LIGO Livingston

LSU Amplifier Experiments

Rupal S. Amin (LSU)

J. Giaime (LSU), D. Hosken (Uni. Adelaide), D. Ottaway (MIT)

LSC/VIRGO Meeting March 2007
Lasers Working Group

DCC-G070147-00-R

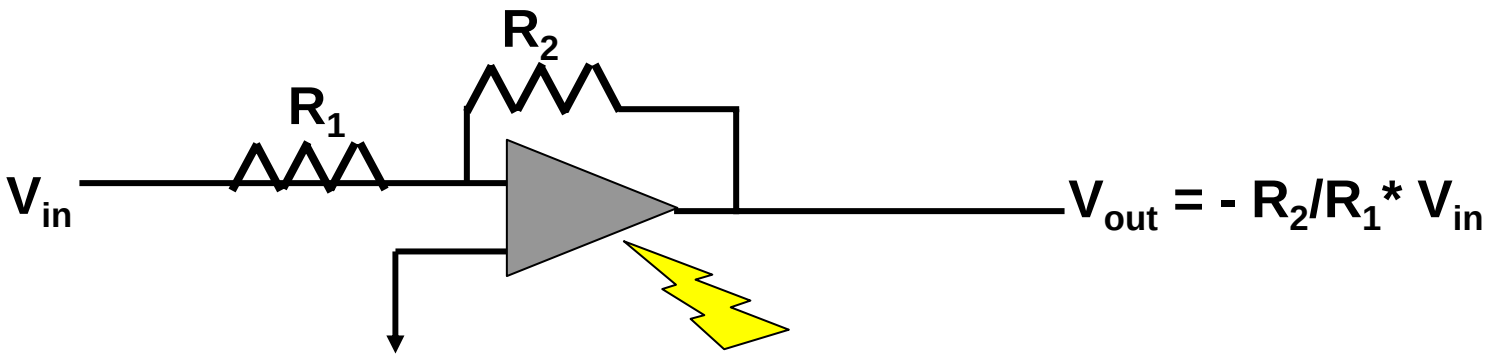
Outline

- Aside
- Motivation
- Setup
- Power amplification tests
- Further Tests
- Challenges
- Conclusions

Aside:

Reminder of Optical Amplifier

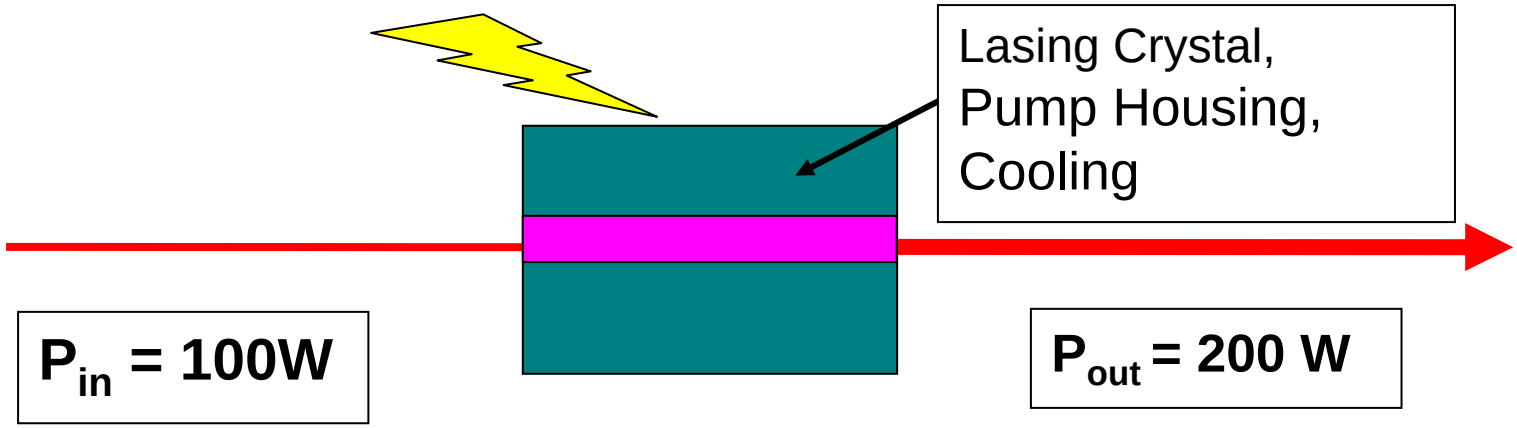
Scheme of an ideal (inverting) electrical amplifier



V_{out}: Amplified signal with identical variations as V_{in}

Aside:

Scheme of optical amplifier



P_{out} : Amplified laser power with identical variations as P_{in}

Motivation

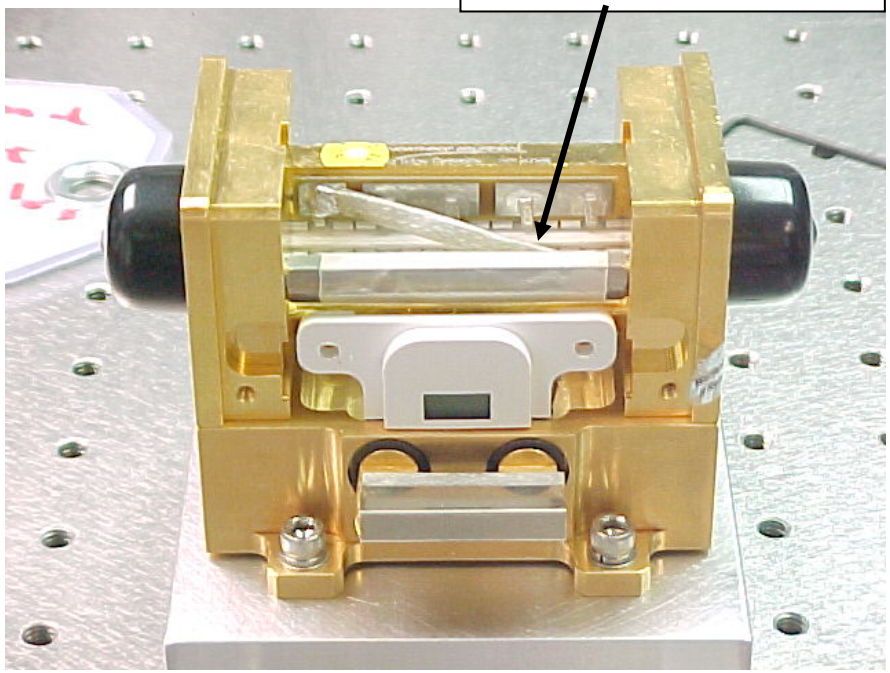
- Competing ideas* in 2004 for Fall 2007 upgrade
  - oAmplifier downstream of MOPA (**LSU**)
  - oNew laser head (LZH)
  - oNew injection locked slave laser
  - oReplace current MOPA's NPRO with more powerful NPRO

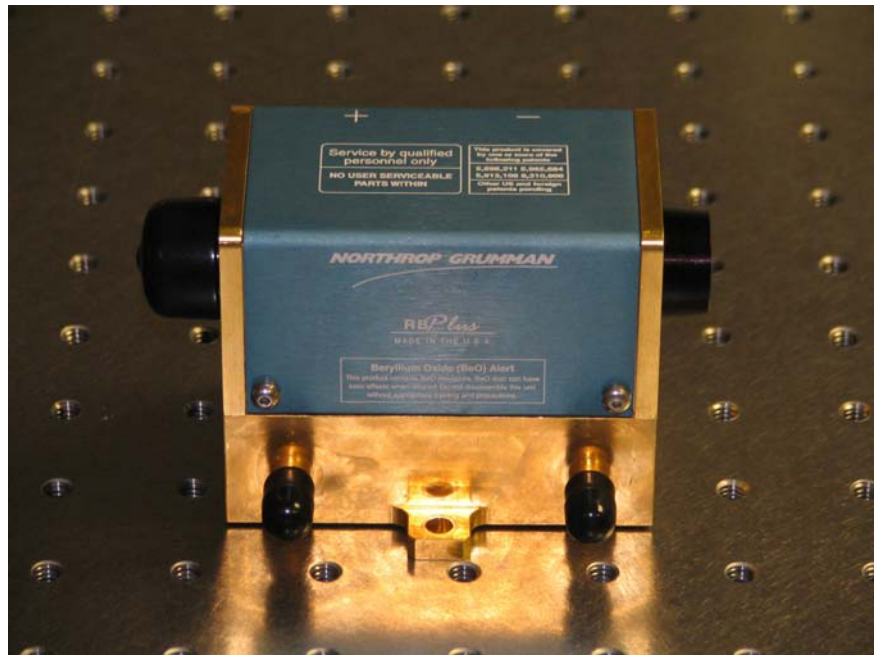
- Investigate and offer a quick upgrade to LIGO
- Offer simple installation using off-the-shelf technology

*: D. Ottaway, LIGO-T040063-00-D

LSU's Amplifier
Model: RBA25
Manufacturer: Cutting Edge Optronics/
Northrop Grumman Corp.

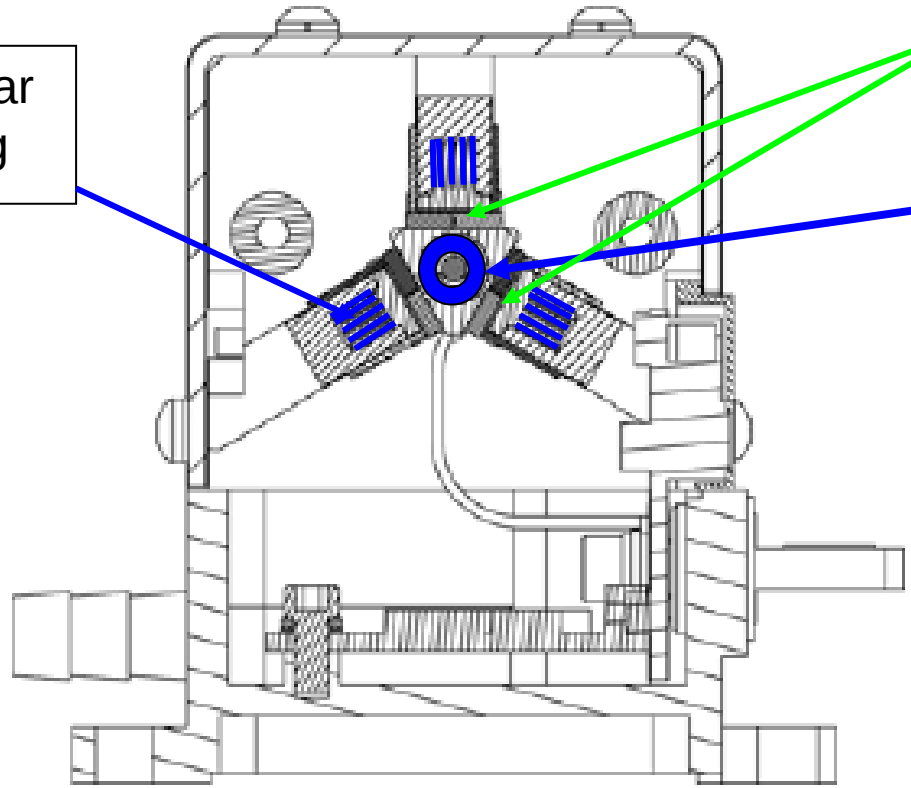
Diode Bar (5/15)





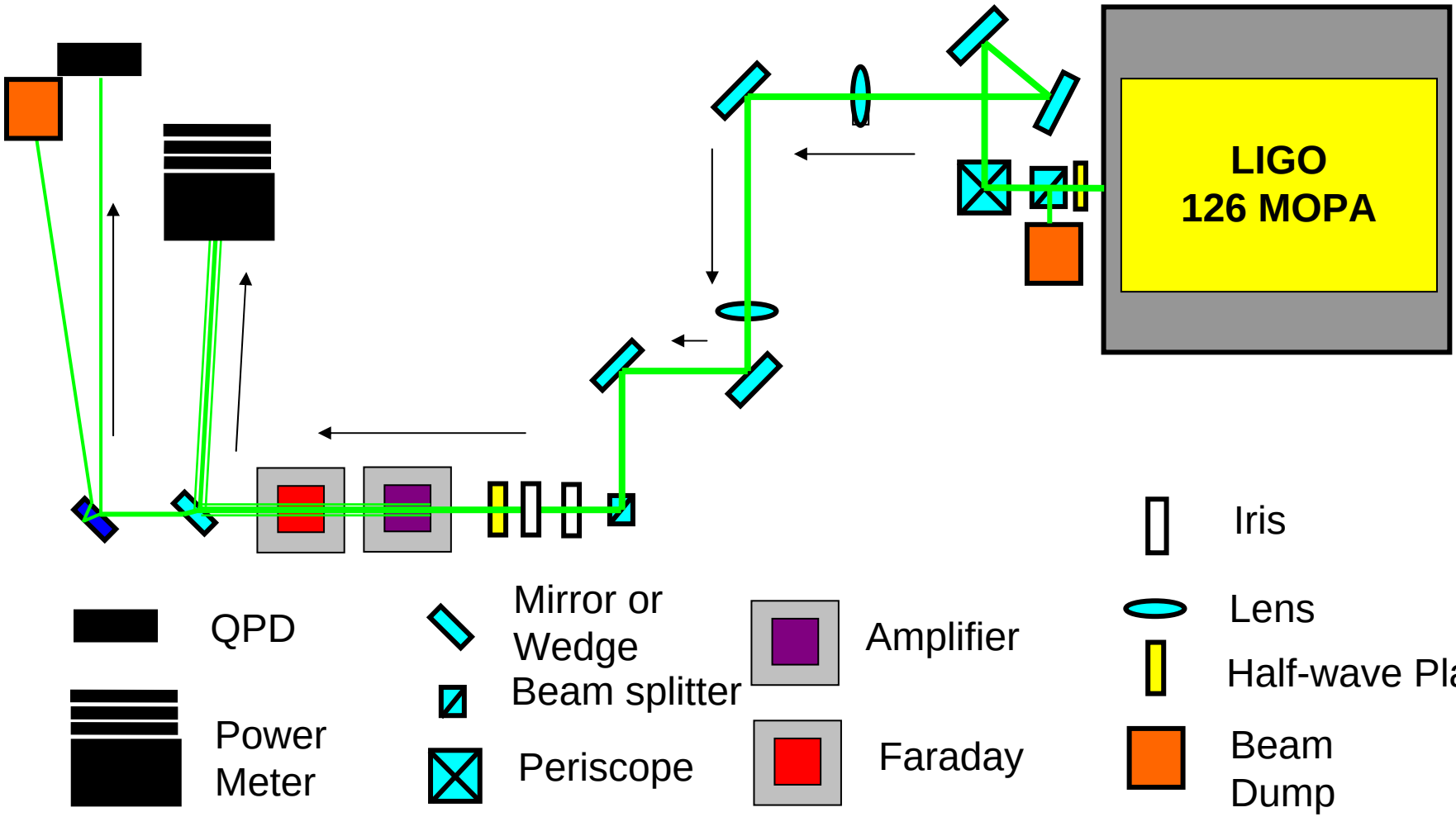
Crystal rod: 2 mm dia by 80 mm length
Water cooled (68 psi/1GPM water flow)

Mechanical Cross Section

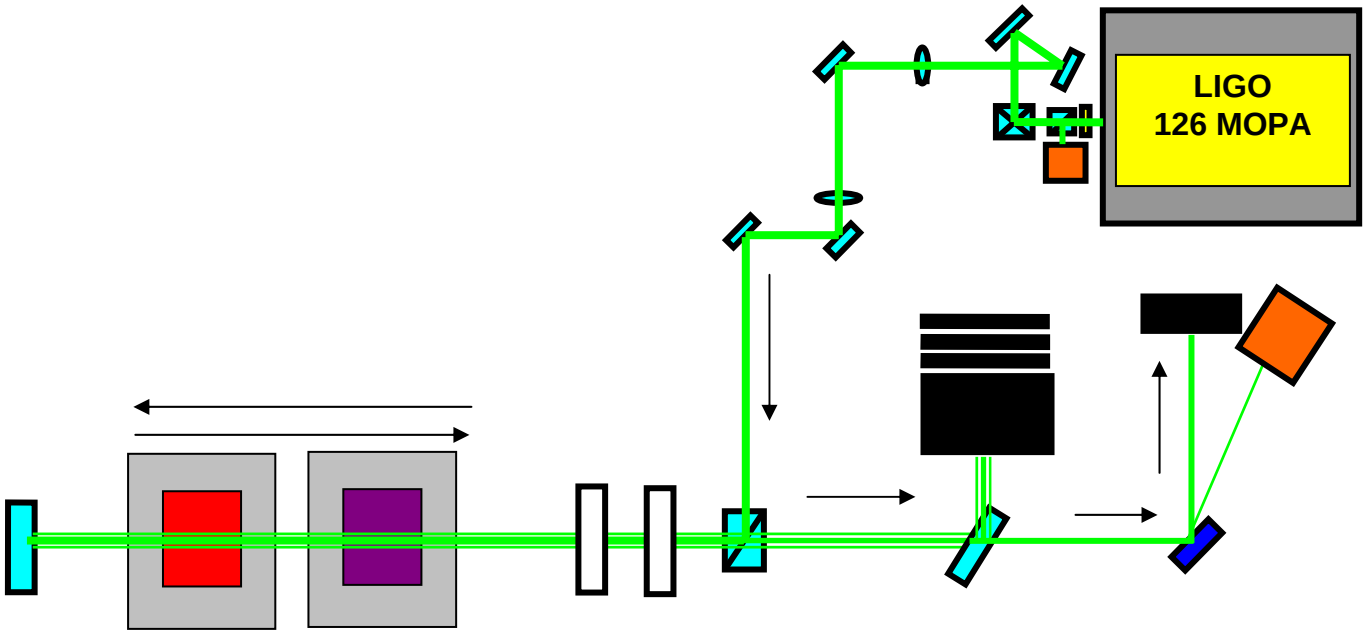


Crystal Suspended in Cooling Jacket by O-rings

LSU Single Pass Optical Setup
2006



LSU Double Pass Optical Setup
2006



QPD

Power Meter

Mirror or Wedge

Beam splitter

Periscope

Amplifier

Faraday

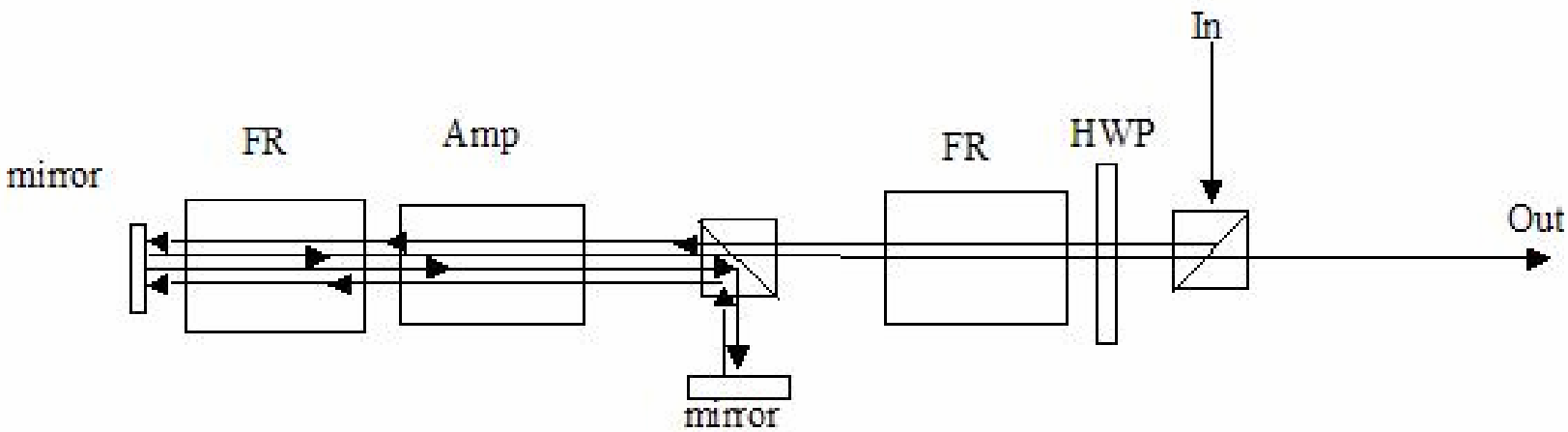
Iris

Lens

Half-wave Plate

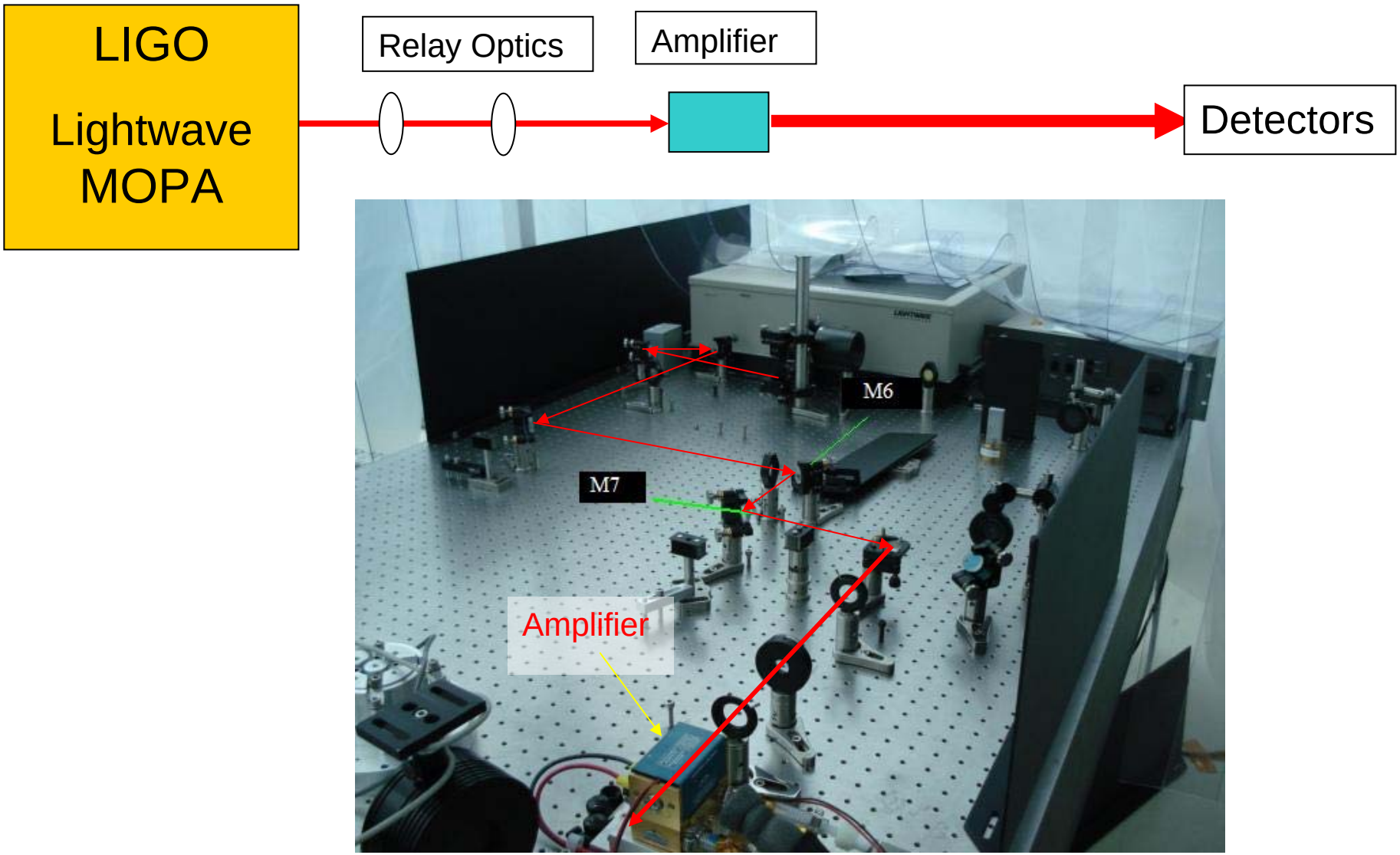
Beam Dump

LSU Quad Pass Optical Setup
Dec 2006



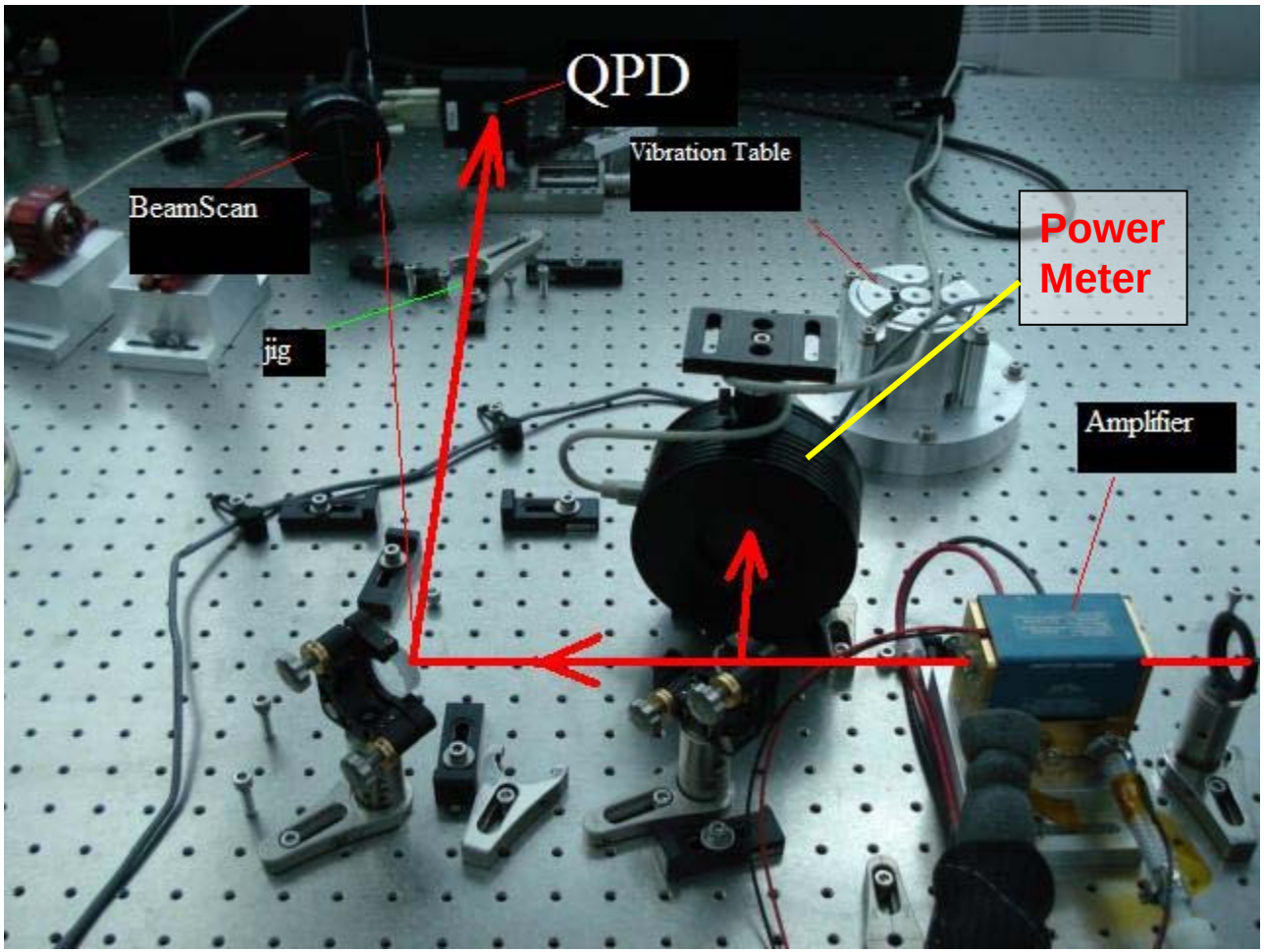
Setup Photos

Single Pass

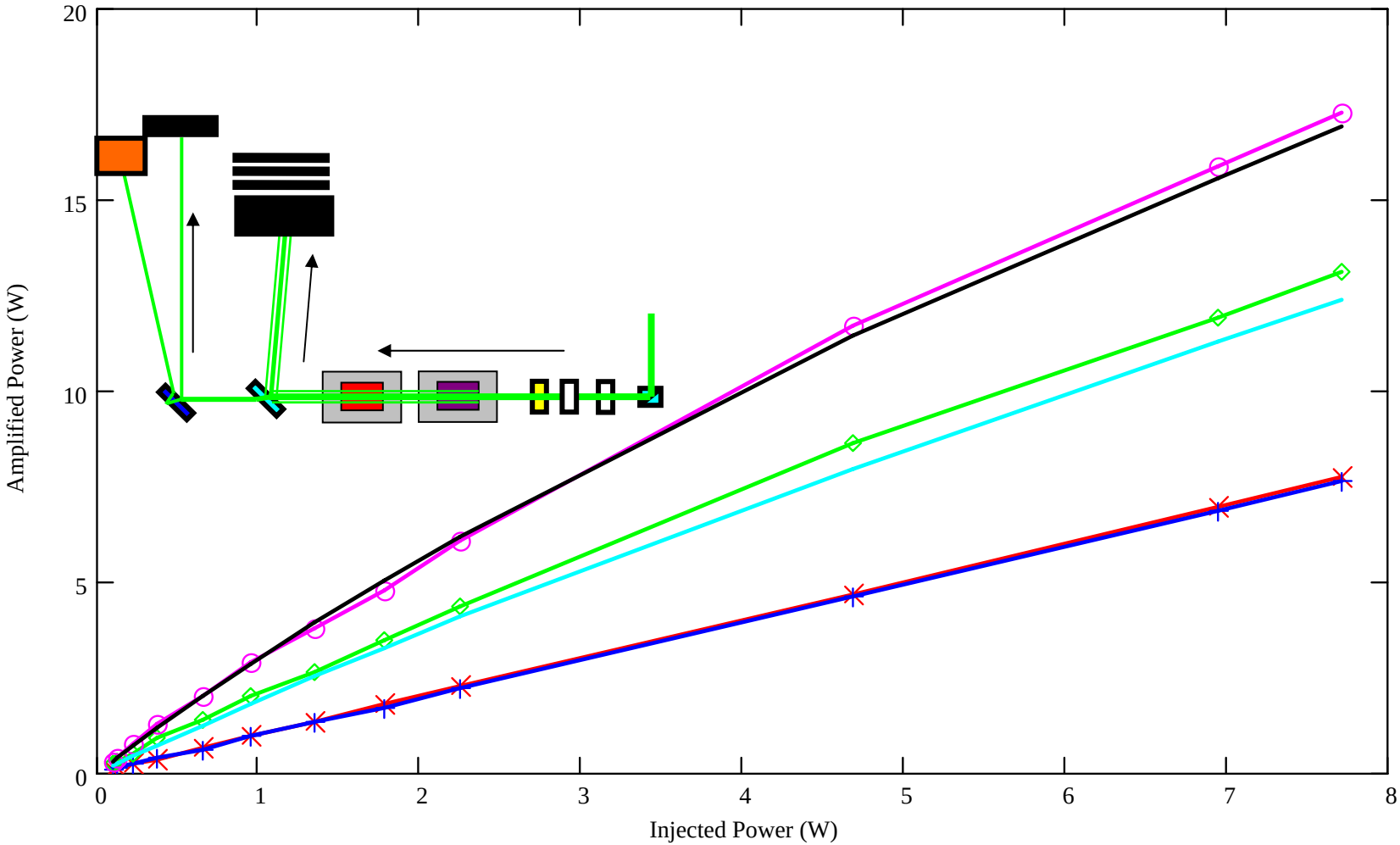


Setup

Single Pass: The Detectors

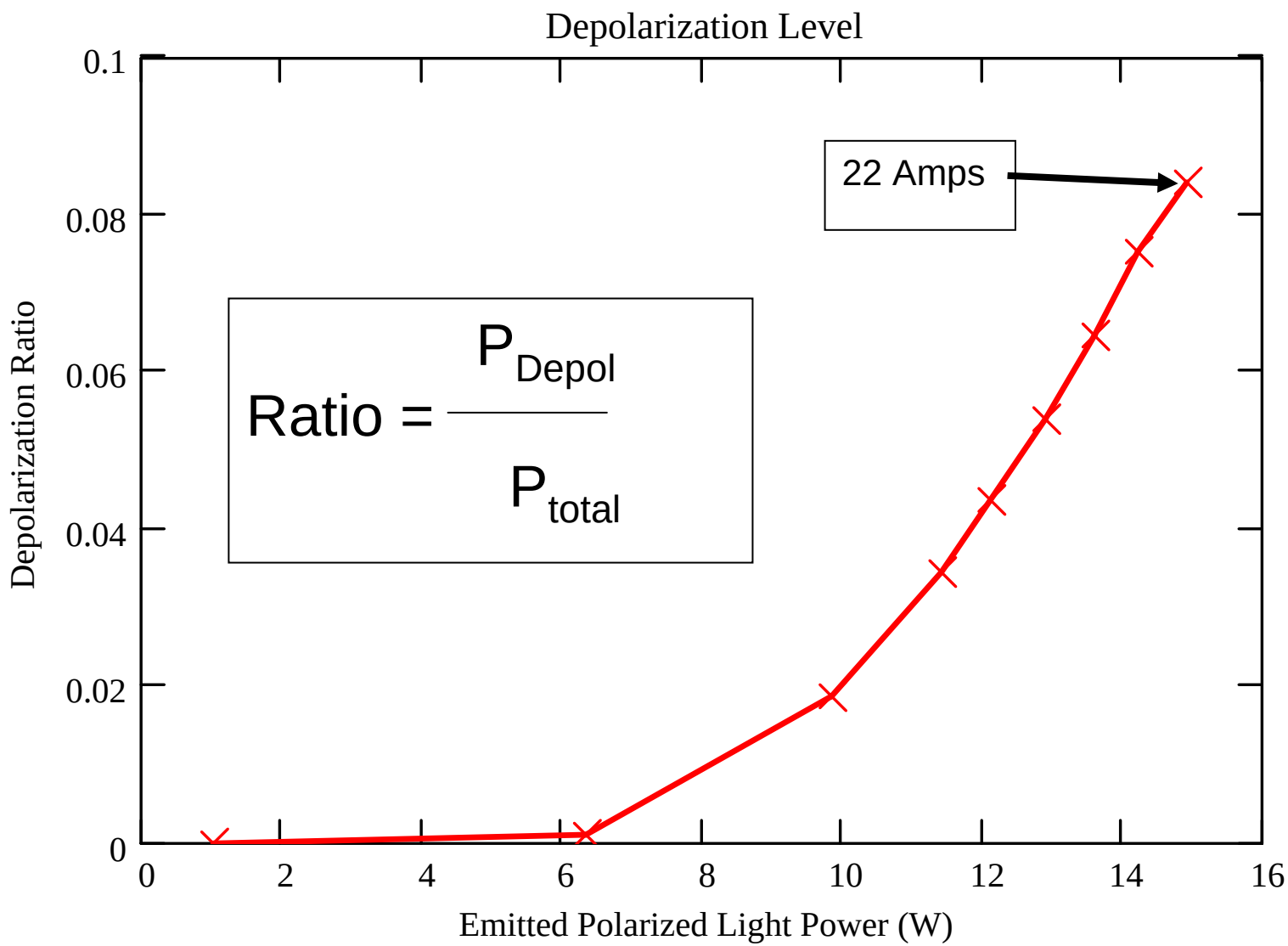


Initial power amplification tests
Single Pass



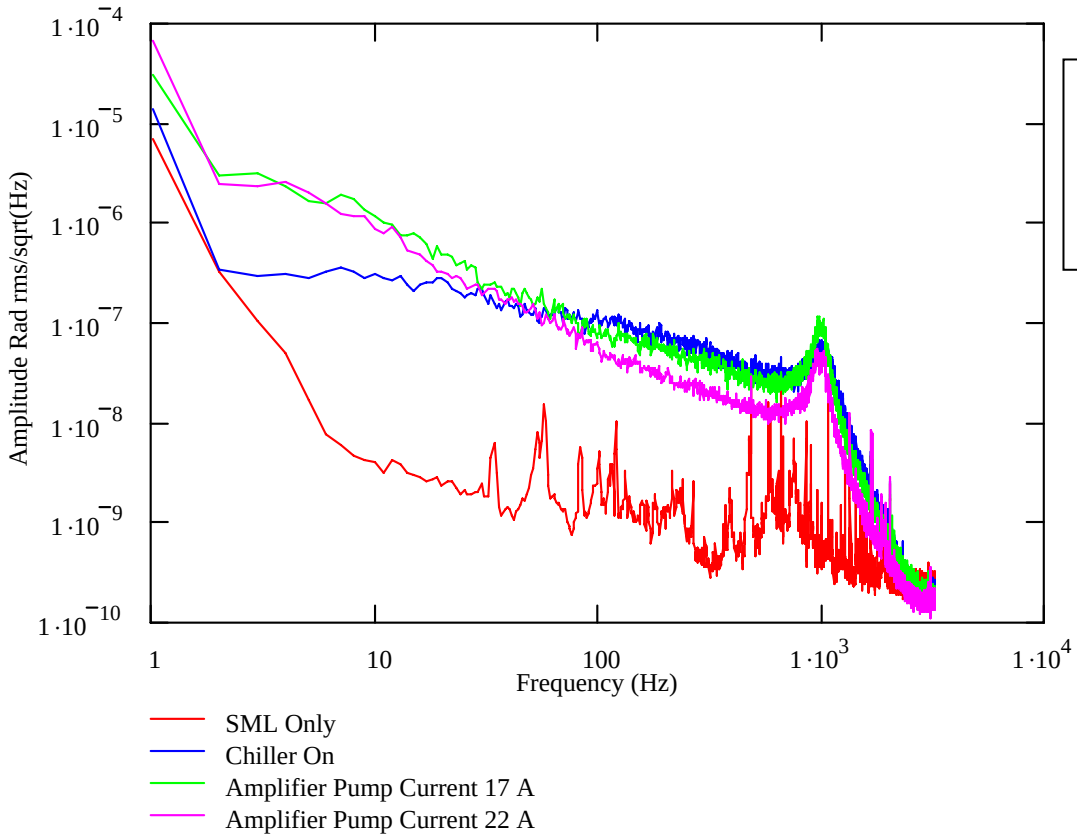
Tests performed at LASTI (MIT)

Depolarization

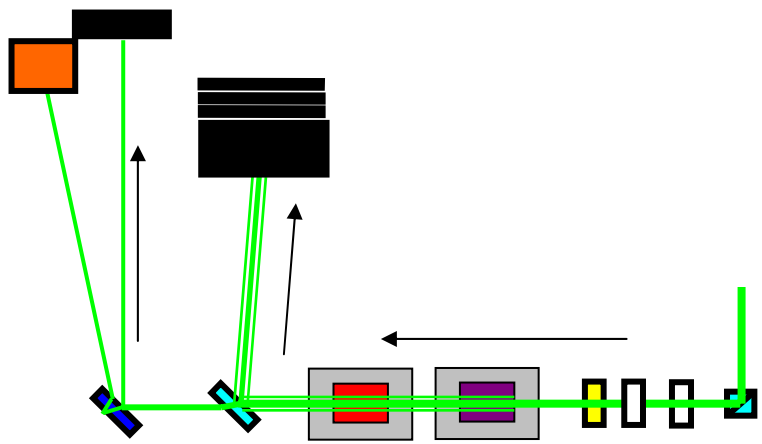


Angular Jitter

A Magnitude of Problems

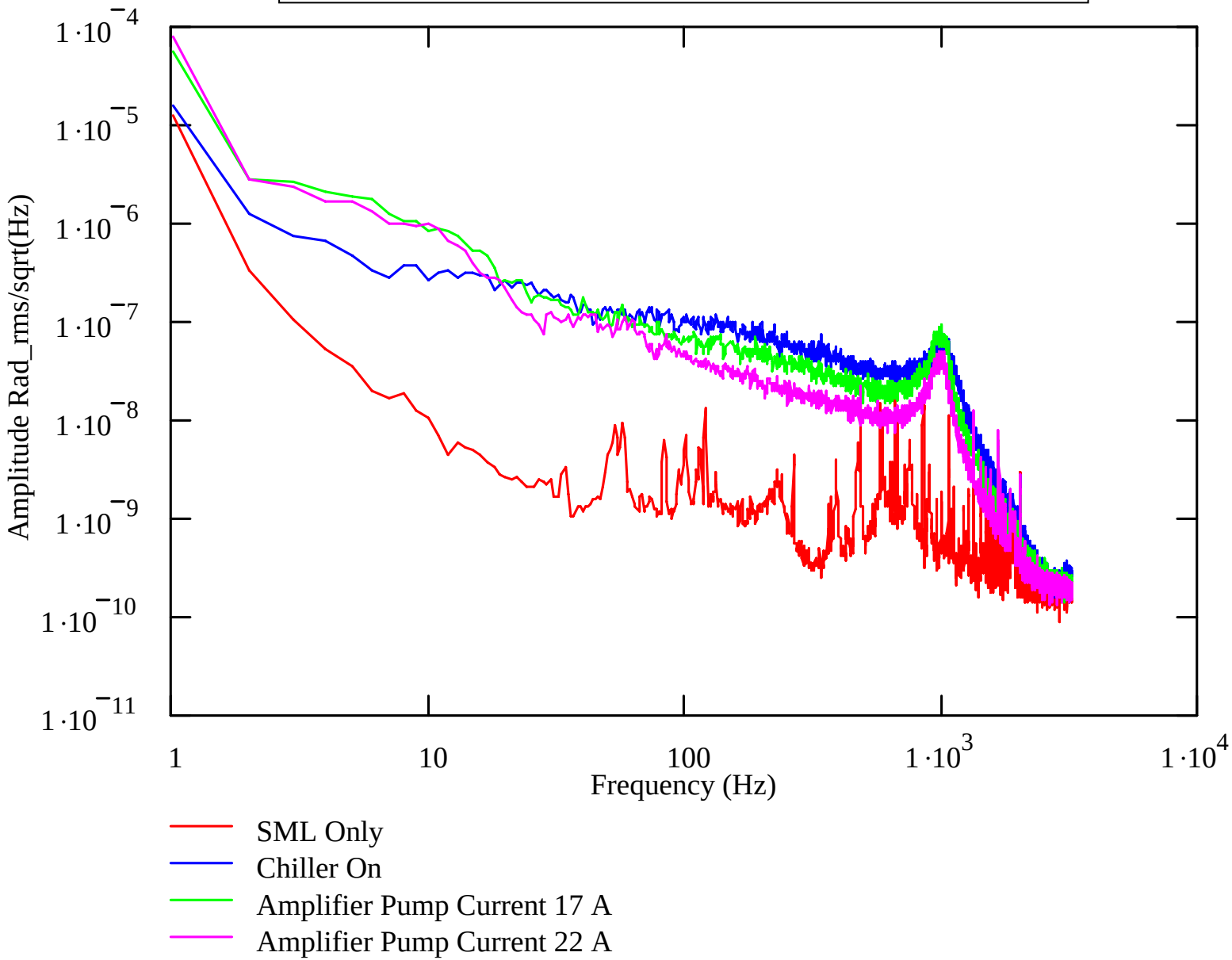


- Jitter peaks >10x above MOPA
- Bump at 1 kHz
- Single Pass



*SML: “Spare Main Laser”

Angular Jitter (No Faraday)
Fall 2006



Angular Jitter

Leads to

- Pointing Problems
- Amplitude variations in downstream cavities

If the problem is caused by Xtal Vibration

- **Phase noise due to crystal bending**
- **Problems in polarization quality**

If the problem is something else on the table, then identify it.

So what is causing angular jitter?

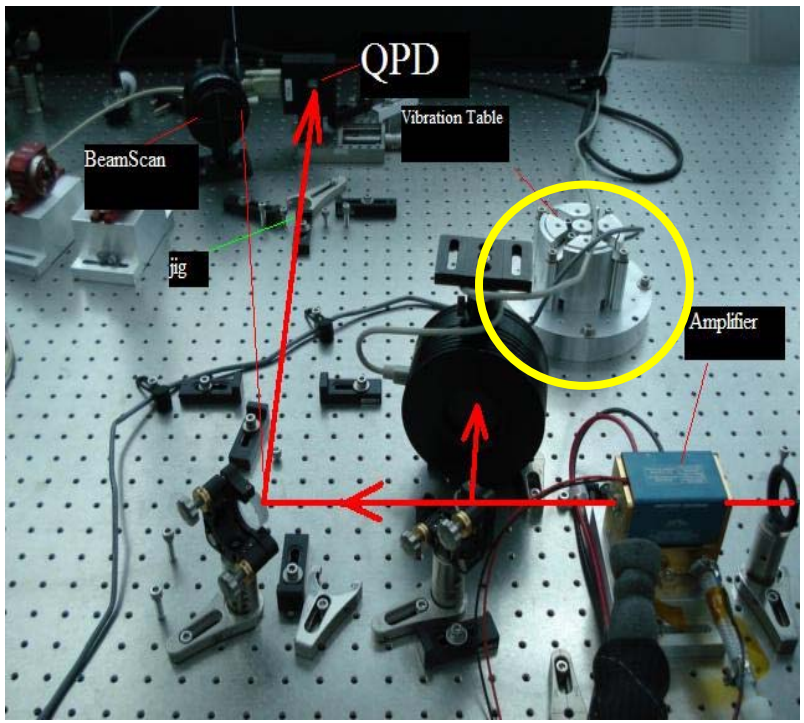
What's the target?

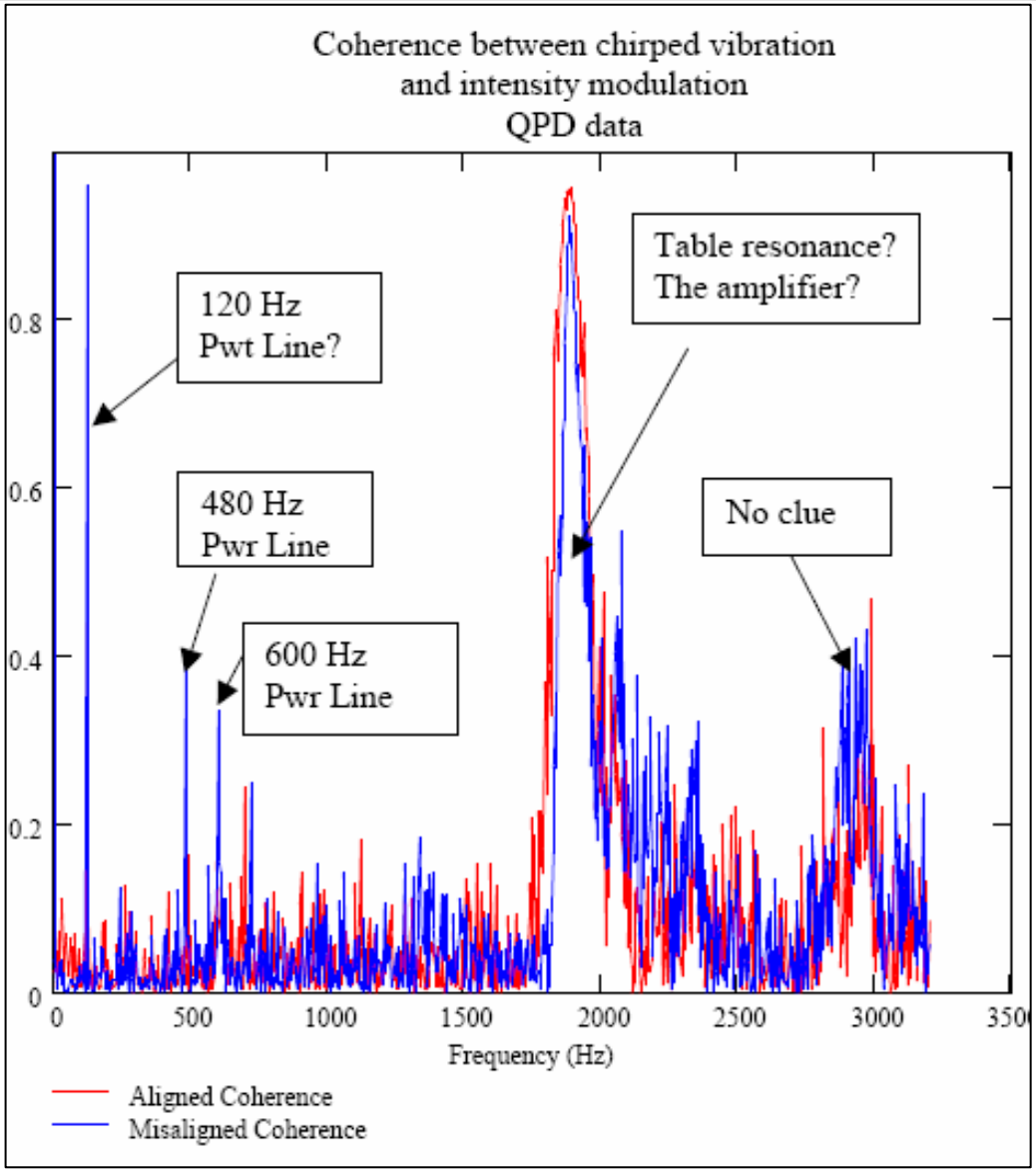
Jitter of LIGO MOPA's

Probable Causes

It is not the table shaking

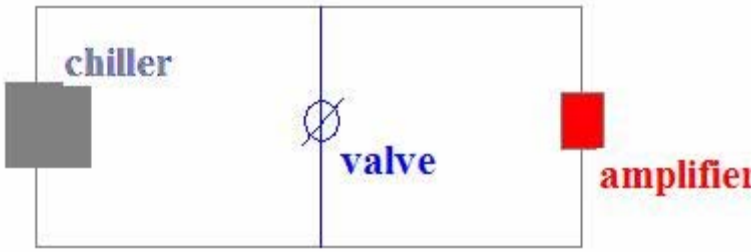
Little coherence at 1 kHz

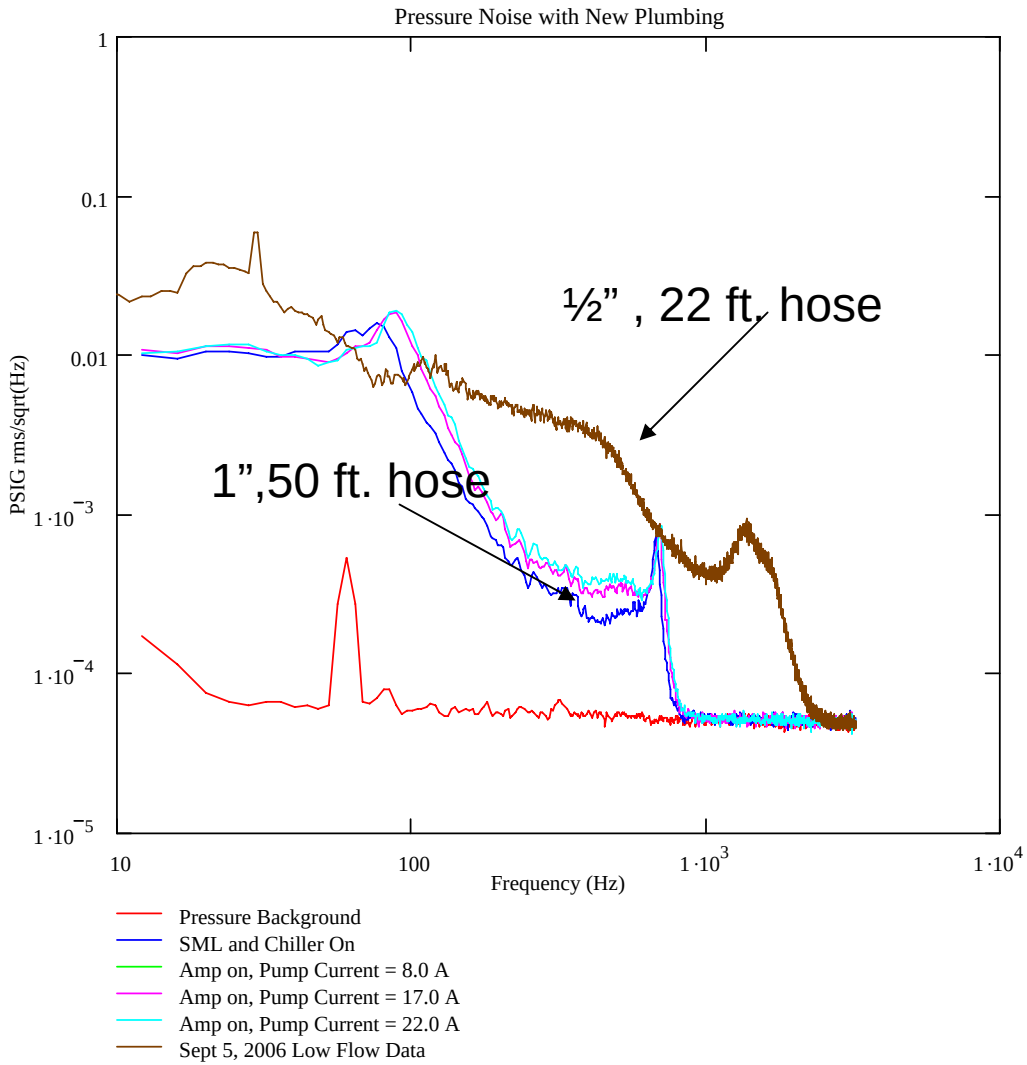




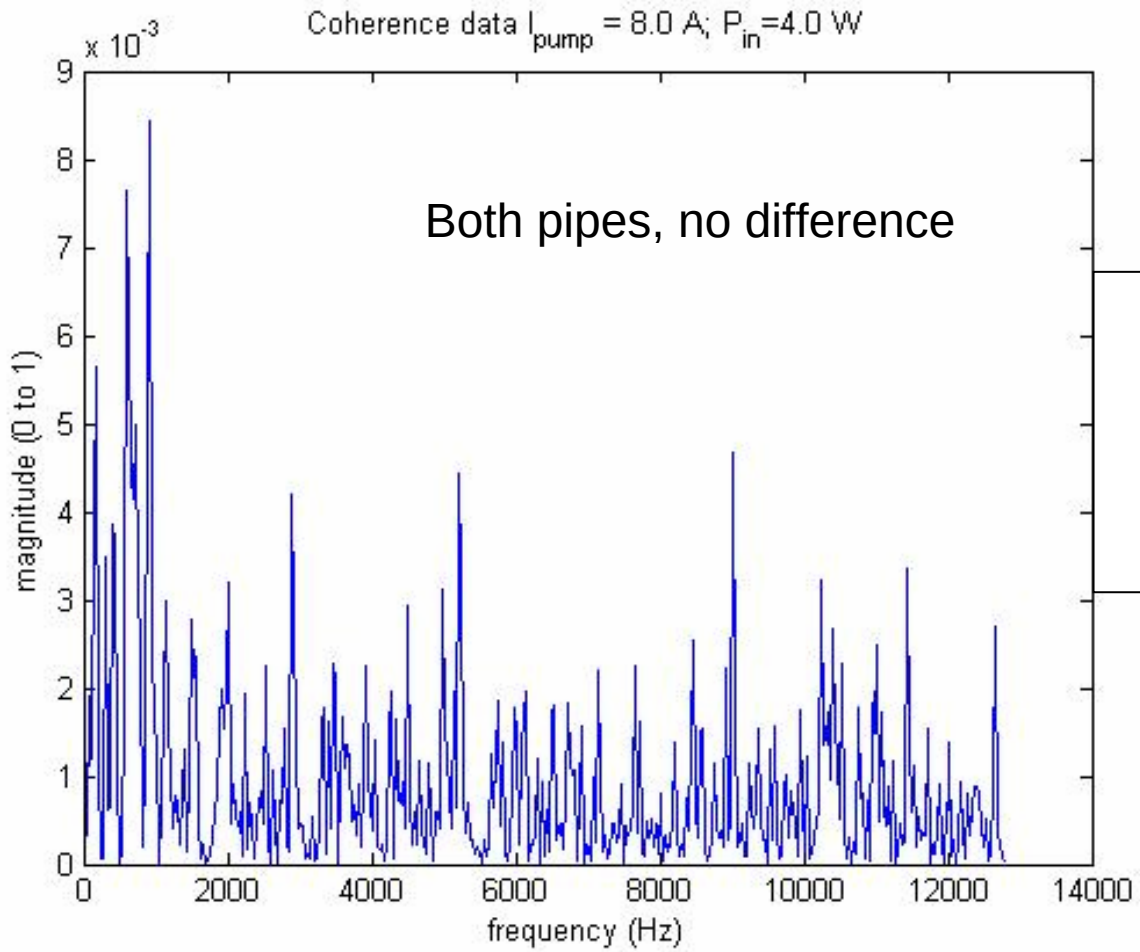
Probable Causes

Pressure waves in the cooling pipes?

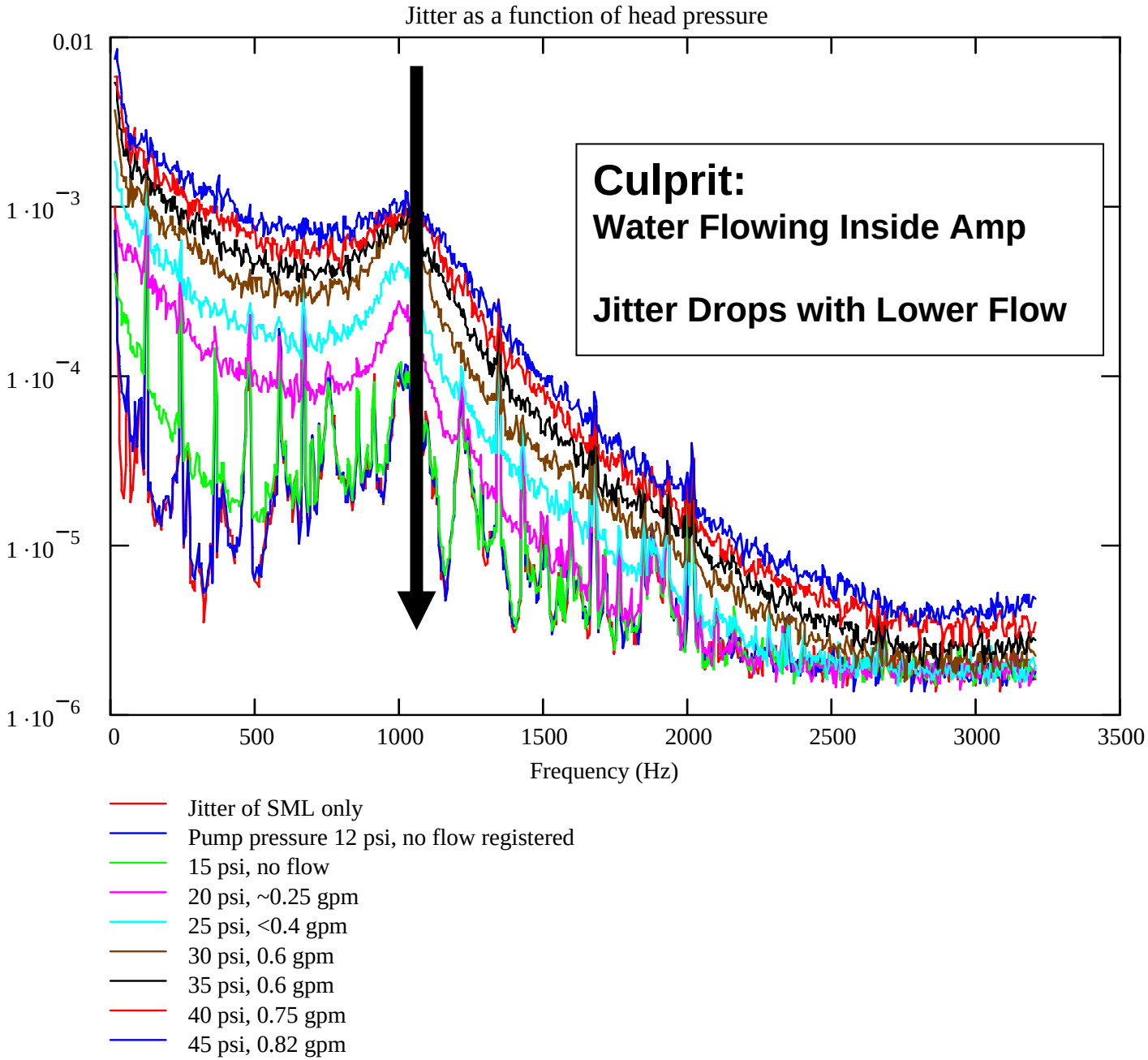




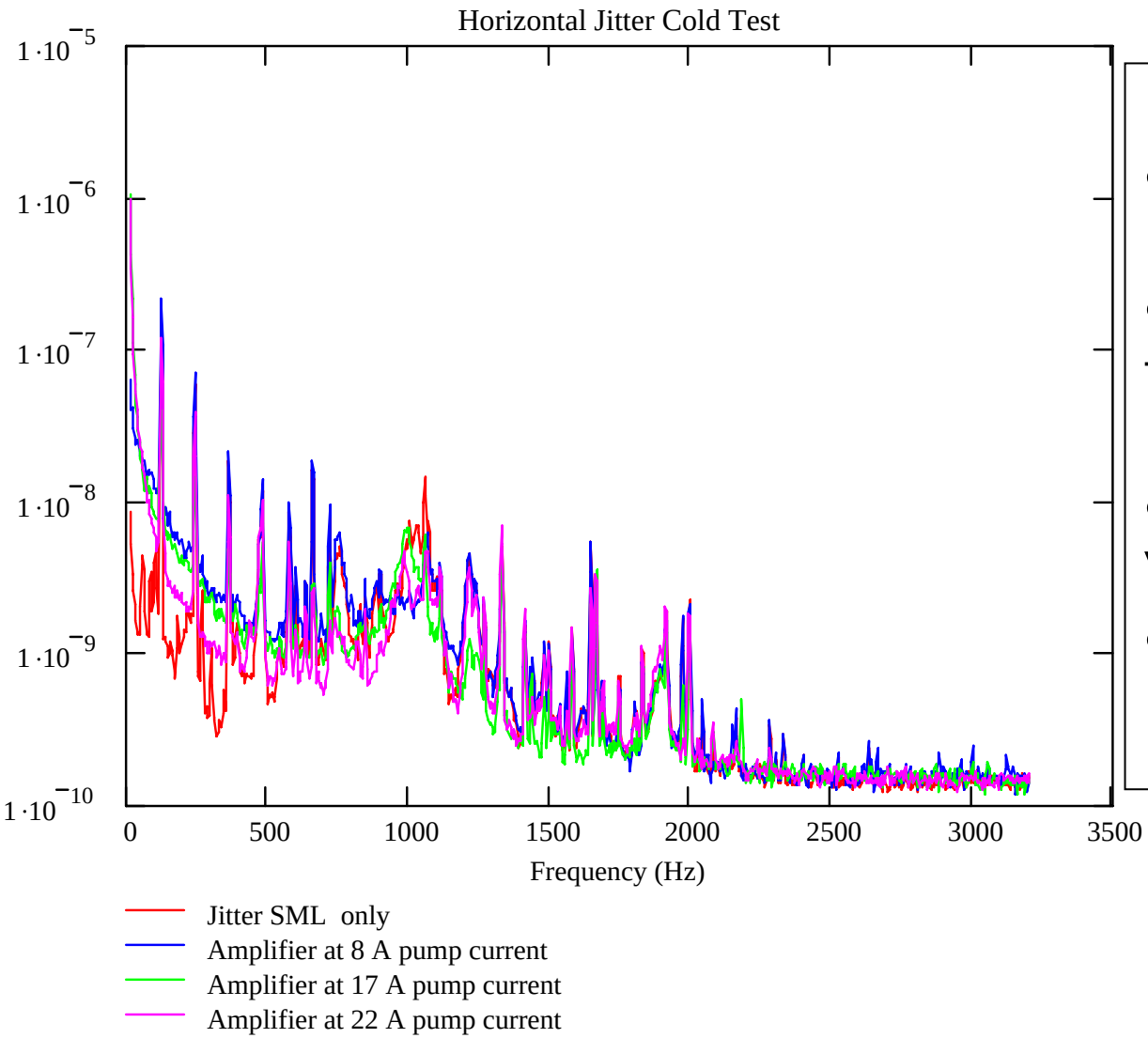
Coherence Data Between Pressure Fluctuations and Jitter



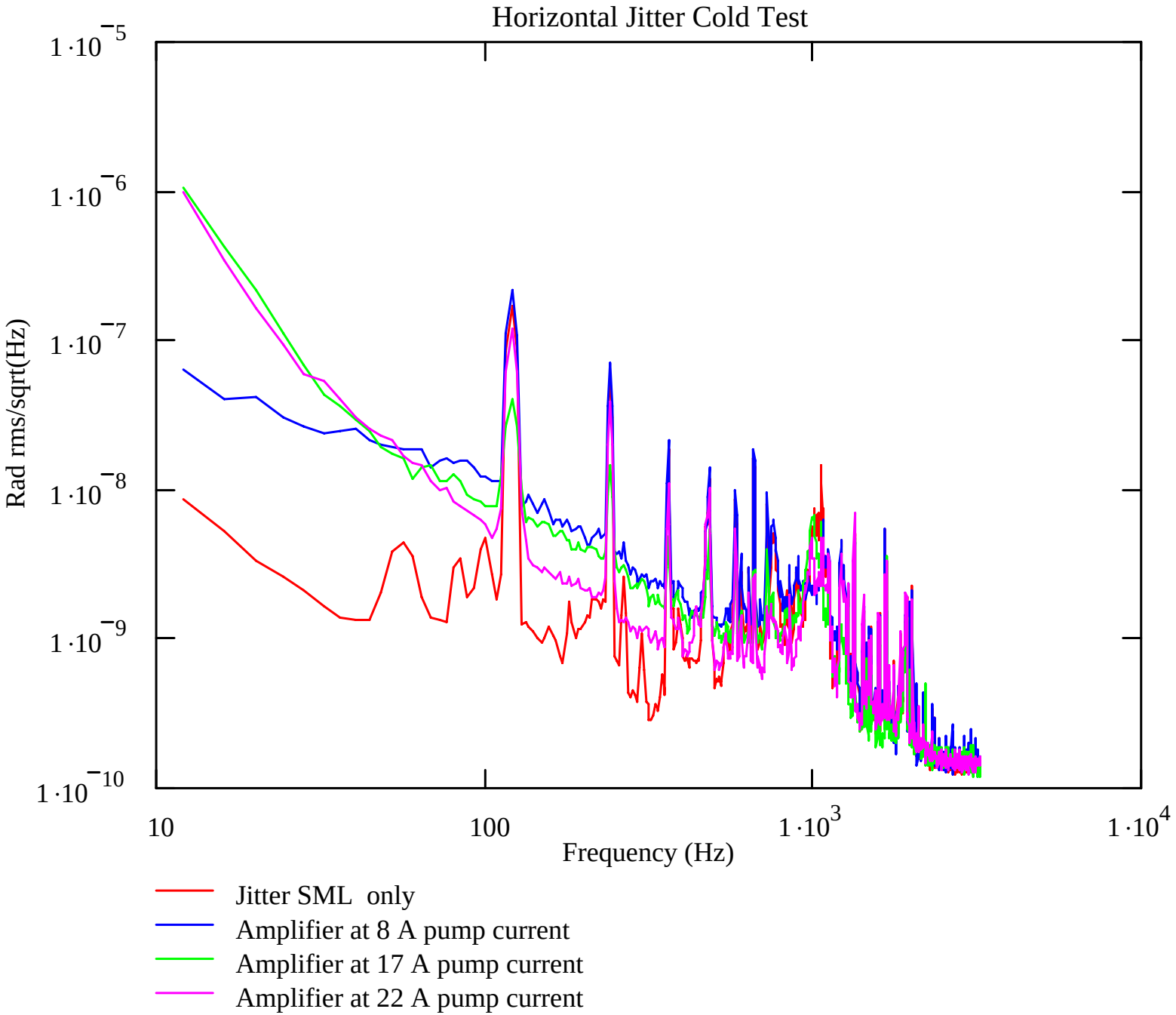
- No Significant Coherence Between Pressure Fluctuations and Pointing Jitter.


Jitter as a function of head pressure
0.01
1 ·10−3
1 ·10−4
1 ·10−5
1 ·10−6
0
500
1000
1500
2000
2500
3000
3500
Frequency (Hz)
Culprit:
Water Flowing Inside Amp
Jitter Drops with Lower Flow
Jitter of SML only
Pump pressure 12 psi, no flow registered
15 psi, no flow
20 psi, ~0.25 gpm
25 psi, <0.4 gpm
30 psi, 0.6 gpm
35 psi, 0.6 gpm
40 psi, 0.75 gpm
45 psi, 0.82 gpm

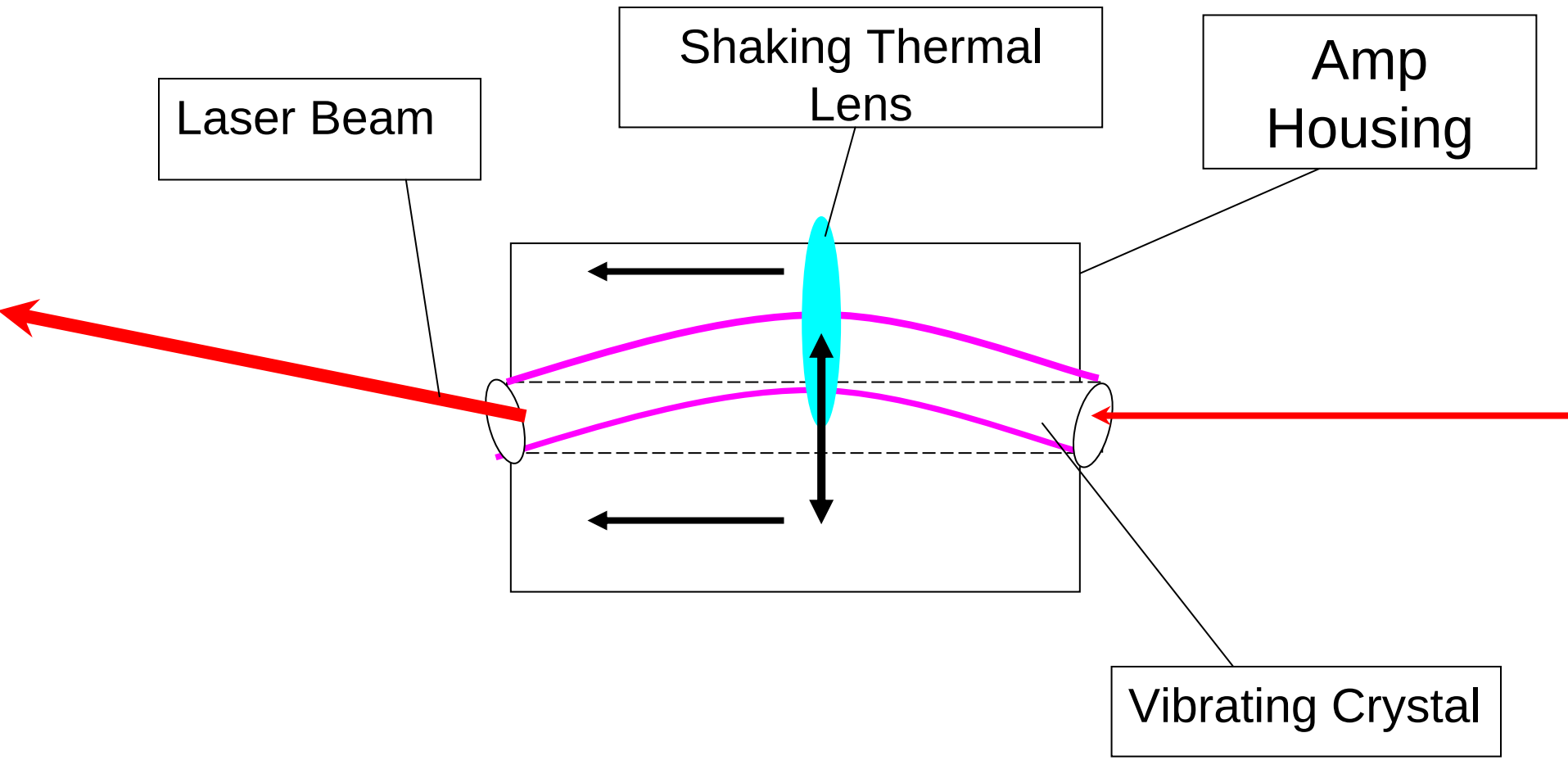
Jitter Spectra at Reduced Flow



- Chiller Pressure 16 PSIG
- Water Temp Reduced from 23 deg C to 16 deg C
- 60 Hz Power Lines Visible
- Better above 500 Hz

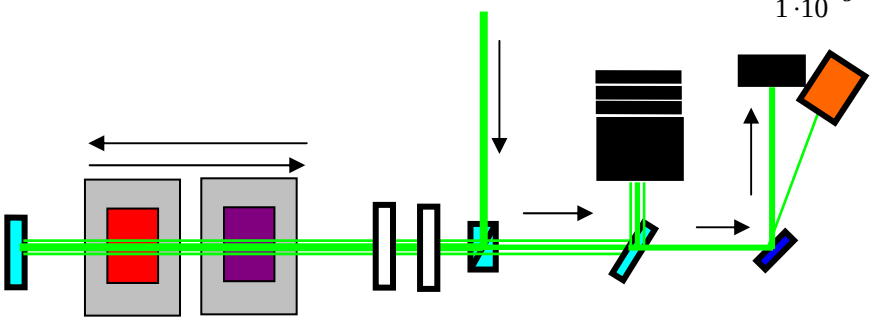

Horizontal Jitter Cold Test
Rad rms/sqrt(Hz)
1·10^-5
1·10^-6
1·10^-7
1·10^-8
1·10^-9
1·10^-10
10
100
1·10^3
1·10^4
Frequency (Hz)
Jitter SML only
Amplifier at 8 A pump current
Amplifier at 17 A pump current
Amplifier at 22 A pump current

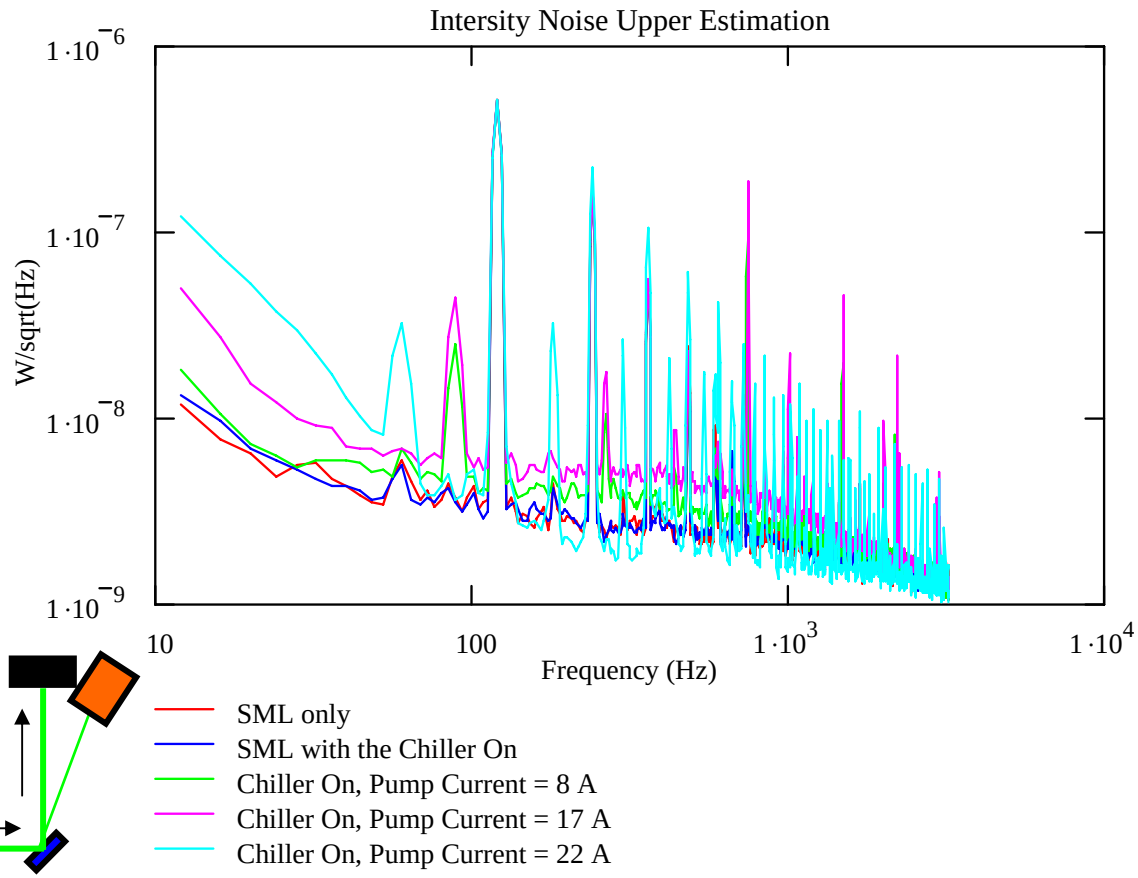
Possible Mechanism for Jitter



Intensity Noise

- Intensity Noise increases with amplifier by ≥2x
- Dominated by 60 Hz components
- Double Pass data





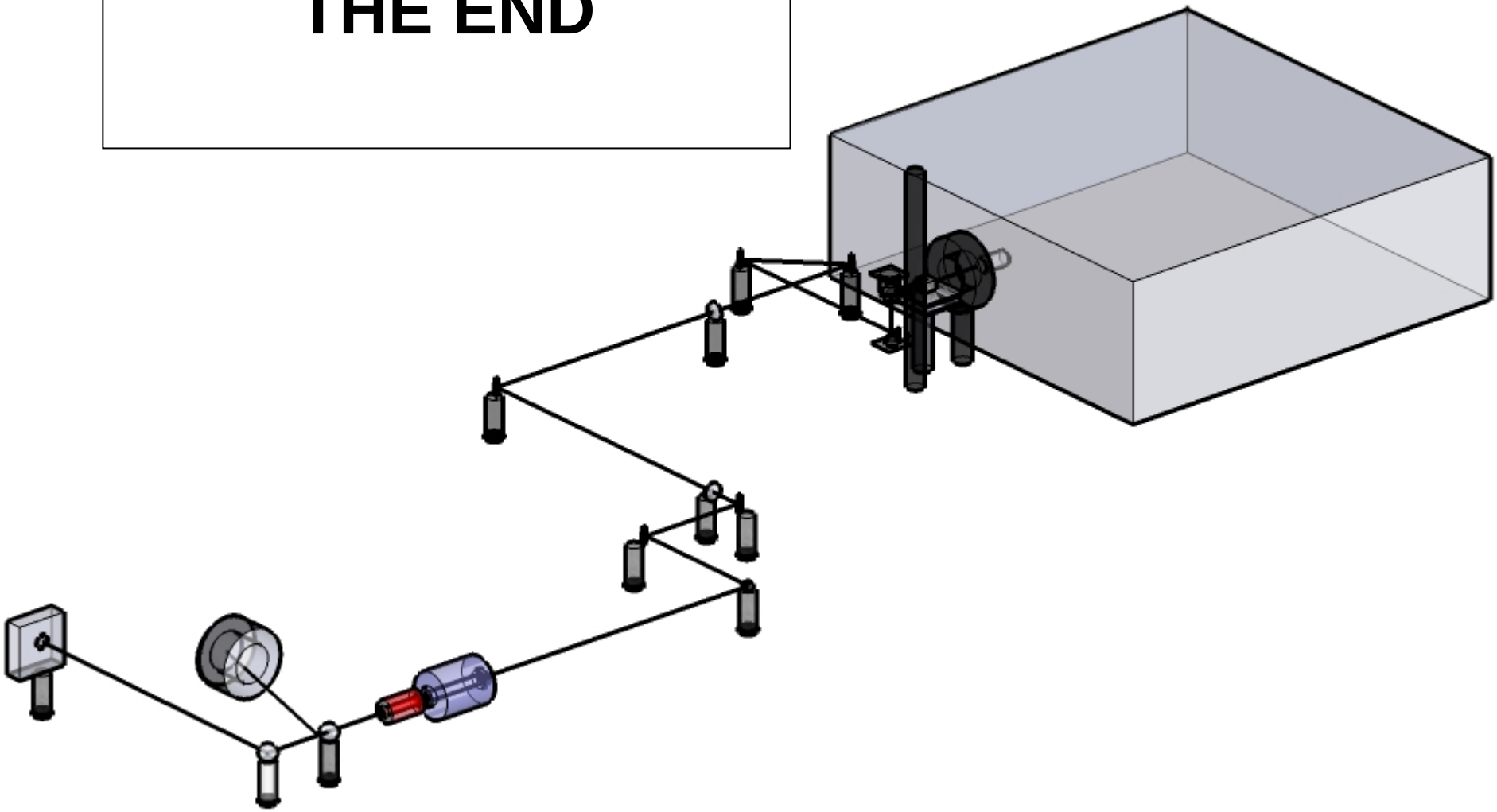
Hurdles

- **Requested power for Fall 2007 upgrade, 30 W**
  - **Maximum power estimated from amplifier quad pass, 22 W**
- **Instrumentation:**
  - **Temperature control of x-tal and laser diodes**
  - **Current/laser power control**
- **Amplitude/Frequency/Phase Noise?**

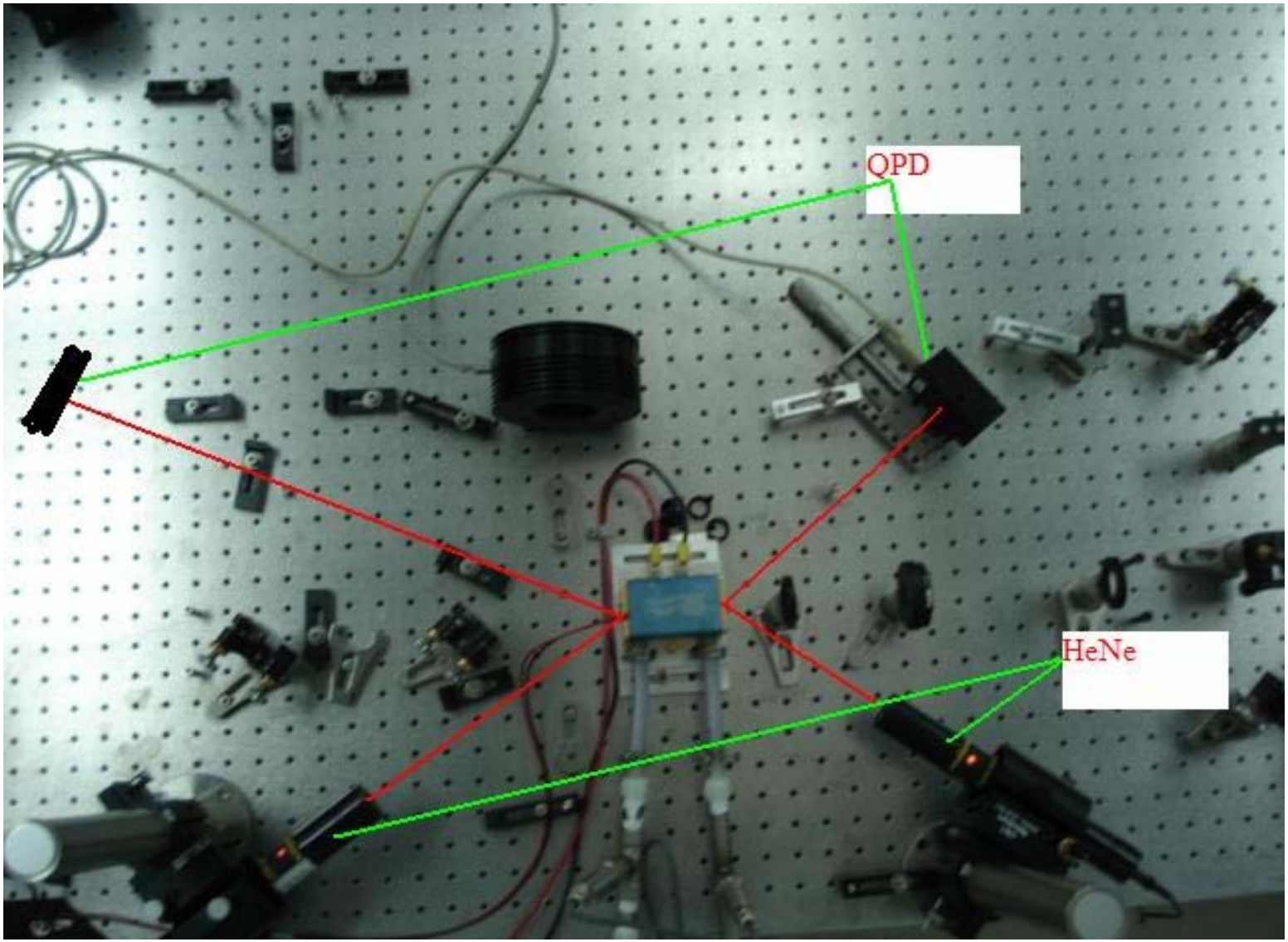
Conclusions

- **Good power output**
- **Require a larger crystal for 30 W**
- **Thicker crystal would reduce beam jitter**
- **Could be used as patch for a failing MOPA**

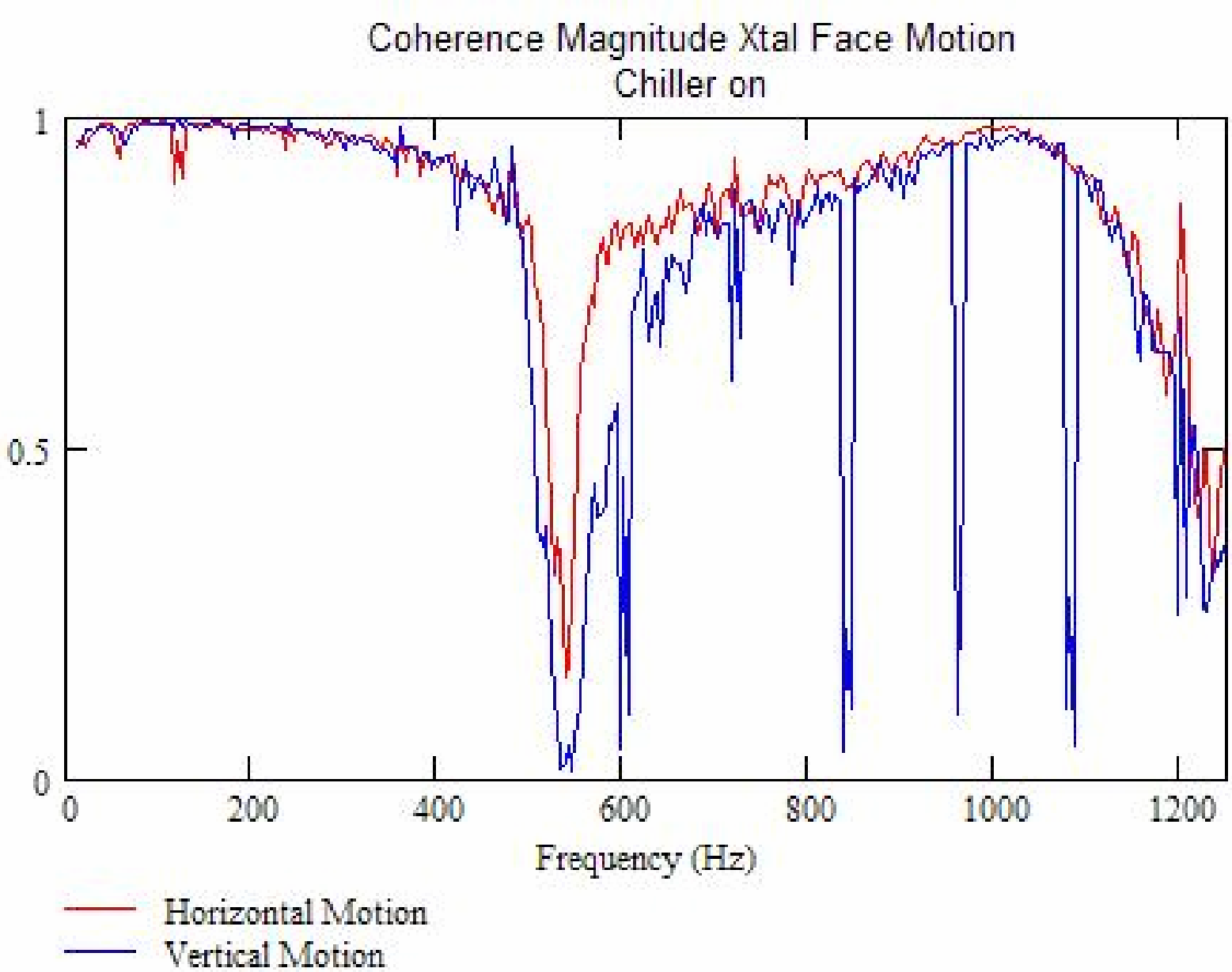
THE END



Tracking Crystal Faces



Coherence data from Crystal Faces



Phase data from Crystal Faces