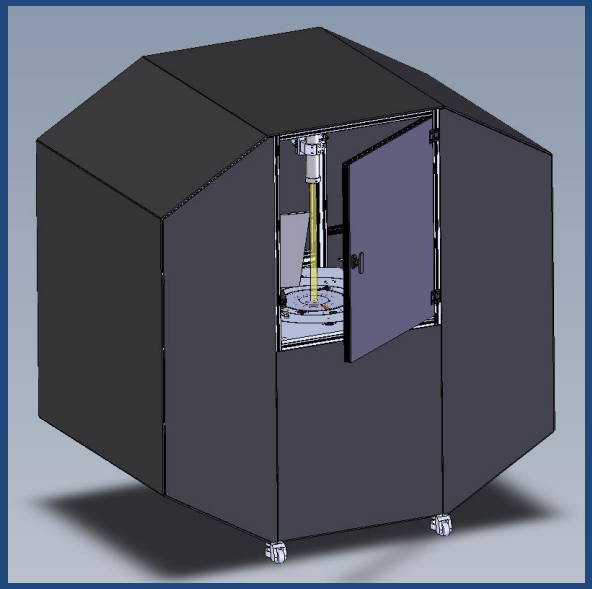
HDR Imaging Based Material BRDF/BTDF (BSDF) Measurement Device

Mark Jongewaard



BSDF: Bidirectional Scattering Distribution Function

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Non-Specular Materials Used in Lighting Devices


Image by Cree

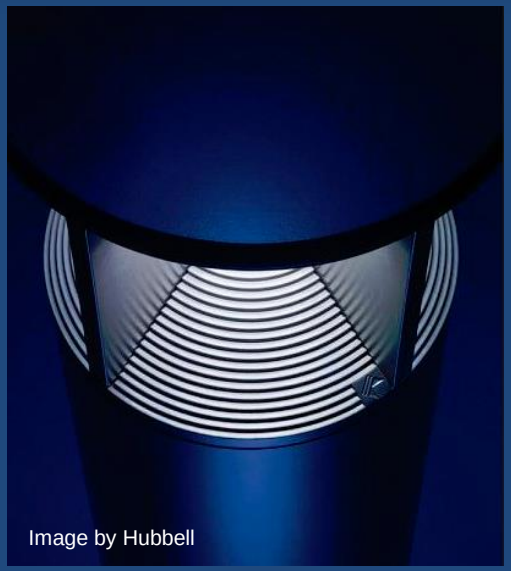
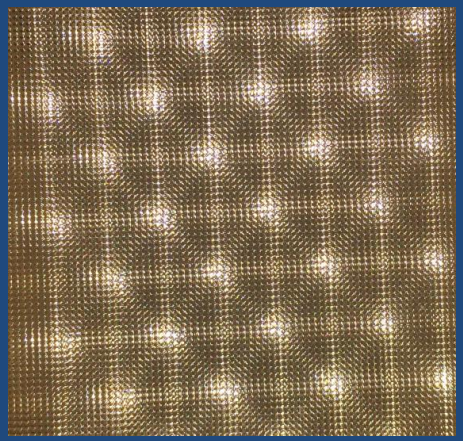
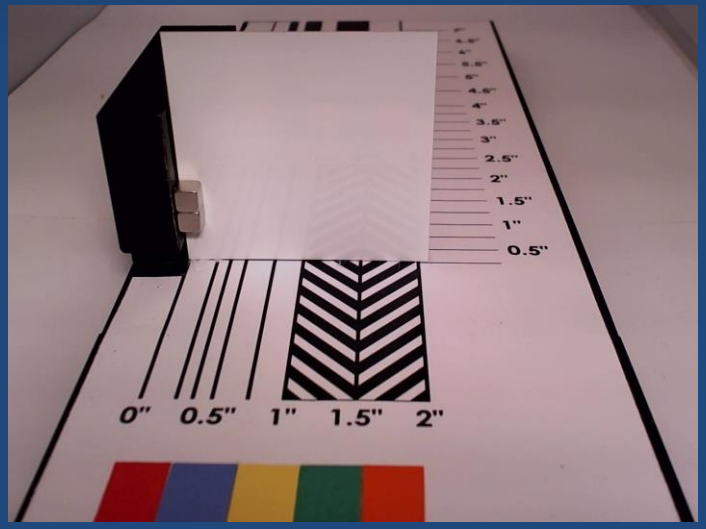
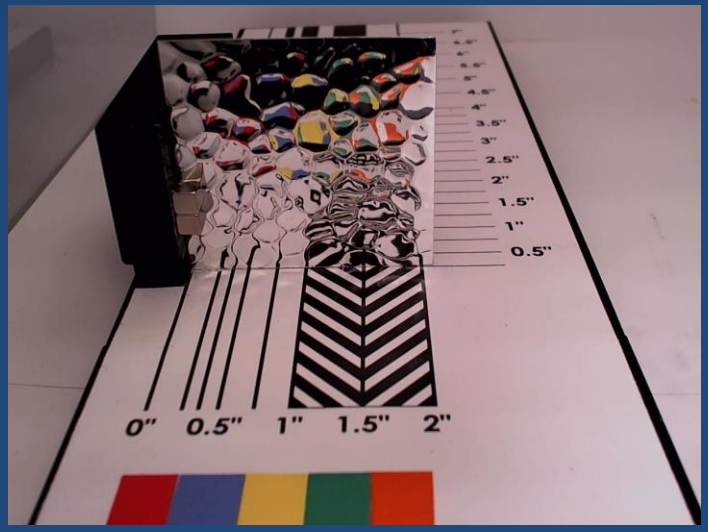


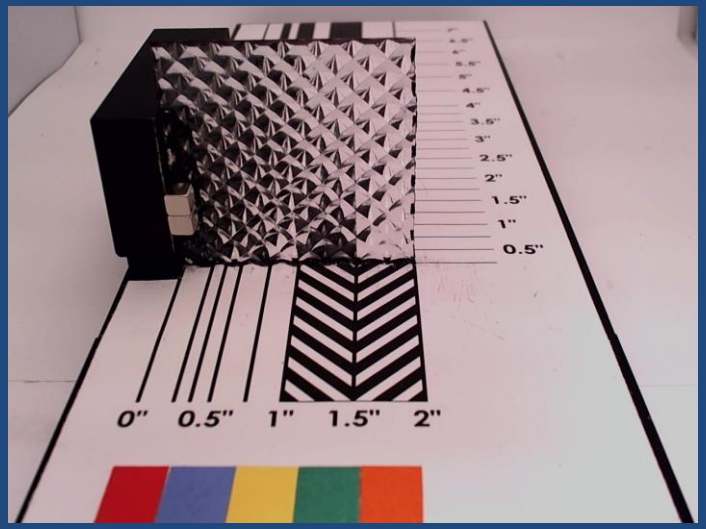
Image by Hubbell

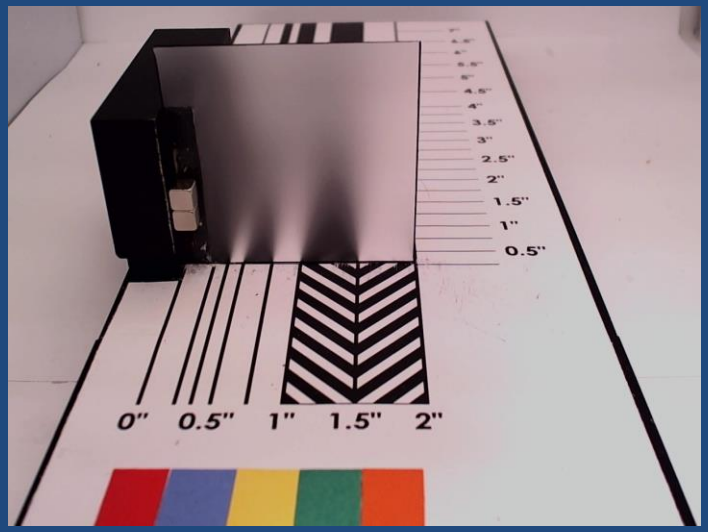


Non-Specular Material Examples

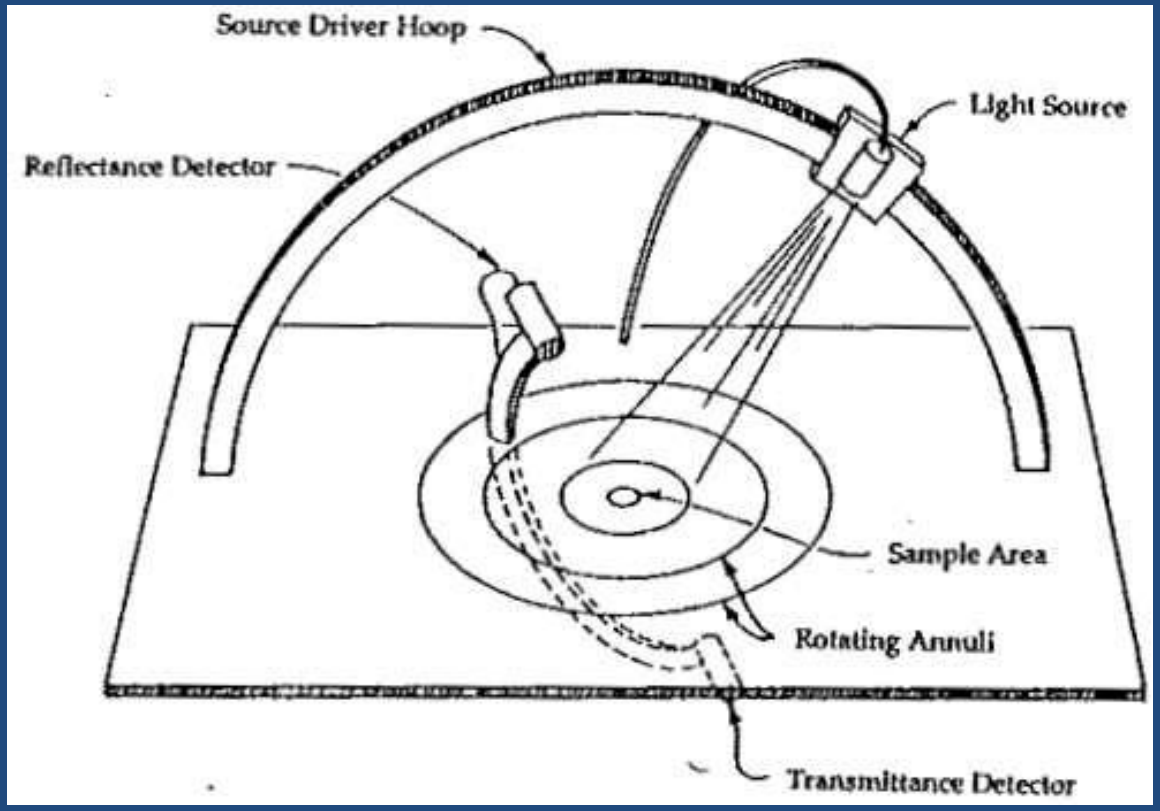








Goniometric BSDF Measurement Device



- Lower data resolution or much longer test times.
- Current LTIO device - Single isotropic reflector measurement takes 4 hours for material & background tests for 3200 data points.
- Anisotropic lens material with unique properties on each side takes several days to measure.
- Angular resolution varies, with more data around the mirror angle.

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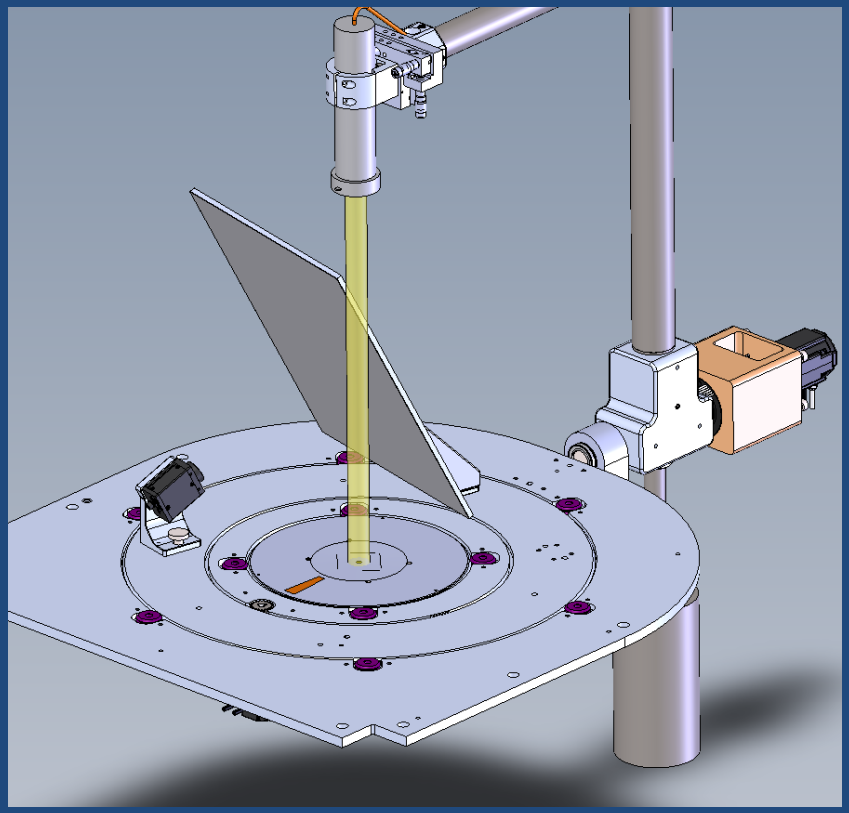
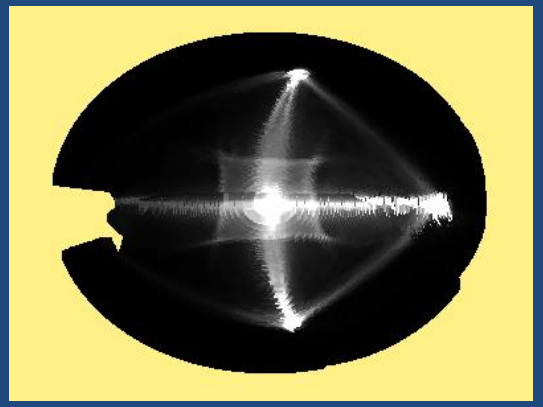
HDR Imaging Measurement Device



- Millions of data points for high resolution output.
- Isotropic reflectance measurement in about 30 minutes
- Double sided, anisotropic lens test in about 14 hours



Example light scatter through prismatic lens material.

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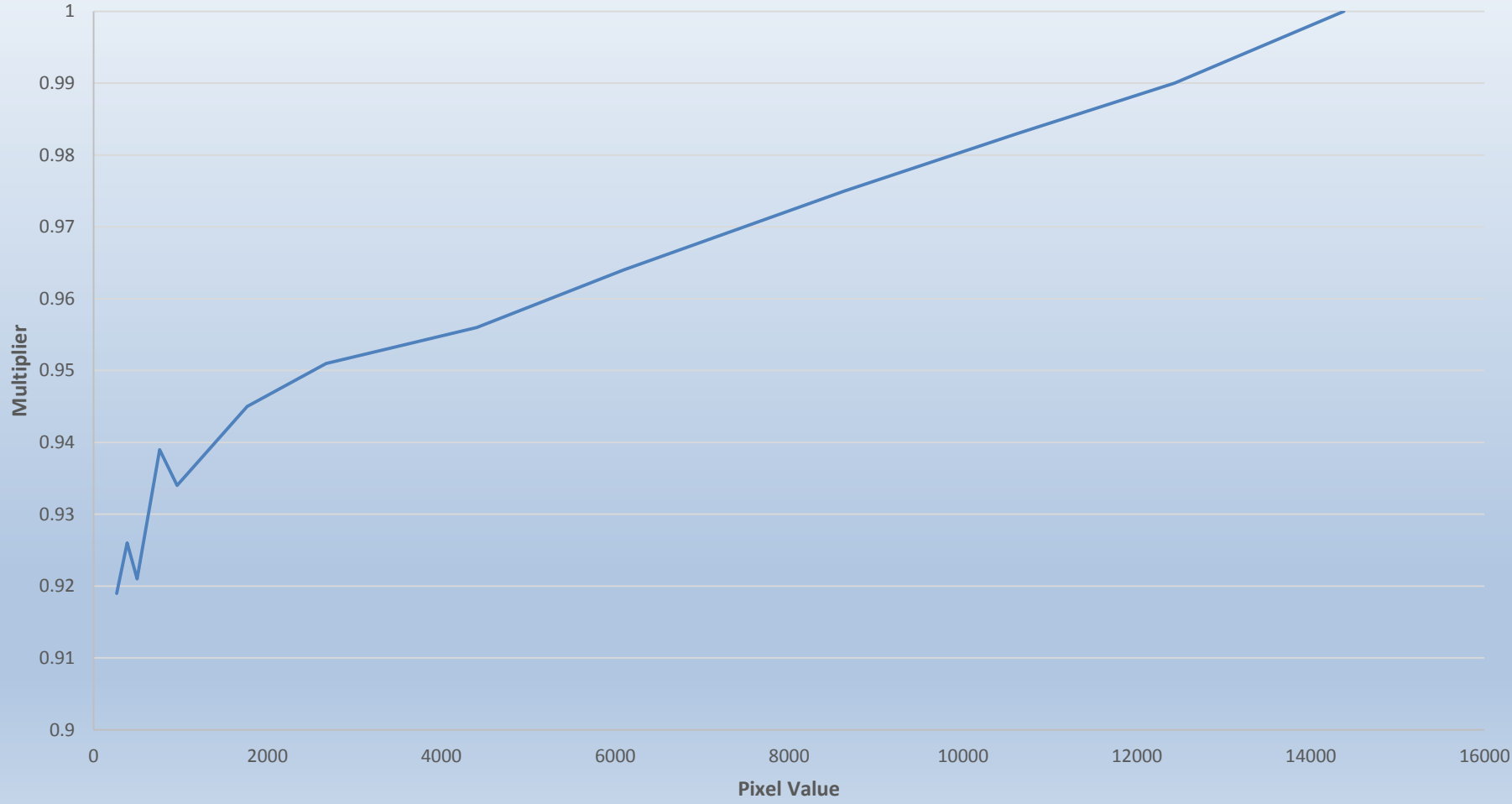
High Dynamic Range (HDR) Imaging

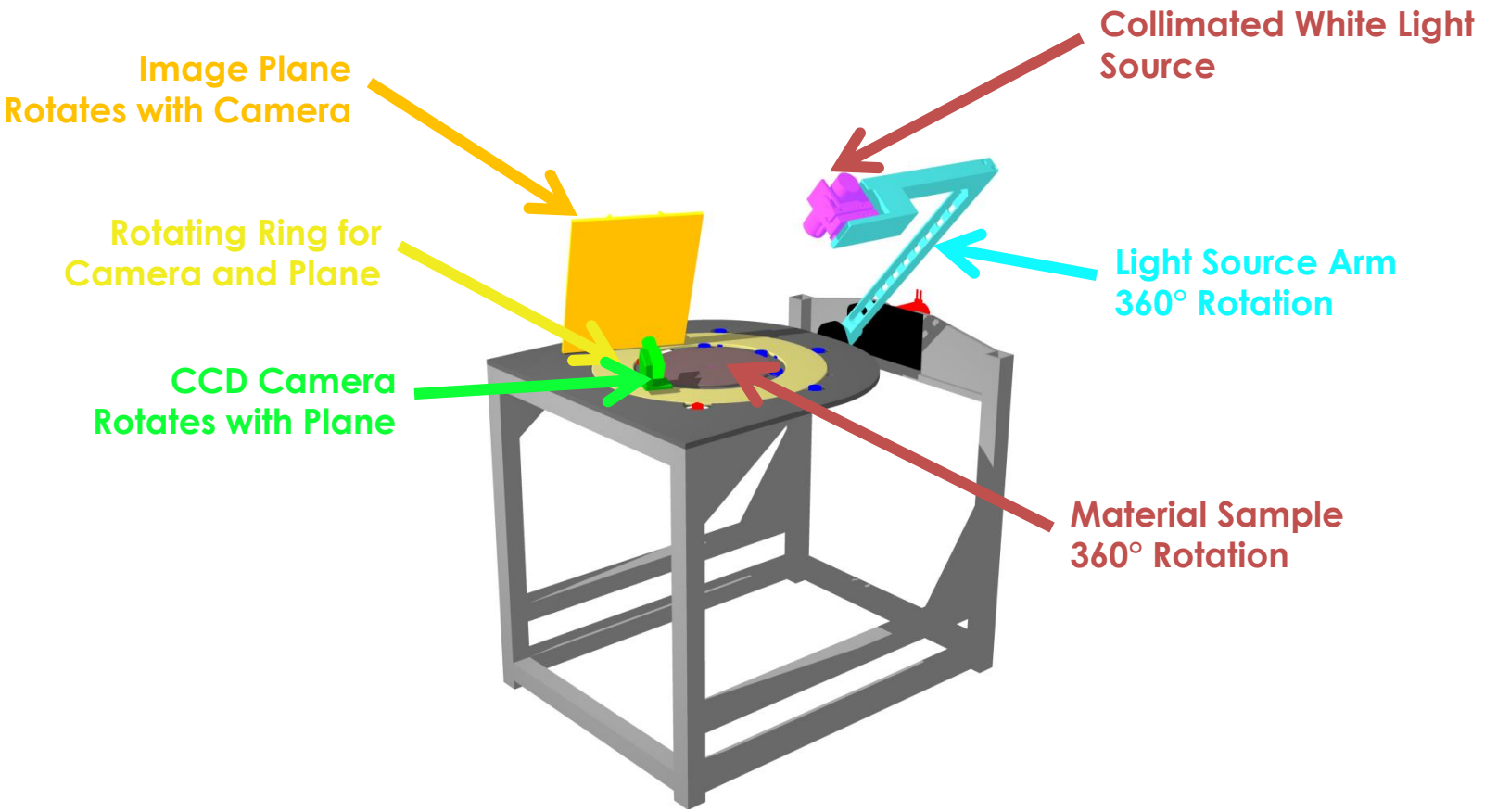
Point Grey Grasshopper Camera.

- 14-bit camera: 0-16383
- 10 exposures: 40μs to 10s
- Discard pixels <2000 & >12000 unless shortest or longest exposures
- Dynamic range: ≈1,500,000:1
- 1.4 MP CMOS sensor

Pixel Multiplier for Linear Response to Luminance for Point Grey Camera CMOS Sensor

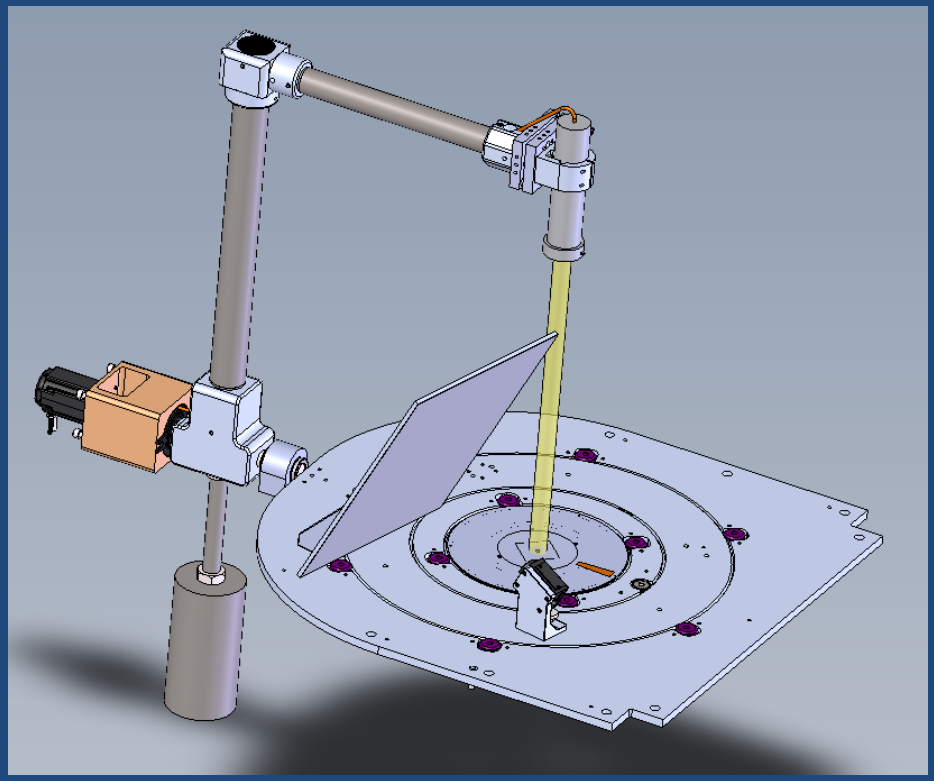


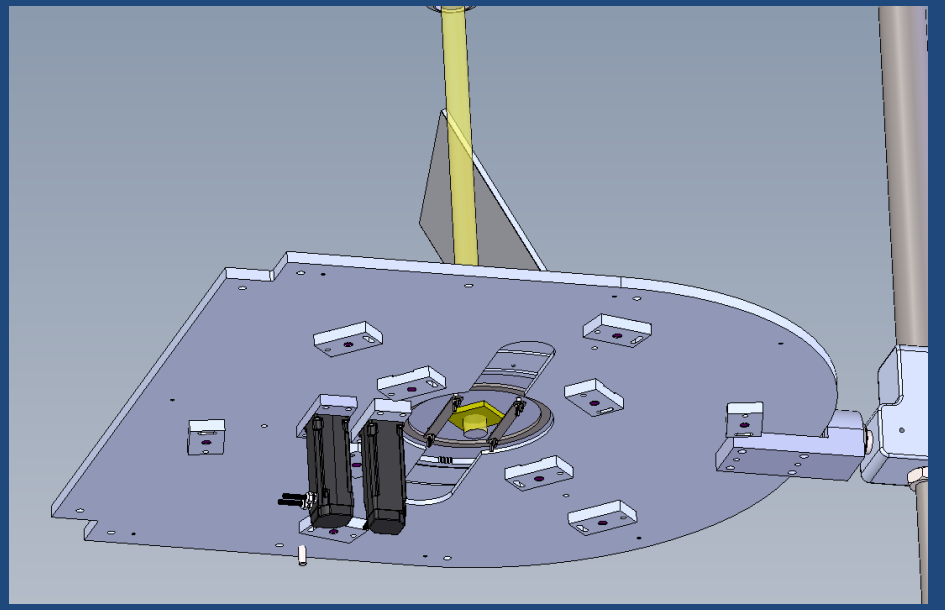
General Configuration of Measurement Table



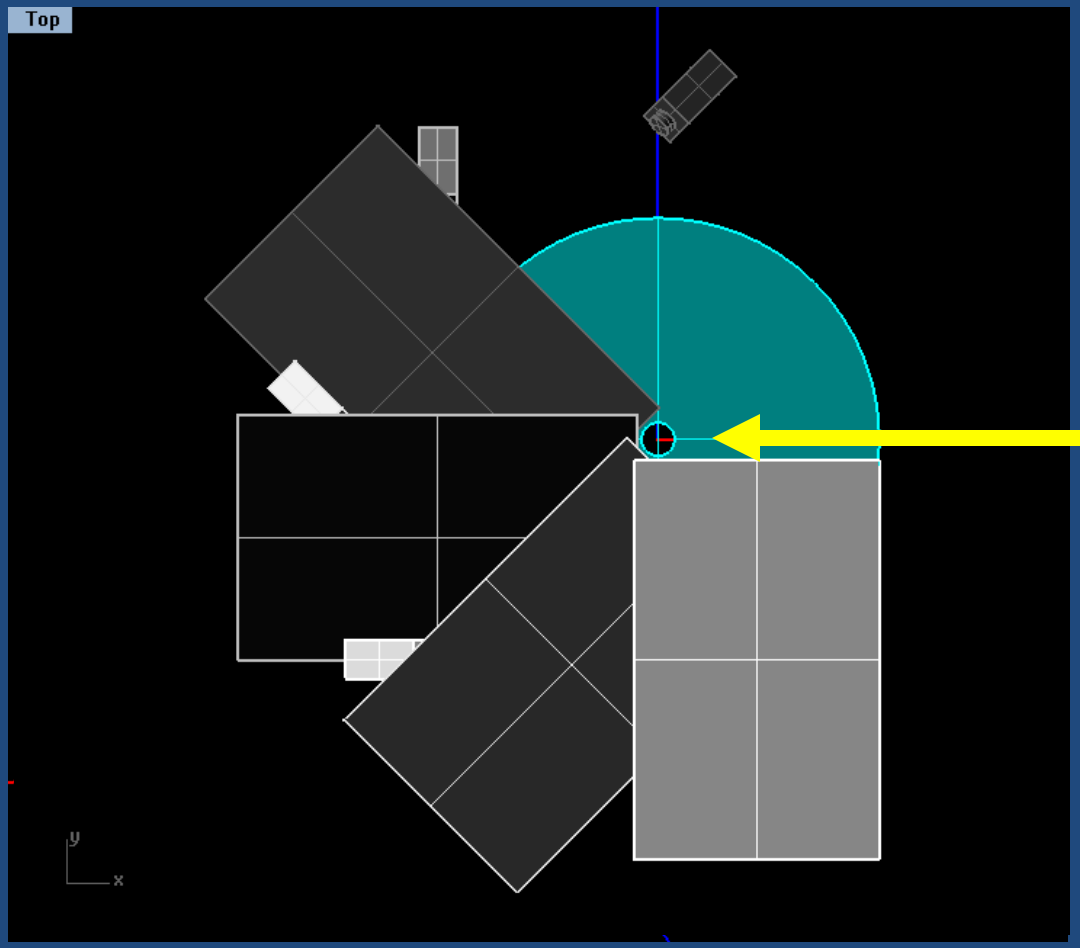
Collecting data on the image plane avoids unwanted interreflected light in the image

Views of Measurement Table



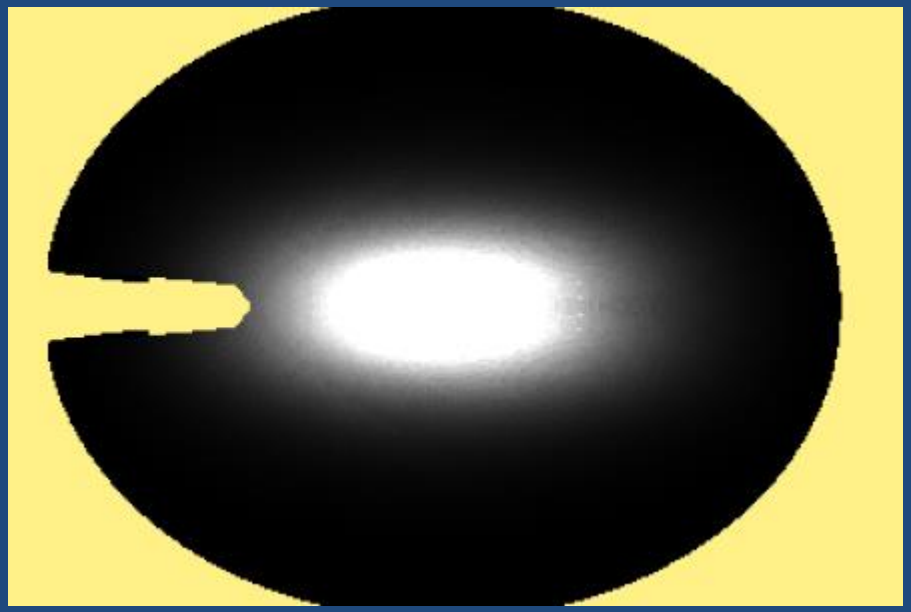


Screen Positions to Capture a Hemisphere of Data



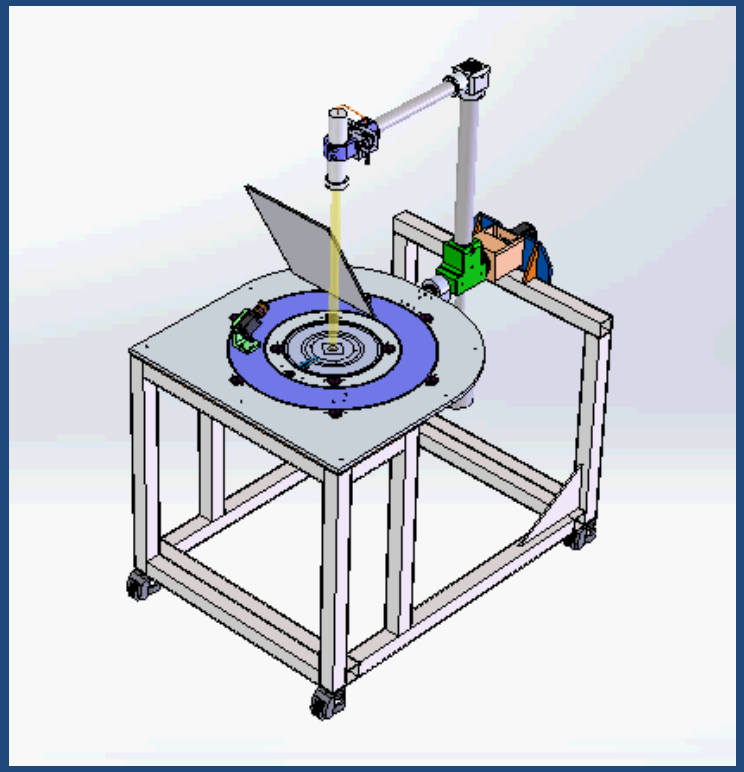
4 positions cover half of a hemisphere.

Region that Can't be Covered by Screens



- Some of the hemisphere needs to be filled in from surrounding data due to the gap required to let the light source illuminate the sample.

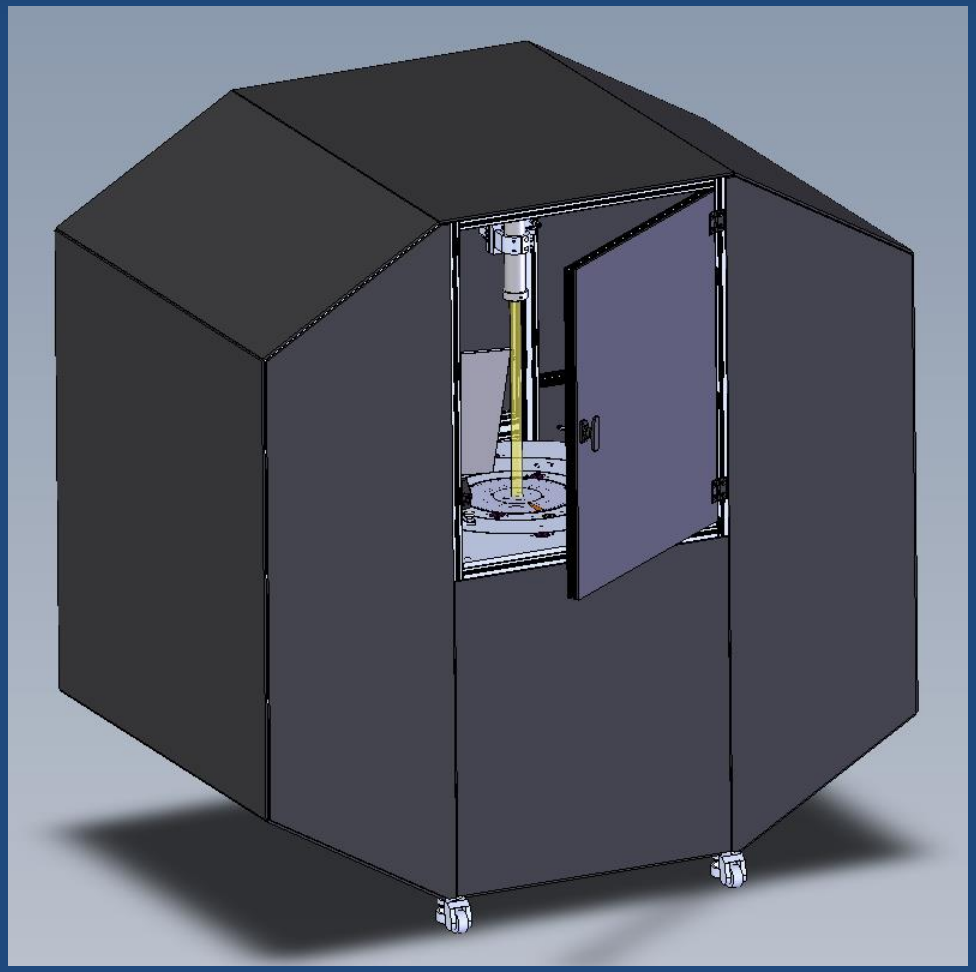
View of General Motion of Light Source, Screen & Camera



** Hover mouse over image to display animation controls.*

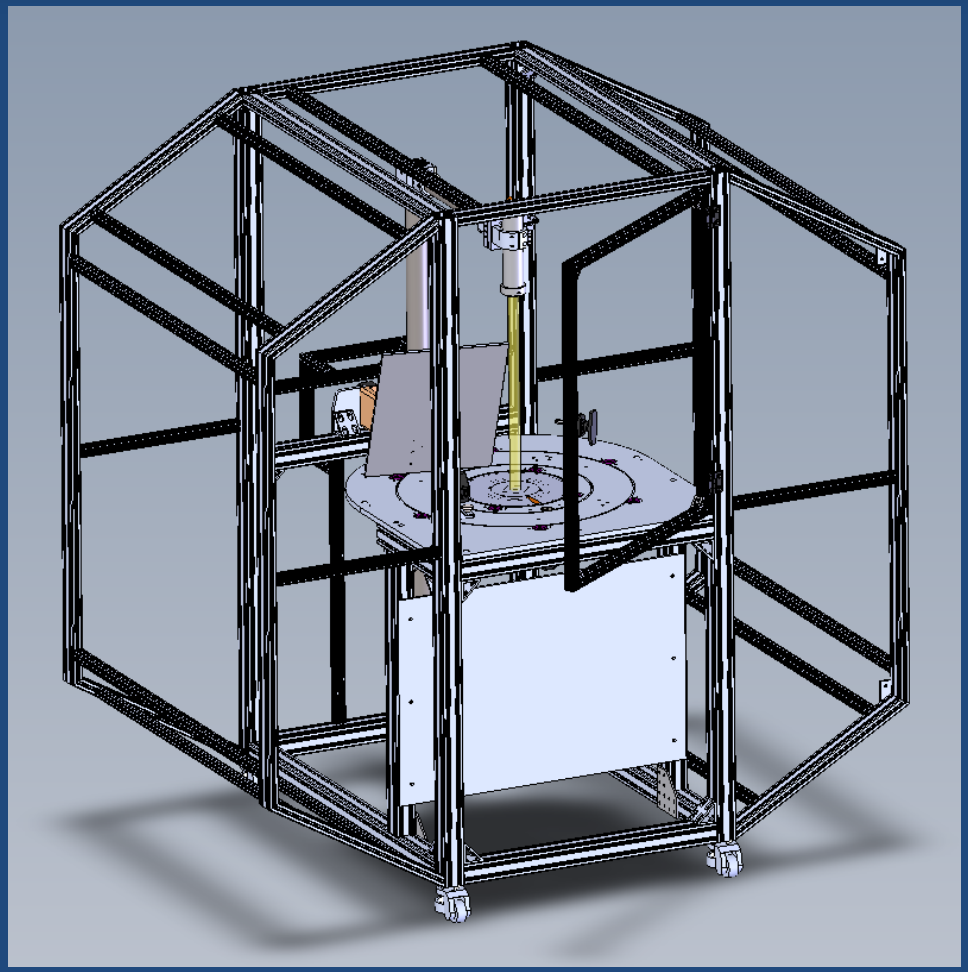
- For each light source incidence angle, the screens rotate 135˚ to capture half of a hemisphere.
- If the material is anisotropic, then screen & camera are moved to the other side of the ring to capture the other half of the hemisphere.
- Light source can rotate to any angle above and below the table.

View of Measurement Device & Enclosure



- The overall device is about 69" tall & 42" deep.

View of Measurement Table Inside Enclosure



- The device is self contained with an onboard computer and controlled via a tablet.

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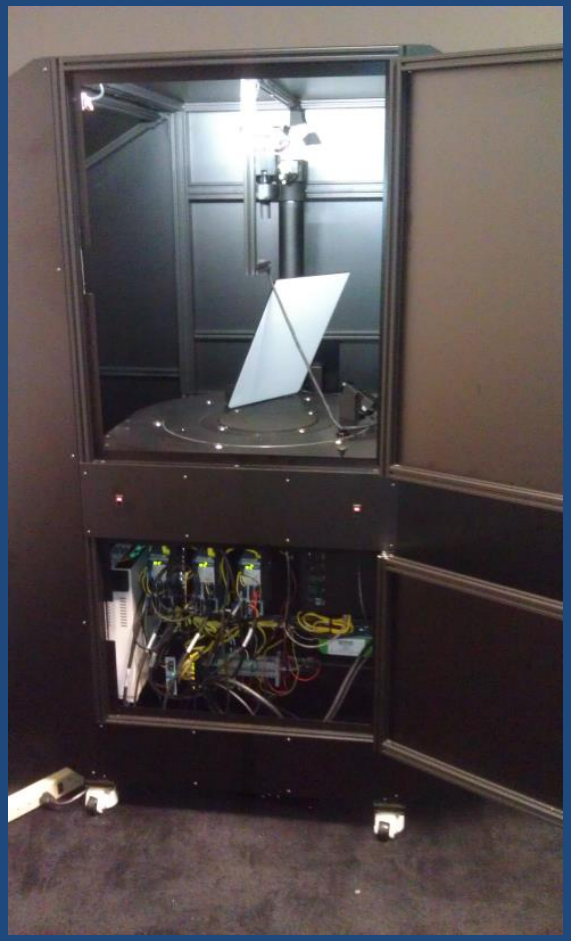
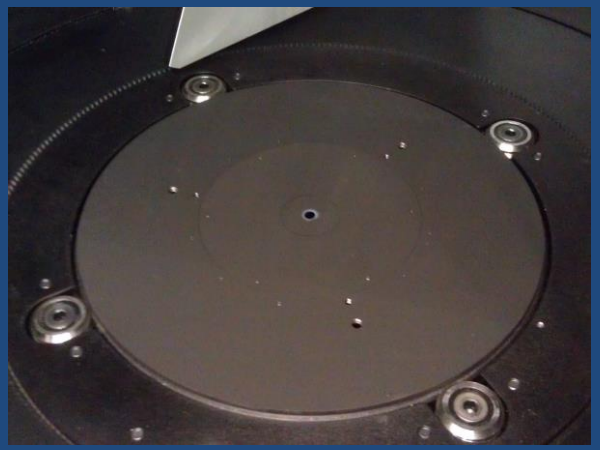
Views of Device, iPad Control Panel & Sample Holder





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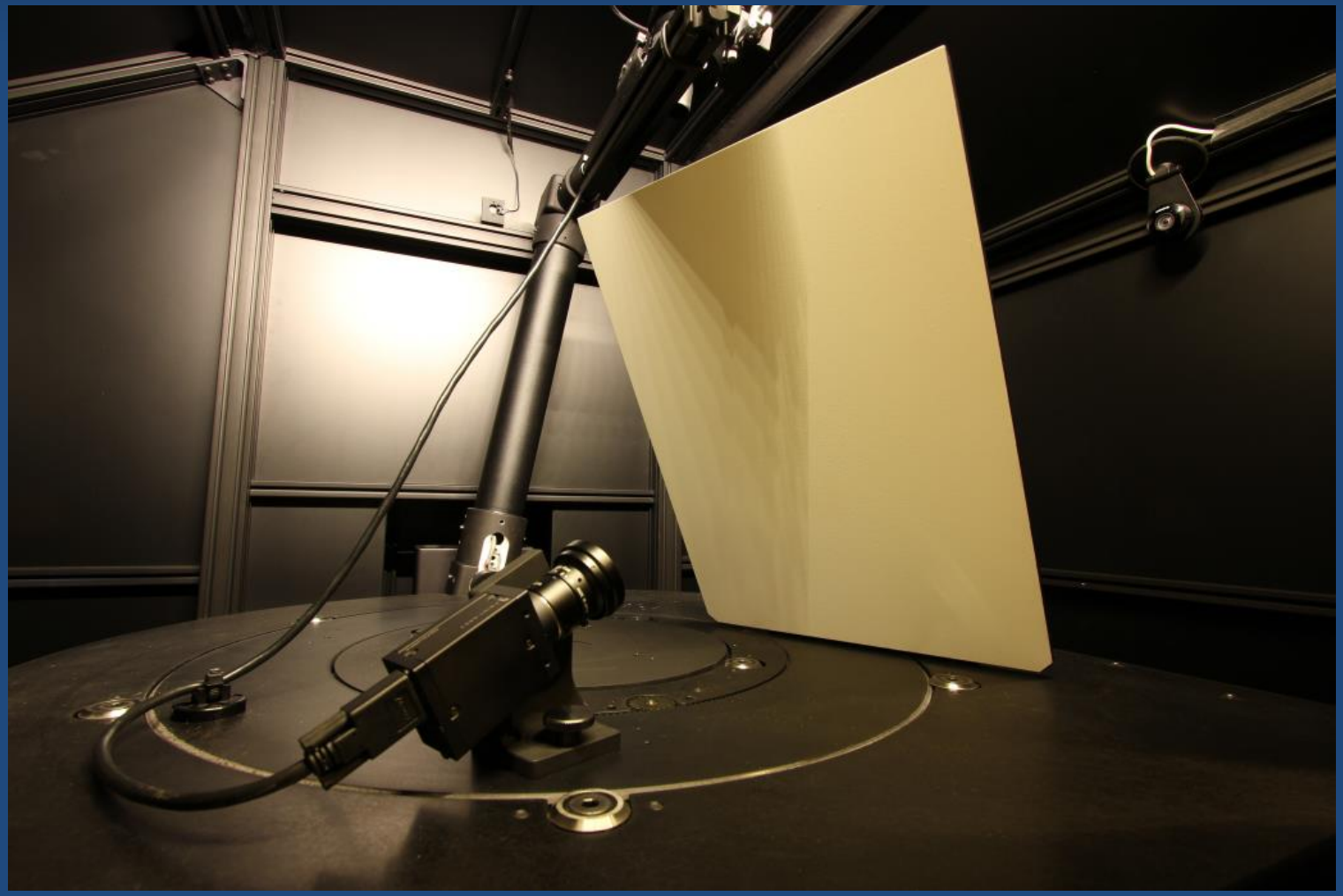
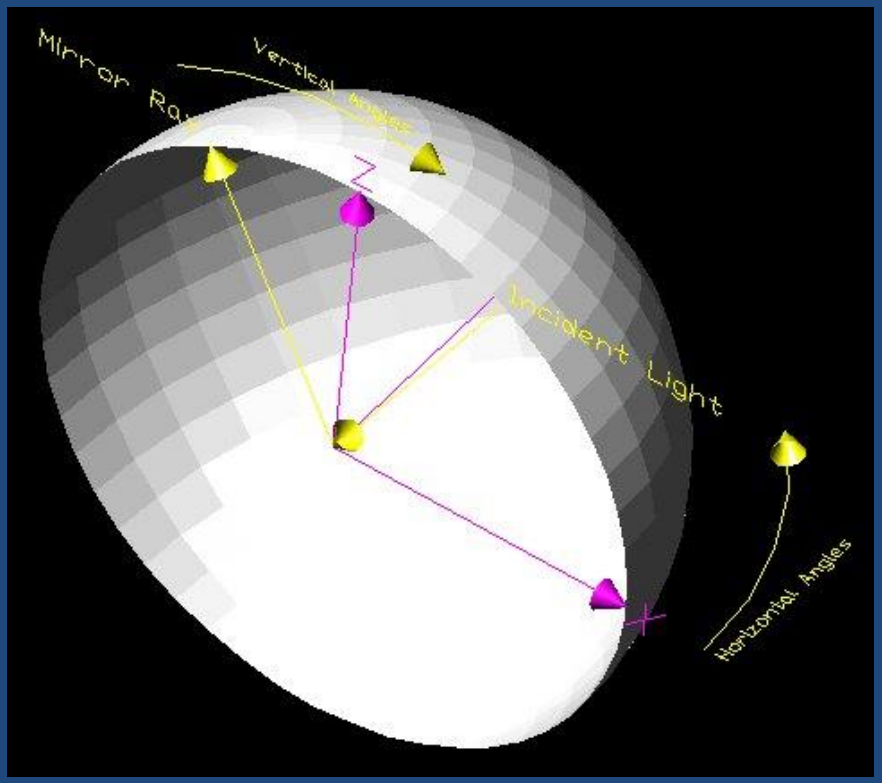
View of Camera & Screen

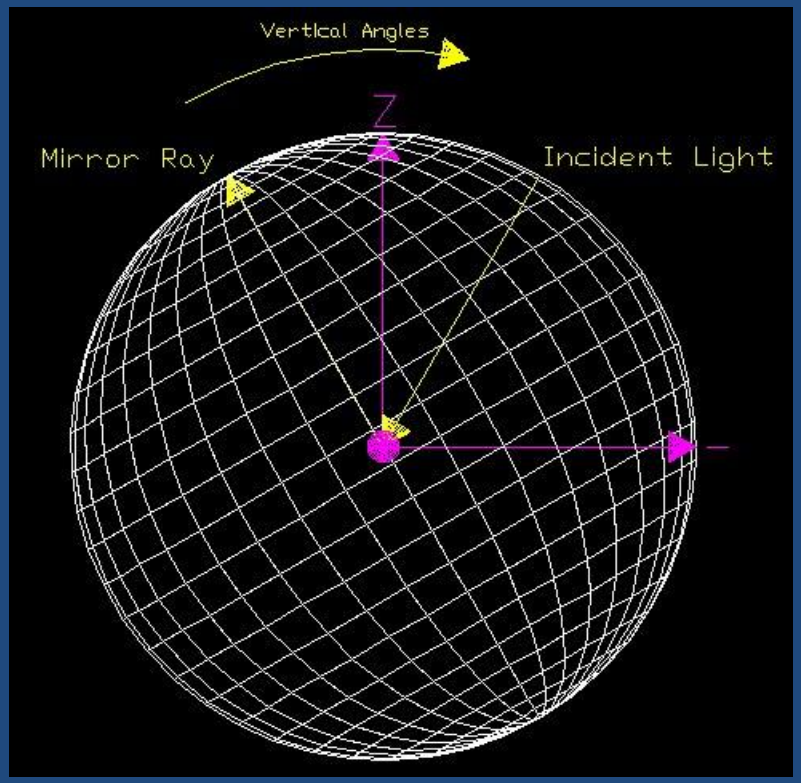


Data Processing

- All screens are projected onto a hemisphere.
- "BSDF" (L/E) isn't directly useful for raytracing, so the data generated is a set of relative luminous intensity distributions (RLID).
- Various virtual sensor size options are used to calculate intensity values.
- Intensity data is stored in a rotated spherical coordinate system, centered about the mirror angle direction.

Relative Intensity Distribution Coordinate System





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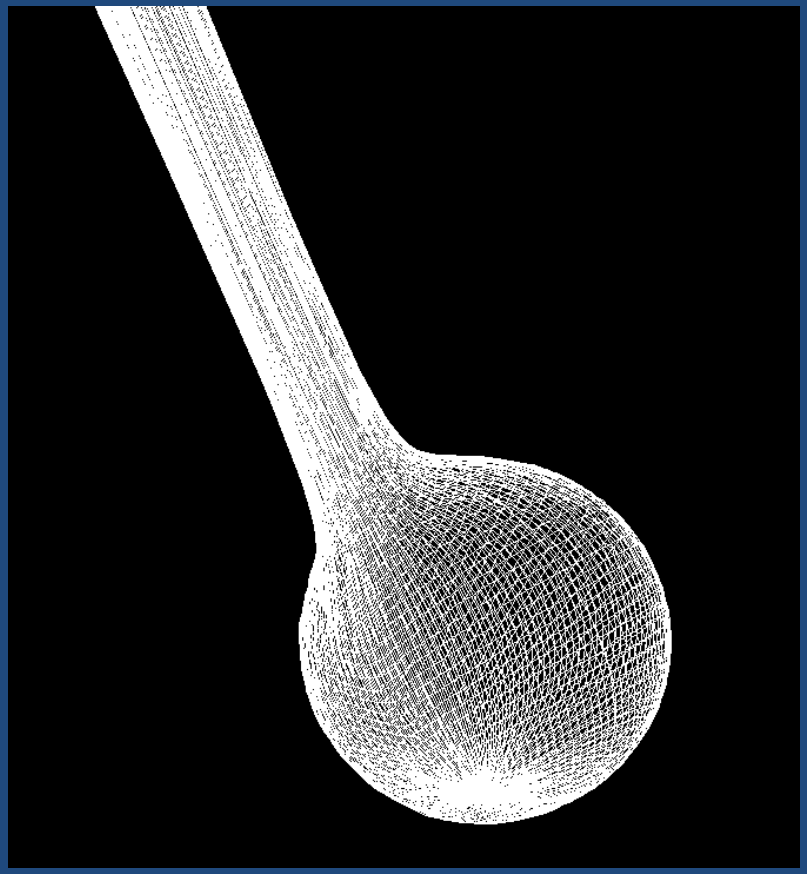
Data Processing

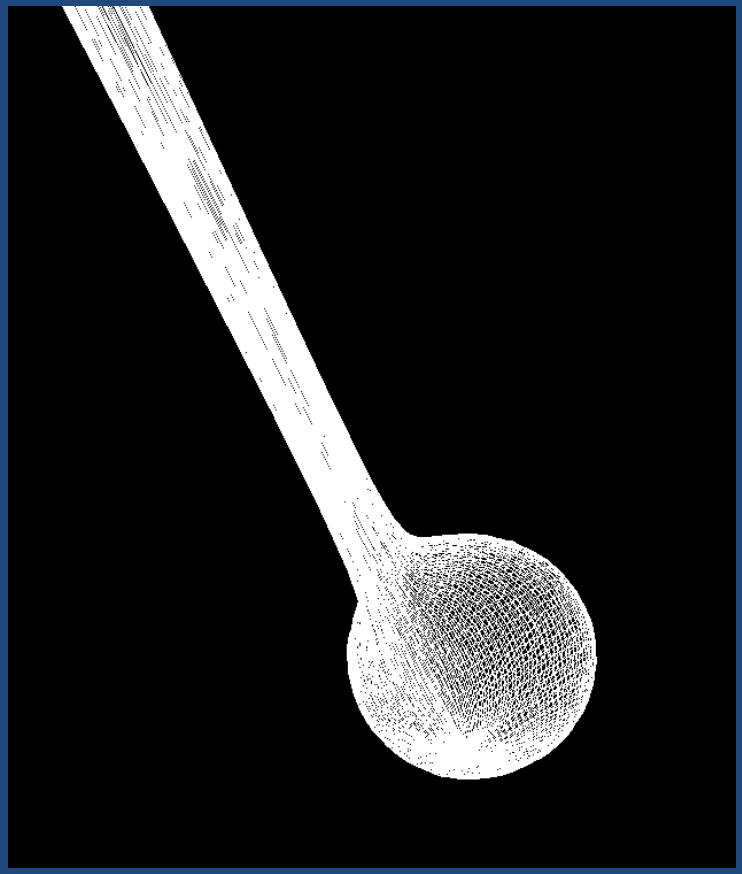
- Calibration done with Spectralon as a “diffuse” standard (accounts for vignetting, non-diffuseness of screen & interreflections with table.

- Separating out the “specular” component is necessary for any raytracing application of the data.

View of BSDF Data from Glossy White Plastic Before Specular Component is Removed

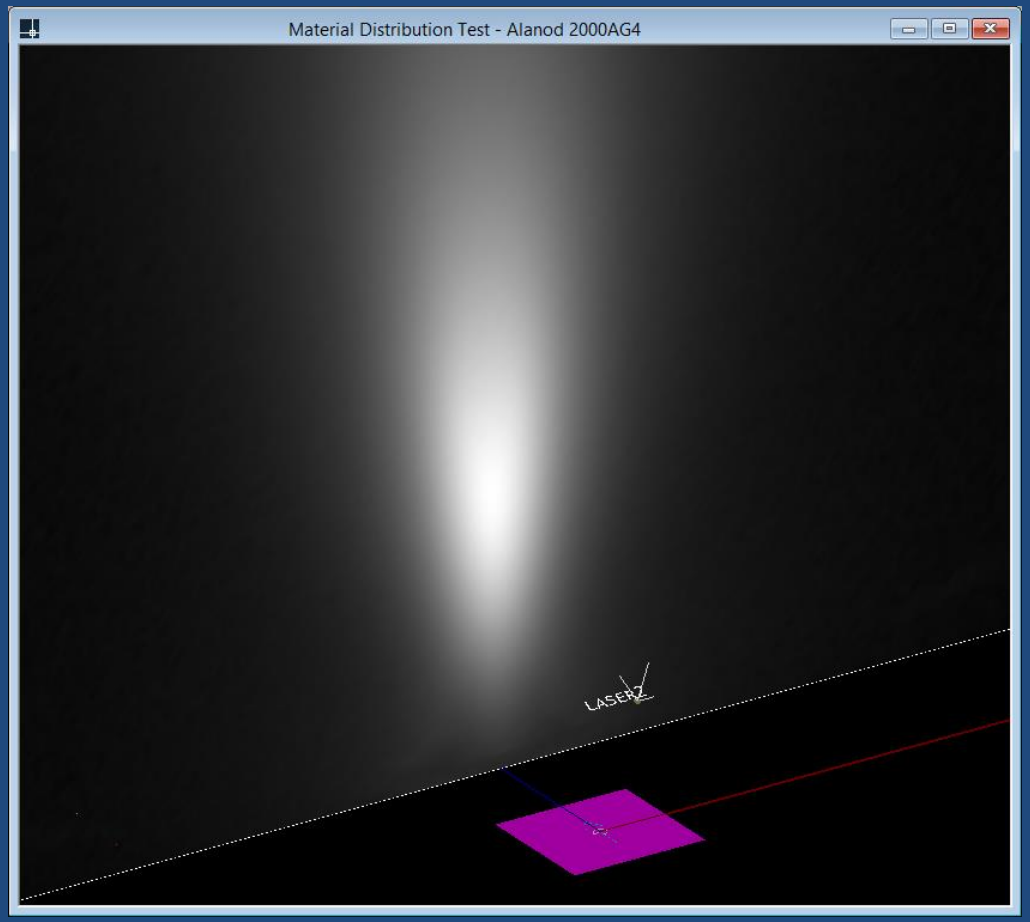


Spherical plot of relative intensity distribution for 35 ° incidence angle.



Spherical plot of relative intensity distribution for 40 ° incidence angle.

View of BSDF Data from Alanod 2000 AG Semi-Specular Aluminum



Photopia simulation of a laser directed onto the material from a 15 °incidence angle, light reflected onto a vertical plane.

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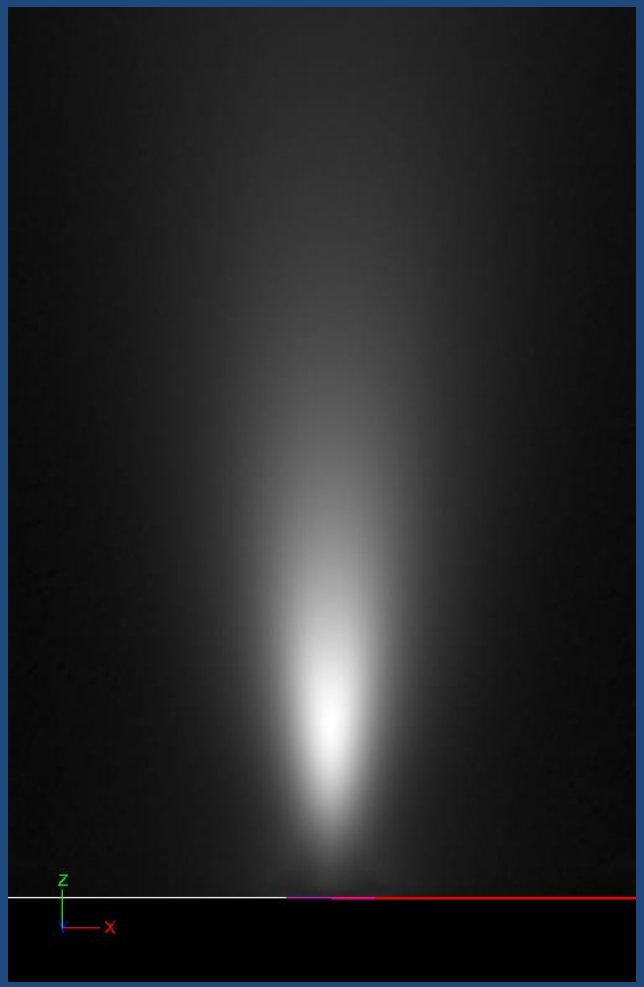
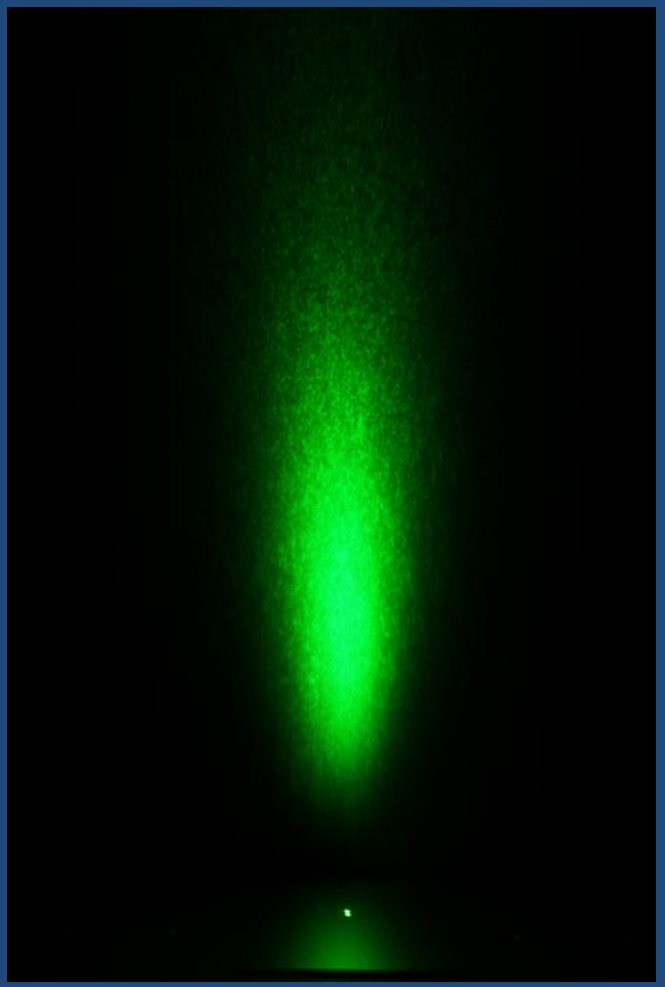
Simulated & Actual Light Reflection onto Vertical Plane for Alanod 2000 AG Semi-Specular Aluminum



Photopia simulation with measured BSDF data.



Laser directed onto actual material sample.

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