LISA Autocollimator

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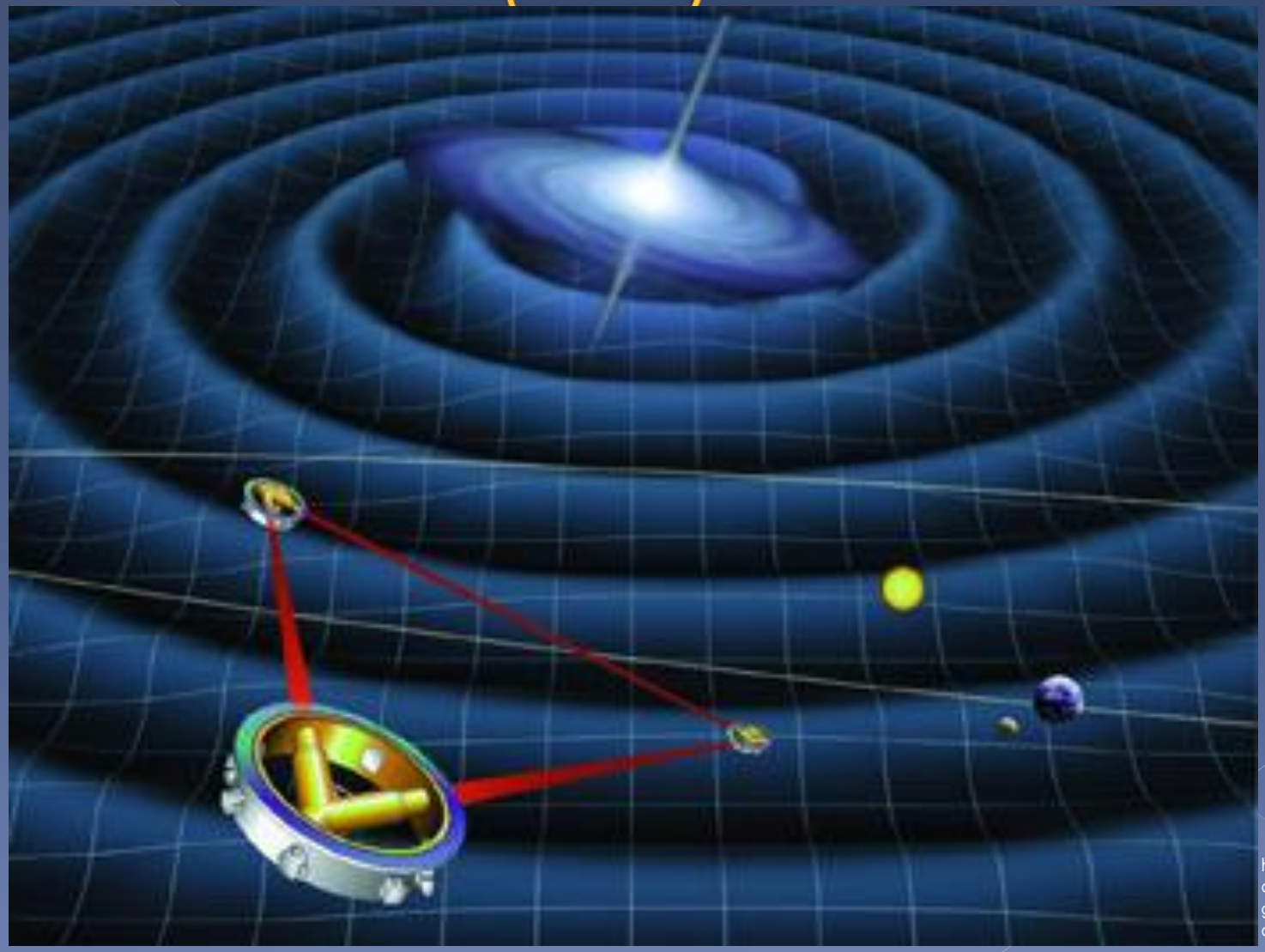
Laser Interferometer Space Antenna (LISA)

- Mission
  - Will detect gravitational waves within a frequency range from 0.03 mHz to above 0.1 Hz
- Structure
  - Three spacecraft in equilateral triangle with 5 million km sides

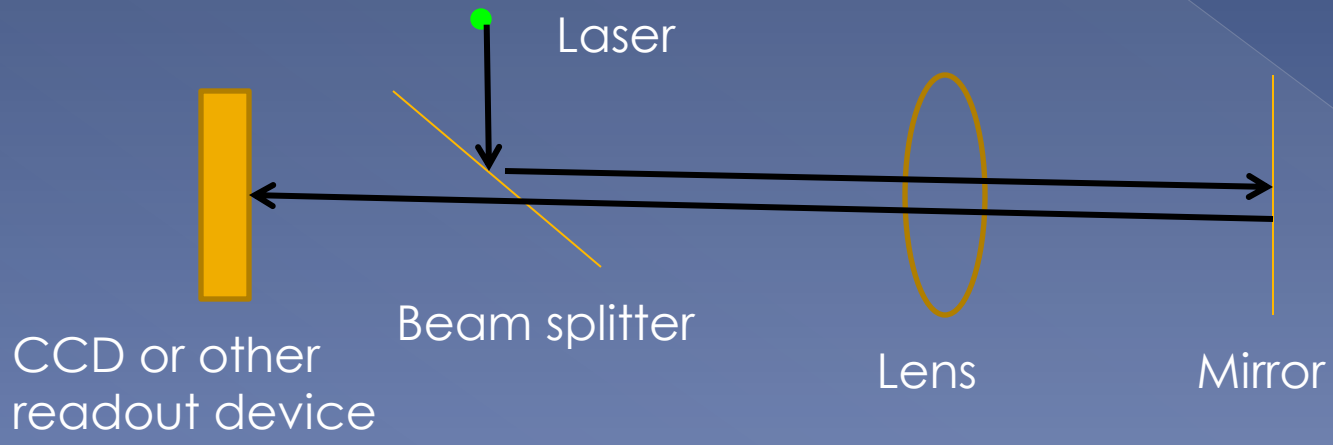
Laser Interferometer Space Antenna (LISA)



http://www.nasa.gov/centers/goddard/images/content/181573main_lisa_LO.jpg

What is an autocollimator?

- Optical device for measuring angles
- Basic idea is to image something on a camera and measure the deflections of the image



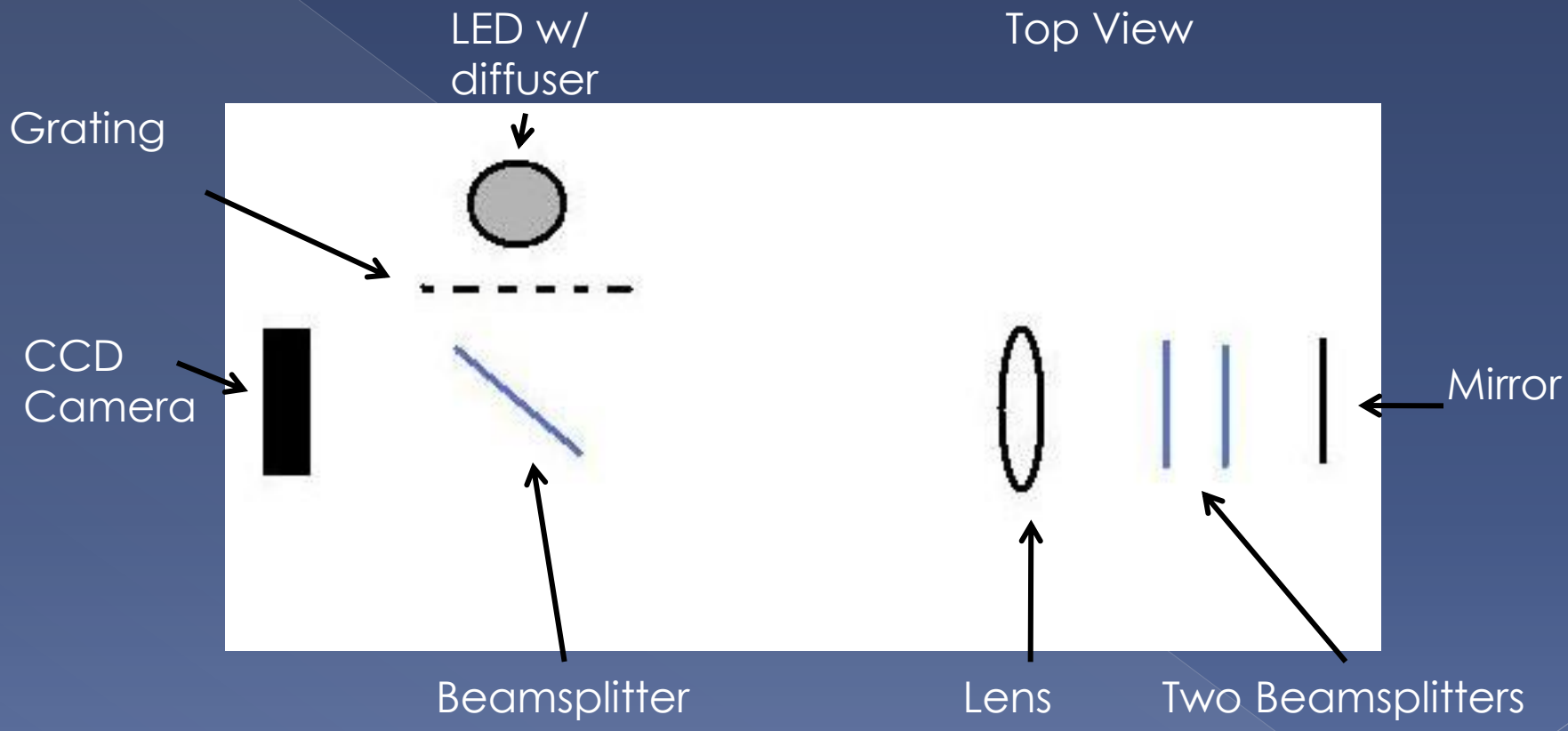
Specifications

- Dynamic range of 1°
- Noise level of 1nrad/√Hz
- Work at a distance of 1m

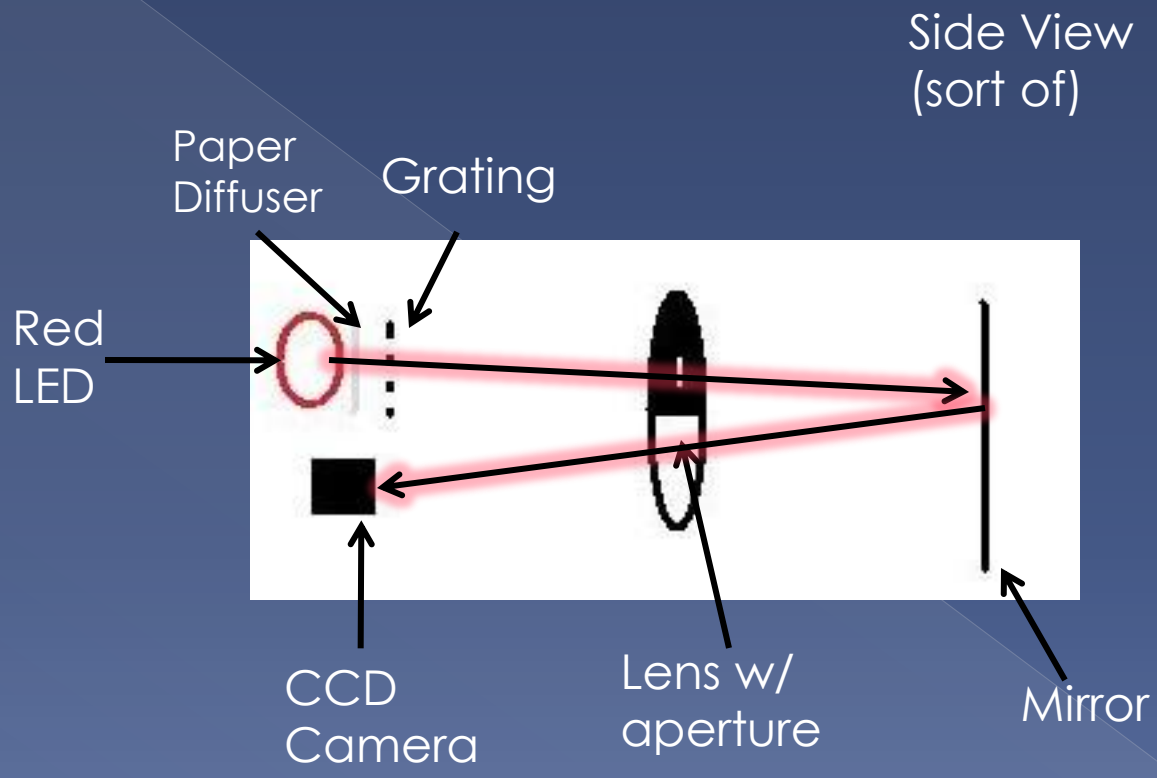
Initial Design Goal

- Instead of point source of light, use a grating
- Instead of imaging just one grating, image three—two stationary reference patterns and one dynamic pattern

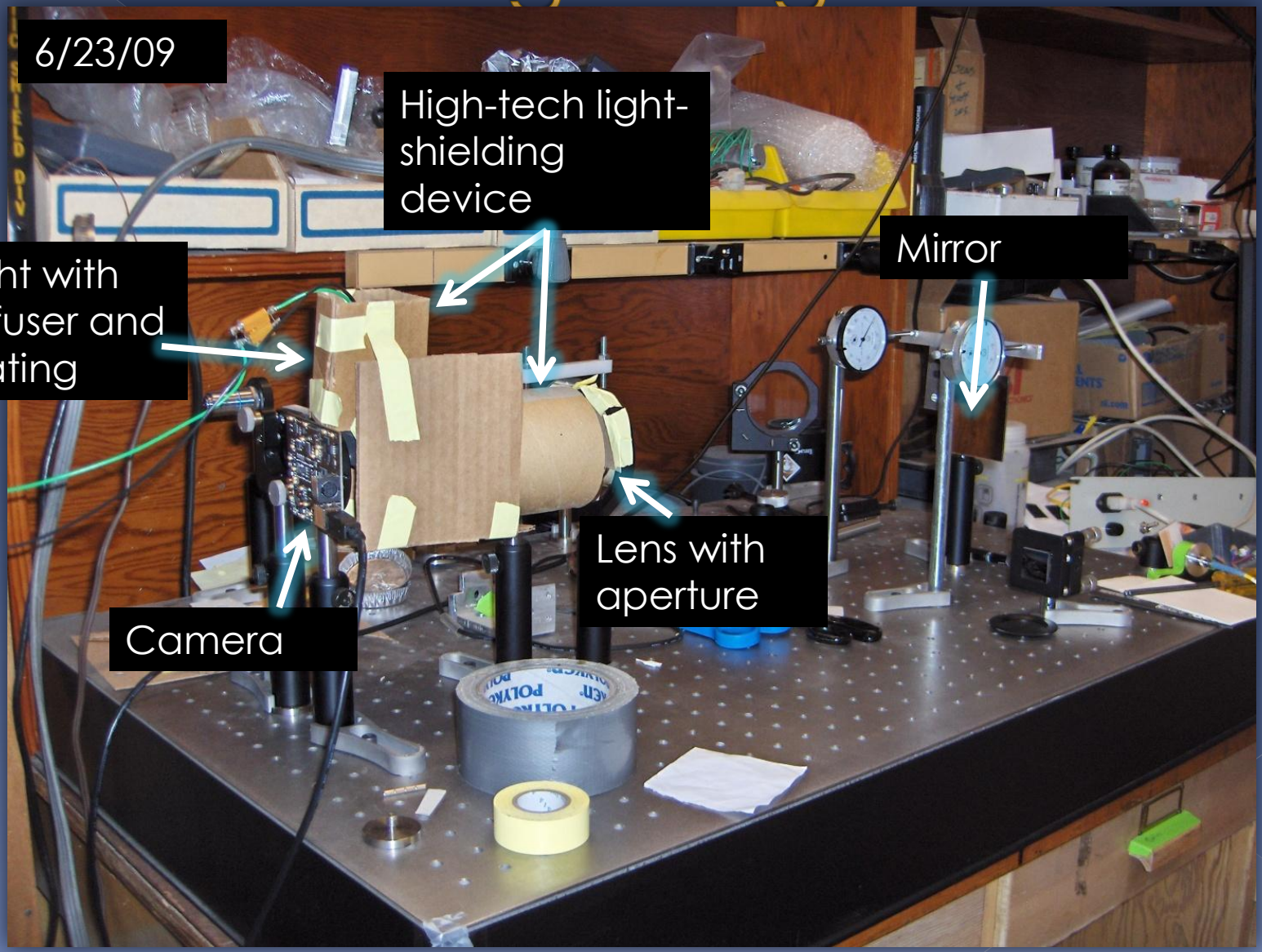
The Plan


LED w/
diffuser
Top View
Grating
CCD
Camera
Mirror
Beamsplitter
Lens
Two Beamsplitters

Humble Beginnings



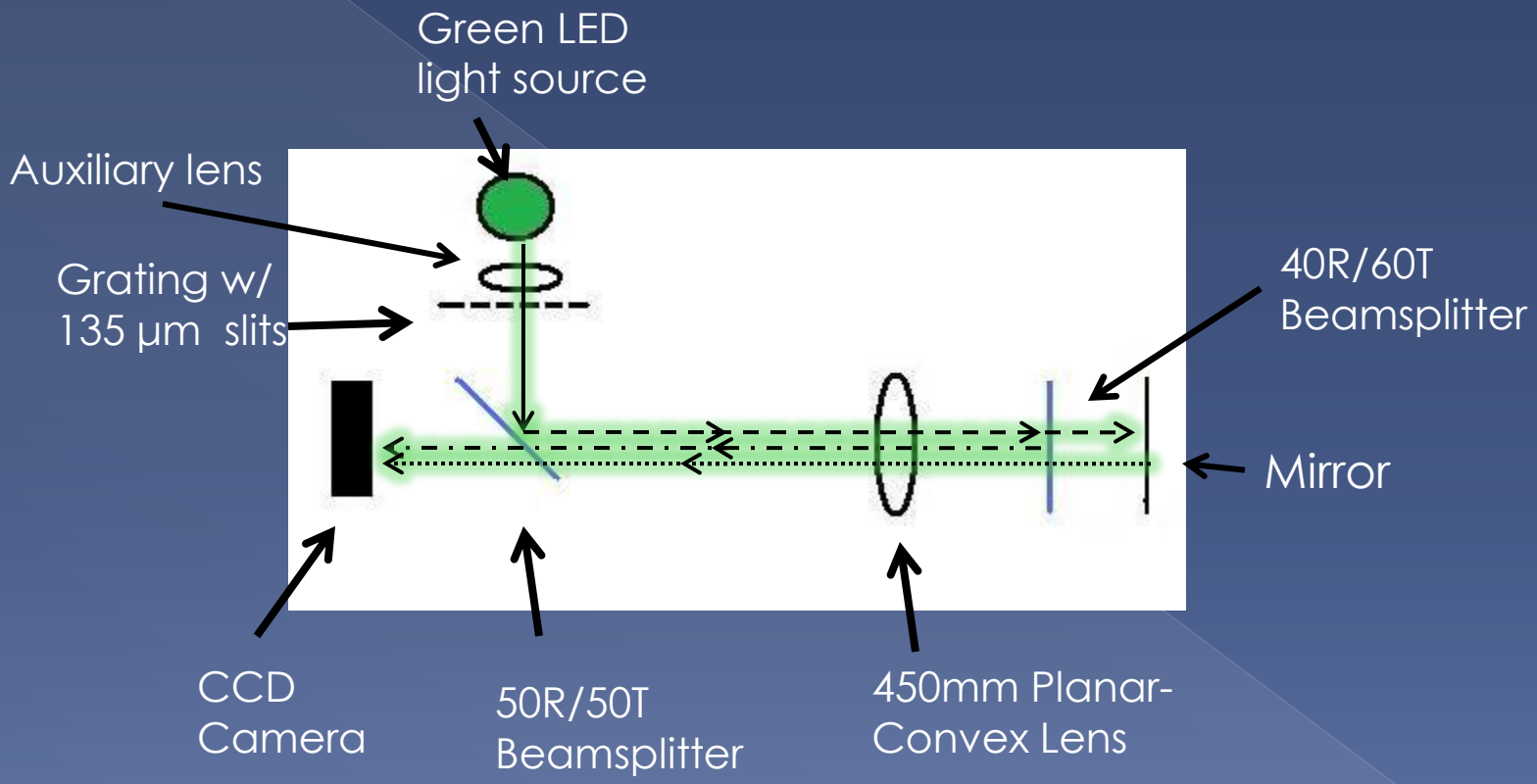
Humble Beginnings

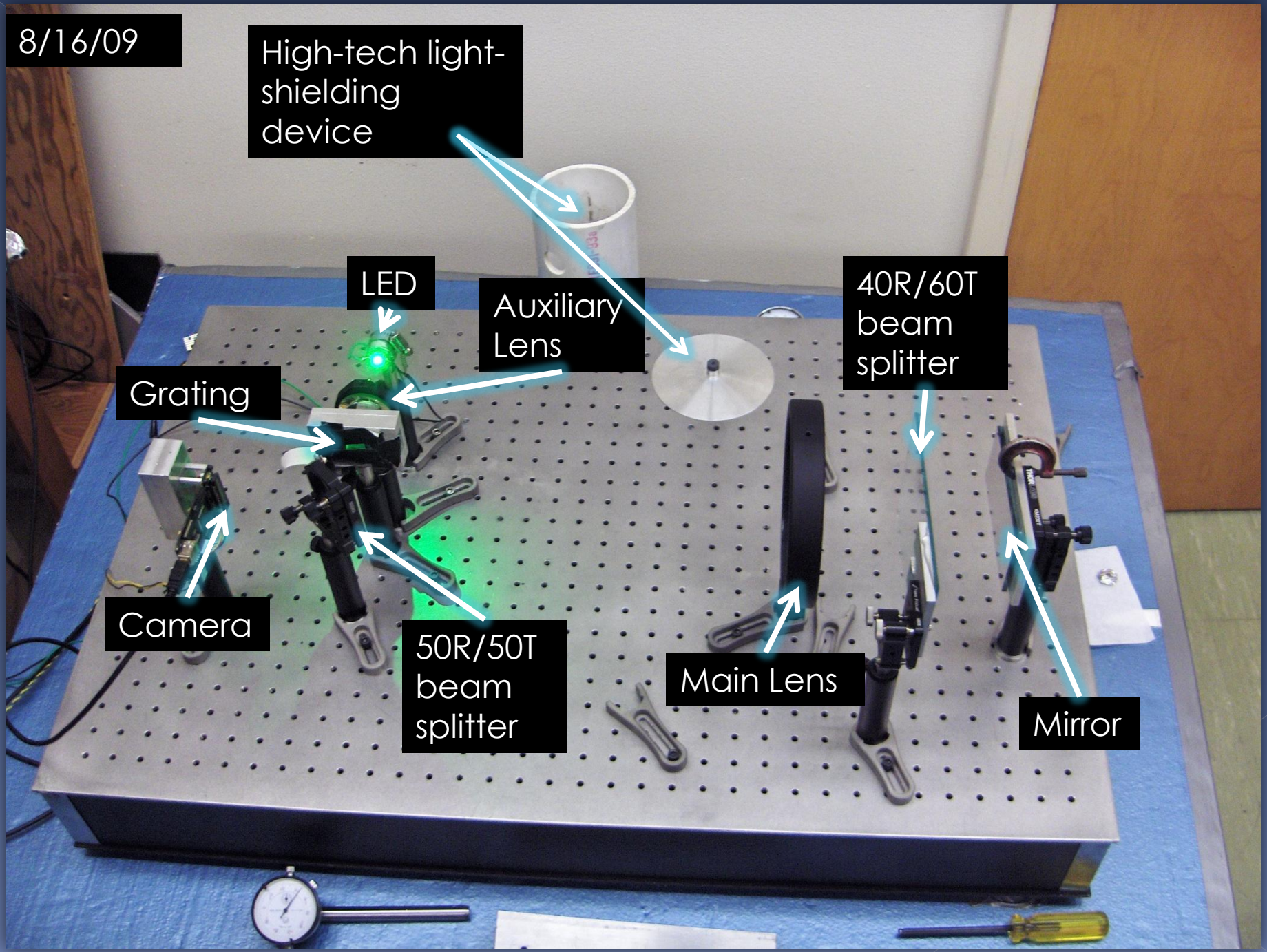


Improvements to the Plan

- double black line in the grating
- converging lens between the LED and the grating
  - Allowed us to get rid of the diffuser
- Switched from red (627nm) LED to green (530nm) LED
- Encased the whole thing in Styrofoam
- Instead of 3 images, just use 1 reference pattern and 1 dynamic pattern (so only one beamsplitter at the end rather than two)

Current Design




8/16/09
High-tech light-shielding device
LED
Auxiliary Lens
40R/60T beam splitter
Grating
Camera
50R/50T beam splitter
Main Lens
Mirror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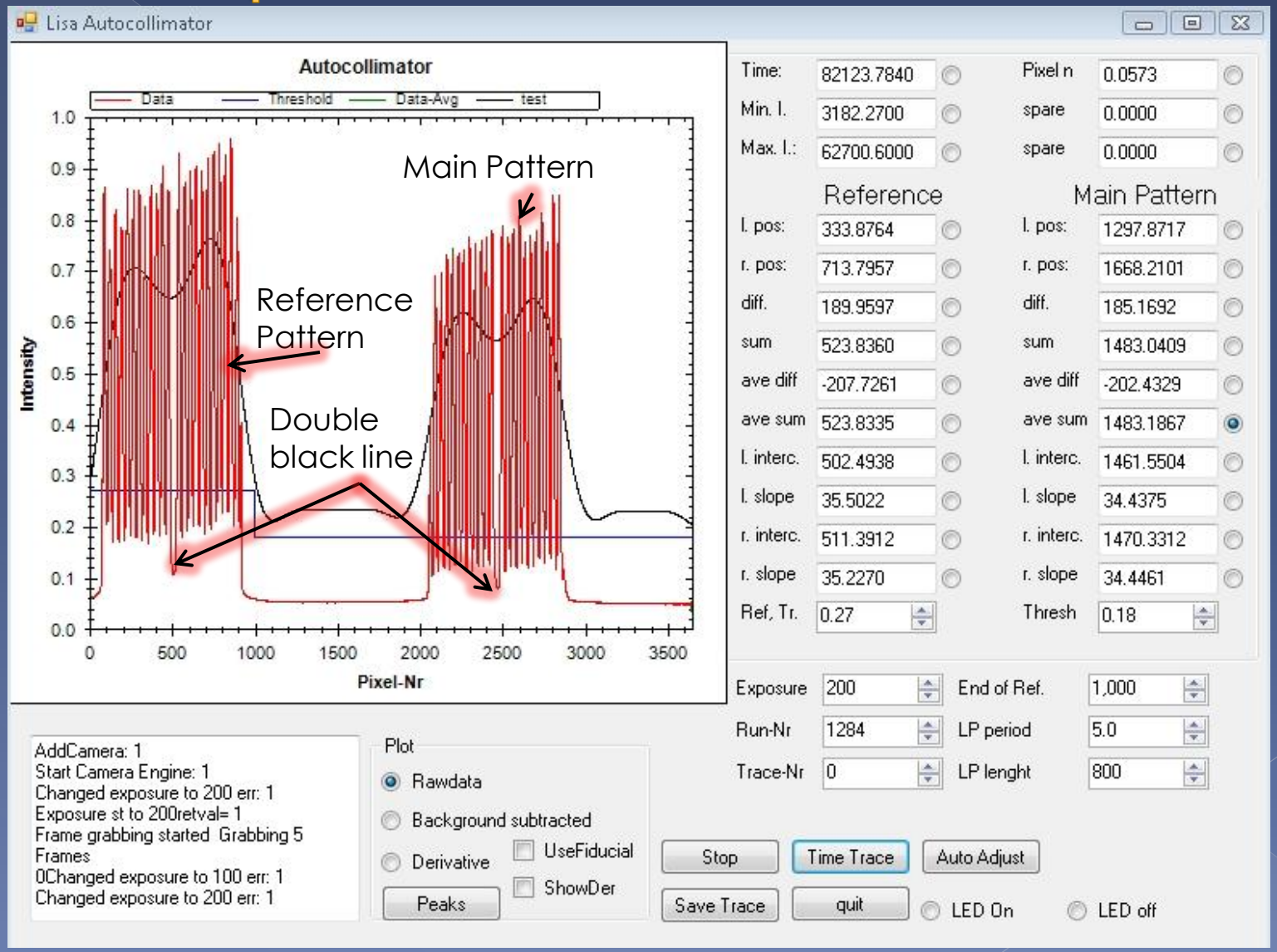
Computer Interface



Current Status

- Dynamic range
  - We can move our pattern across the length of the camera (3648 pixels)
  - only limited by the size of the pattern
  - about 25 peaks in each pattern
- Operating distance
  - still able to get a clear pattern at 1m
  - The mount was so unstable though, the noise was useless to measure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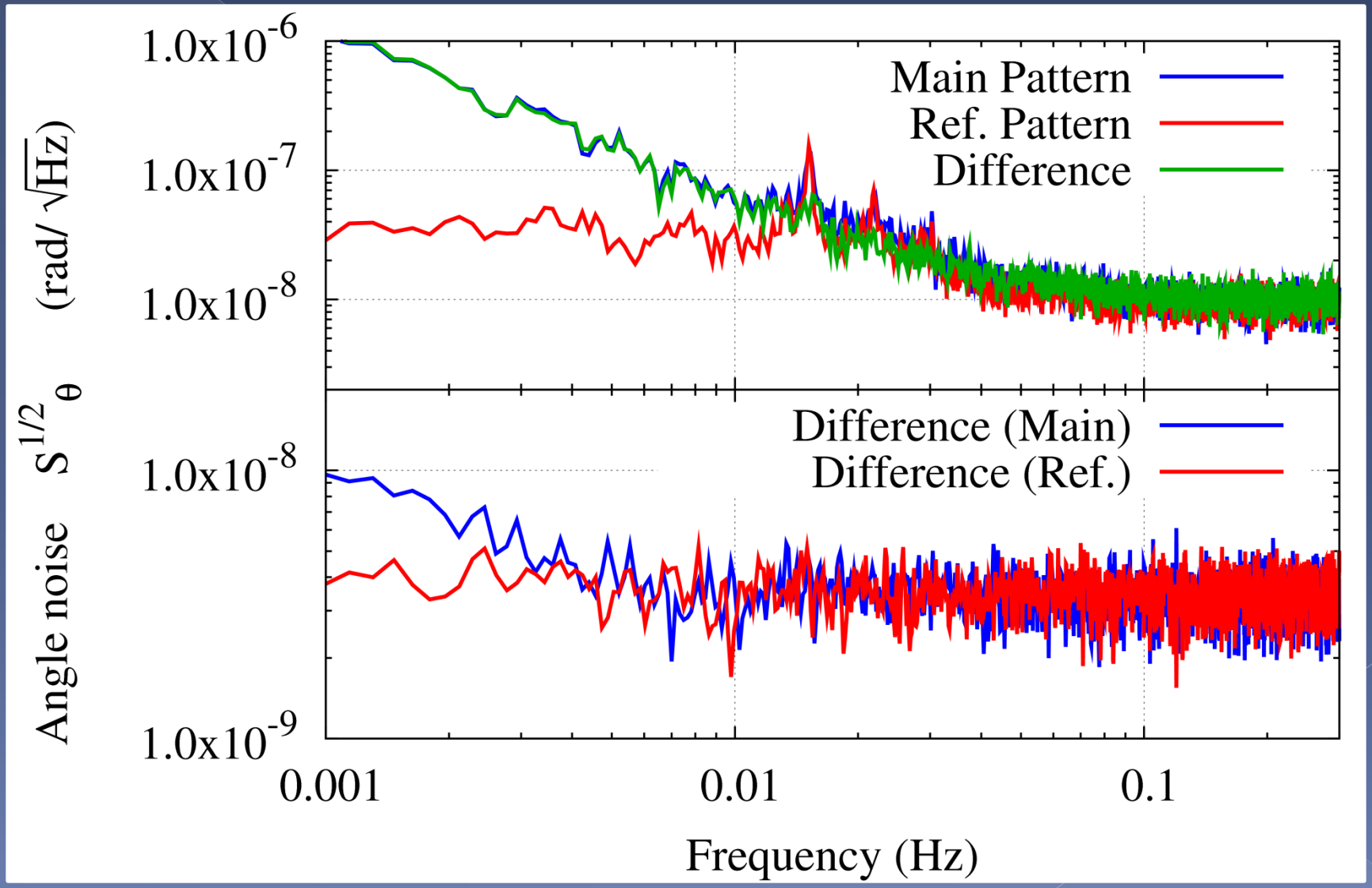
Noise


1.0x10-6
1.0x10-7
1.0x10-8
Main Pattern
Ref. Pattern
Difference
Angle noise Sθ1/2 (rad/√Hz)
1.0x10-8
1.0x10-9
Difference (Main)
Difference (Ref.)
0.001
0.01
0.1
Frequency (Hz)

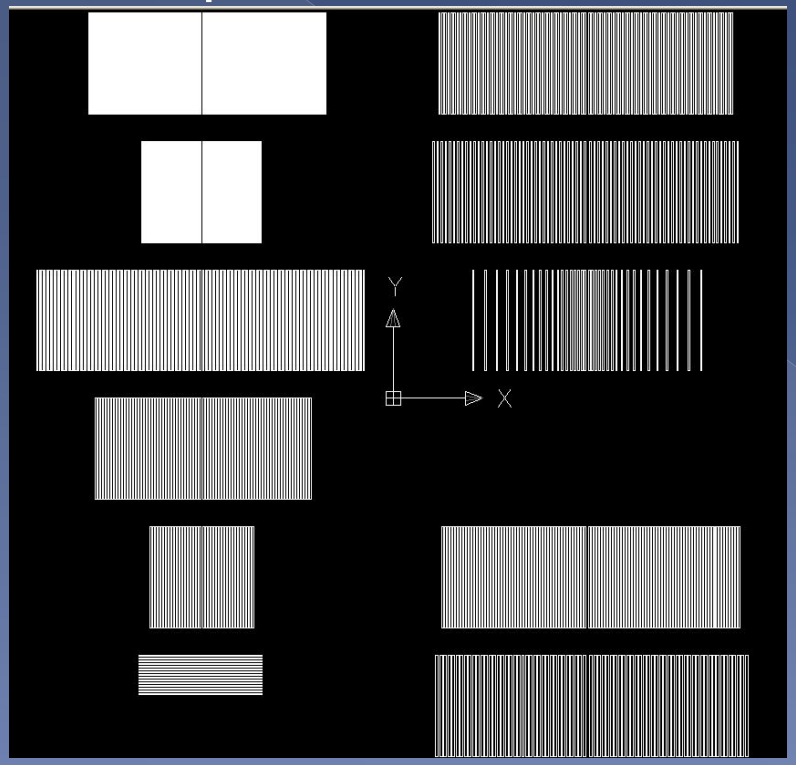
Noise

- We have shown that some of our noise is coming from fluctuations in the magnification of the image

- Possible causes:
  - Most likely the expansion and contraction of our grating, which is composed of thin plastic
  - Vibrations might be causing tiny physical movements of the optical components

Next steps/Improvements

- Test photomask grating
- Stabilize mirror and beam splitter mounts
- Find the best way to take advantage of the reference pattern in the data analysis



Photomask AutoCAD drawing with test patterns

In the long run

- Make the setup more compact
  - Folding the beam path
  - Finding the ideal size for the main lens—as small as possible without sacrificing the quality of the image
- Design stable mounting structure and housing for the device
- While it's being designed for LISA, its low noise level and large dynamic range make it useful for a variety of applications