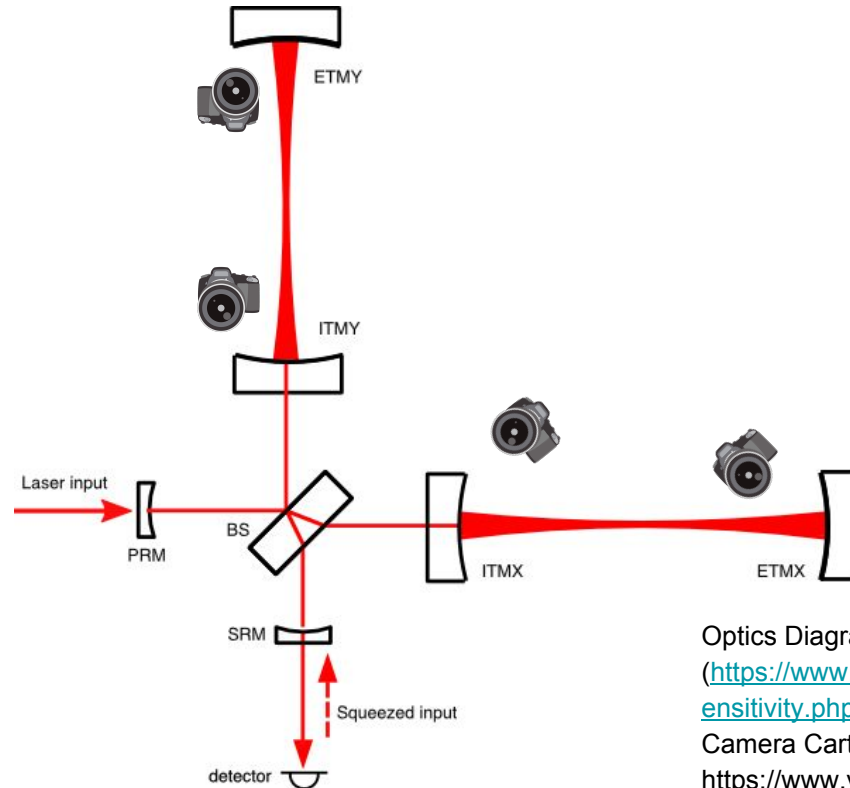# Measuring Scattering Off LHO Test Masses

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Mentor: Keita Kawabe

LIGO Test Mass Scattering


Optics Diagram from GWoptics.com,
(https://www.gwoptics.org/finesse/examples/aligo_sensitivity.php.)
Camera Cartoon from:
https://www.vexels.com/png-svg/preview/139838/camera-cartoon

Camera Calibration and Image Sensors

-Photosensitve semiconductors

-Counts ~ Photons absorbed

    -Each of the pixel is made of 4

individual subpixels
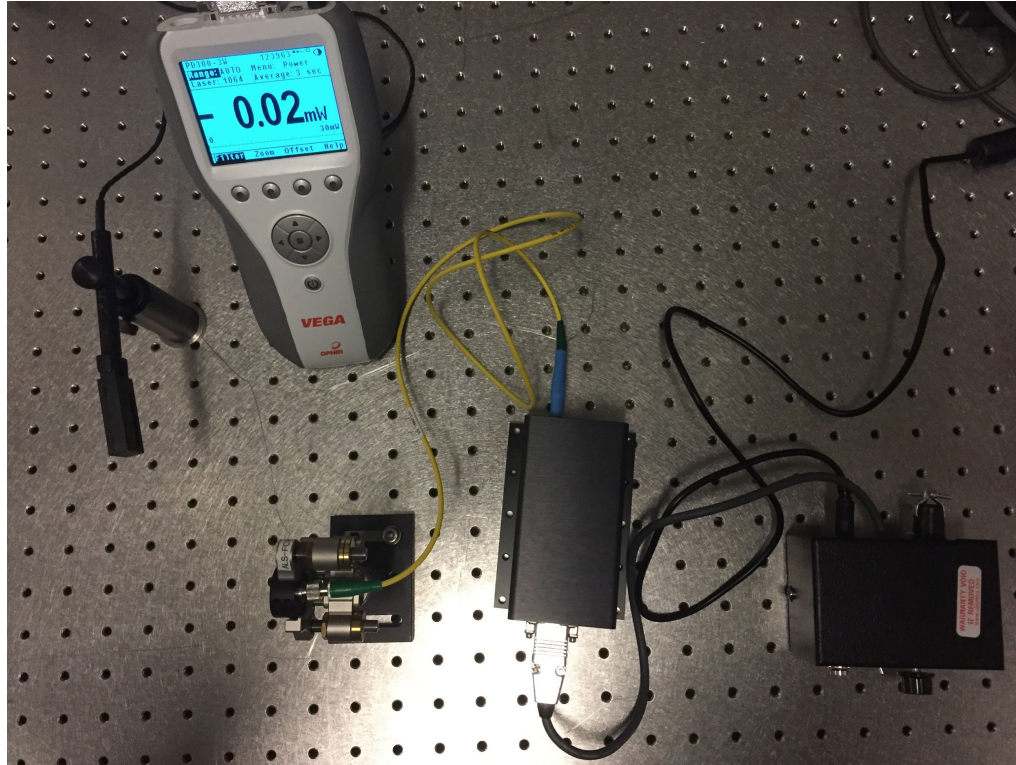
    -Bayer filter
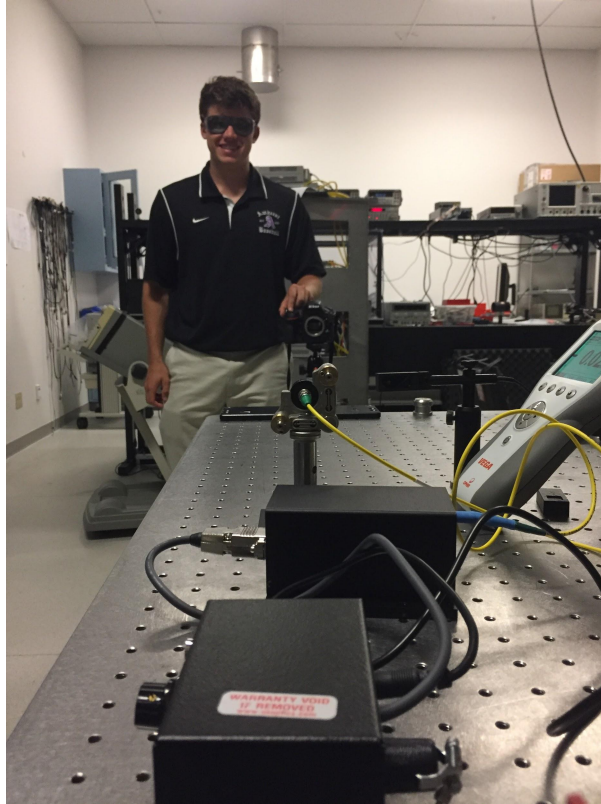
-Calibration: Counts / (unit energy)
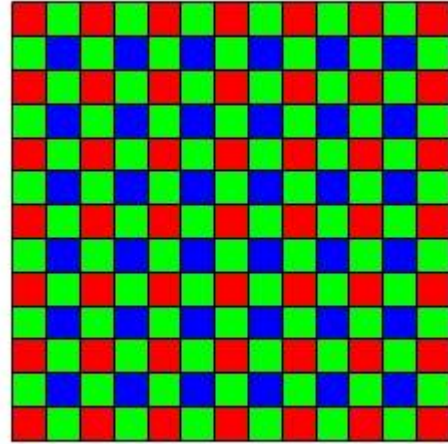
Bayer filter

© 2000 How Stuff Works

Image from HowStuffWorks:
(http://s.hswstatic.com/gif/digital-camera-bayer.jpg)
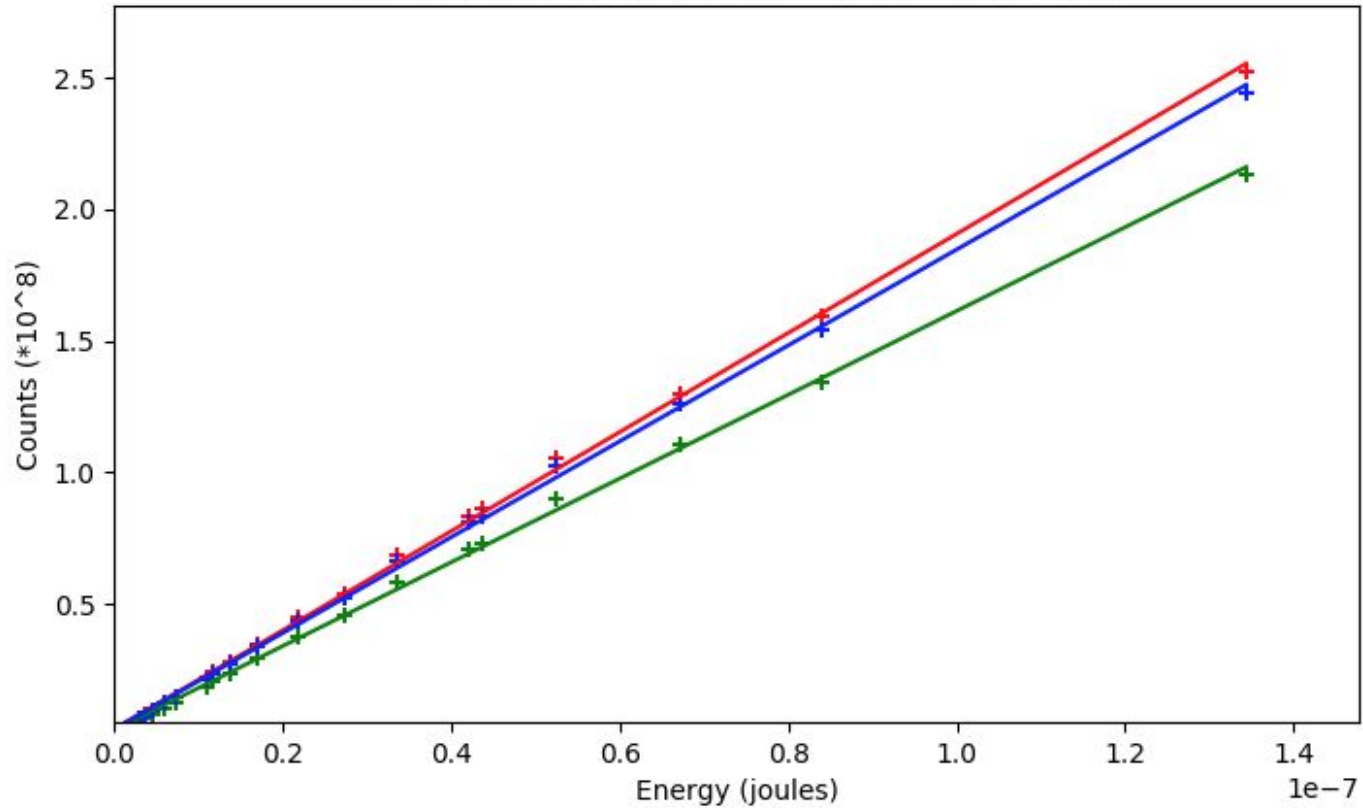
Experimental Setup

Experimental Setup

Camera Calibration

-Varied shutter speed and power incident on the sensor

-Used RAW camera files

-Kept ISO constant

-Ambient light subtraction

Calibration Results, 1064 nm
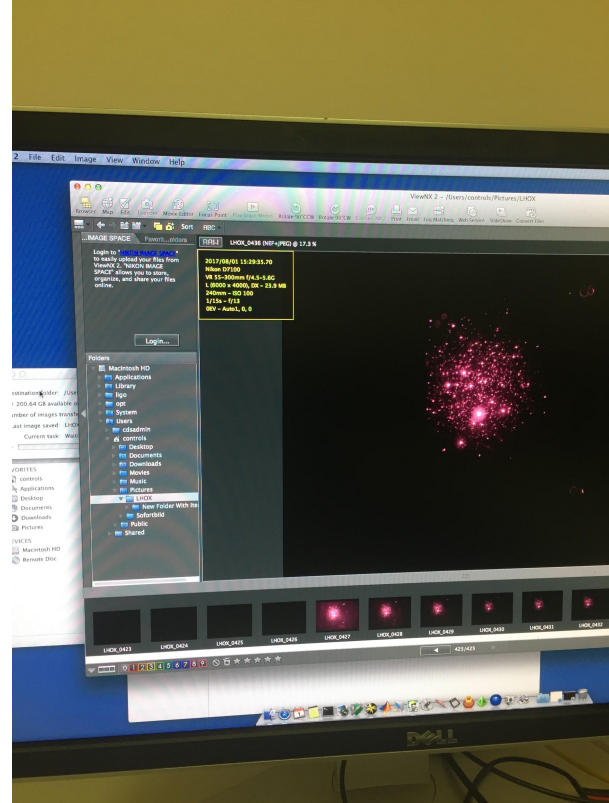

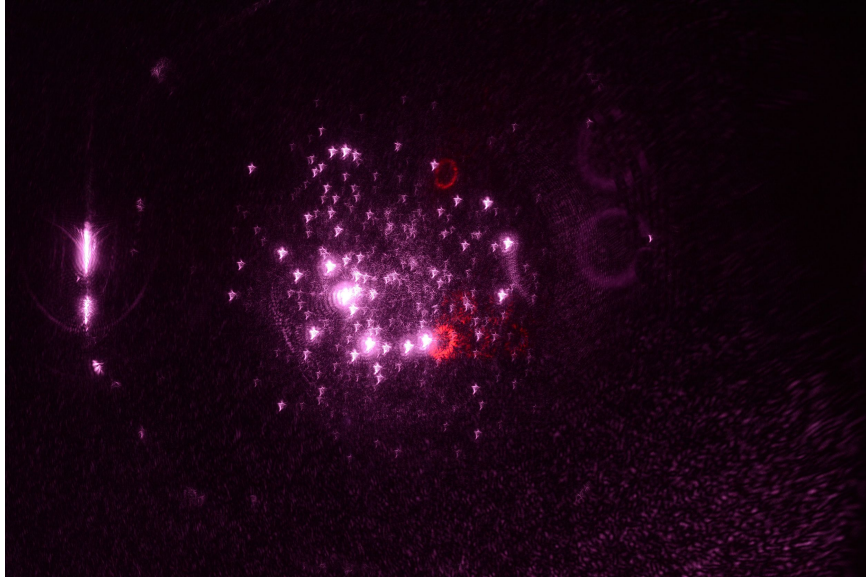Pixel Counts vs Energy (Nikon D7100, 1064nm)

Calibration Results

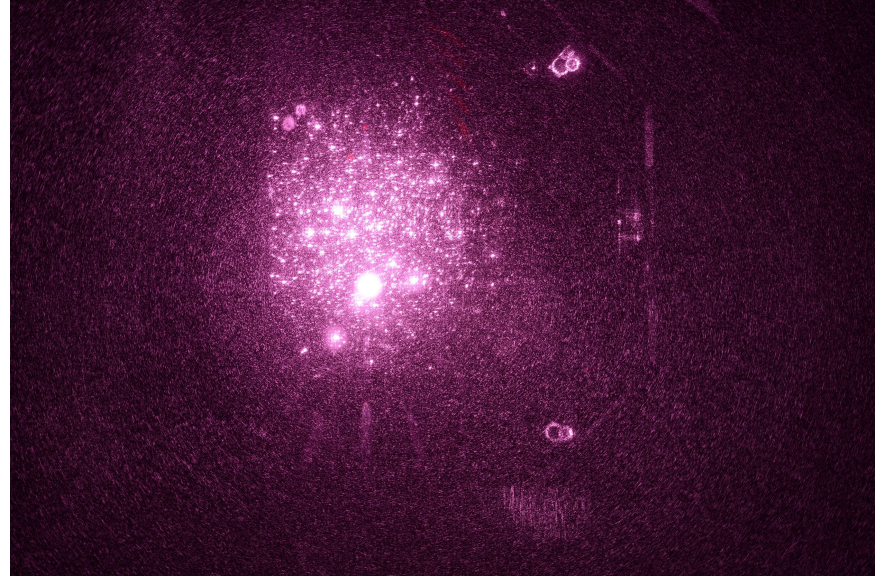| Laser Wavelength (nm)	Color	Slope (Counts/Joule)	Standard Deviation of the fit
1064	Red	1.61E+16	9.32E+13
1064	Green	1.45E+16	8.26E+13
1064	Blue	1.65E+16	9.52E+13

Measuring Test Mass Scattering

Measuring Test Mass Scattering

ITMx, 30s exposure
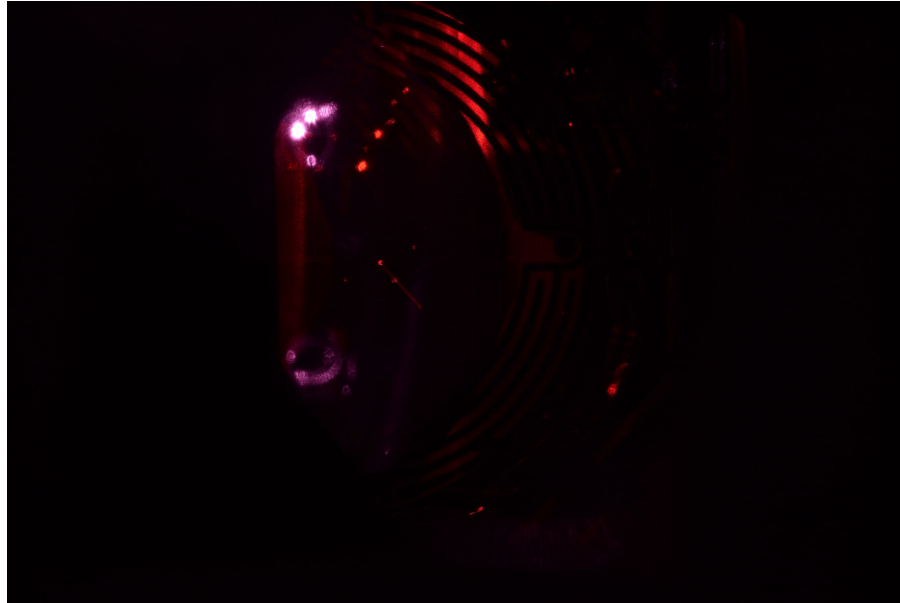

ETMx, 1s exposure

Measurement Limitations

Addressed:

-Ambient light from other lasers

-Camera electronics noise (read noise)

-Dynamic range

    -Saturated Pixels
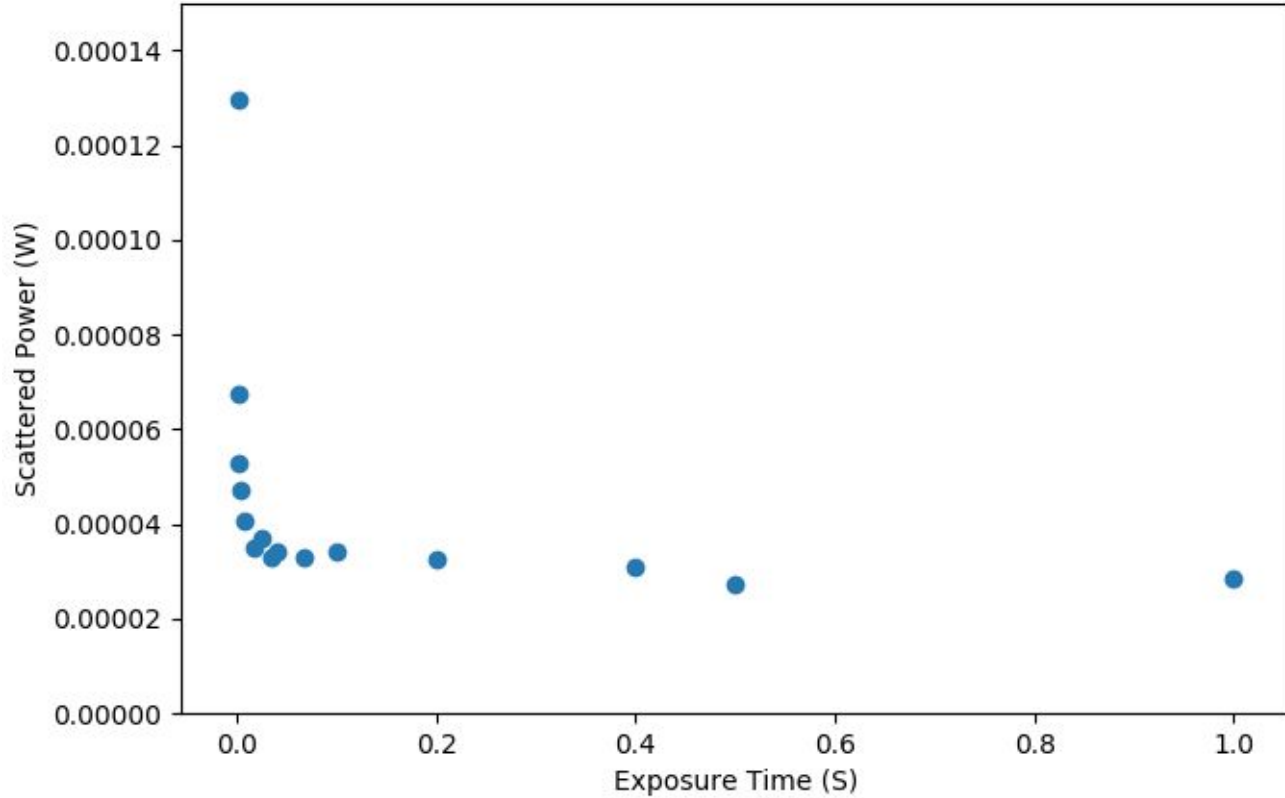
Not Addressed:
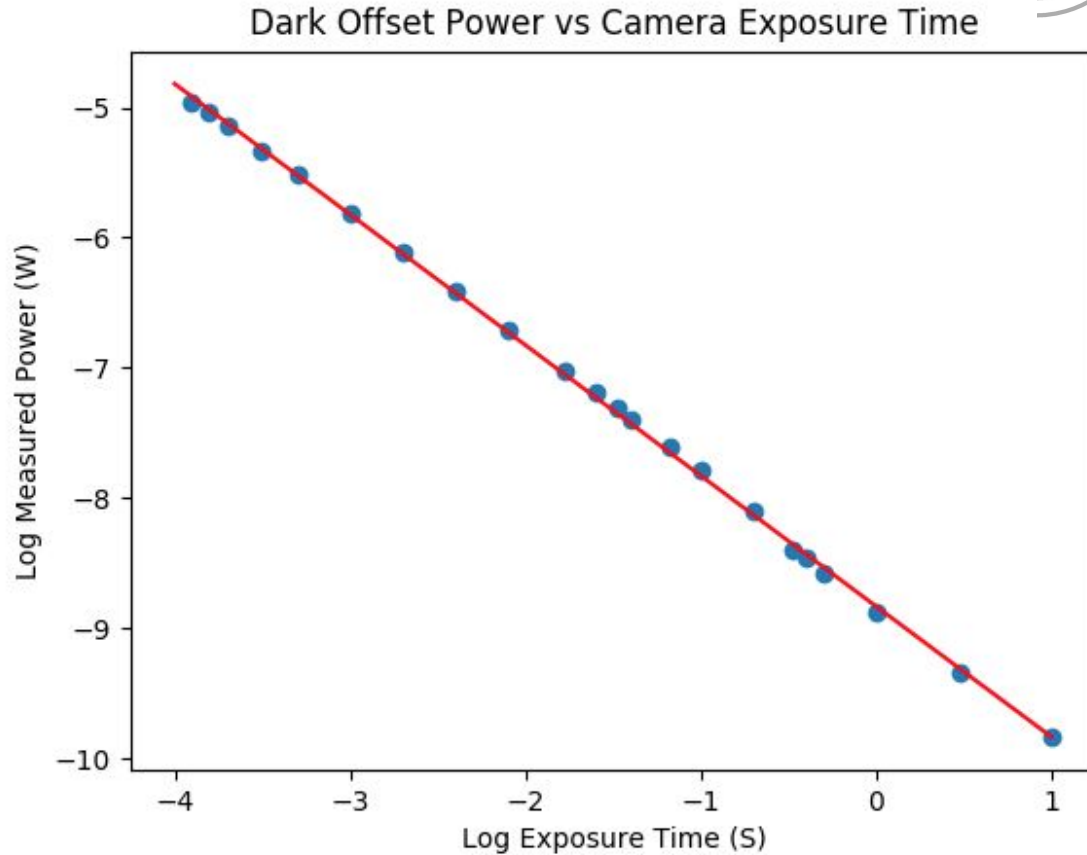
-Nonuniform scattering

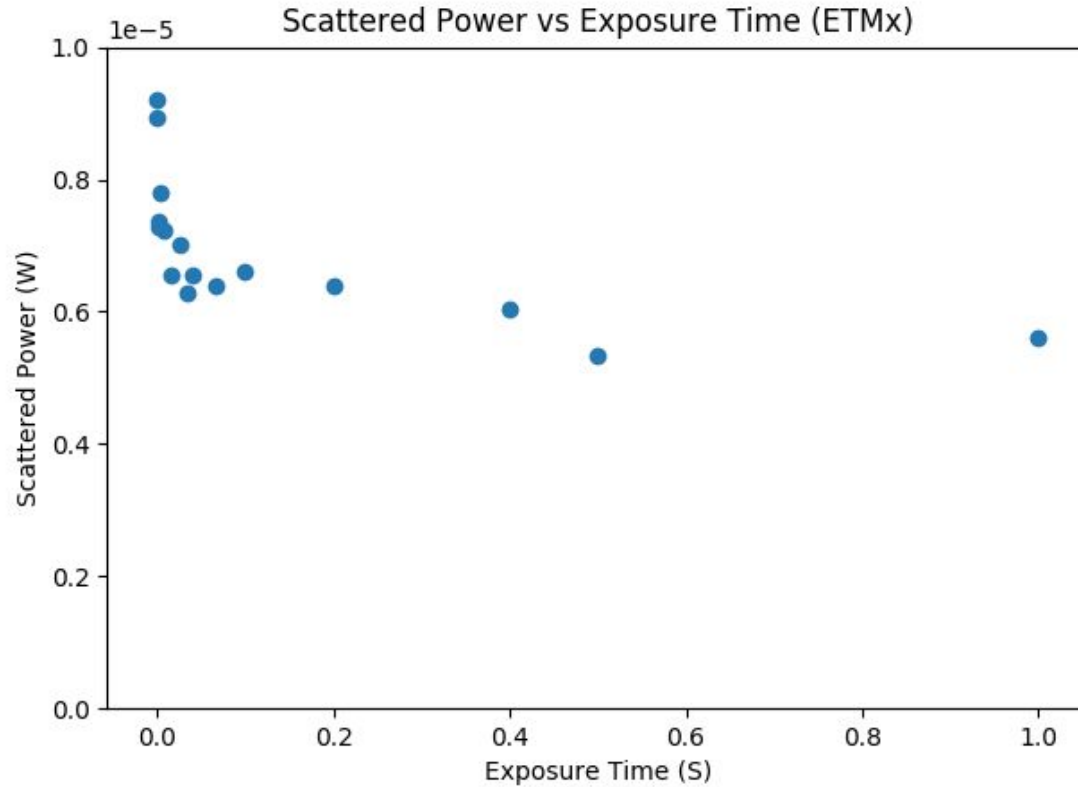# Ambient Light Subtraction

ETMx Background, 20s

Read Noise

Scattered Power vs Camera Exposure Time (ETMx)

Read Noise

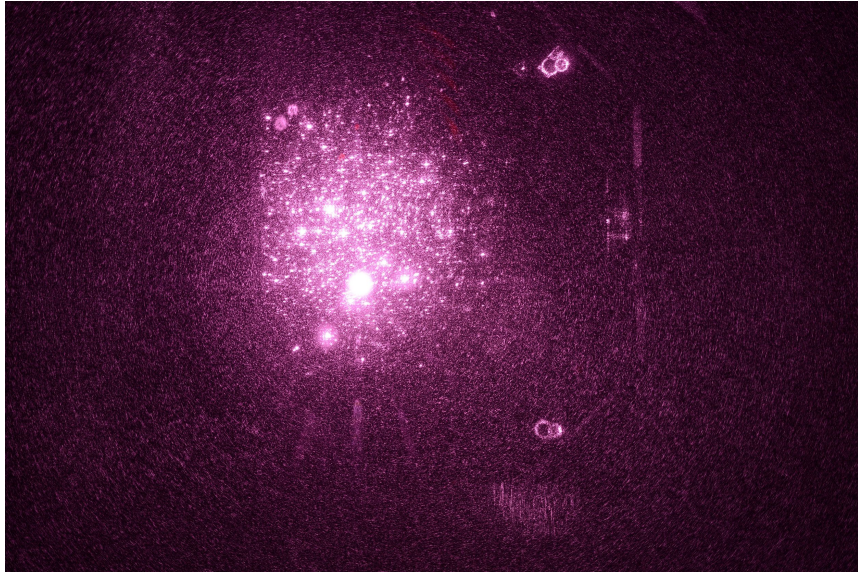Dark Offset Power vs Camera Exposure Time

Read Noise

Scattered Power vs Exposure Time (ETMx)

Dynamic Range

1 second exposure

1/40 second (still saturated)

Extending the Dynamic Range

ETMx Scattered Power (EDR)
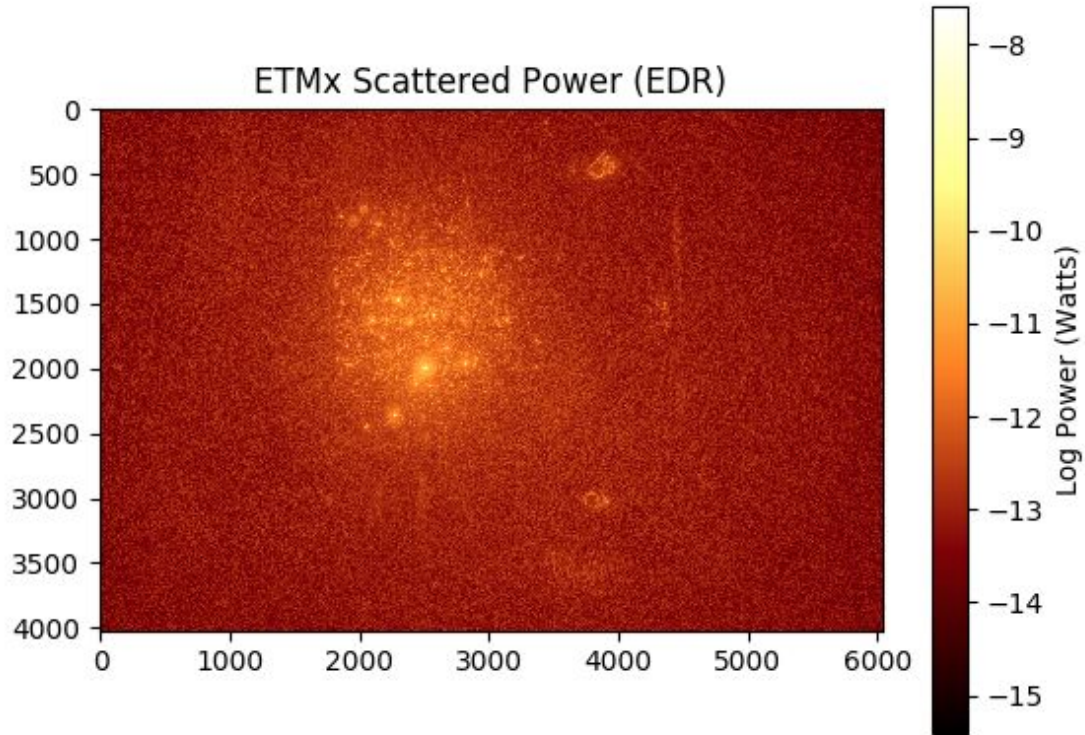
Results

My results:

ETMx: 10 watts/steradian @ 10.6 degrees

ITMx: .0142 watts/steradian @ 1.52 degrees

From Vincent Roma (T1600085), using photodiodes:

ETMx: 3.68 watts/steradian @ ~10 degrees

ITMx: 42.22 watts/steradian @ ~1.5 degrees

Thank You