High Fidelity Probe of Optical Scatter from Point Defects

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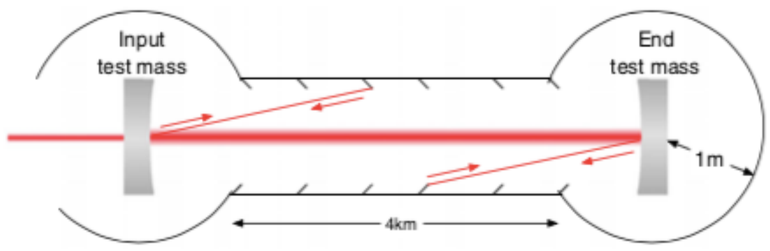
Abstract

This poster describes the efforts to study the scattered light in the LIGO 40m prototype with the help of a digital CCD camera installed into the camera system that currently monitors the beam spot on the mirrors/test masses.

Backscattered Light

- Current sensitivity: 10^{-23} $1/\sqrt{Hz}$ around 100 Hz
- Current range of LIGO: 10 Hz to 1000 Hz
- Scattering is a critical noise source below 30 Hz.



- ❑ Backscattered light modulates the phase and amplitude of main beam and introduces a random phase noise.
- ❑ Loss from scattered light reduces optical squeezing and will limit the sensitivity in the future upgrades.

In-situ Measurement of Scattered Light

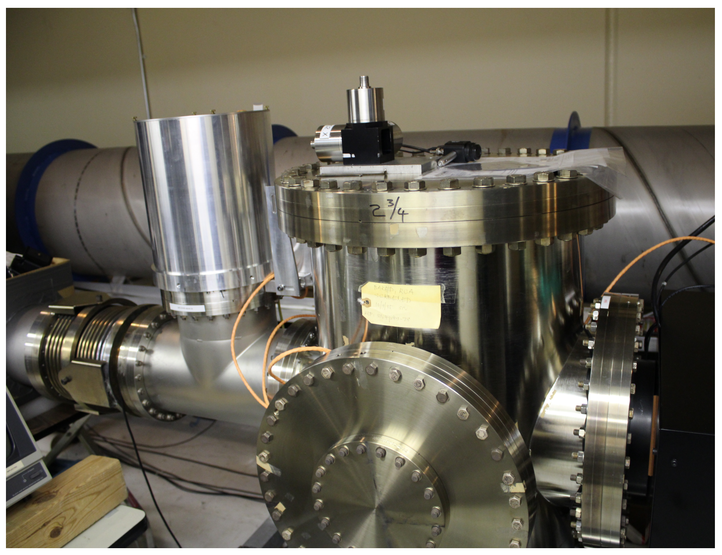
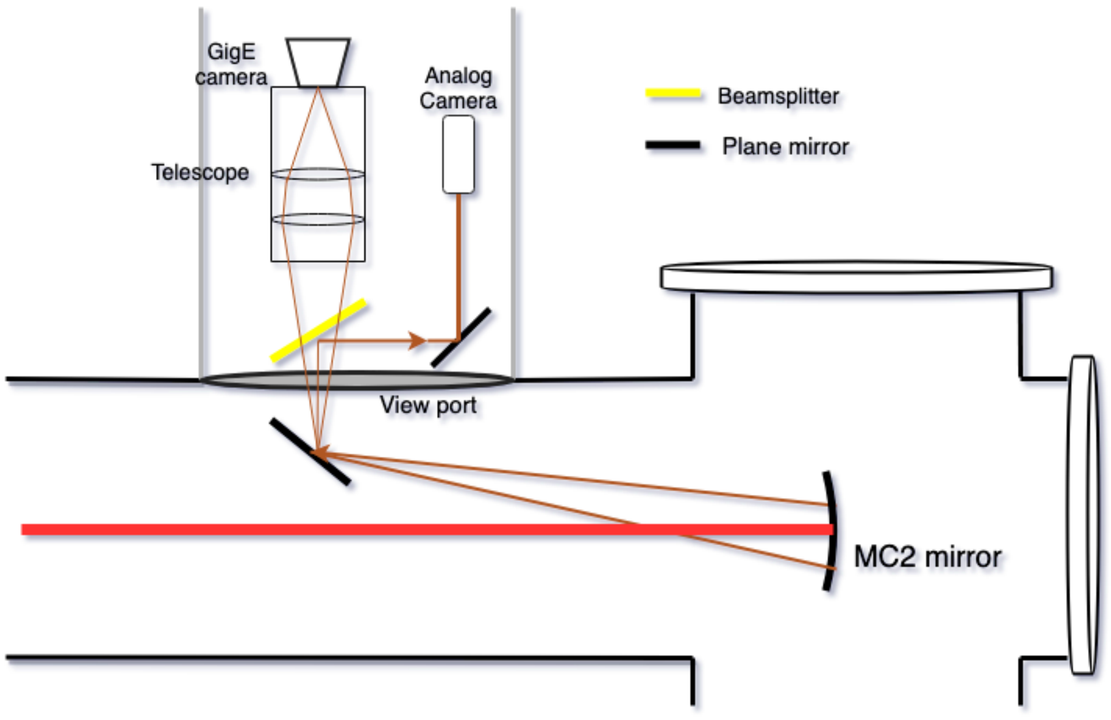


Image of MC2 chamber and the camera system

Mirrors/test masses are inside the vacuum chamber ⟹ limited access!

- Using a digital CCD camera (GigE camera) we can capture images with different **exposure times**.
- A **two lens telescope** system is used to focus the beam spot onto the GigE camera sensor while ensuring optimum utilization of the CCD pixel array.
- By performing a **radiometric calibration** of the GigE camera, we can measure the power of scattered light from the captured images.



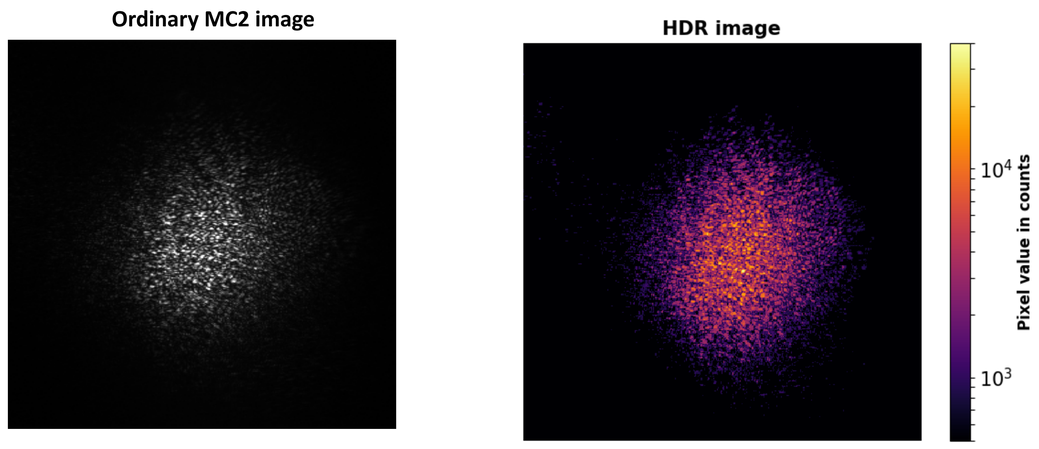
Schematic of MC2 camera setup

Uses of the Image

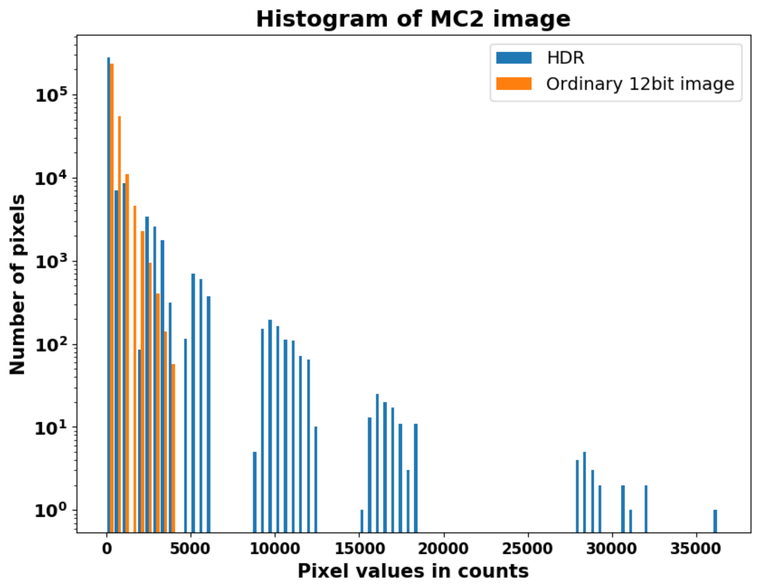
Images of the mirror captured using the above setup can be used to:

- Analyze the **size** and **spatial distribution** of point scatterers.
- Estimate the **fraction of scattering** is due to point scatterers.
- Understand the effectiveness of **cleaning methods** of optics.
- Study how **different coatings of the mirror** affect scattering.

High Dynamic Range Images

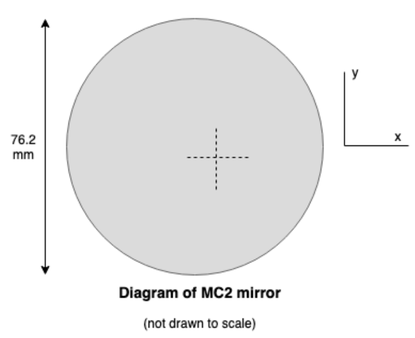


- Dynamic range is the ratio of intensity corresponding to the brightest region of the image and to the darkest.
- HDR image resolves the **contrast** and **image details** much better than an ordinary image which might be limited by **pixel saturation.**

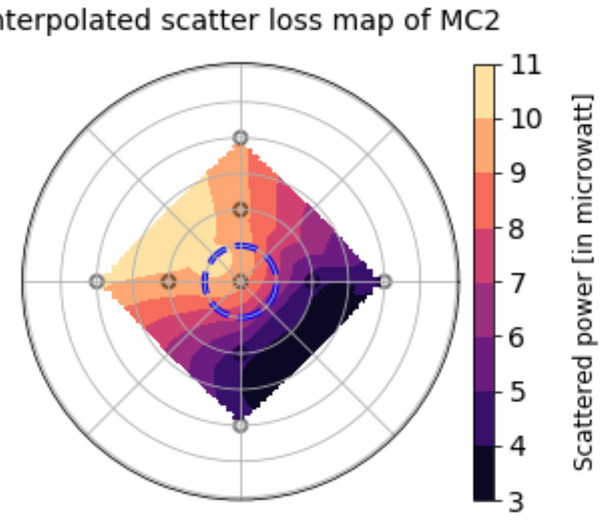


- Dynamic range of an ordinary 12-bit image:
- **0 to 4096**
- Dynamic range of a HDR image obtained: **0 to > 35000**
- New bit depth = **15**

Scatter Loss Map



Blue dashed circle indicates approximate beam size, solid circles are points at which beam was centered on MC2 for loss measurement



- ❑ High amount of scattering indicates large number of **point defects** in that region
- ❑ Identifying the regions on the mirror with maximum number of point defects and centering the beam spot on a region with few points defects ⇒ **Reduced scattering**

Note: The measured power of scattered light corresponds to the light scattered at a particular angle, not the total light scattered, as our setup only collects scattered light at a fixed angle as seen in schematic.

Future work

With the infrastructure that has been set up, we further aim to study the sources of scattering - point defects and other surface imperfections, estimate the optical loss due to scattering and characterize the random phase noise introduced due to scattered light. And thereby, gain an overall understanding of the effects of scattered light in the LIGO interferometer.

Acknowledgements

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References:

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F Magana-Sandoval et al, Technical Note LIGO- T1400252-LSC. (2014)