PRINCETON OPTRONICS

Powering the Optical Frontier

IMPACT Industry Day
May 15, 2008

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Princeton Optronics Capability Related to IMPACT

Princeton Optronics is a Leading Developer of VCSEL Technology

- DARPA SHEDS program- efficiency at 52%
- Single device 3W, 4.7mm array 230W
- Single mode devices to 300mW of power
- High reliability, high temperature operation- million device hours in accelerated life test

Leading Developer of High Stability, Narrow Linewidth Laser

- DARPA Phor-Front program- directed towards low noise narrow linewidth lasers
- Narrow linewidth of 10Hz demonstrated
- Stability of +/- 150kHz over 7 hrs
- Noise of -160dB/Hz @1MHz

Able to combine the two technologies for 10Hz stability ultrastable, low noise VCSELs

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Comparison Between VCSELs and Edge Emitters

Properties	Edge Emitters	VCSELs at PO	Comments
Multi-mode Single Device and Bar/Array Power, Power Density	10W single device 200W arrays, 500W/cm2	3W single device, 230W array, 1kW/ cm2 CW; 3.6kW/ cm2 QCW as they can be close packed	Power density of VCSELs can be increased dramatically, working on 20kW single chip.
Single mode Device, Bar/array Power	1W single device, 20W from a bar	300mW single device, 100W from a 5x5mm array	Working towards 1kW from a 5x5mm array
Single Device Reliability (FIT- failure in billion device hours)	FIT~500 for best telecom edge emitters	FIT~10-3 without ESD- by many companies	Have collected million device hours of accelerated life data
Operating temperature	20 deg C	High reliability 80 deg C operation-	>100,000 device hrs at junction temp of 130 deg C
Efficiency	60% Commercial	52% peak	VCSEL goal - 60% by end 2008,
Linewidth and stability	<500kHz	Measured data <1MHz	Can be reduced to <10Hz
Noise	-150dB/Hz	-150dB/Hz	Can be made lower because of lower mode partitioning noise.

Single-mode VCSEL (Small Aperture)

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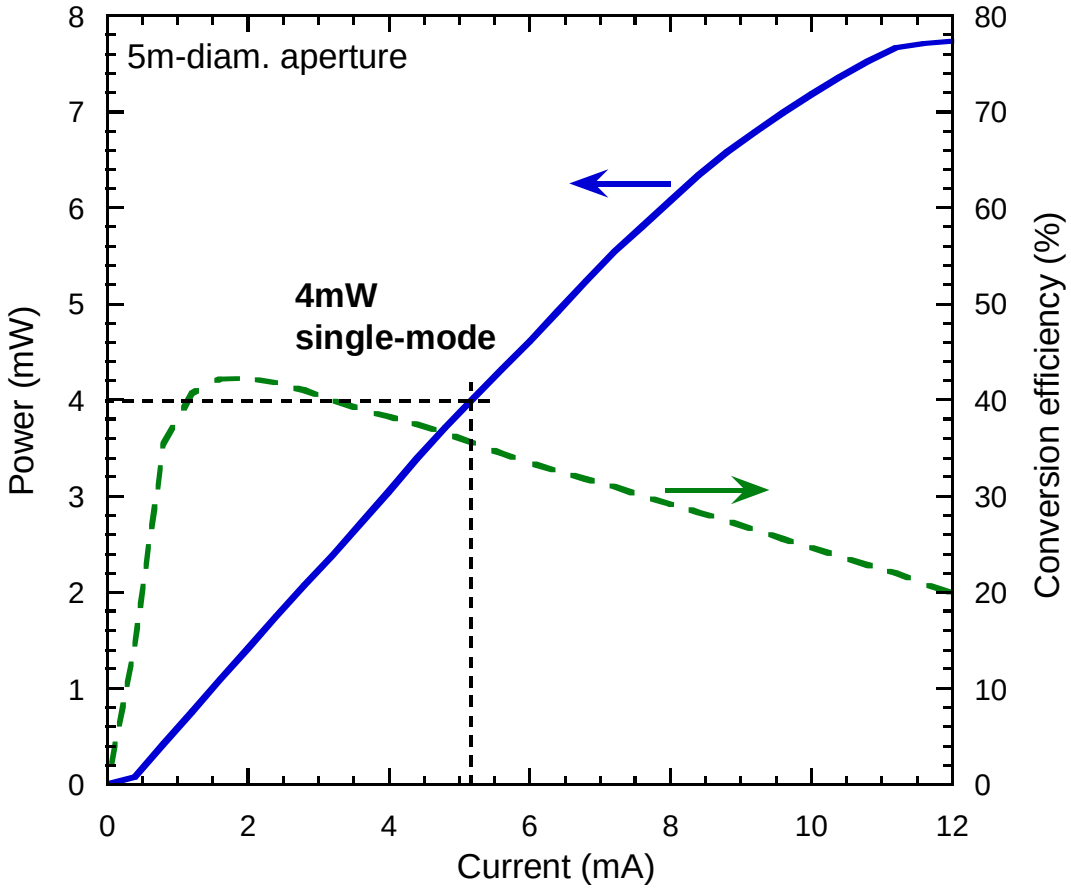

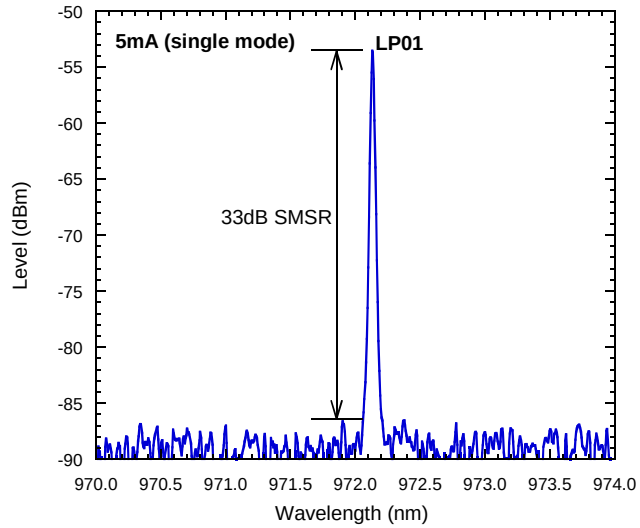

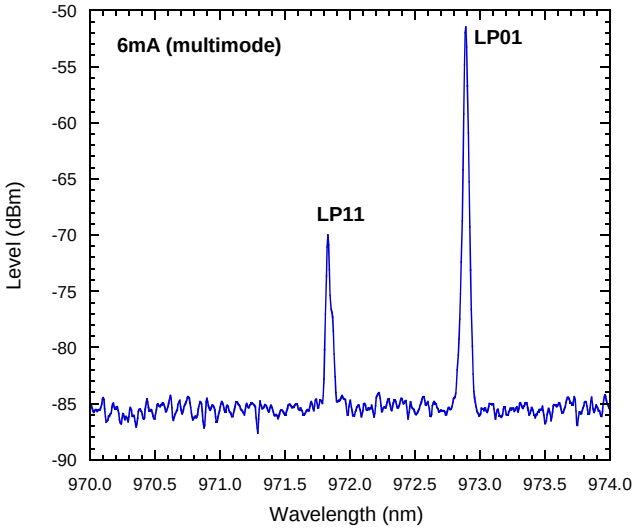

- **Demonstrated up to 8mW single-mode power from a small, efficient monolithic VCSEL device.**
- **Demonstrated array power of 100W coupled to 400u fiber (0.4NA)**
- **Demonstrated 300mW from a single mode device**

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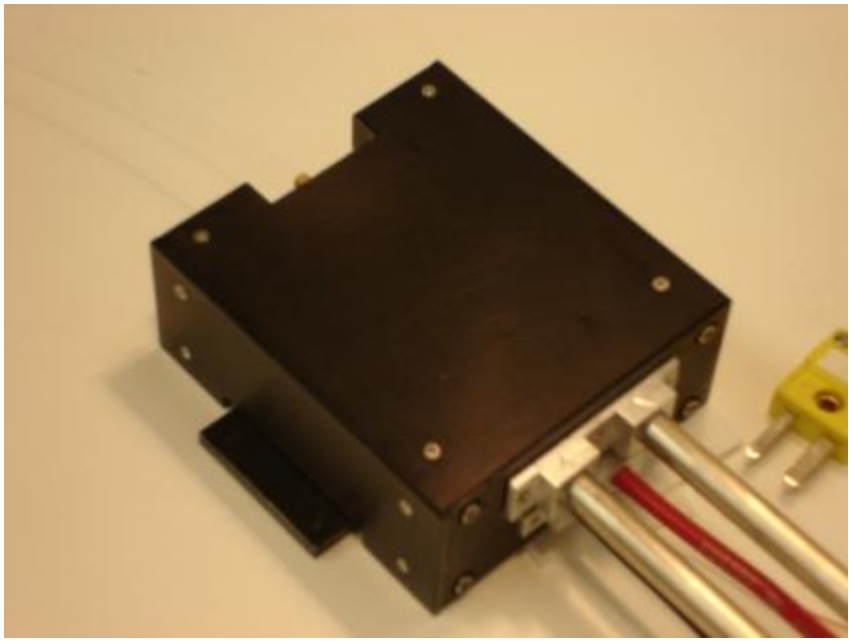
Single VCSEL package



VCSEL Array Package (2x1.5x0.5”)
100W demonstrated--1kW feasible in near future

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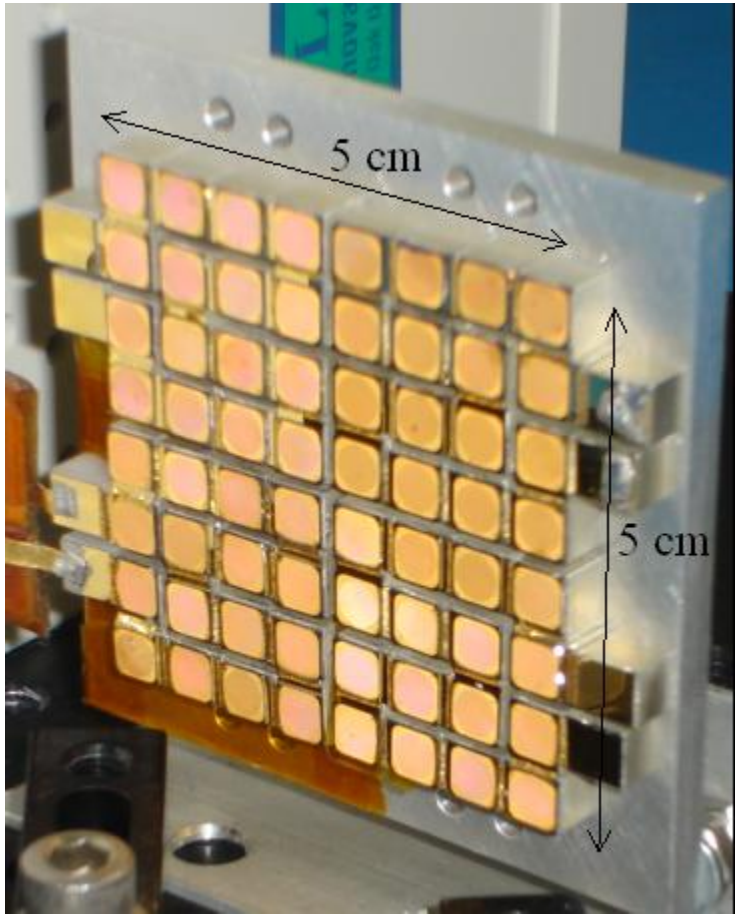
VCSEL Arrays (8x8 arrays connected together)



8x8 VCSEL Array 980nm
•Delivering 5mJ from 30nS
•Peak power of 150kW
• Rep rate of 10- 100kHz achievable
• QCW Power @ 100kHz will be 500W for 20ns pulses

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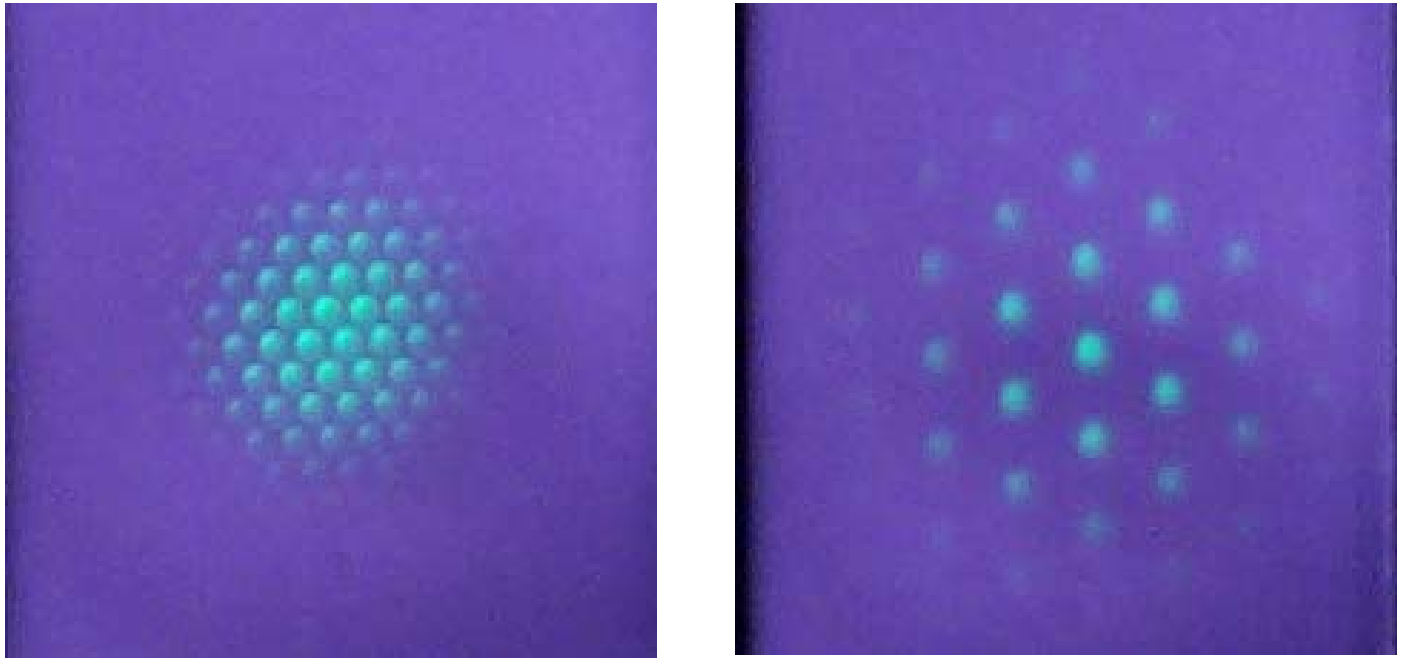
Phase Coupled Coherent Array 740 devices



Near field image (left) and far field (right) output of a coherent array with 740 elements in coherence

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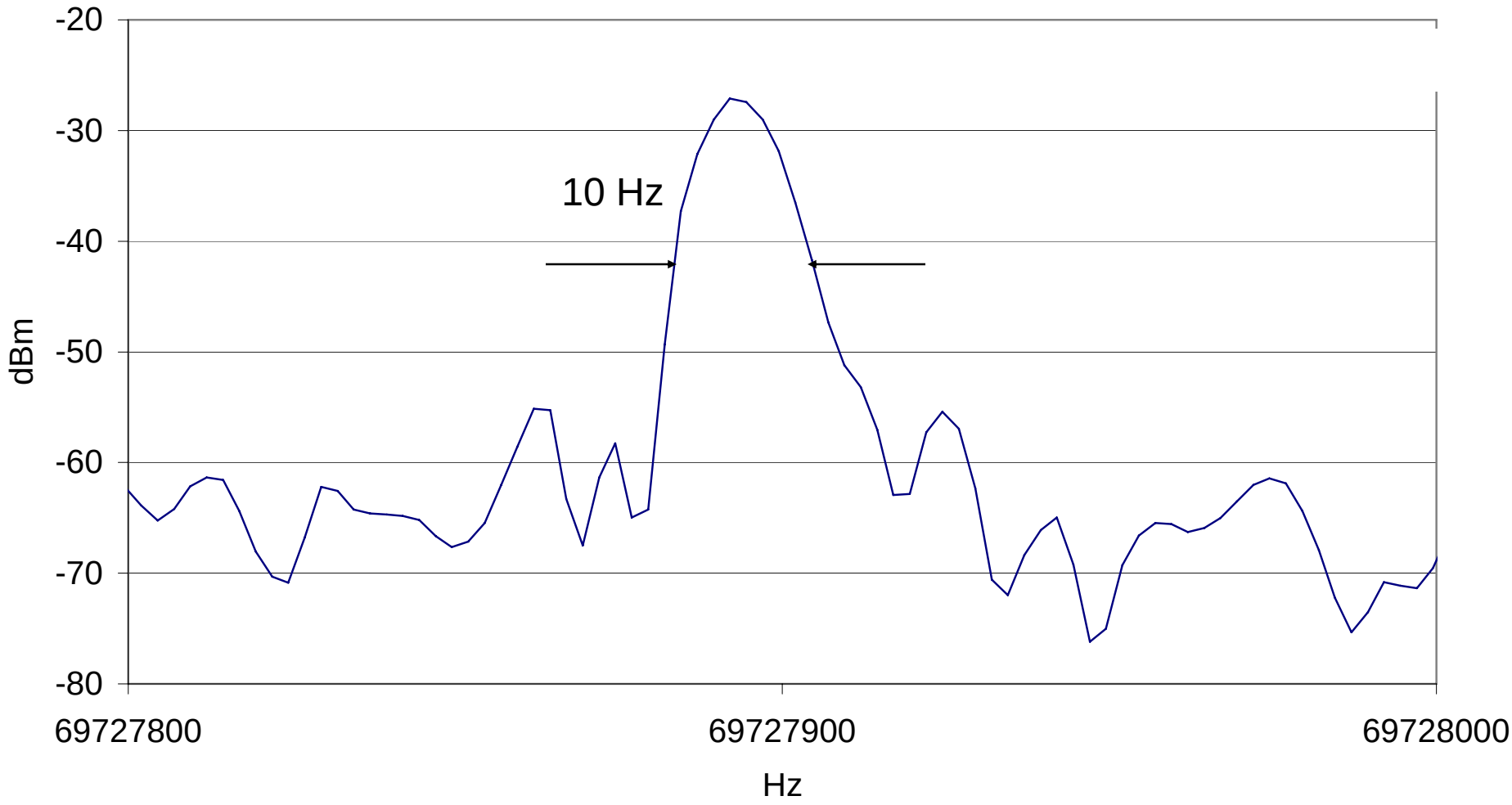
Laser Linewidth Data



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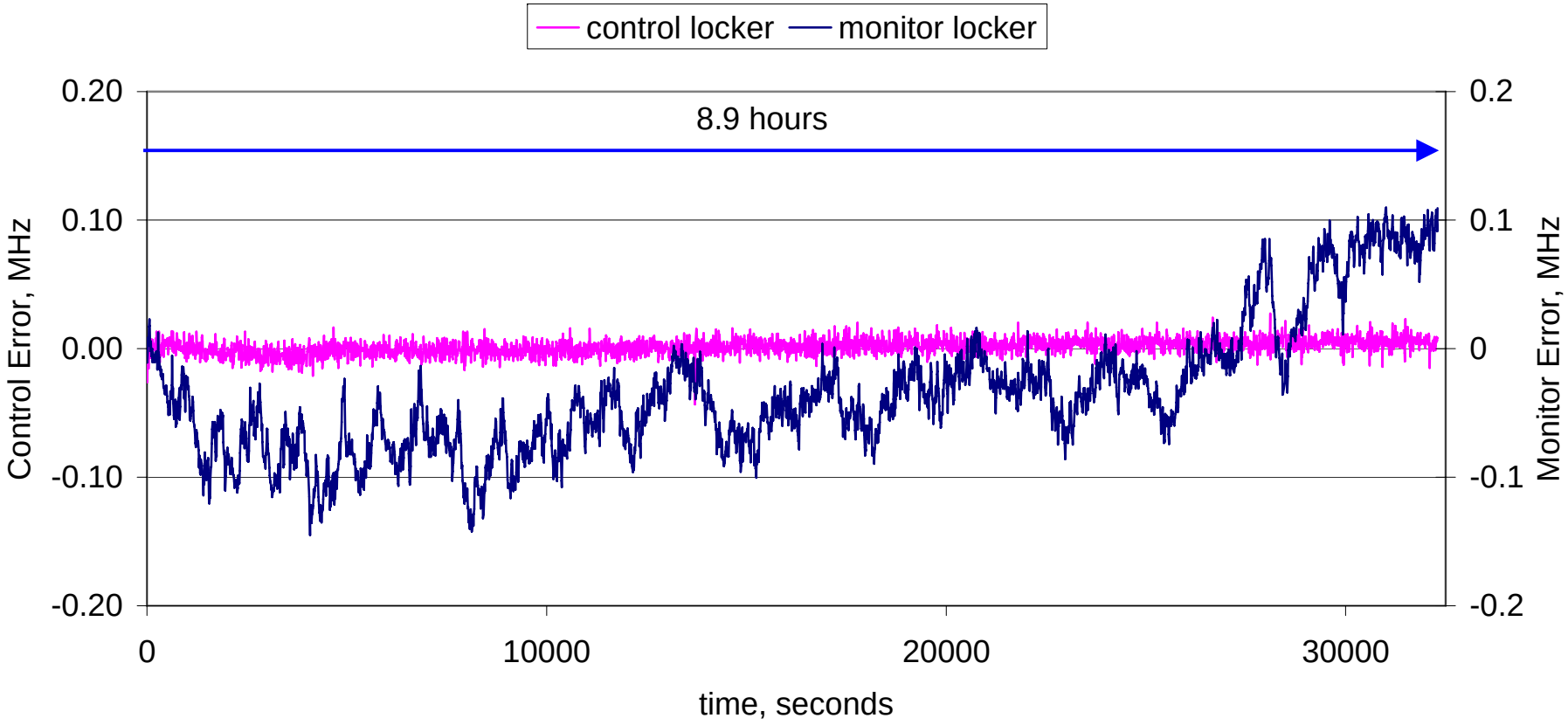
Long Term Frequency Stability Result

TLM 20601 drift 08/07/07



Phase I - 1MHz RIN Result

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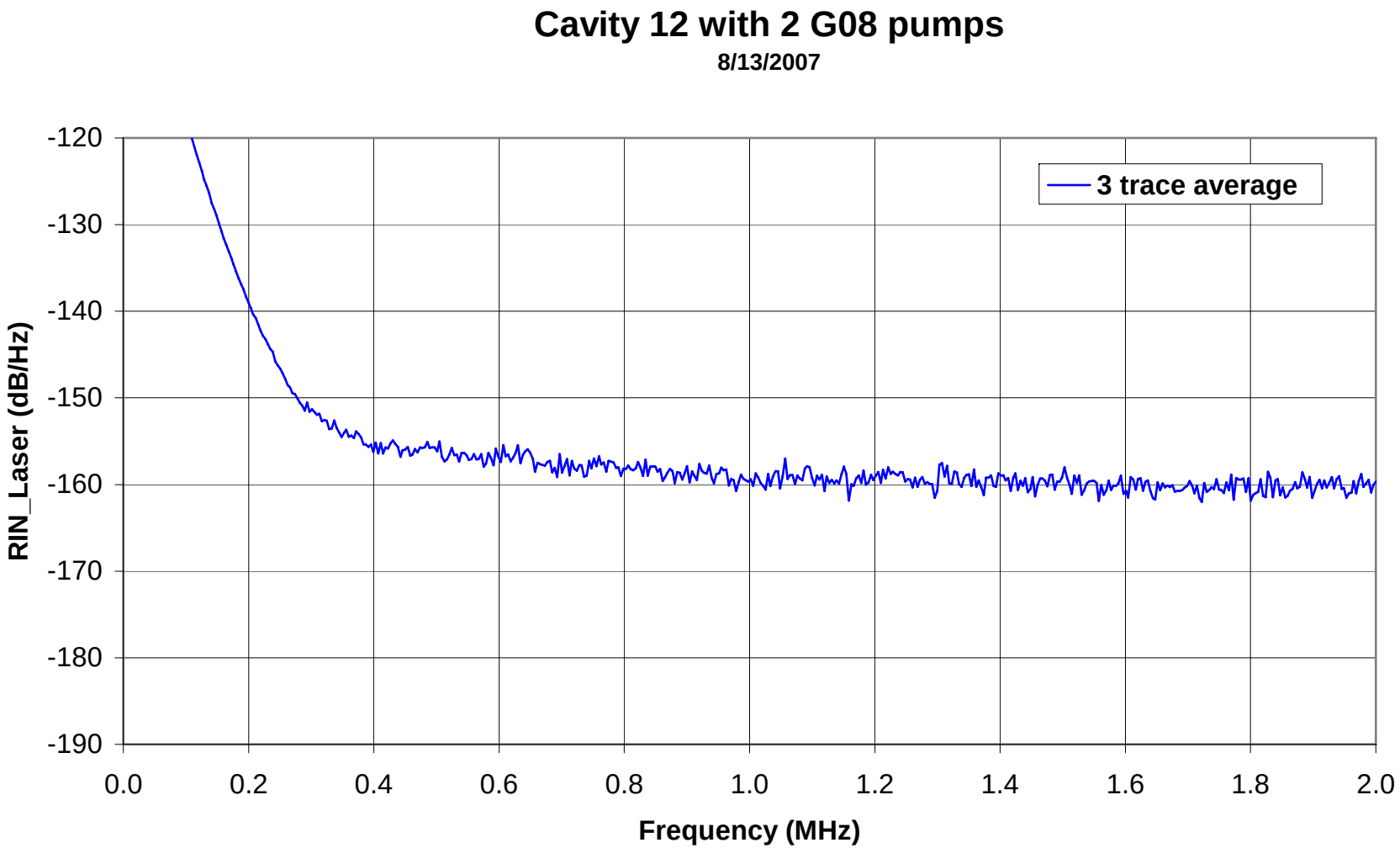
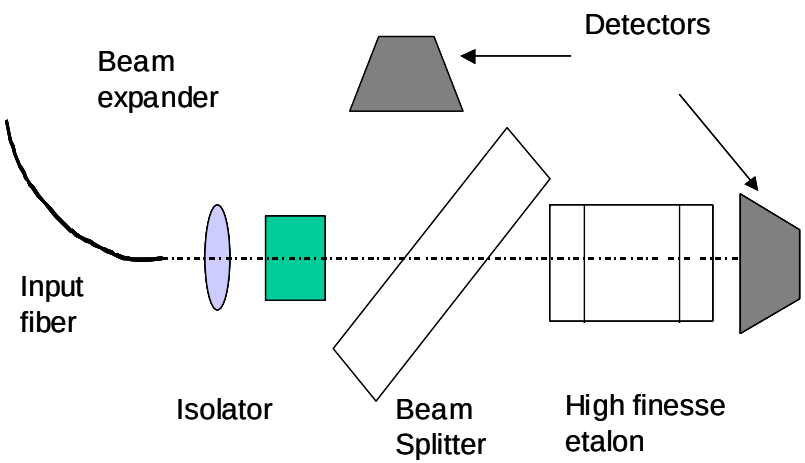
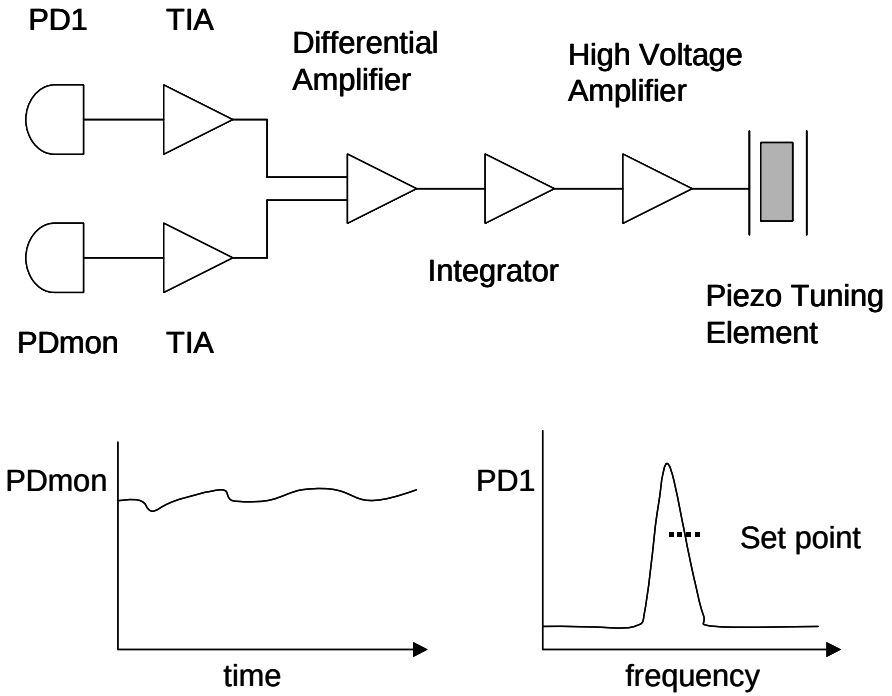


RIN is adjusted for Shot noise– no RIN peak anywhere.

Locker for Stabilizing Laser and Linewidth Control





- High Finesse etalon using Zerodur Glass
- Temperature stabilization to <0.01 deg C
- Fringe Side Locking for frequency control

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Summary

- Princeton Optronics has outstanding VCSEL technology developed with self funded and DARPA funded research
- Capable of delivering various kinds of VCSELs with low noise, narrow linewidth, high stability, frequency modulated etc– if you have a difficult requirement, please speak with us
- Looking forward to teaming with a Prime in this program