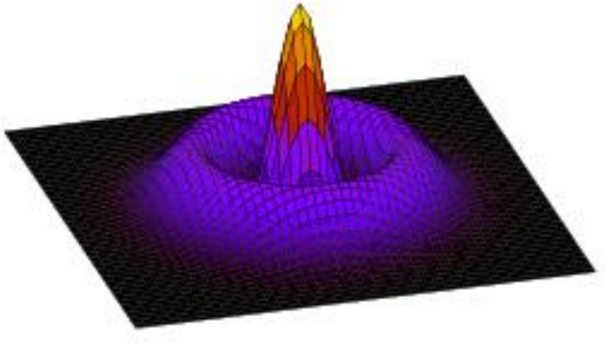
Using *Finesse* for Simulations of Light Behavior in Optical Cavities

FINESSE 0.99.8

Frequency domain INterferomEter Simulation SoftwarE

Andreas Freise



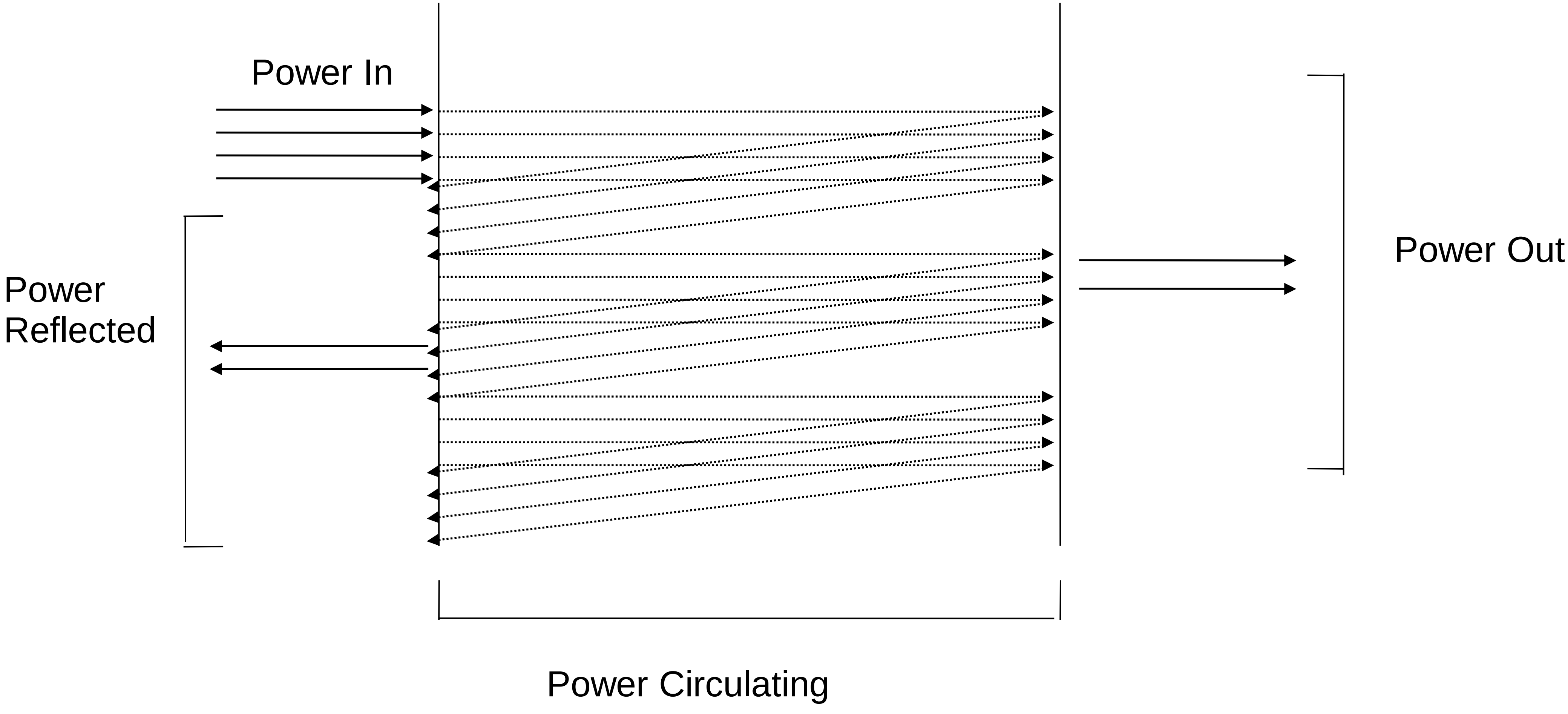
Nicholas Pratt

Abstract and Purpose

- Simulate basic optical cavities and research their qualities.
- Simulate the Holometer in an ideal environment.
- Pinpoint configuration of largest power build-up.
- Simulate errors in the system to replicate actual experimental results.
- Aid in the remedying of imperfect configurations.

Power Build-Up

- Two mirrors create a cavity
- Power is built up in this cavity



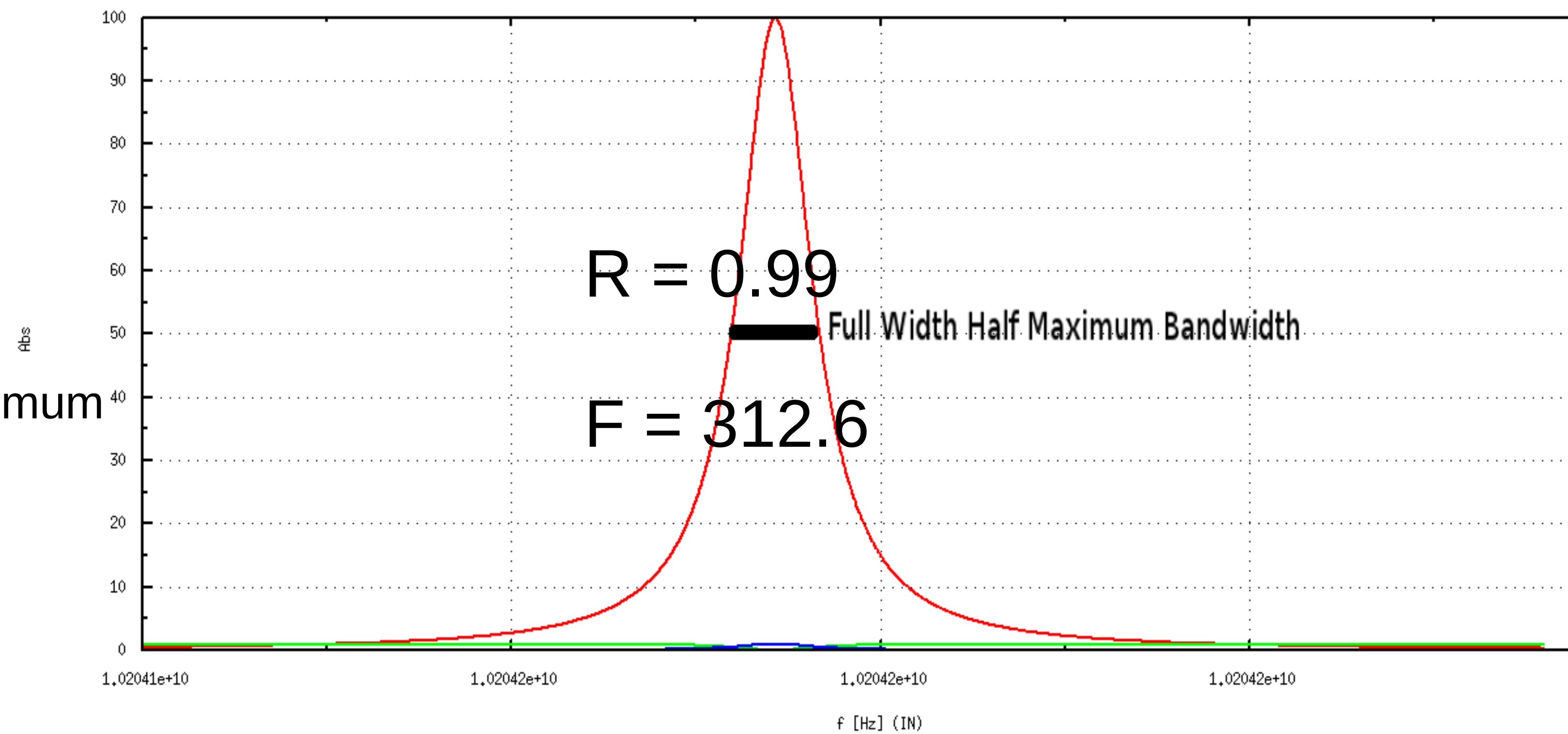
Basic Power Build-Up
Fabry-Perot Interferometer

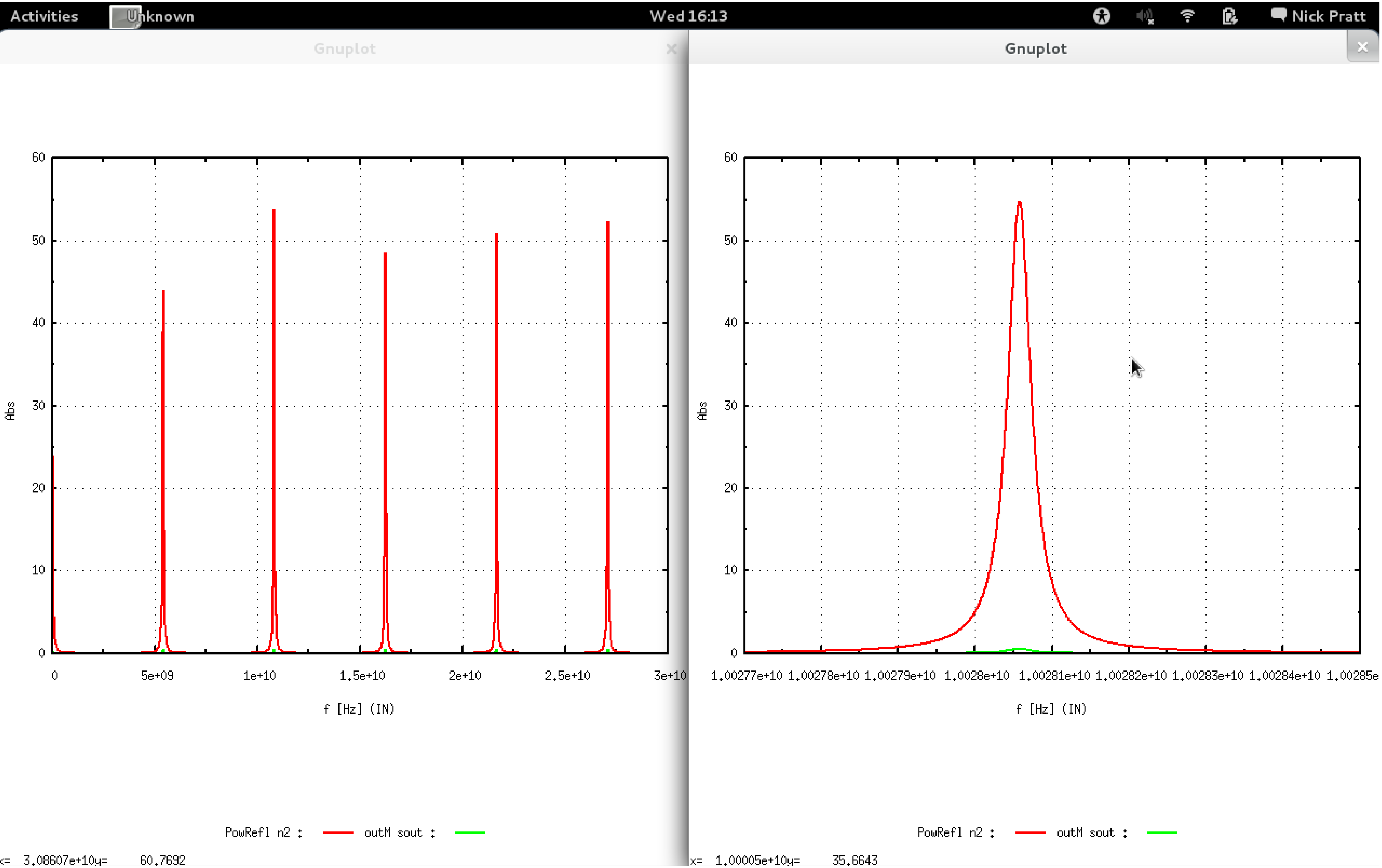
- Very little buildup at most frequencies
- Definite resonant frequencies
- Power build-up
- Some useful attributes include:

Free Spectral Range:
FSR = c/2L

Full Width – Half Maximum Bandwidth

Finesse:
F = FSR/FWHM
$F = \frac{\pi \sqrt{R}}{1 - R}$





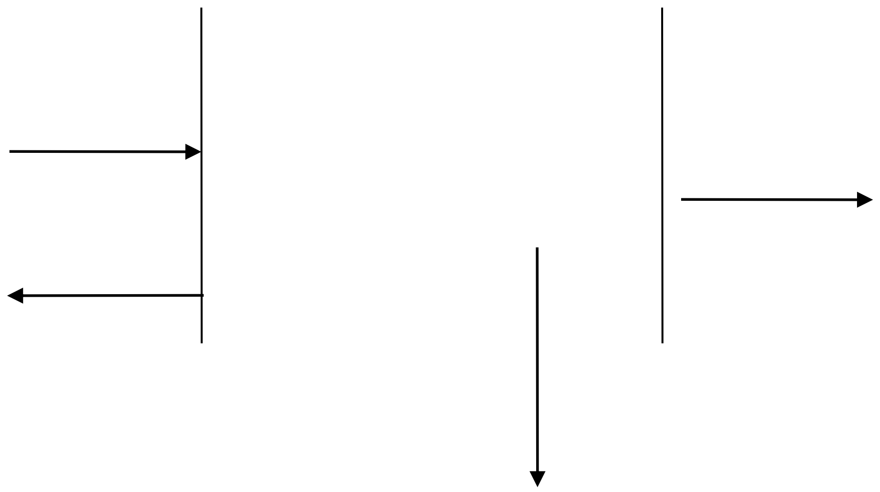
Activities
Unknown
Wed 16:13
Nick Pratt
Gnuplot
Gnuplot
60
50
40
30
20
10
0
Abs
0
5e+09
1e+10
1.5e+10
2e+10
2.5e+10
3e+10
f [Hz] (IN)
PowRefl n2 :
outM sout :
x= 3.08607e+10y= 60.7692
60
50
40
30
20
10
0
Abs
1.00277e+10 1.00278e+10 1.00279e+10 1.0028e+10 1.00281e+10 1.00282e+10 1.00283e+10 1.00284e+10 1.00285e
f [Hz] (IN)
PowRefl n2 :
outM sout :
x= 1.00005e+10y= 35.6643

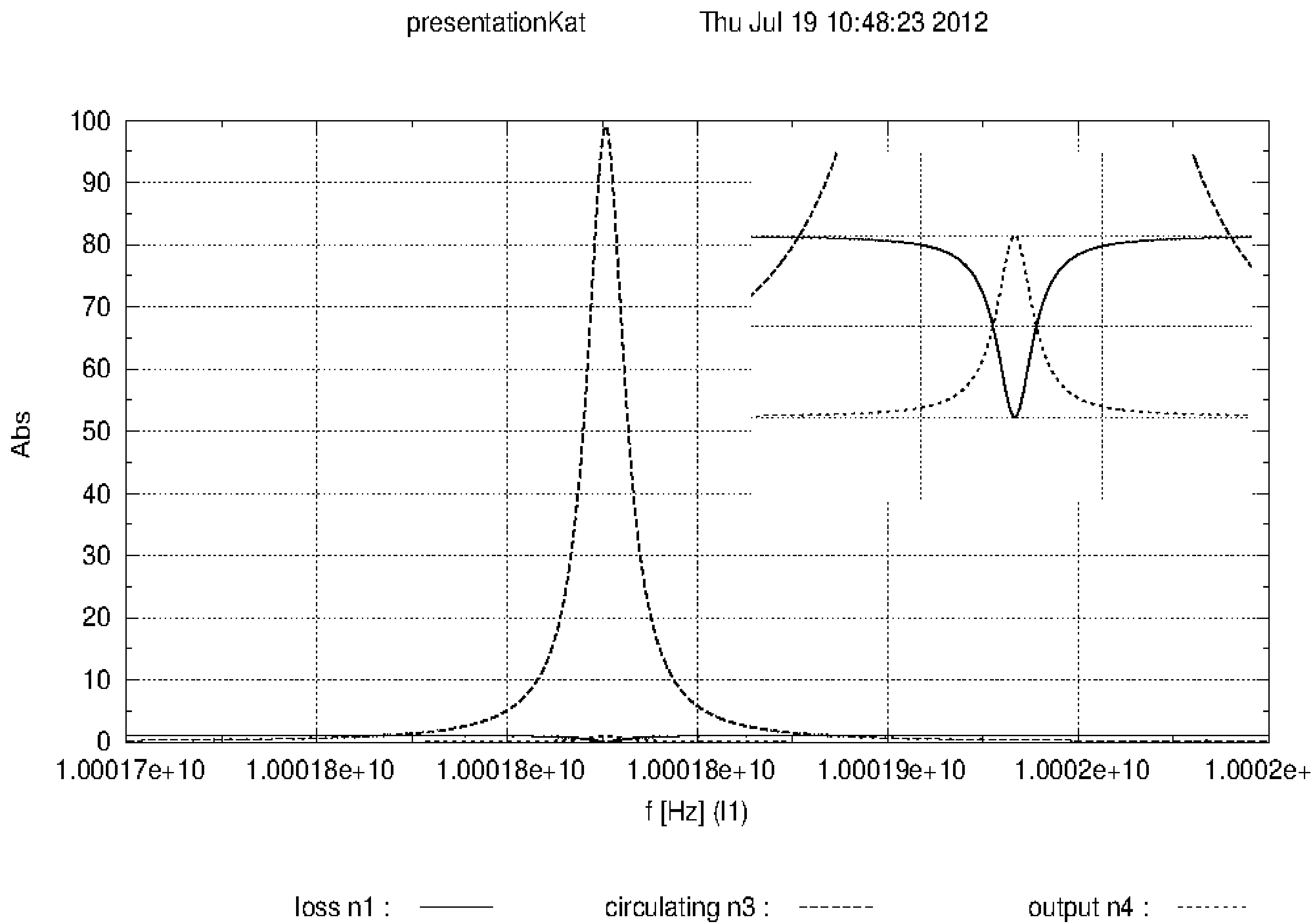
Why Use *Finesse*?

- Avoid messy calculations
- Presentable graphical format
- Simple to change simulation parameters
- “Invisible Detectors”
  - Detectors can be placed in spots where they couldn't be in experiment.
- Quick data collection
  - 1 Second – 2 Minutes
- Change multiple parameters

A Simple Cavity

```
l l1 1 0 n1
m m1 .99 .01 0 n1 n2
s s1 40 n2 n3
m m2 .99 .01 0 n3 n4
pd loss n1
pd circulating n3
pd OUTPUT n4
xaxis l1 f lin 1.00017e+10 1.0002e+10 1000
```

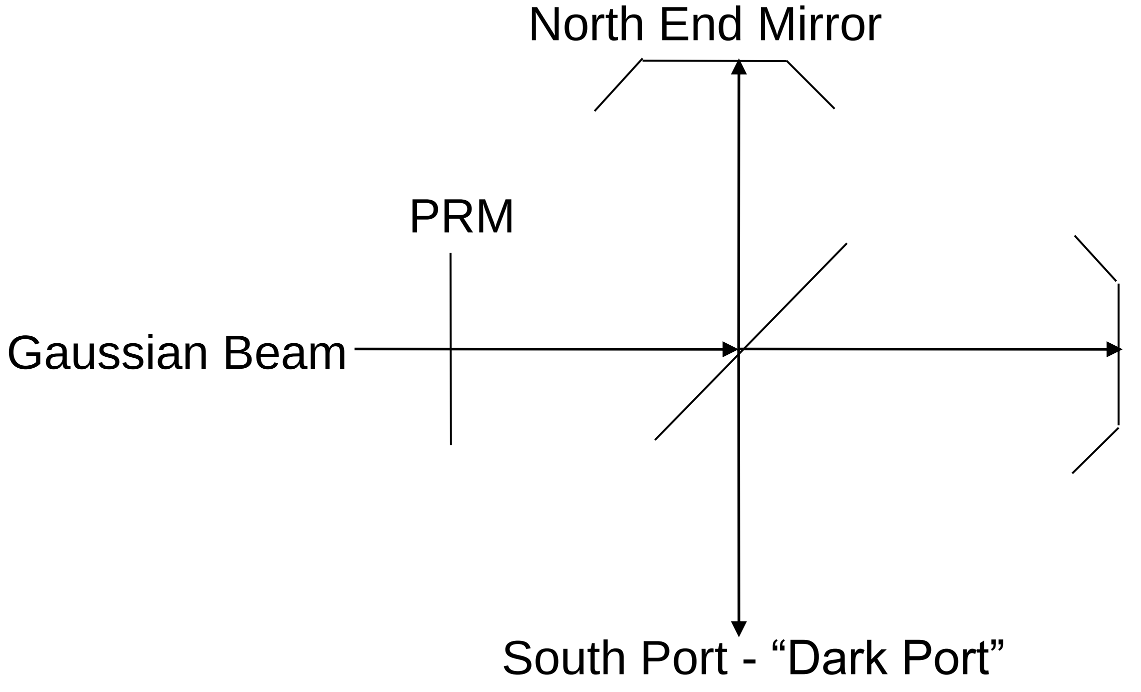




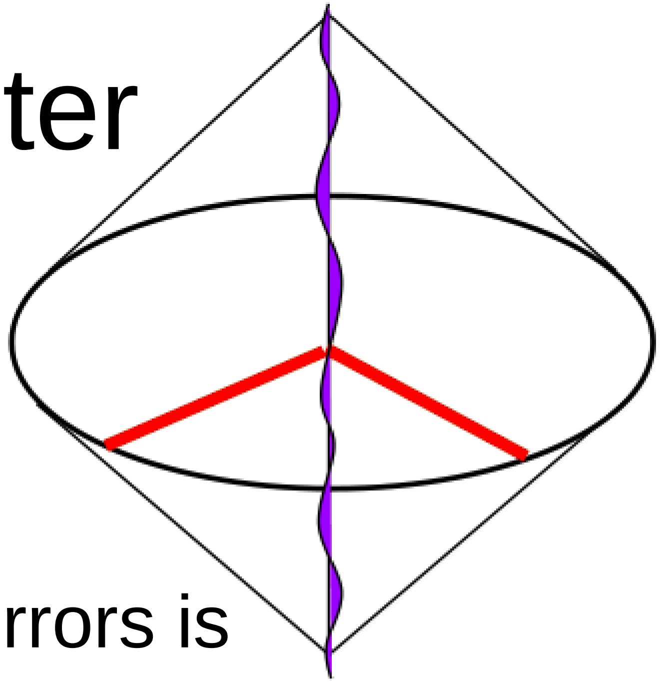
presentationKat
Thu Jul 19 10:48:23 2012
100
90
80
70
60
50
40
30
20
10
0
Abs
1.00017e+10
1.00018e+10
1.00018e+10
1.00018e+10
1.00019e+10
1.0002e+10
1.0002e+
f [Hz] (l1)
loss n1 :
circulating n3 :
output n4 :

Fermilab Holometer

- Two nested/back-to-back Michelson Interferometers
- Power Recycled



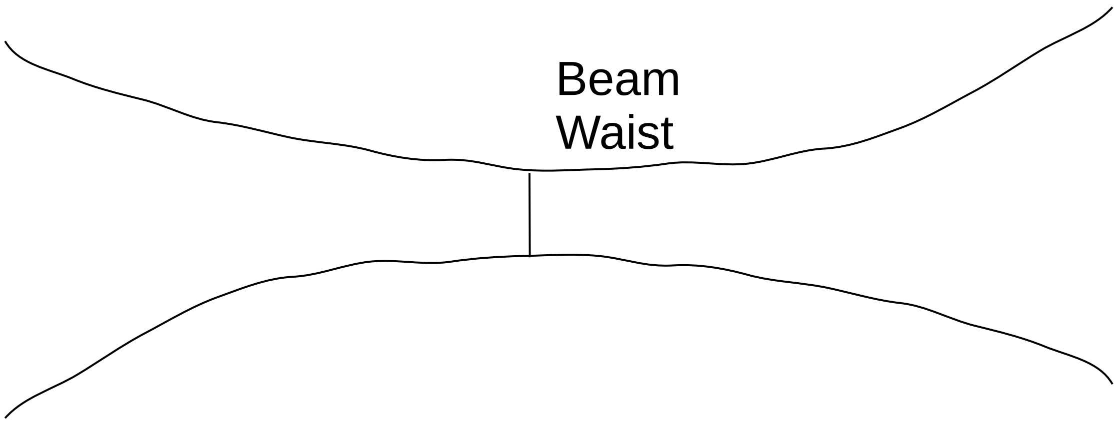
Fermilab Holometer



- Sensitive to beam splitter position
- Laser light reflected back from the end mirrors is measured
- Microposition of the end mirrors affect the results
- Background noise causes sensitive materials to wobble out of place
- Seismometers measure this noise directly

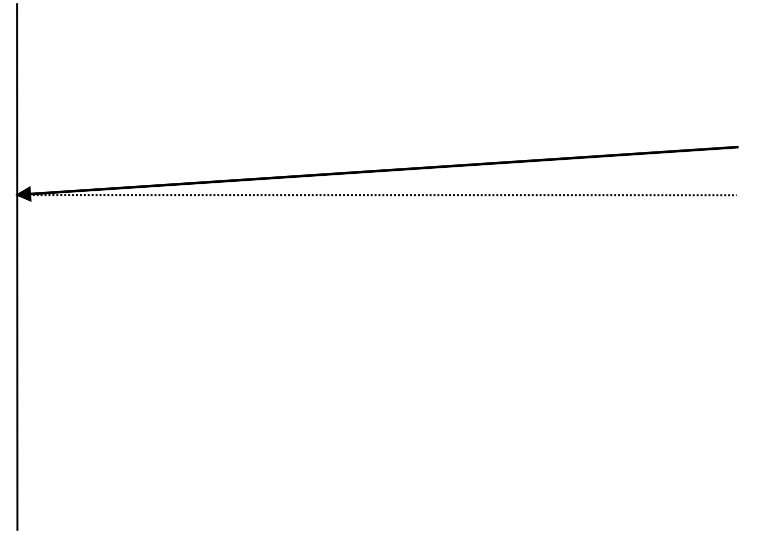
Gaussian Beam

- Describes how real laser beams propagate
- Useful Attributes
  - Beam Waist – Width of thinnest spot
  - Rayleigh Range – Steepness of change
  - Radius of Curvature
  - Angular Alignment
  - Mirror microposition

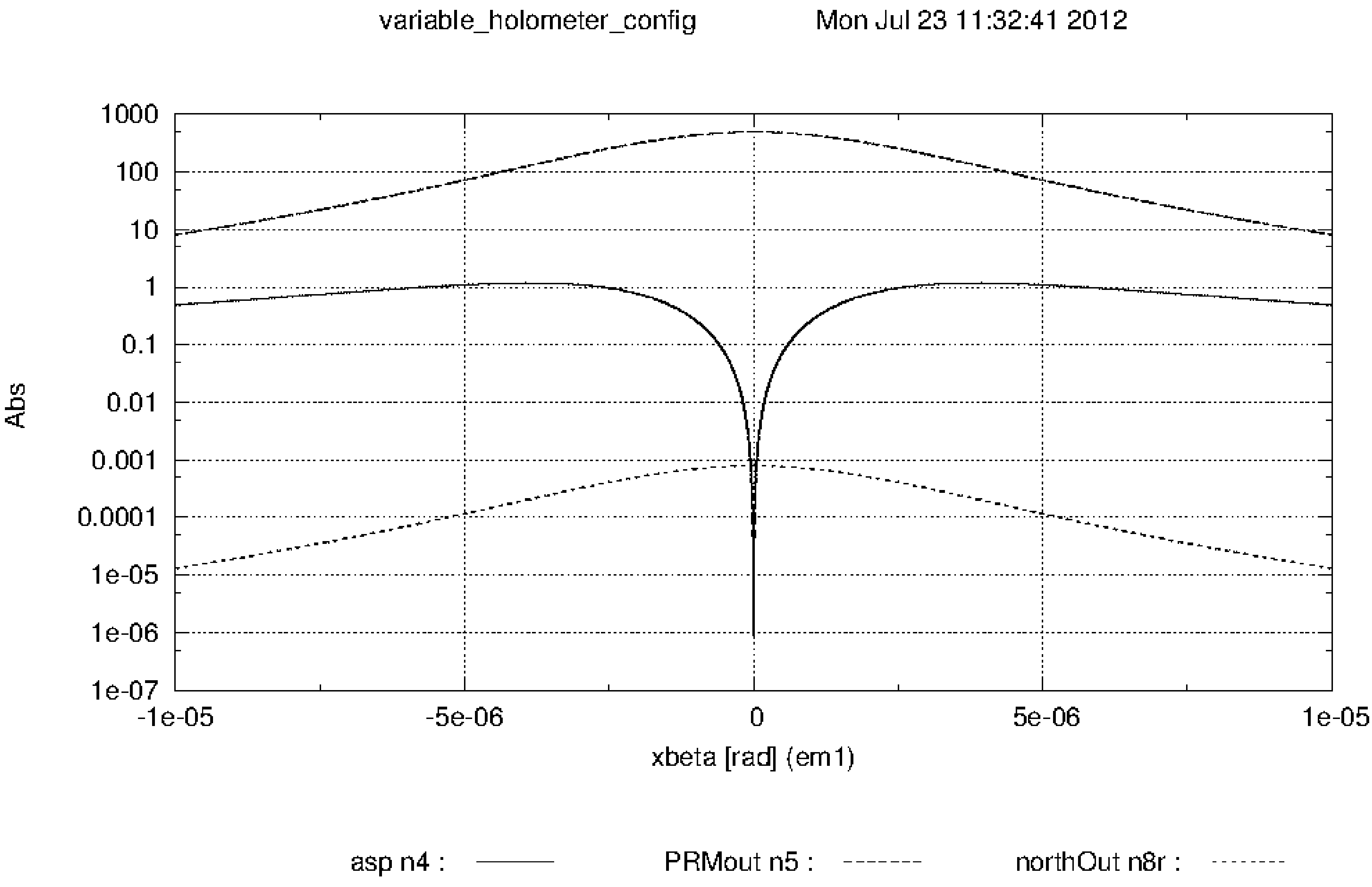


Laser Misalignment

- Four possible misalignment directions:
  - X, Y, X', Y'
- X and Y movement not possible to simulate
  - Infinitely large optics
- X', Y' simulate angled misalignments



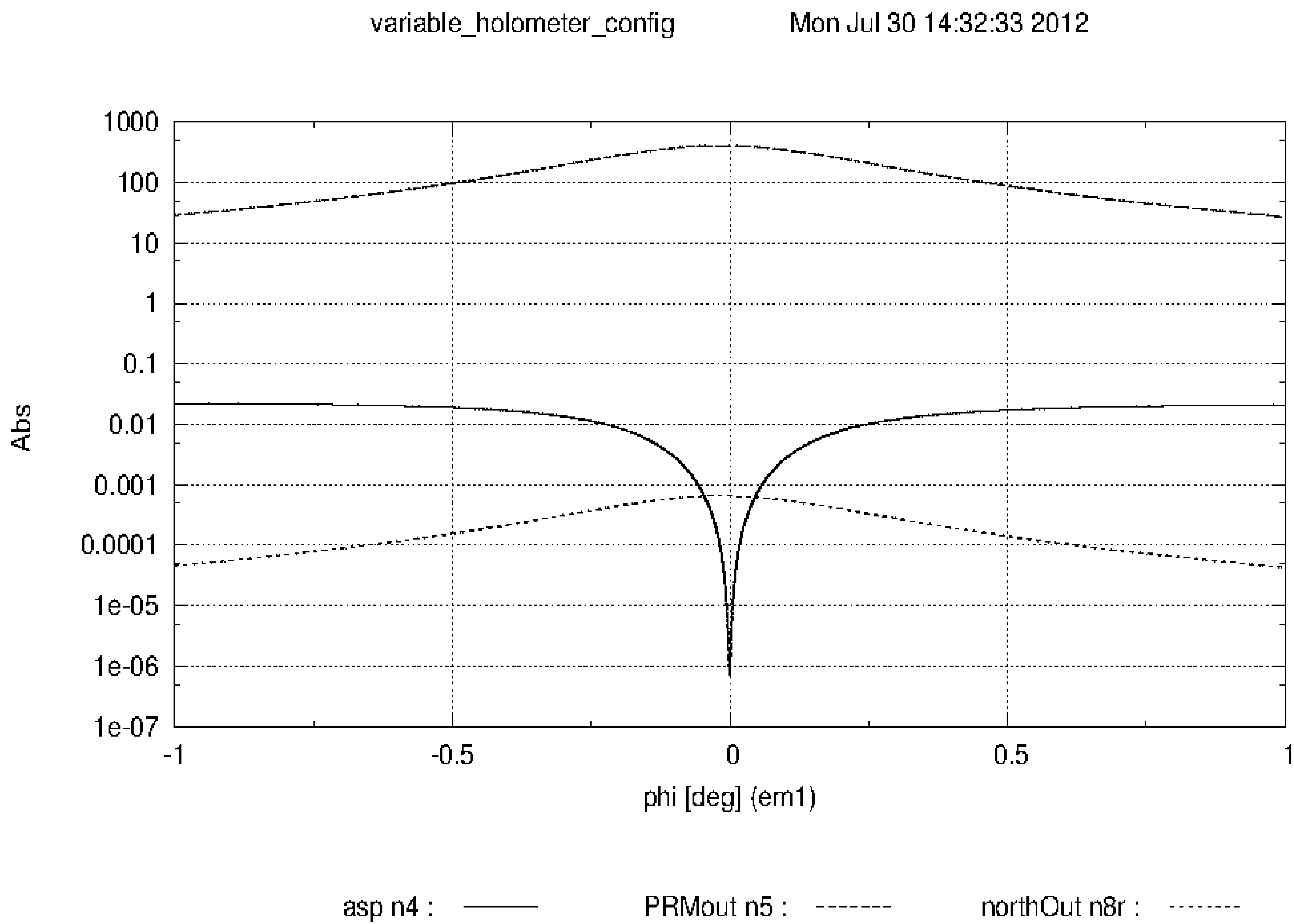
xbeta



variable_holometer_config
Mon Jul 23 11:32:41 2012
1000
100
10
1
0.1
0.01
0.001
0.0001
1e-05
1e-06
1e-07
Abs
-1e-05
-5e-06
0
5e-06
1e-05
xbeta [rad] (em1)
asp n4 :
PRMout n5 :
northOut n8r :

Differential Arm Length (DARM)

- End mirror position changed by microns (micrometers)
- North and East end mirrors changed separately to keep average length the same
    - One increases, one decreases
- Data from sensitive seismometers can be used to aid in the cushioning of noise.



variable_holometer_config
Mon Jul 30 14:32:33 2012
1000
100
10
1
0.1
0.01
0.001
0.0001
1e-05
1e-06
1e-07
Abs
-1
-0.5
0
0.5
1
phi [deg] (em1)
asp n4 :
PRMout n5 :
northOut n8r :

Results

Peak Values and FWHM

Rayleigh Range
- Peak: 37.412 m
- FWHM: ~33.0 cm

Z Length
- Peak: -0.988 m
- FWHM: ~36.3 cm

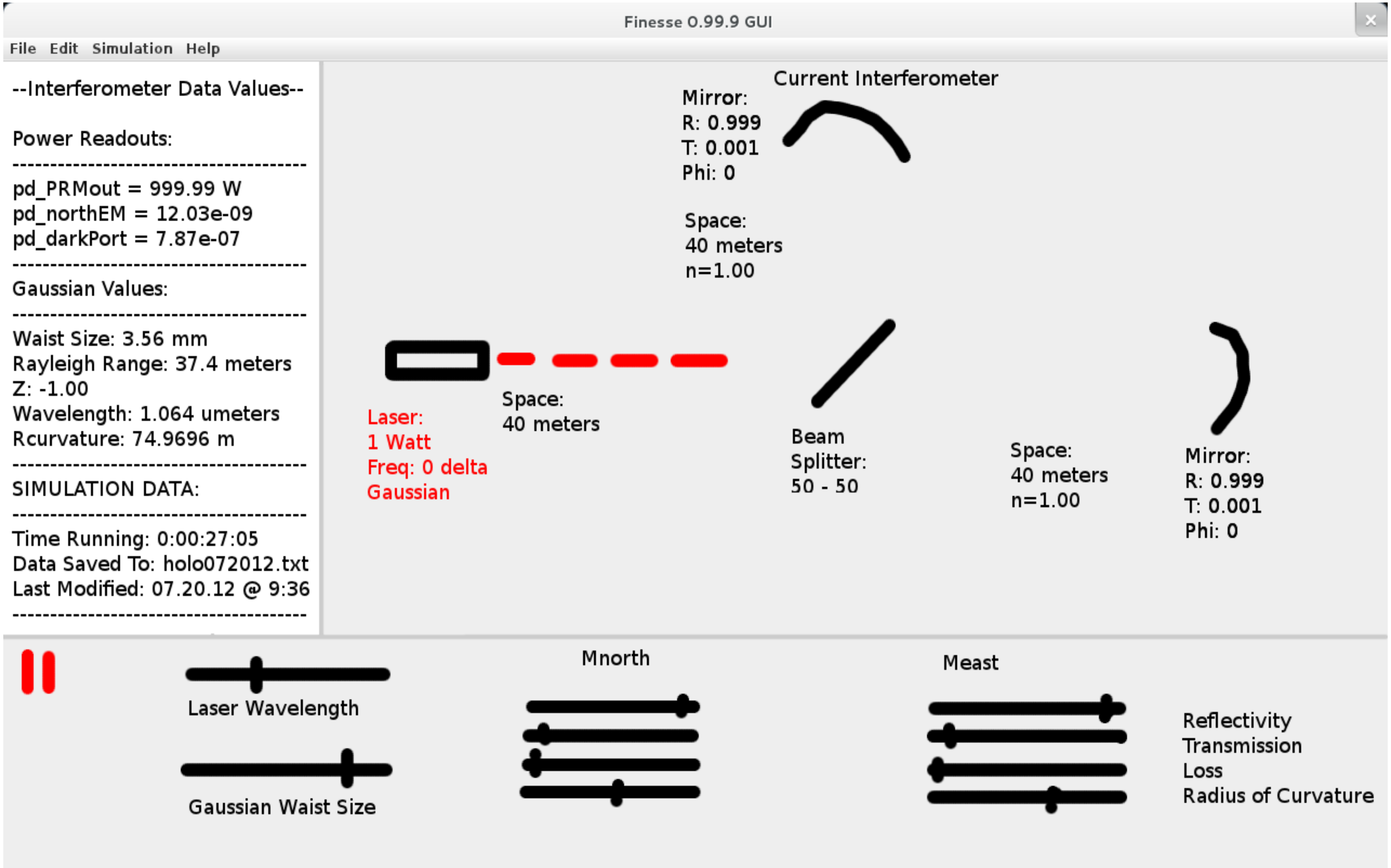
Radii of Curvature
- Peak: 74.976 m
- FWHM: ~36.4 cm

xbeta
- Peak: 0 rad
- FWHM: ~3.42 urad

Mirror Tuning
- **Peak: ±1.182 pm**
- **FWHM: ~1.45 nm**

What's Next?

- Graphical User Interface
- Interactive / Real time simulator
- Further experiments with mirror maps



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