Simulation Of Sidewall Scattering Losses For Light Pipes

C. Madsen[1]

[1]Texas A&M University, College Station, TX, USA

Abstract

The impact of surface roughness on the optical transmission of light pipes has been addressed using a geometric optics approximation (GOA); however, there has not been a comparison between the GOA and a wave optics solution to evaluate the relative impact of diffraction effects on the surface scattering loss. Using the COMSOL® software, multiple random flat surfaces are generated to create a hexahedron light pipe. The roughness parameters can be varied through the choice of amplitudes and spatial frequencies.
The Ray Optics Module is used first to evaluate the transmission over a range of surface roughness parameters. An important metric for estimating sidewall scattering loss, which surpasses the RMS roughness as a loss indicator, has been identified in GOA simulations as the distribution of localized surface slopes. The distribution of slopes will be assessed for a range of simulated random surface parameters. A simple light pipe geometry is chosen as a starting point, with a uniform 1mmx1mm cross-section and 10mm length for an SiO2 light pipe in air, or surrounded by a cladding material. Then, the Wave Optics Module will be used to evaluate the transmission. A comparison of the results will help to quantitatively evaluate the limitations of the GOA and guide further work.
The desired impact is to understand the limitations of applying a GOA to the evaluation of loss due to surface roughness and specifying surface quality for optical elements using total internal reflection. Glass light pipes have been fabricated using femtosecond laser irradiation followed by chemical etching. After etching, the surfaces are rough and may require subsequent polishing to achieve optical quality smoothness. The degree of smoothness will impact the transmission, so simulation work aims to understand the tradeoffs in surface roughness parameters and induced loss to guide further fabrication work.

Figures used in the abstract

Figure 1 : Light pipe ray tracing and mesh showing surface roughness.