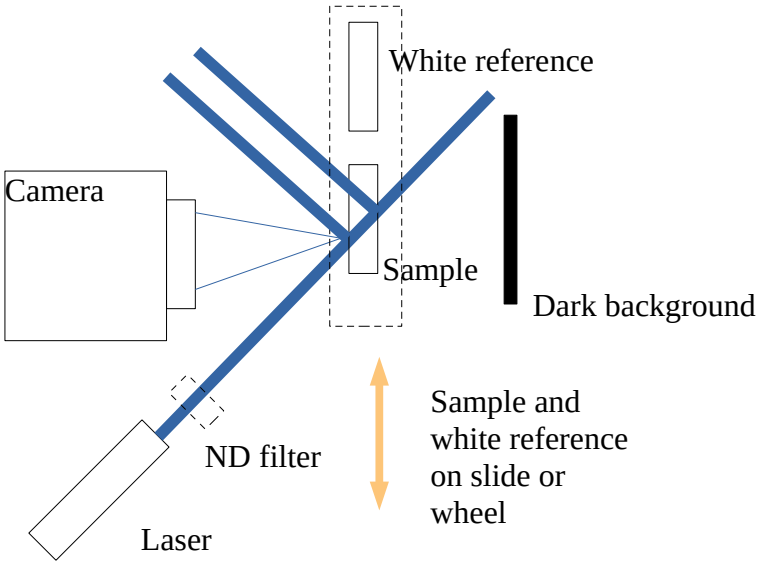
Scattering measurement system

Introduction

We describe here a simple integrated scattering measurement system. It measures total diffuse scattering, by comparing with a white diffuse reference standard. The specular part of the reflection is not included, so it basically is a measure of surface defects and haziness on a polished surface, and can be used before or after coating.

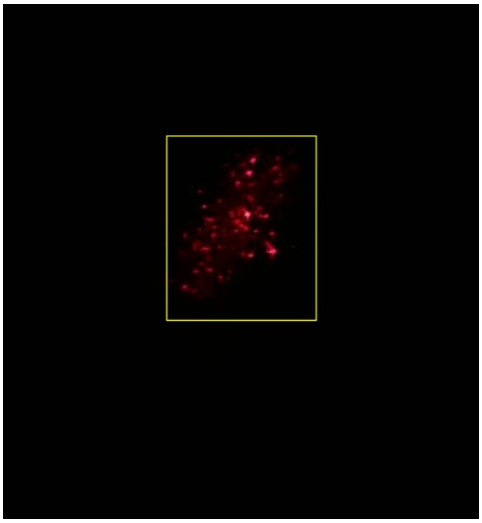
If you have ever qualitatively looked at scattering of an optical element by looking at it in a bright light, you basically understand the measurement. This is a quantitative implementation of that same process.

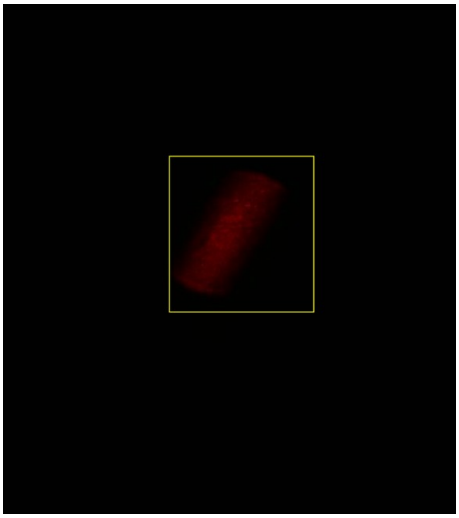
The basic measurement is sketched below.



The diffuse reflection from the laser makes a spot on the surface, which is imaged by the camera. The sample can be replaced by a white reference with a slide mechanism. For the case of a white reference, an ND filter is added to the laser beam, so that the sample and reference spot can be imaged with the same exposure level. A dark image is also recorded, with no sample.

The results of the measurement are three images, which I call Sample, Reference, and Dark. Below are example images for a Sample and Reference.





The diffuse scattering is then given by

$$S_d = T_f \cdot \frac{(Sample - Dark)}{(Reference - Dark)},$$

where here T_f is the transmission of the neutral density filter.

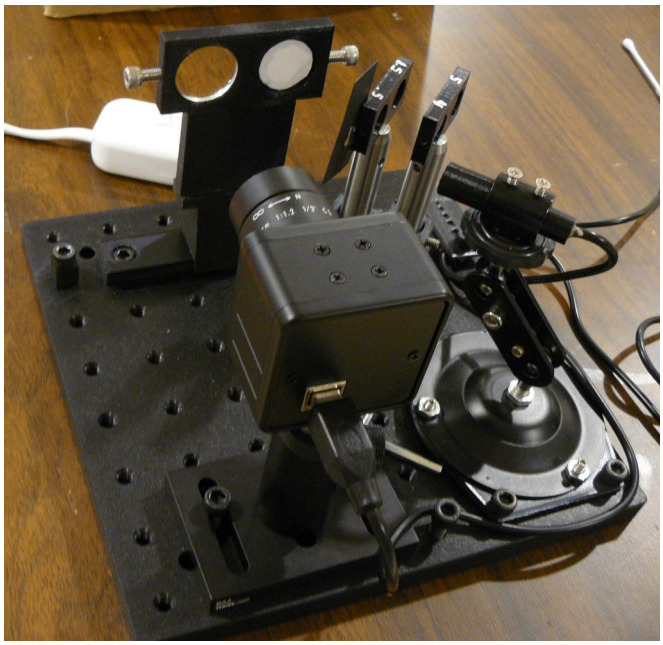
If the white reference and the sample are not perfectly matched, then the above expression is not valid pixel-by-pixel, but it is still quite valid if we sum over the pixels in a selected region of interest, as indicated by the yellow square above.

$$S_d = T_f \cdot \frac{(Sample - Dark)}{(Reference - Dark)} \ .$$

Technically it makes sense to take a separate dark image for the reference and sample, especially if different exposures are used.

There are some details to be considered. If the sample is thick and the spot size is not too large, then the front surface entrance spot can be separated from the back surface exit spot by using the region of interest (yellow square above). If this sample is thin, then it might be easier to simply measure both surfaces at the same time, especially if you want to use a fairly large beam that covers a larger area. Index matching fluid onto a thick plate also works to eliminate the back spot on a thin sample.

Below is a photo of a scattering measurement setup that is nearly identical to the system that we propose here.



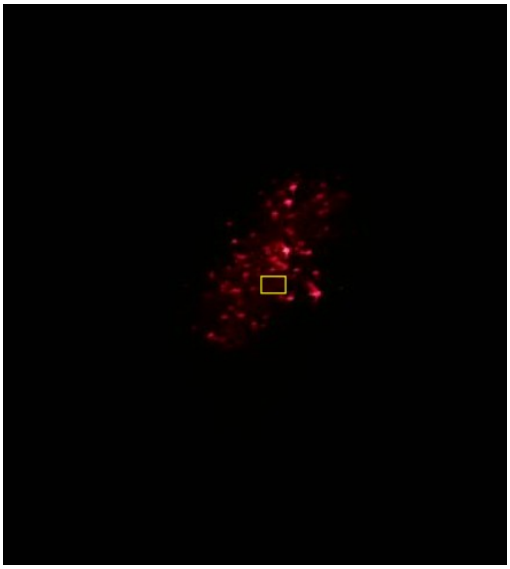
Here the reference is actually white paper with a dab of a certain brand of “white-out.” This is actually fine for practical measurements, and it scatters only about 1% less than a much fancier commercial white reference piece. The commercial reference piece is an option that is listed below. Other options are also discussed below.

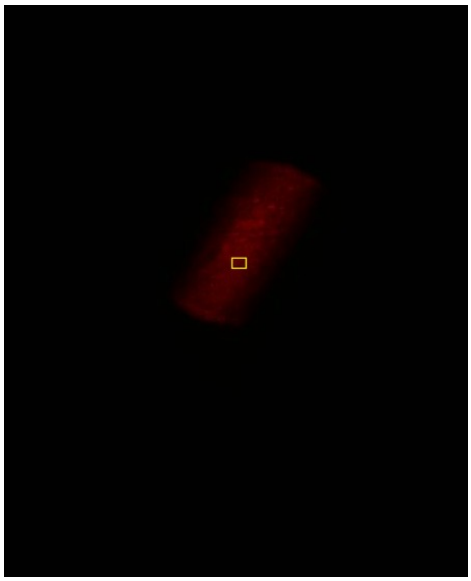
Two types of scattering measurements

It is useful to discuss two different types of scattering. One type is the “fundamental” scattering from a large number of very small defects. The blue sky is an example of this type of scattering, and above I referred to it as the “haziness.”. Another type of scattering is from fewer large and distinct defects. The measurement from this system can be either “total scattering” that includes both defect and fundamental scattering, or the “fundamental scattering” only.

The example above was a total scattering measurement. There the region of interest is selected to be the whole beam, for both the sample and for the reference beam. The scattering is the ratio of the sum of the signals, also taking into account the strong filtering factor.

Next we show the same images, but we have selected a region of interest that is within the beam.





Again the white reference image is shown on the right. Notice that the selected region of interest does not include defects, and so the scattering measurement is now the "fundamental scattering" that is due to a large number of very small defects, and not including visible defects.

Cost

The basic scattering measurement system is very inexpensive, but please call for the latest price. The hardware for the basic system is listed below:

- Laser, low cost with mount and adjustable beam width
- Industrial camera (low-end)
- ND filters. (3 of them)
- Small optical breadboard
- Post, post holders, base plates, screws

Software

Software for this measurement is quite simple. The measurement process is done in two steps: (1) Snap photos; and (2) An analysis program reads the photos, enables the selection of the region of interest, and gives the result. The software for the first part is the basic camera software, and is useful for many other purposes if you choose to share the camera for other purposes. The analysis program is a simple script.

Options

The following improvement options are available. I generally recommend against them unless there is a good reason as discussed.

1. Commercial white reference part. The main benefit is that it looks a little better. This option is just a few hundred dollars.

2. Add NIST traceable calibration to the commercial white reference. This is not at all necessary, but if you are shipping parts to a low scattering spec, then this lets you claim that the measurement is NIST calibrated.

3. Sample holders for other sizes. These are generally 3d printed and very inexpensive.

4. Fancier camera. The low-cost system uses a low-cost camera, that works fine for this purpose. It is often handy to use the camera for other purposes, and for some purposes a higher-quality camera is desirable.

5. Incorporate results into a spread sheet for a pretty, formatted certificate. This option is useful if parts are being shipped to a scattering limit specification. The certificate is printed or archived from a spread sheet, which managers can easily modify to incorporate formatting such as color schemes and company logos.