New FFT simulation tool and a few applications

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- Introduction
  - » Requirements to be identified for AdvLIGO
  - » LIGO I research tool
  - » old FFT, melody and new FFT
- Static IFO Simulation
  - » Physics
  - » Implementation
- A few applications
  - » surface aberration and loss
  - » Parametric Instability
    - – by Bill Kells and Hans Bantilan

Introduction

- AdvLIGO, to be analyzed
  - » Tolerance of radius of curvature of COC mirrors
    - – Yi Pan's estimation of 2076 +3m - 1m too stringent
  - » Surface aberration
    - – Requirements of the surface quality to satisfy the limit of loss in arm, total of 75ppm
    - – Loss due to dusts
  - » Parametric instability
    - – highly distorted field, hard to be expressed by simple functions
- LIGO I, how MIT-FFT was used
  - » Base design
    - – IFO basic parameters, surface figure requirements, etc
  - » Commissioning
    - – Thermal effect, as-built mirror effect, realistic optical gain, etc

LIGO

Introduction

- Motivation of new software
  - » old MIT-FFT
    - – coded for specific configurations
    - – some physics not easily simulated
    - – hard to use as-built data information
    - – hard to modify
  - » melody - modal model
    - – limited spatial resolution
    - – not quite reliable for degenerate configurations, or when modal expansion with finite modes is not enough

Static IFO Simulation

- Object oriented code using C++
  - » ease of modification, adding compensation plate, degenerate to non-degenerate Michelson cavity, etc
- FFT using adaptive grid size
  - » The beam size changes a lot in a concentric configuration.
  - » Higher order mode needs this treatment for proper propagation.
- Cavity lock using “error” signal, similar to real LSC
- Ease of loading a variety of formats of data file
  - » Wyko, ...
- Mirror surface aberration generator with proper spectrum
- Distributions can be specified by analytic formula
- FP completed -> advLIGO underway

LIGO

Input file specifying a FP

```
% Basic FFT setup
Nfft = 256
Wfft = 0.70
...
% mirror definition = [ aperture, thickness, mech, opt ]
ITM.aperture = 0.34
...
% mirror mechanical data = [ x, y, z, tX, tY, tZ ]
% mirror optoical data =
  [ T, R, ROC, reflIndex, "phasemap_xy", "phasemap_file" ]
ROC = 2076
ITM.opt.HR.ROC = ROC or
ITM.opt.HR.d = “r*r/(2*ROC)”
...
% mirror noise data = [ rand_seed, rms, power, "weightExp", WykoIndex ]
% cavity definition = [ L0, delL, matchToInput ]
% inputBeam definition =
  [ "BeamType", index1, index2, waistSize, waistPosition, matchToCavity ]
```

Running the program

```
next action

        lock          calcField     timeTrace     delL
        modeAmp       saveField     mirrorInfo    storeMap
        simSpec       runSpec       summary       exit

Select 1 item(s)
```

- Lock
- Calculate field under a given condition
- View fields using mode expansion
- Save fields
- change configuration
- ...

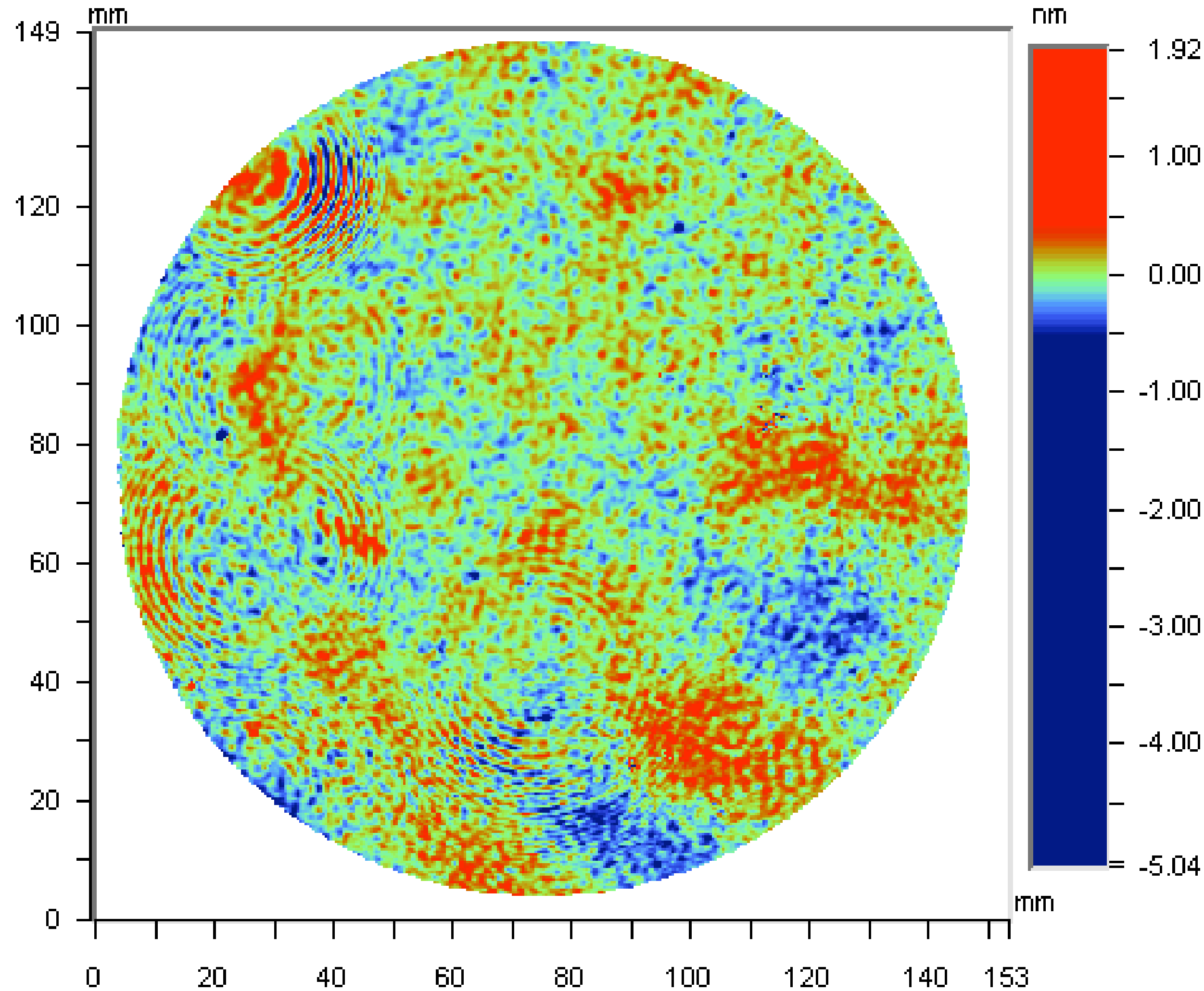
Loss due to mirror aberration

- Upper limit of total loss per arm : 75ppm
- assuming the issue of the spotty bright point losses are solved, what is the requirement of the surface aberration to satisfy this condition?
- Is the known signature of CSIRO polishing, orange peel, significant?

Orange peel
- psd shows bumps at ~0.3 cm -

loss ~ 2 ppm

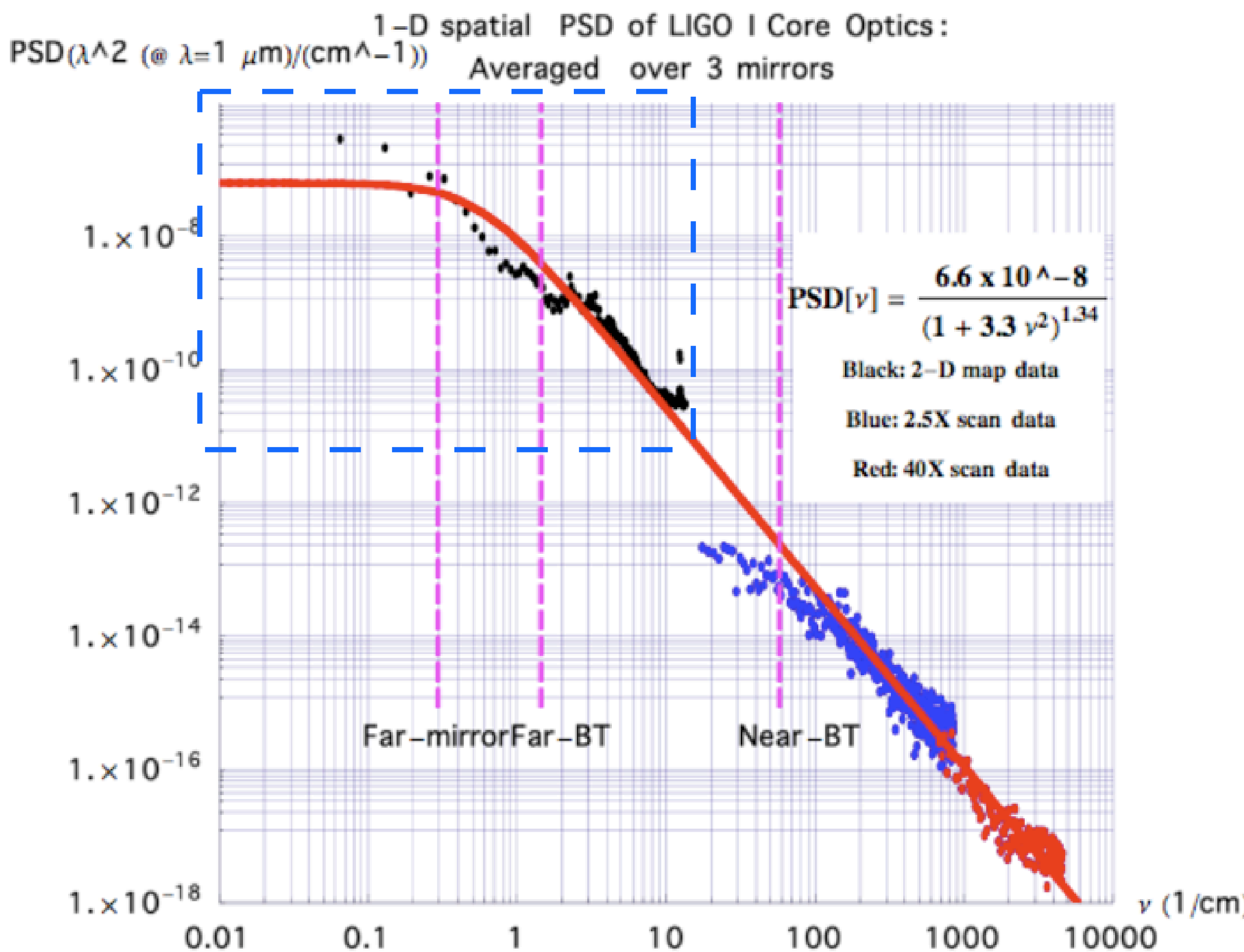
FFT grid size
= 0.14 ~ 0.28cm



G060386

1-D spatial PSD

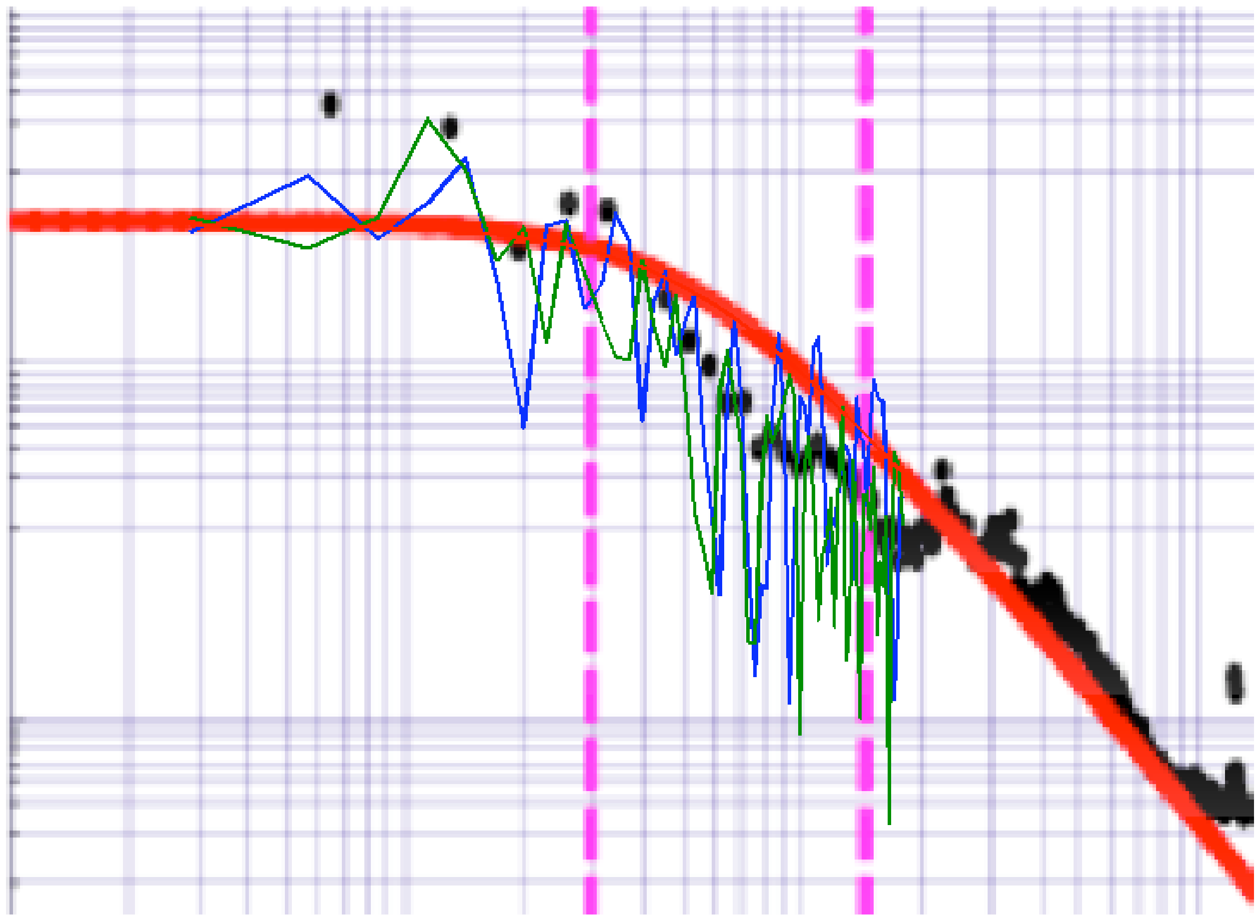
LIGO I Core Optics : Lazzarini T060013



1-D spatial PSD
LIGO I Core Optics vs simulated noise

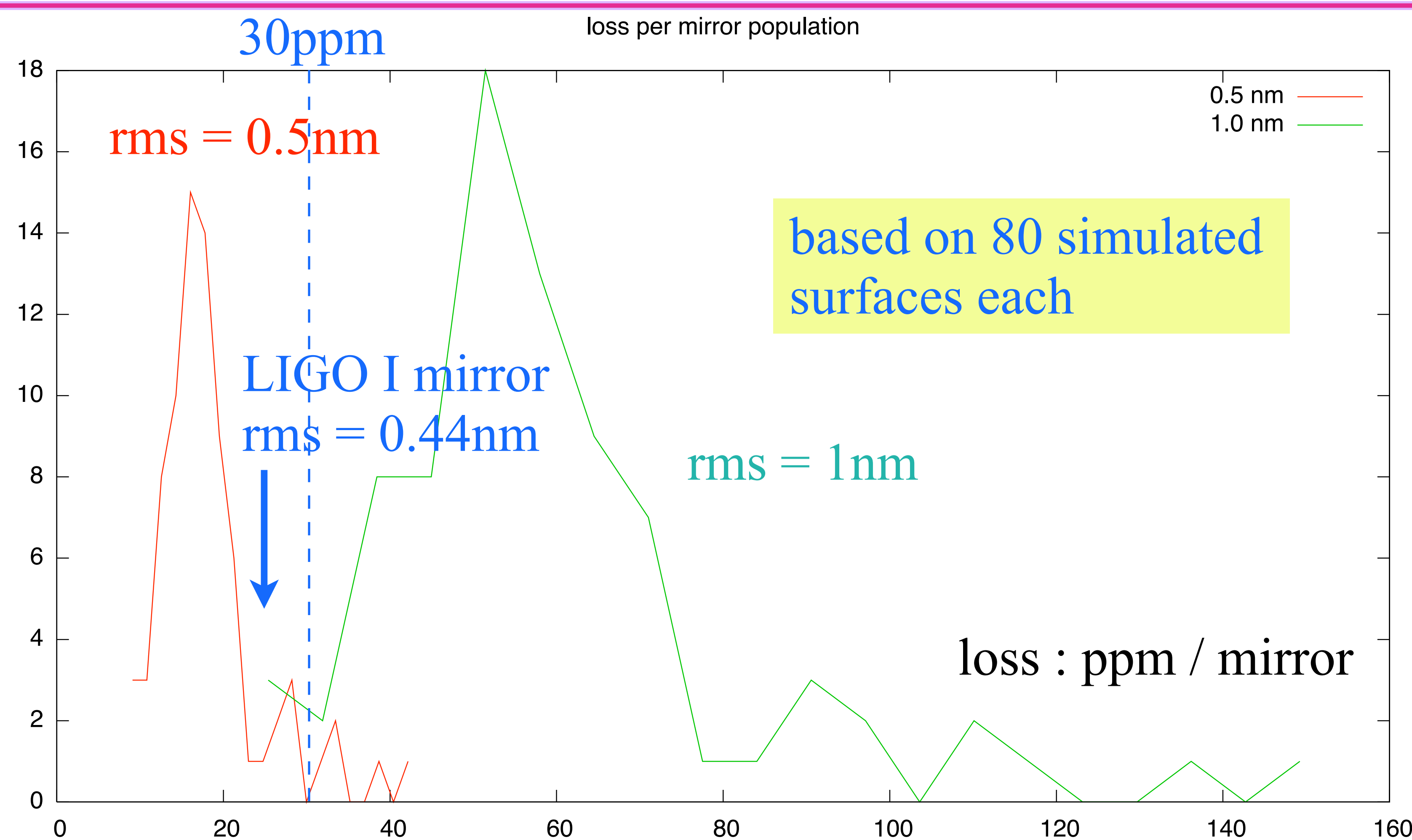
N = 256
W = 70cm

rms : 0.5nm
2 surfaces
with loss
25ppm & 35ppm



Loss per mirror

rms = 1nm vs 0.5nm



New FFT at August 06 LSC mtg

Investigating a Parametric Instability in the LIGO Test Masses

- SUFR project by Hans Bantilan, mentored by Bill Kells
  - G060385-00-Z
- Simulate a stationary field for a given acoustic mode, instead of using modal expansion, to calculate the overlapping integral
- Combined with Dennis' FEM package to calculate acoustic modes
- 9061 modes for f < 90KHz

R value plots

- preliminary -