Rough Surface Characterization by Profilometer at Spatial Frequencies Appropriate for Light Scattering Predictions

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A study has been underway to provide a better scattering model for front surface reflectors that are optically rough. Scatter from optically smooth surfaces (mirrors) is well related to surface roughness by using Rayleigh-Rice vector perturbation theory. This expression relates the bidirectional reflectance distribution function (BRDF) to the surface power spectral density (PSD) for given set of scattering parameters (incident angle, wavelength and polarization). There is a one to one relationship and either quantity can be found if the other is measured. Thus for optically smooth surfaces the perturbation relationship could be checked by changing the scattering parameters. This resulted in different BRDF expressions, but for smooth, clean front surface reflectors the same PSD was found. Unfortunately the situation is not so easy for optically rough surfaces.

Since the one to one relationship between BRDF and PSD no longer exists for rough surfaces several different PSDs can produce the same BRDF. This makes calculation of the PSD from the BRDF impossible, and it becomes necessary to characterize the surface PSD with a profilometer. This raises a couple of problems. First, profilometers report 1-D PSDs. That is, they consider spatial frequencies propagating only in the direction of the scan, but BRDF is related to 2-D PSDs, which contain frequencies propagating on the surface in all directions. Secondly, most profilometers have a high frequency cutoff of about $0.1\,\mu\mathrm{m}^{-1}$. For visible light this corresponds to light scattered into a three degree cone about the specular beam. The rest of the scattering hemisphere cannot be predicted from profilometer generated PSDs, and thus these PSDs cannot be used to check the rough surface scattering model.

This presentation discusses the issues associated with solving these two problems. The 1-D to 2-D problem is solved by working with isotropic surfaces where a conversion expression can be used. The high frequency cutoff issue is more difficult. To solve this, a correction transfer function has to be found for the profilometer. This is developed by measuring a 2-D optically smooth surface and relating the profilometer PSD to that found using the perturbation expression. This is then applied to the measured PSDs of the rougher surfaces. A serious concern is the assumption of linearity (in profilometer response) that may not be true for the rougher surfaces; however, at least early modeling results seem close enough that this may not be an issue.

Of equal importance to the rough surface scattering modeling that this work will facilitate is the issue of specifying optics for low scatter with profilometer measurements. Although used throughout the optics industry, it is simply an indicator — not metrology.