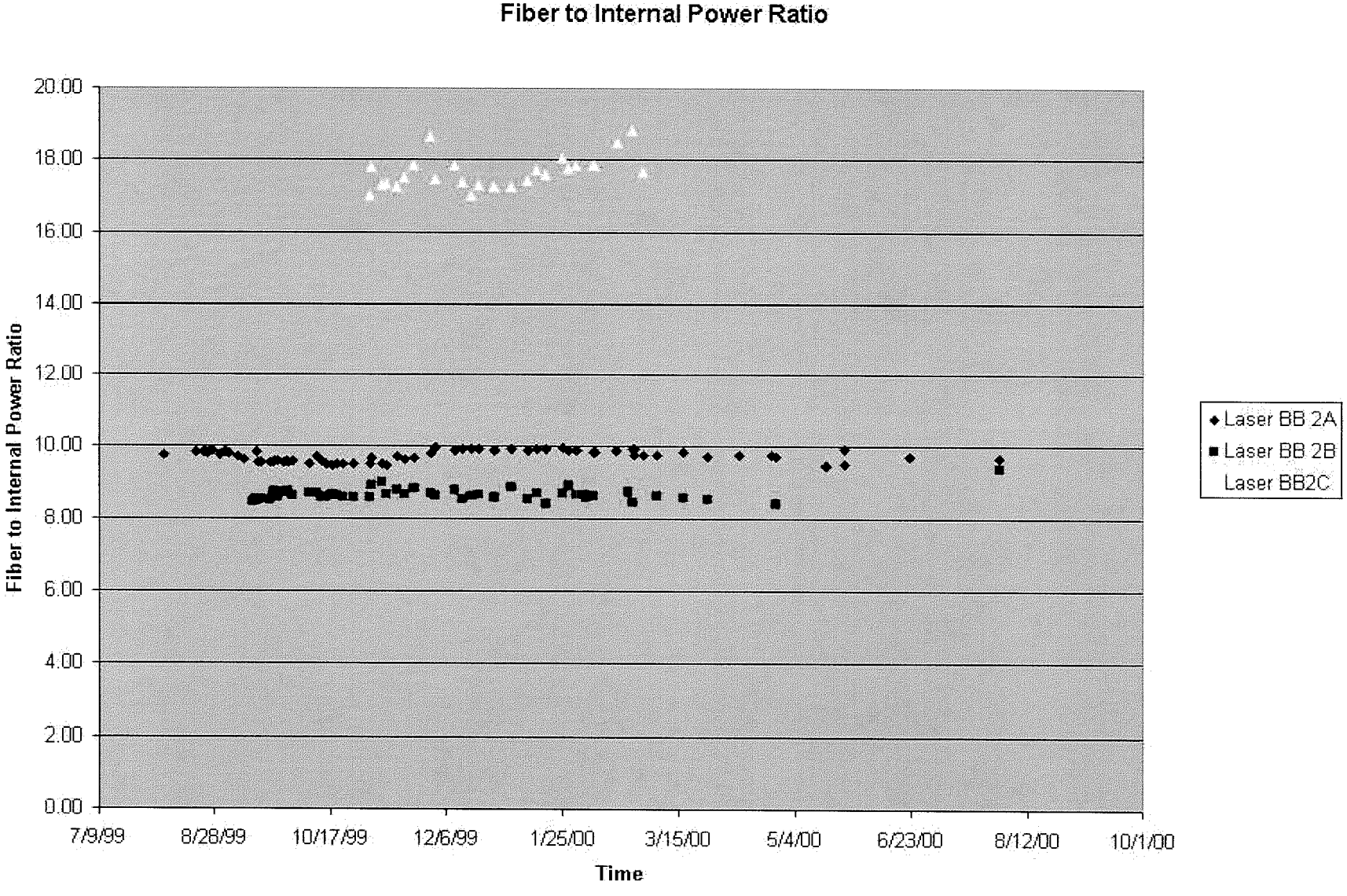
Environmental Test Results

Test	Results		
	BB 2A	BB 2B	BB 2C
Vibration Tests Sine and Random Overall: 22.3 g-rms	Unchanged	Unchanged	Unchanged
12 Thermal Cycles -20 to +55 deg C	Unchanged	Fiber to Internal Power Ratio unchanged; Internal Power ↓ 10% (bad pump fiber connector)	--
12 Thermal Cycles -20 to +70 deg C	--	--	Catastrophic failure due to unsuitable fiber jacketing material and assembly method

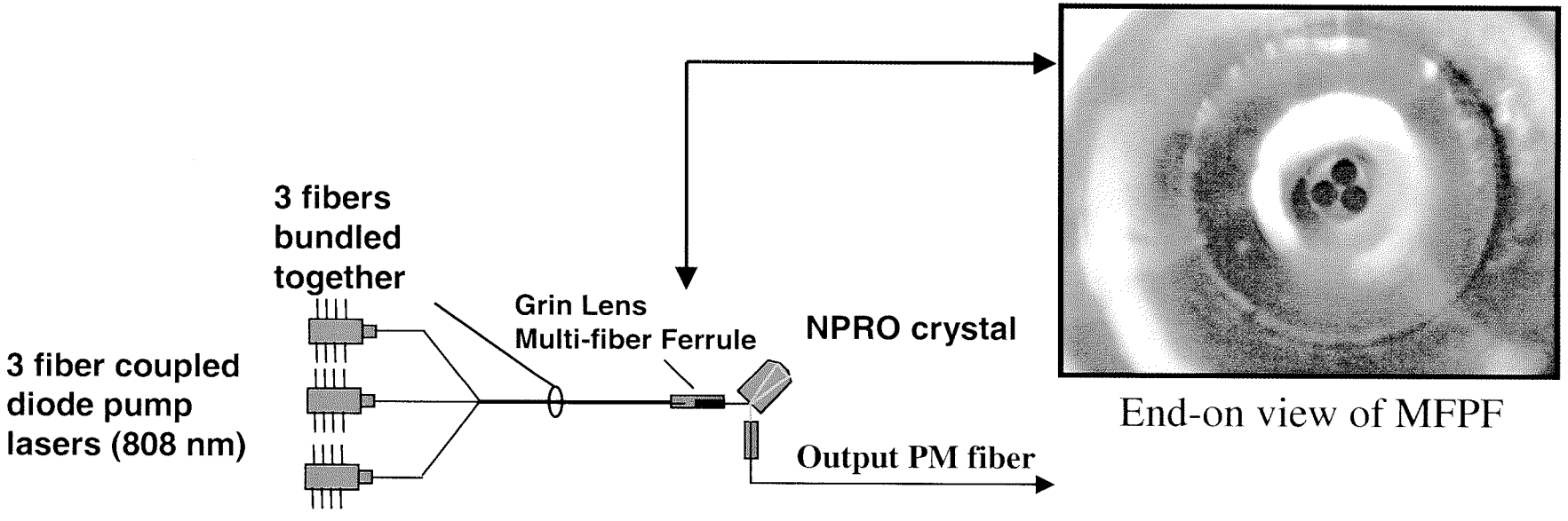




Brassboard II Laser Stability



Multi-Fiber Pump Ferrule



End-on view of MFPF

- Addresses pump diode reliability concerns
- Enables use of redundant pumps without additional components
- Designed for parallel or standby operation

MFPF Performance

	Pump Diode Combinations						
	A	**B**	**C**	**AB**	**AC**	**BC**	**ABC**
Pump Power	1.0 W	0.710 W	0.9 W	1.7 W	1.9 W	1.6 W	2.6 W
Output Power	117 mW	67 mW	82 mW	222 mW	227 mW	177 mW	300 mW
Efficiency	12 %	9.4 %	9.1 %	13 %	12 %	11 %	12 %

- Increased maximum output power
- Reduced laser efficiency compared to single fiber pump ferrule
- Standby redundancy is the most reliable, so we need to:
  - Improve laser efficiency using individual pumps in MFPF
  - Find vendor that can produce reliable 1W pumps at 808 nm

Summary

- What we've done:
  - Built a simplified, ruggedized NPRO-based laser using laser welded techniques for packaging
  - Brassboards tested well under vibration and thermal cycles
  - Excellent long-term alignment stability
- Future Work:
  - Design a fiber pigtail that survives high temp
  - Optimize efficiency of MFPF
  - Environmentally test new fiber pigtail and MFPF
  - Work with diode laser vendors to improve reliability