Brigham Young University

IMPLEMENTING THETA-2-THETA MEASUREMENTS TO MEASURE MIRROR REFLECTANCE

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BACKGROUND

Our research group studies multilayer mirrors for use in space-based telescopes. The mirror property we are most interested in optimizing is reflectance. In the past, measuring the reflectance of our sample mirrors was difficult, as we either had to travel to the Advanced Light Source in Berkeley, California or we had to conduct and combine the data from many single-axis scans by hand. This made measuring reflectance tedious, error-prone, and time-consuming. By adding an automated theta-2-theta scan to our system, I removed these issues, allowing us to study our mirrors much more efficiently.

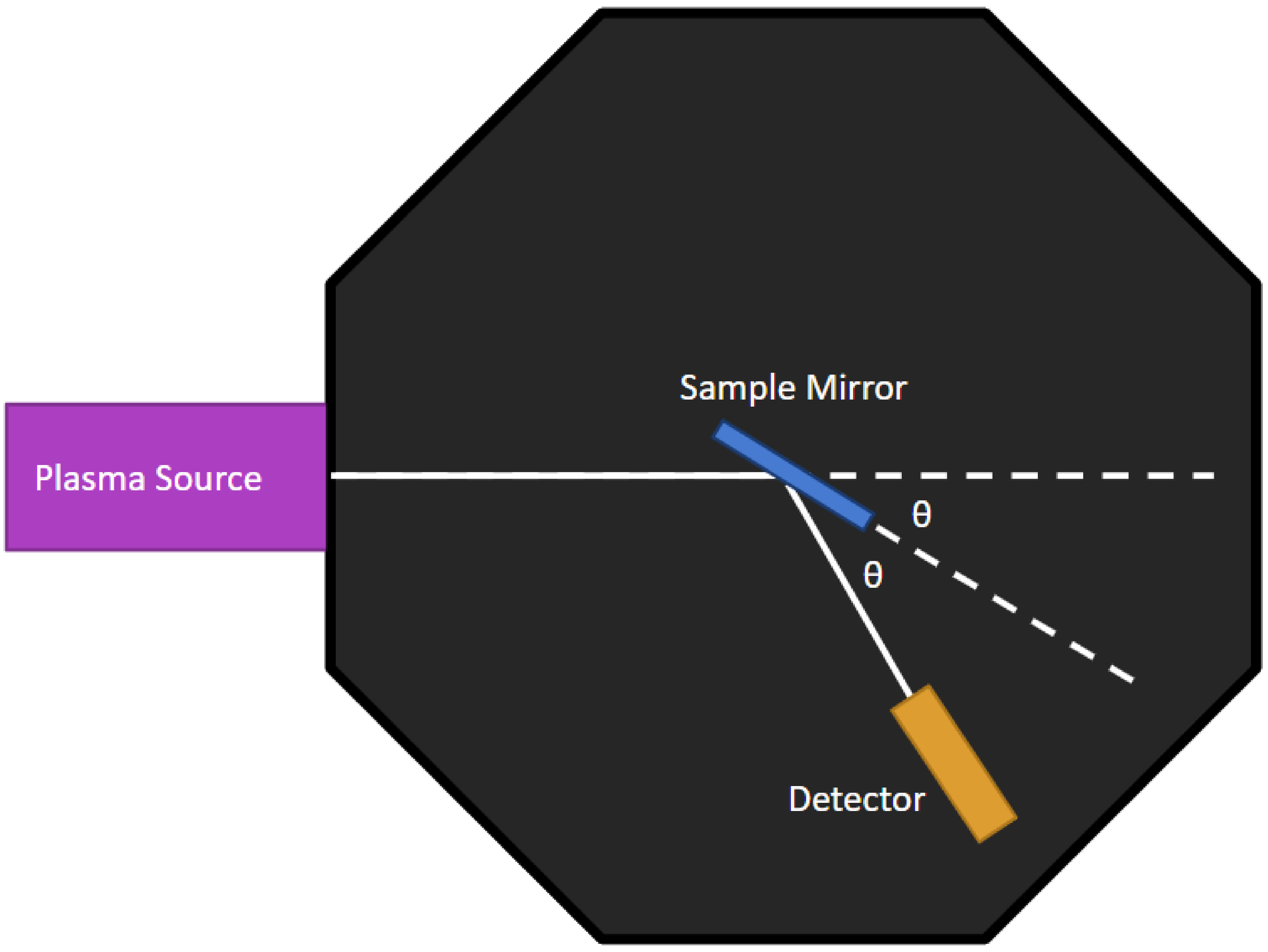

Figure 1: A top view of our vacuum system showing light from the plasma source reflected off a sample mirror into the detector. The angle theta (θ) is the angle of the sample mirror compared to the incident beam where 0° is at grazing.

HOW A THETA-2-THETA SCAN WORKS

In theory, a theta-2-theta scan is fairly straightforward: given a list of angles to scan over, move the sample mirror to each angle, known as θ (theta), and the detector to 2θ (two times theta). In practice, the scan is a bit more complex. In our system, the detector cannot catch the full width of the beam at once, so instead of moving the sample to θ and the detector to 2θ and taking a single measurement, we move the sample to θ and do a detector scan. A detector scan starts at an angle slightly less than 2θ and goes to an angle slightly greater than it, taking multiple data points in between. This ensures the whole beam is captured at each θ. Done for each angle, the detector scans measure how much light is reflected off of the mirror.

For a reflectance calculation, another piece is needed: how much incident light is hitting the mirror. This can be measured with an I0 (I naught) scan. In an I0 scan, the sample mirror is moved out of the way of the beam and a detector scan is performed at 0°, which measures the beam directly from the plasma source. Since our plasma source varies in intensity over time, I0 scans are performed periodically between the regular detector scans. The system then interpolates the I0 intensity value over time for the calculations.

COMPLICATIONS

One of the problems with using detector scans at each θ is figuring out what single intensity value should be used for the reflectance calculation. Our group is still researching the best algorithms for turning a detector scan's data into a single point. These algorithms need to take noisy data into account, as well as an off-centered peak as shown in Figure 2.

Another problem with our theta-2-theta system is background noise from the detector. As you can see in Figure 2, the areas outside the peak are not quite at zero counts. This noise must be detected and accounted for in reflectance calculations.

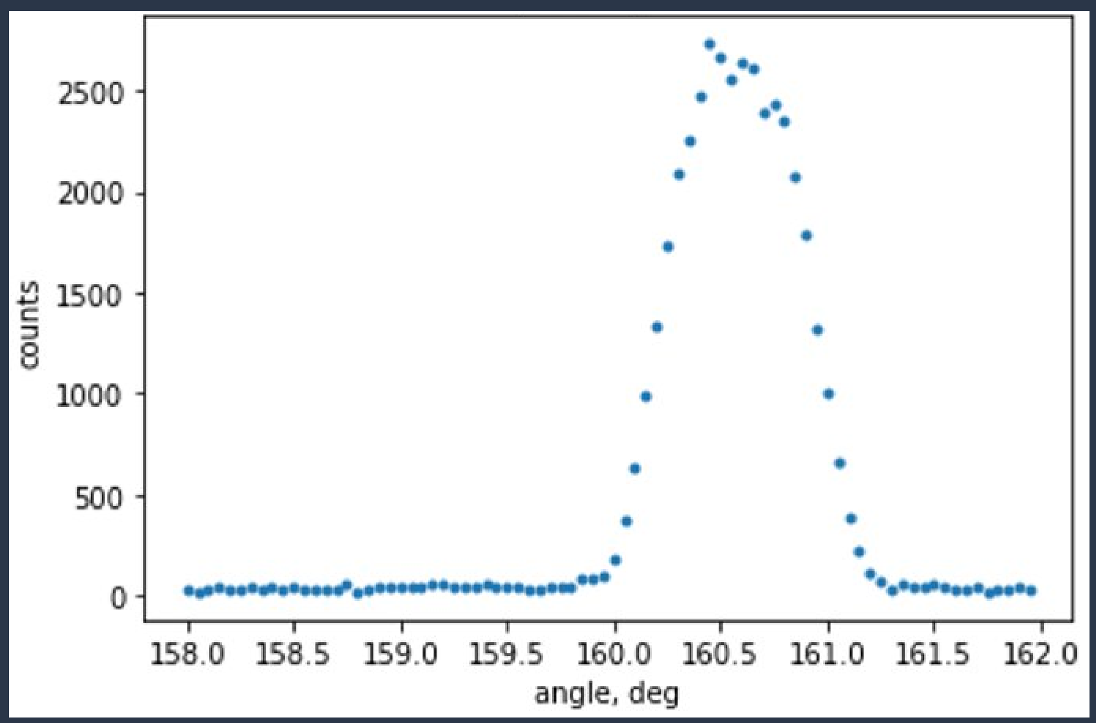

Figure 2: An example detector scan at θ=80°. The horizontal axis shows the detector angle in degrees and the vertical axis shows the number of counts registered by the detector.

SCAN RESULTS

Though we have not used the new automated theta-2-theta scan functionality much due to COVID-19 restricting access to our lab, the reflectance data resulting from the those scans would look something like Figure 3. The program that runs the scans displays a similar graph in real time during the scan, and upon completion it can be exported as JSON for further processing with Python or other languages.

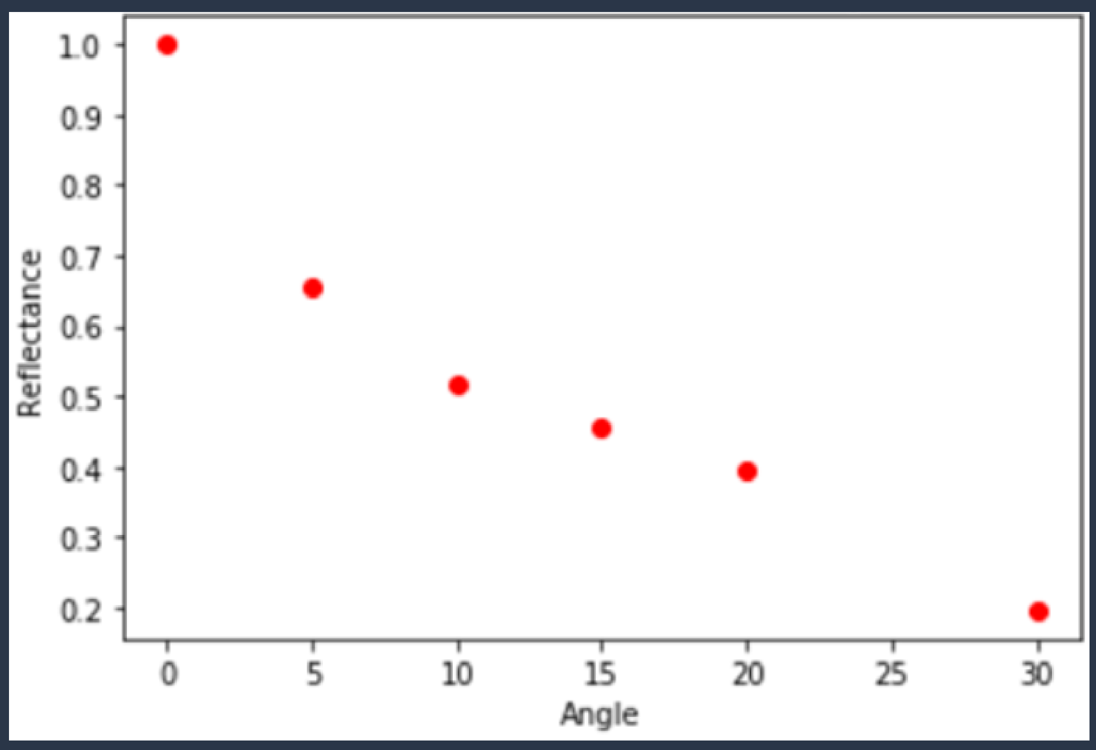

Figure 3: An example of a reflectance graph showing the reflectance vs angle θ in degrees.