The High-finesse Fabry-Perot Cavity

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PREx Collaboration Meeting
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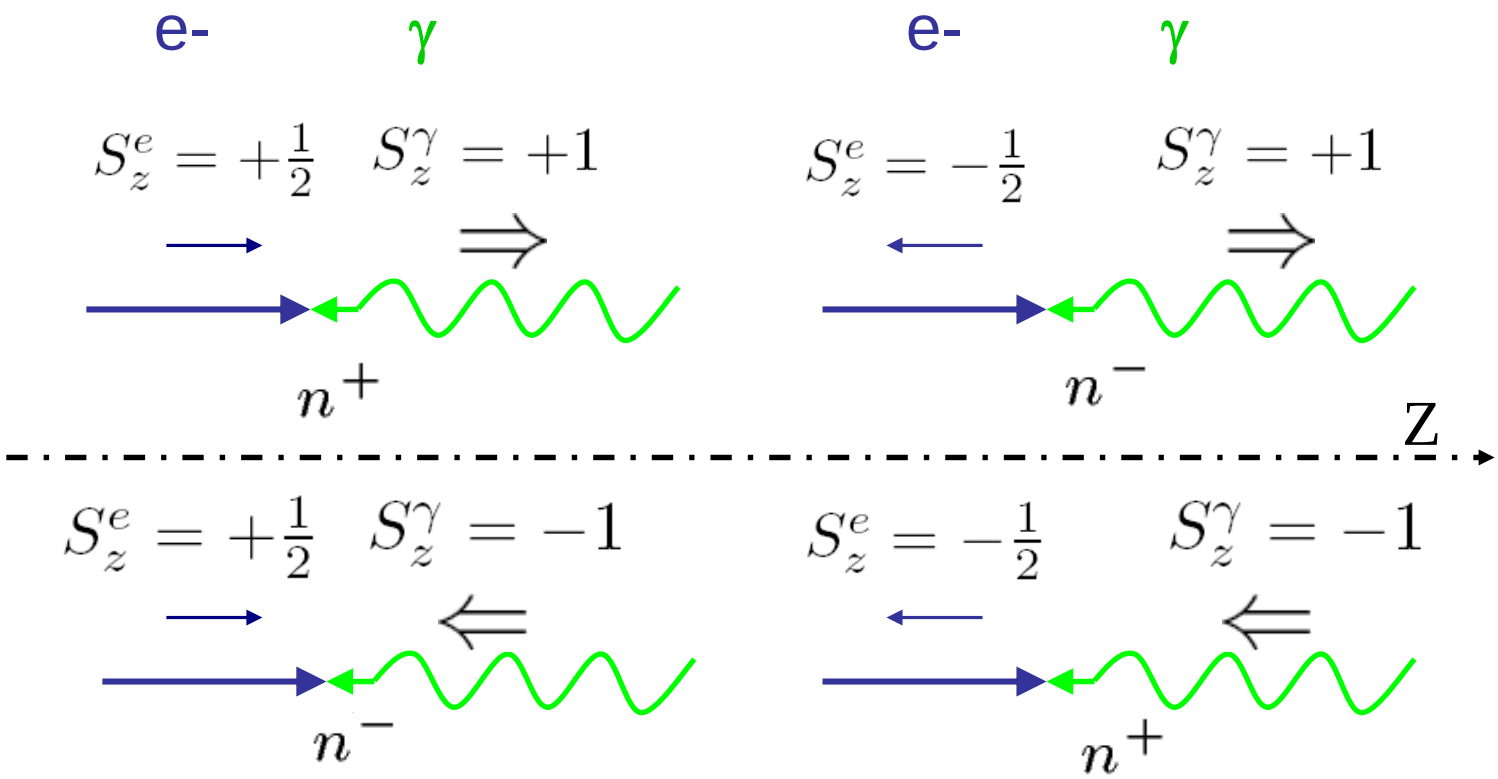
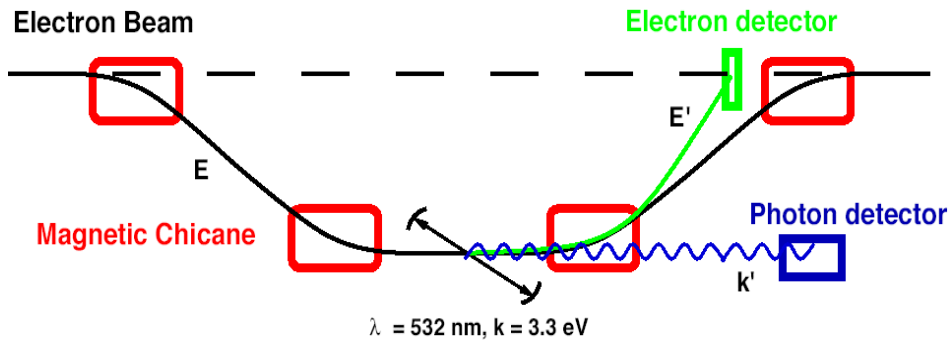
Outline

- Compton Upgrade at Jefferson Lab
- Principles of the Fabry-Perot Cavity
- Cavity Parameters & Prometheus Laser
- Mode Matching
- Cavity Locking
- Conclusions and Future Plans

Compton Polarimeter:



$$A_{\exp} = \frac{n^+ - n^-}{n^+ + n^-} = P_\gamma \times P_e \times < A_{th} >$$



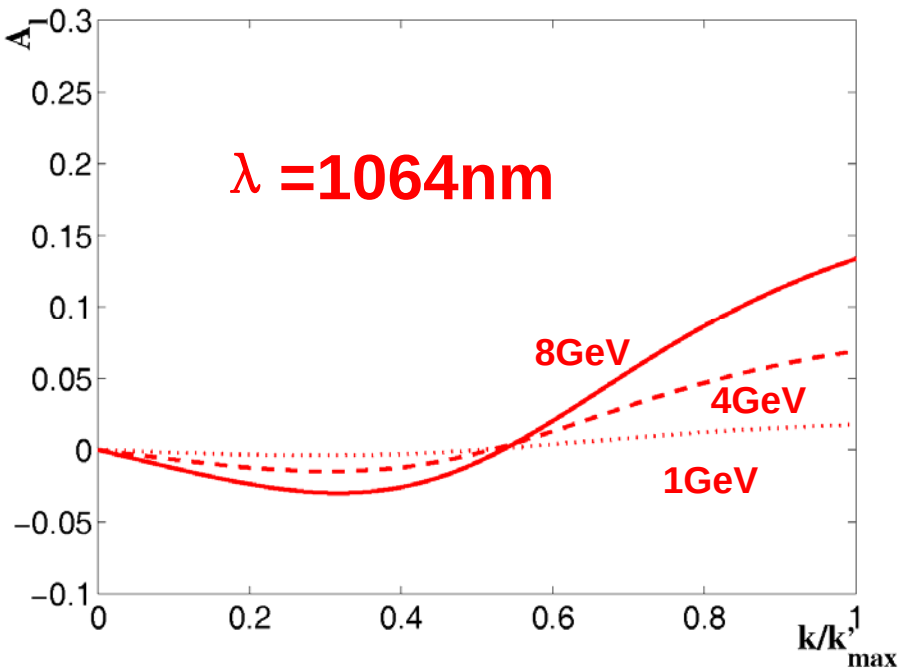
Compton Upgrade:

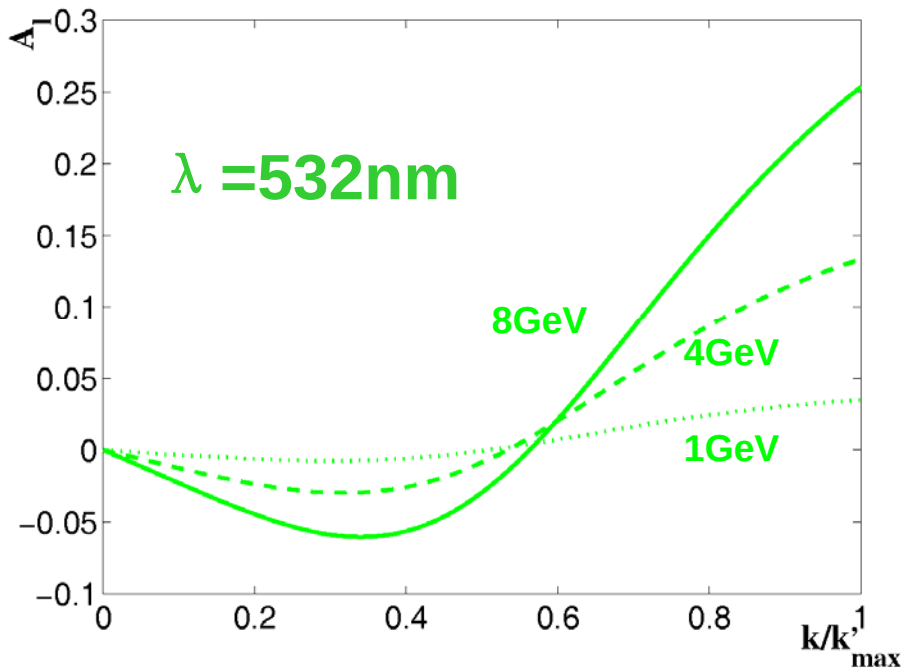
$$\frac{\Delta P_e^{stat}}{P_e} \propto \frac{1}{A_l \sqrt{L\sigma\Delta t}}$$

$$\frac{\Delta P_e^{syst}}{P_e} \propto \frac{1}{A_l}$$

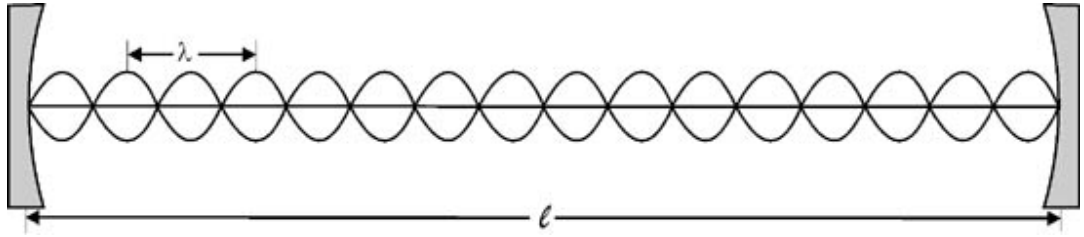
Gain: 7000 15000

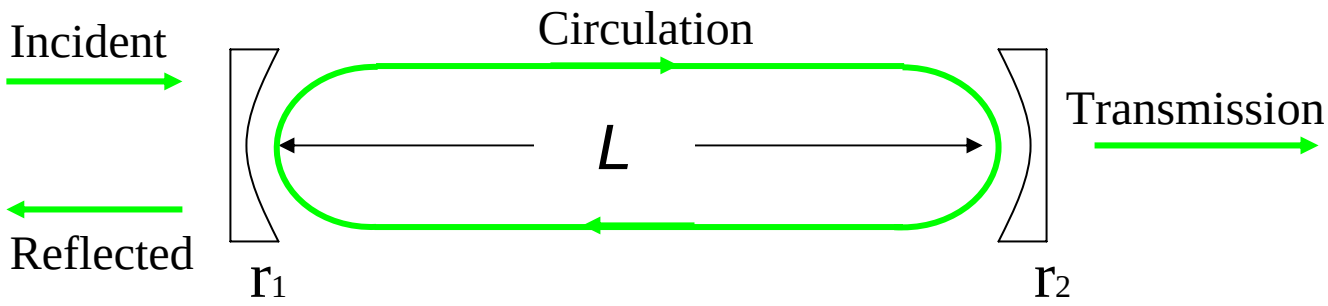
Parameter	Symbol	Specification
Fabry-Perot Resonator		
Finesse	F	49,000
Power Gain	G	14,990
Q-factor	Q	1.8×10^{11}
Length	L	0.85 m
Free Spectral Range	$\Delta\nu_{FSR}$	153 MHz
Cavity Bandwidth	$\delta\nu_{cav}$	3.12 kHz
Beam Waist Size	σ	60 μm





Fabry-Perot Cavity:

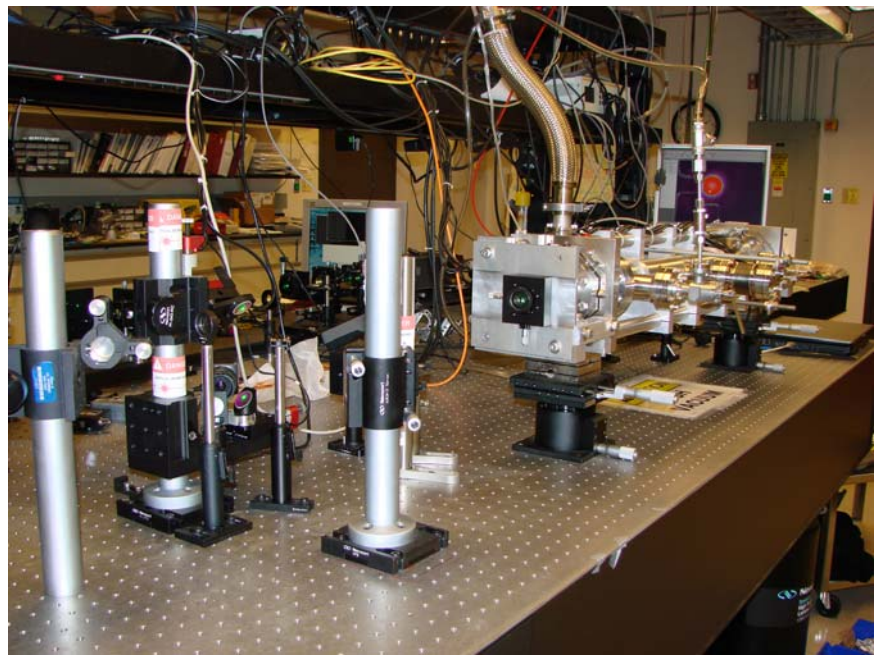




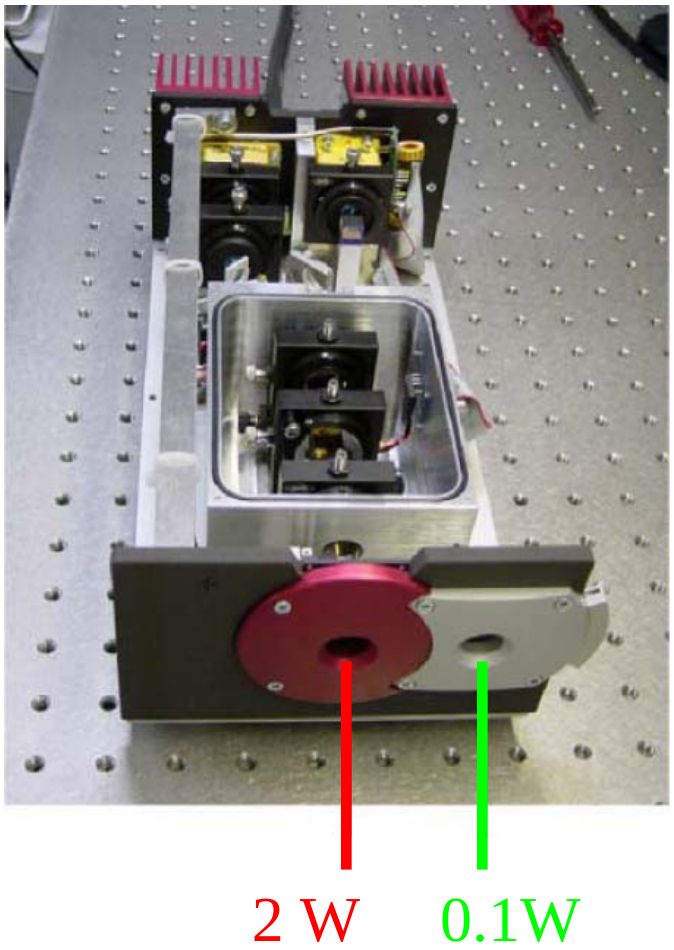
Previously locking was successful with a **G~2,000**

Current Cavity Mirror:

Los Gatos Research, Inc. (LGR)
Type: Plano-Concave
Radius of Curvature: 1 m
Reflectivity: 99.987±0.001%
G=6,000
F=18,000



Prometheus Laser:



Innolight GmbH, Germany

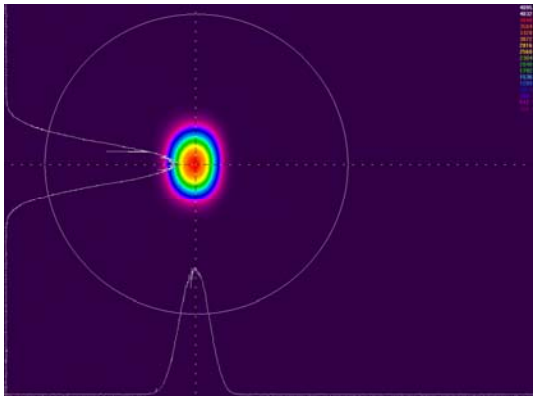
- 809 nm Pump Diodes
- 1064 nm Nd:YAG
- 532 nm SHG via PPKTP

Wavelength	532 nm
Output power	100 mW
Mode	TEM00
Beam roundness	<1.1
Beam diameter	0.38 mm
Beam divergence	2.8 mrad
Polarization	>100:1
Thermal tuning coefficient	-6 GHz/K
Thermal tuning range	60 GHz
Thermal response bandwidth	1 Hz
PZT tuning coefficient	2 MHz/V
PZT tuning range	±200 MHz
PZT response bandwidth	100 kHz
Spectral line width	1 kHz/100 ms
Coherence length	>1 km
Frequency drift	2 MHz/min
Relative intensity noise (RIN)	> -90 dB/Hz
Noise eater option RIN	> -140 dB/Hz

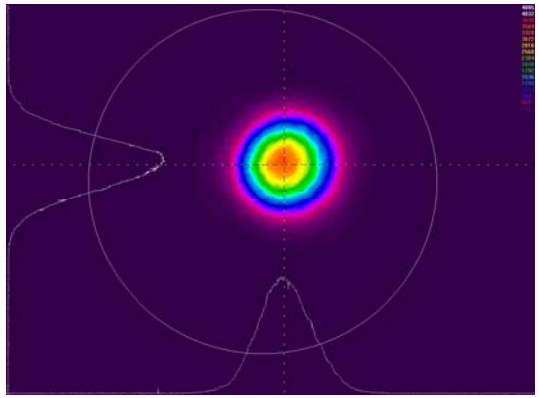
Prometheus Laser Profile:

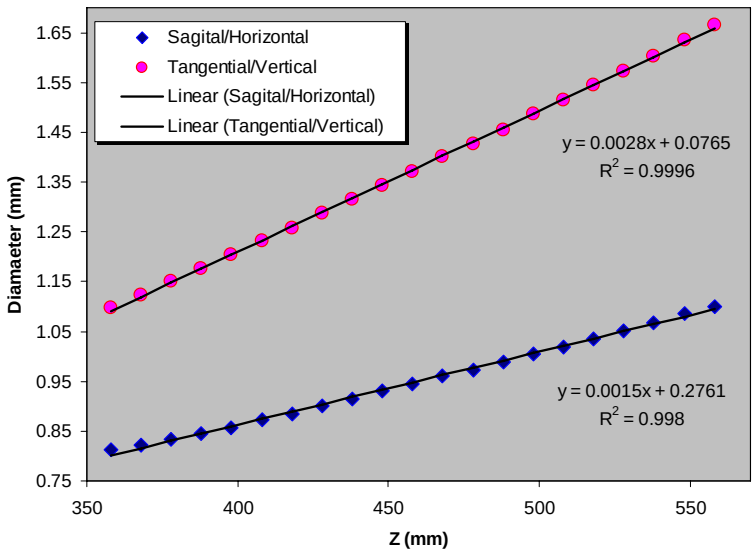
Beam is highly elliptic, circularization is needed

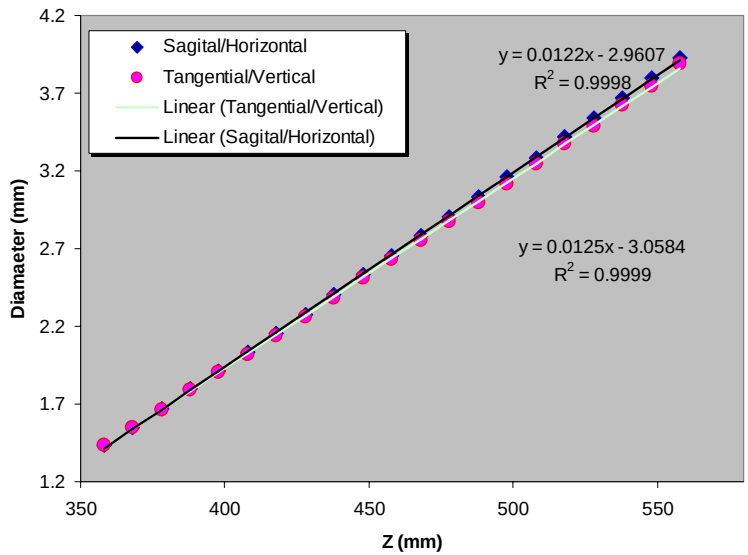
Before



After



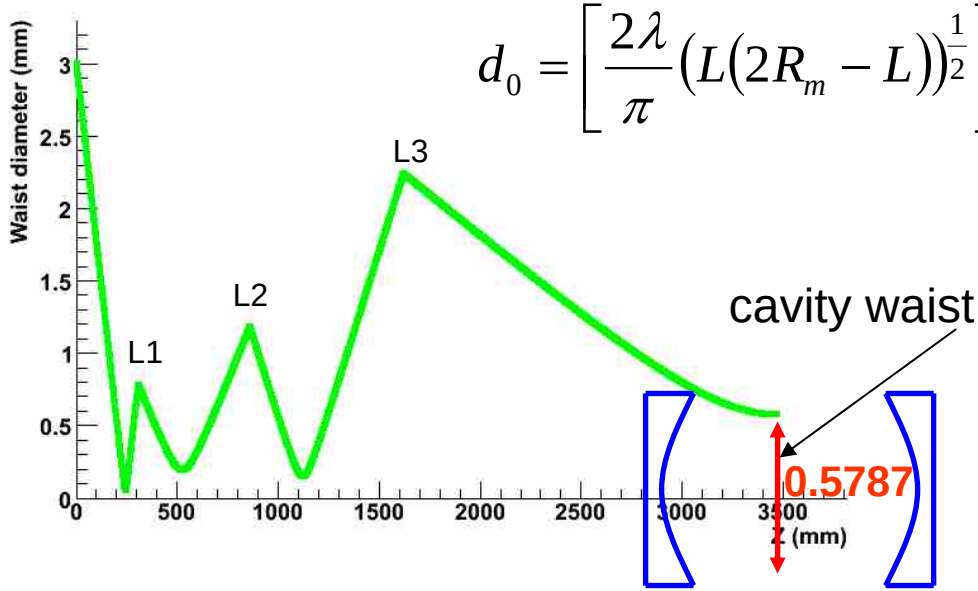




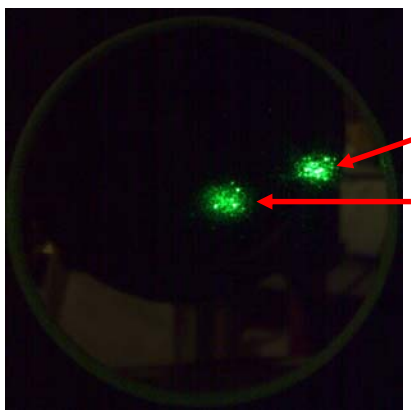
Mode-Matching:

- laser mode (beam) should match the cavity resonator mode
- beam waist at the center should match the natural waist of the cavity

$$d_0 = \left[\frac{2\lambda}{\pi} \left(L(2R_m - L) \right)^{\frac{1}{2}} \right]^{\frac{1}{2}}$$



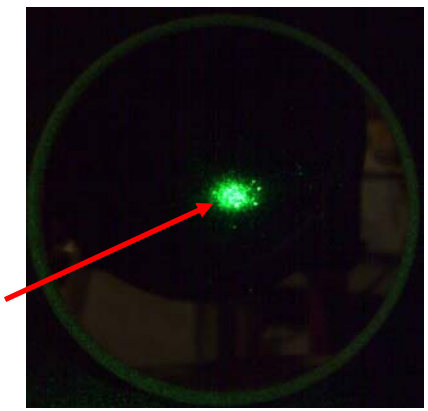
TEM00 mode

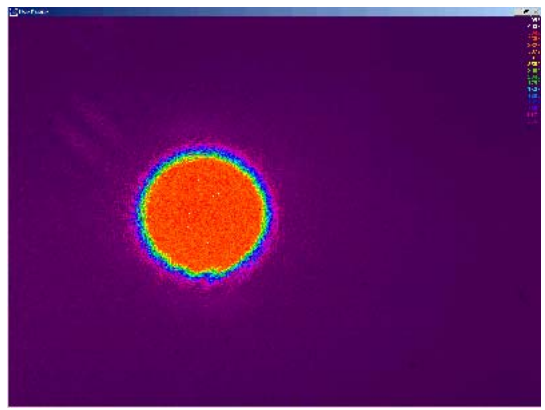


incident

reflected

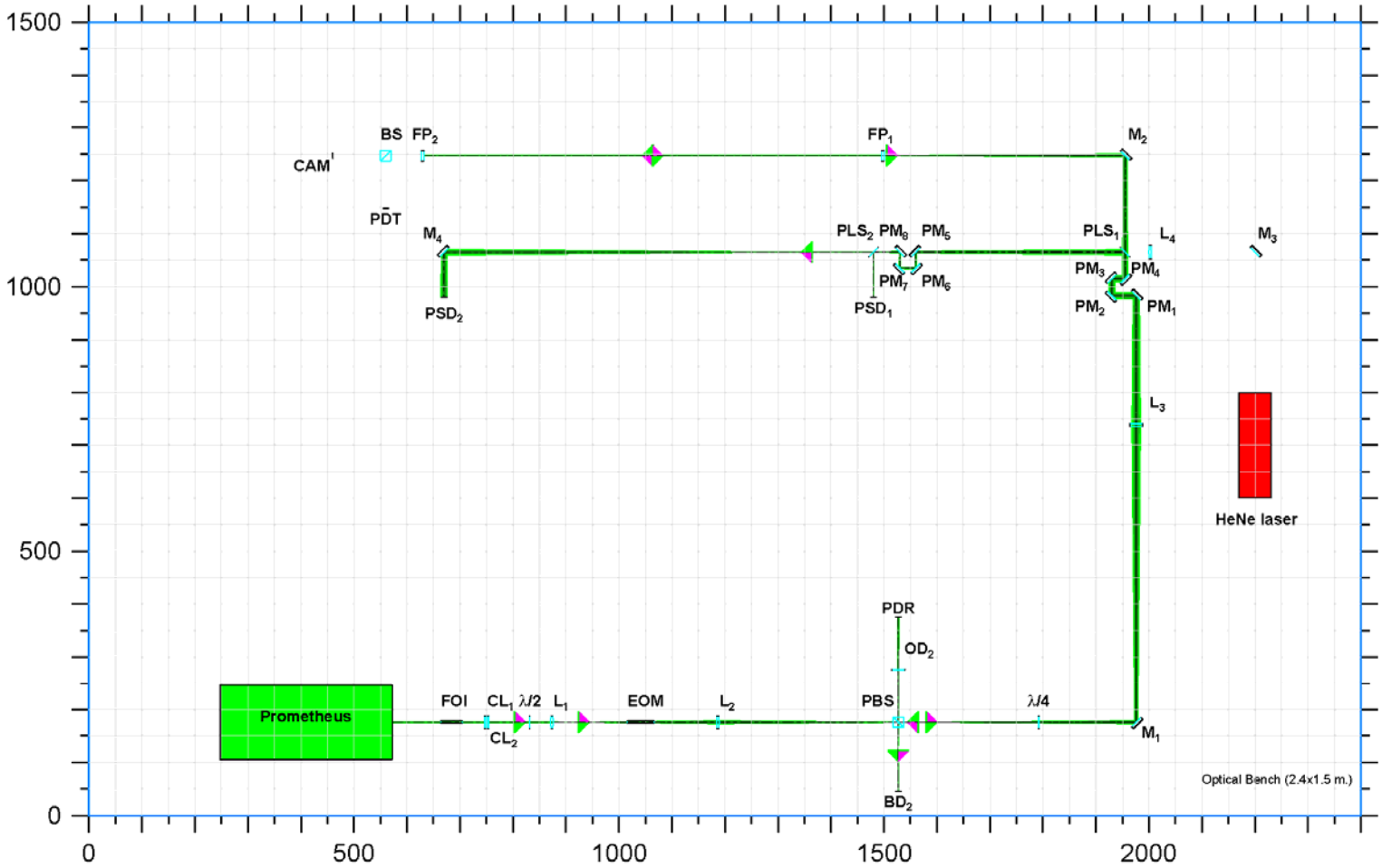
mode matched





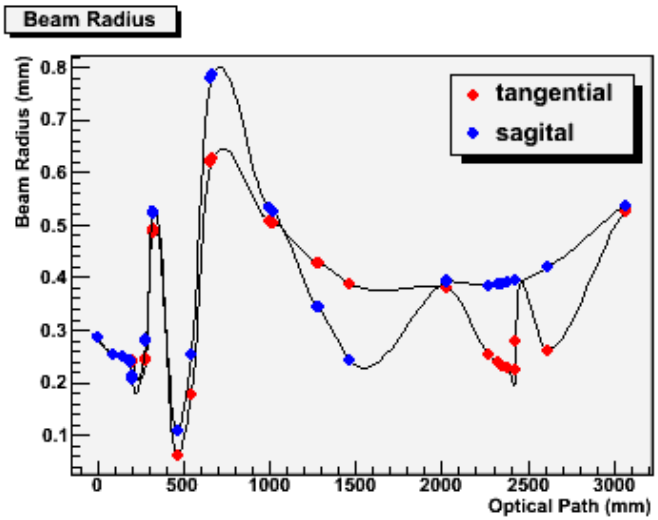
OptoCad:

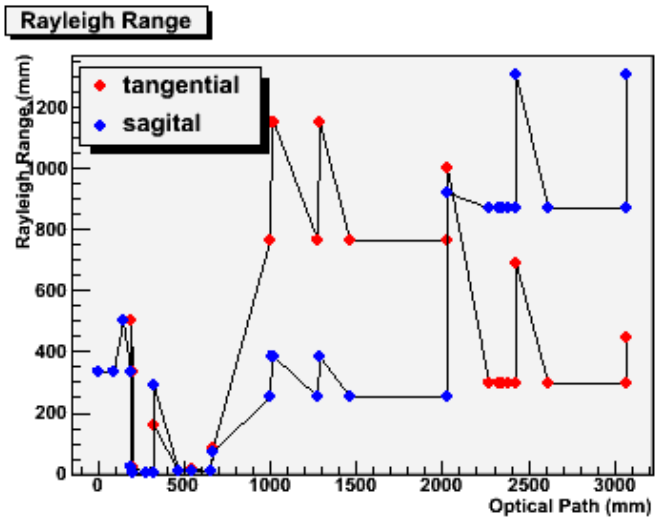
FORTRAN90 program for tracing Gaussian beams
computes the parameters of the optical system

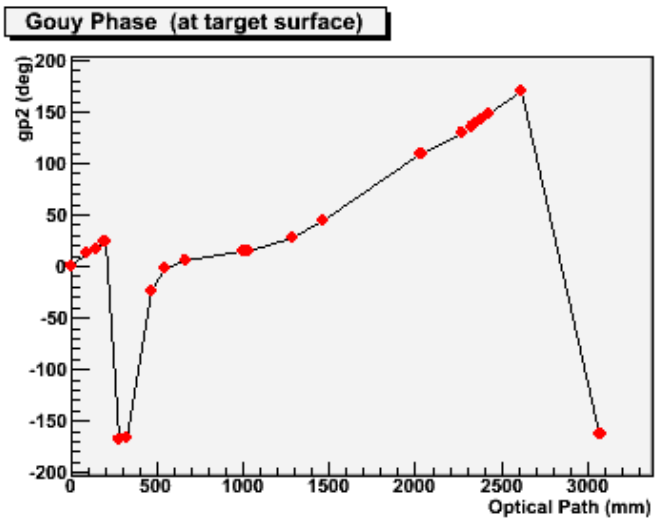


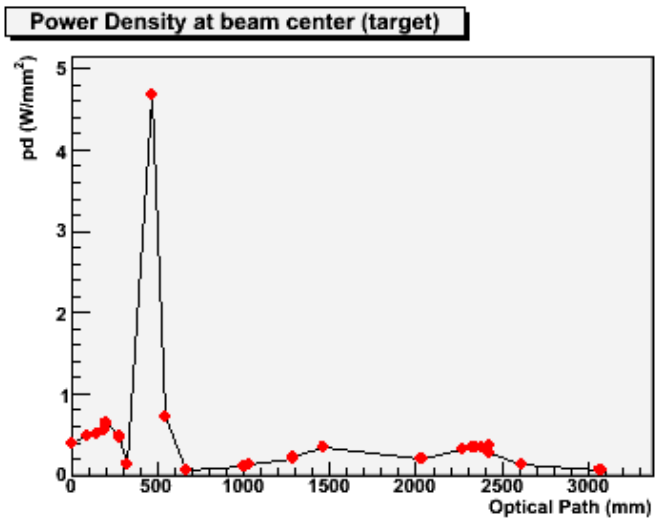
Green cavity optical layout by OptoCad

Complete ray tracing by OptoCad (in development):



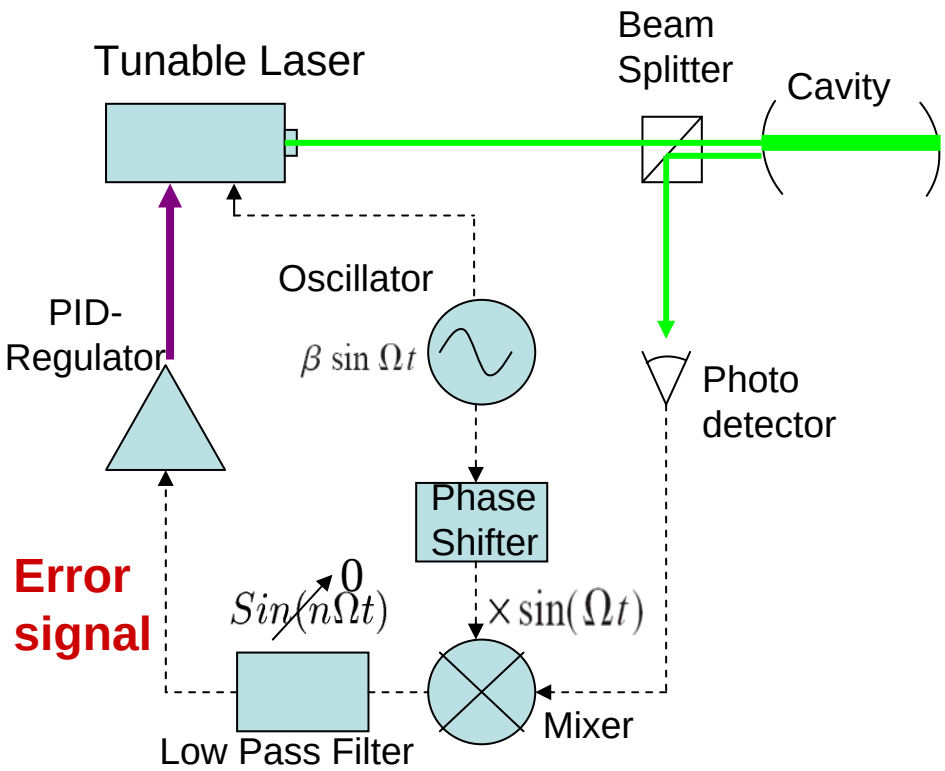




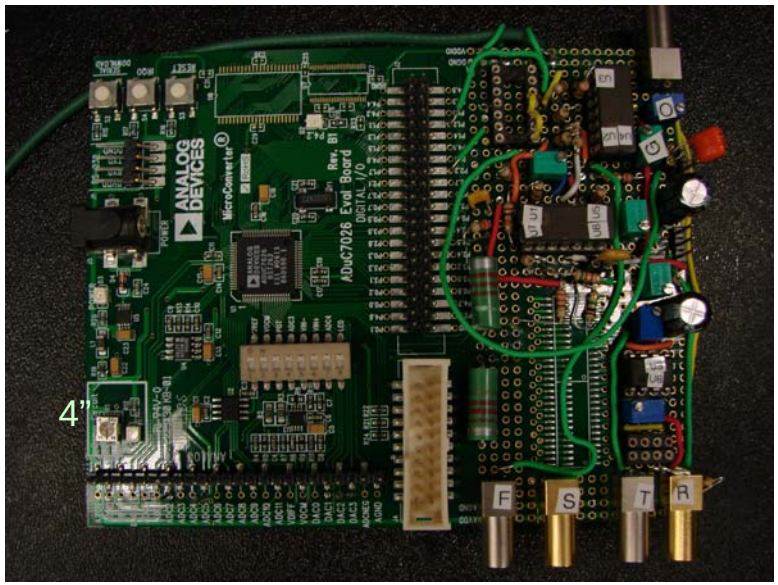


Pound-Drever-Hall (PDH) Locking Scheme:

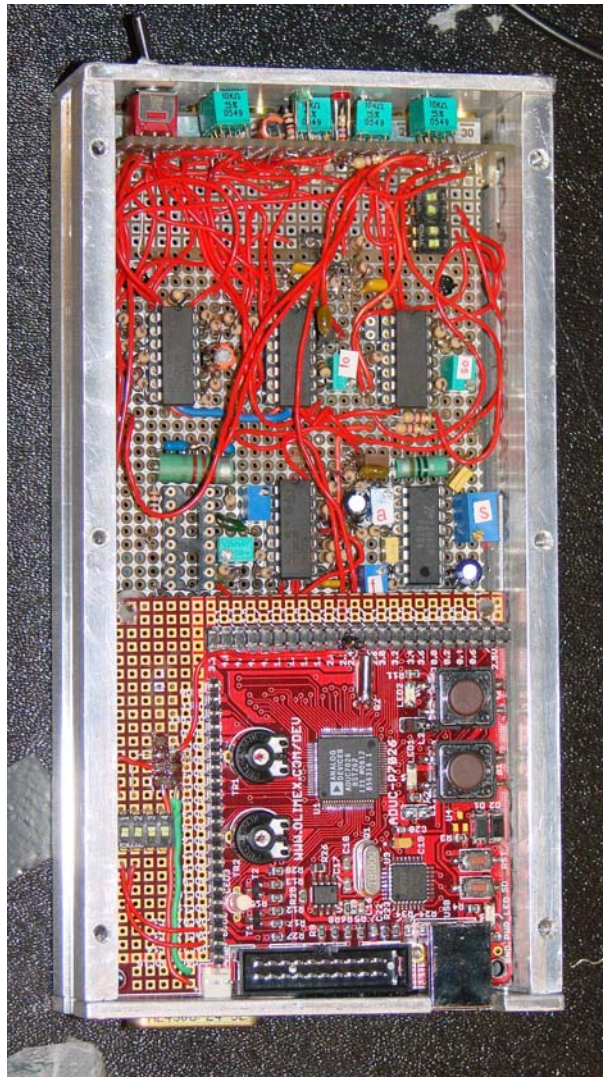
Detect phase of the resonance from reflected light
Feedback to tunable element to stay “locked” to resonance



Digital CavLock Electronics (Homemade):

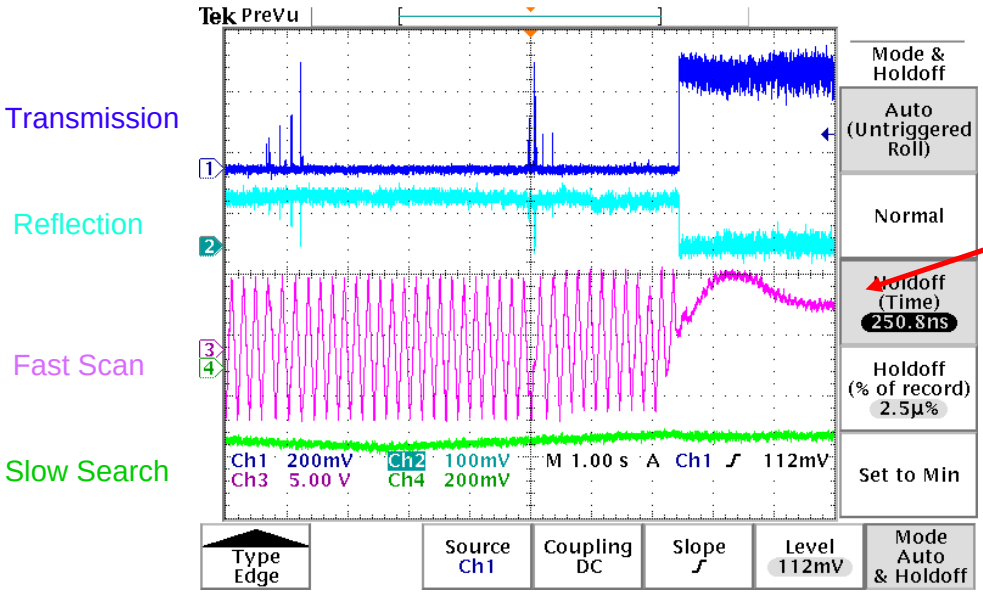


previous



current

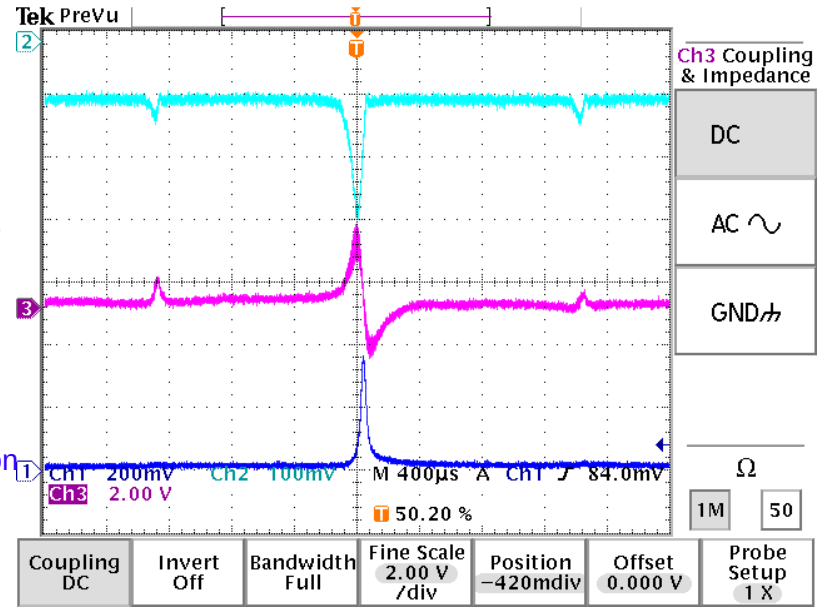
Search / scan / lock logic:



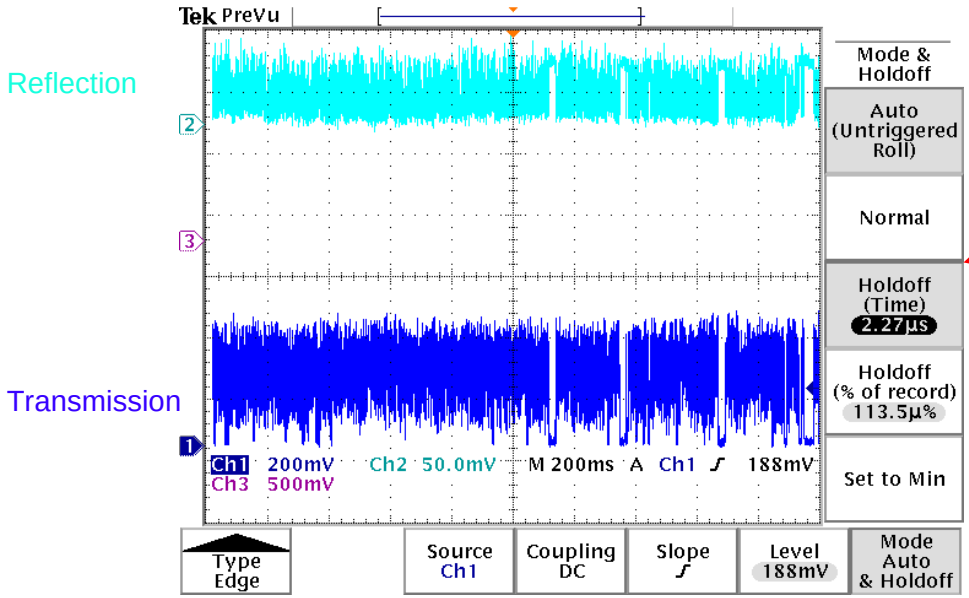
Successful locking with low gain cavity

Reflection

Signals of LGR cavity

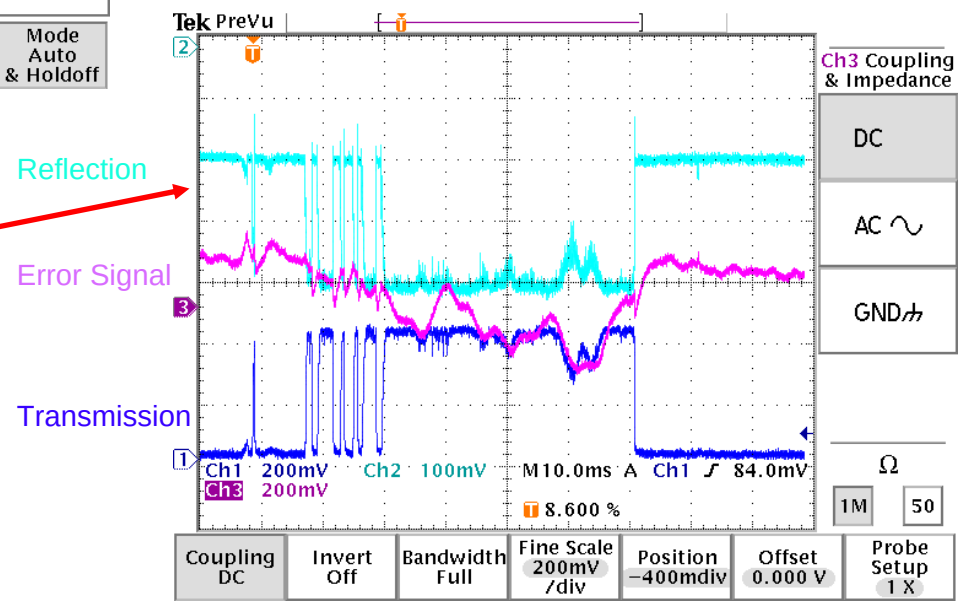


Cavity Locking:



2 sec level lock, only with fast PZT feedback, but unacceptable due to large fluctuations

reworked electronics, 40 msec level short lock with fast PZT feedback only



Feedback loop tuning in progress

Conclusions:

- Prometheus Laser has been reprofiled
- Mode matching of LGR mirror has been accomplished
- Complete ray tracing of the system by OptoCad is in development
- Cavity feedback loop tuning in progress
- Short duration lock has been achieved

Thank you !

Cavity Parameters:

Free Spectral Range : $FSR = \frac{c}{2d}$

Gain: $G = \frac{(R_1 R_2)^{\frac{1}{4}}}{1 - \sqrt{R_1 R_2}}$

Finesse: $F = \frac{FSR}{FWHM} = \pi \bullet G$

Band Width: $\Delta \upsilon = \frac{FSR}{F}$