Study On Modulation Transfer Function Stability In Optical Windows With Metal Grids

Sanghyuk An[1], Wooki Jung[1], Youngho Kim[1], Kisu Lee[1]

[1]Agency for Defense Development, Daegeon, Republic of Korea

Abstract

In modern optical systems, such as those used in automotive cameras, aerospace sensors, and surveillance equipment, optical windows serve as protective layers while allowing light to pass through. These windows must maintain high transmittance and simultaneously preserve image quality. While metal grids or patterns are often introduced on these surfaces-for purposes such as EMI shielding or heating-they risk degrading imaging performance, especially the Modulation Transfer Function (MTF), a critical metric for system resolution and contrast.

In this study, we use the Ray Optics Module in COMSOL Multiphysics to evaluate the MTF of a transparent optical window patterned with a metallic grid. Although transmittance is commonly evaluated in such components, MTF provides a more accurate measure of their impact on image quality. The simulation setup involves ray tracing through a multilayer structure consisting of a transparent substrate and a surface metal grid. Material properties, pattern geometry, and ray incidence conditions are defined, and LSFs (Line Spread Functions) at the image plane are computed to obtain MTFs via Fourier transformation

Results show that the metal grid introduces negligible MTF degradation across a wide range of parameters. Even with finer grid structures, the MTF remains close to that of a bare window. This indicates that well-designed metal patterns can be applied to optical windows without compromising imaging quality.

Our findings are particularly relevant for applications where both physical protection and optical performance are critical. The study highlights COMSOL's utility in accurately simulating such trade-offs, helping designers ensure optimal system function.

Reference

J. P. Bordes et al., Pixel Crosstalk and Correlation with Modulation Transfer Function of CMOS Image Sensors, Proc. SPIE, 4306, 240-251(2001).

Figures used in the abstract

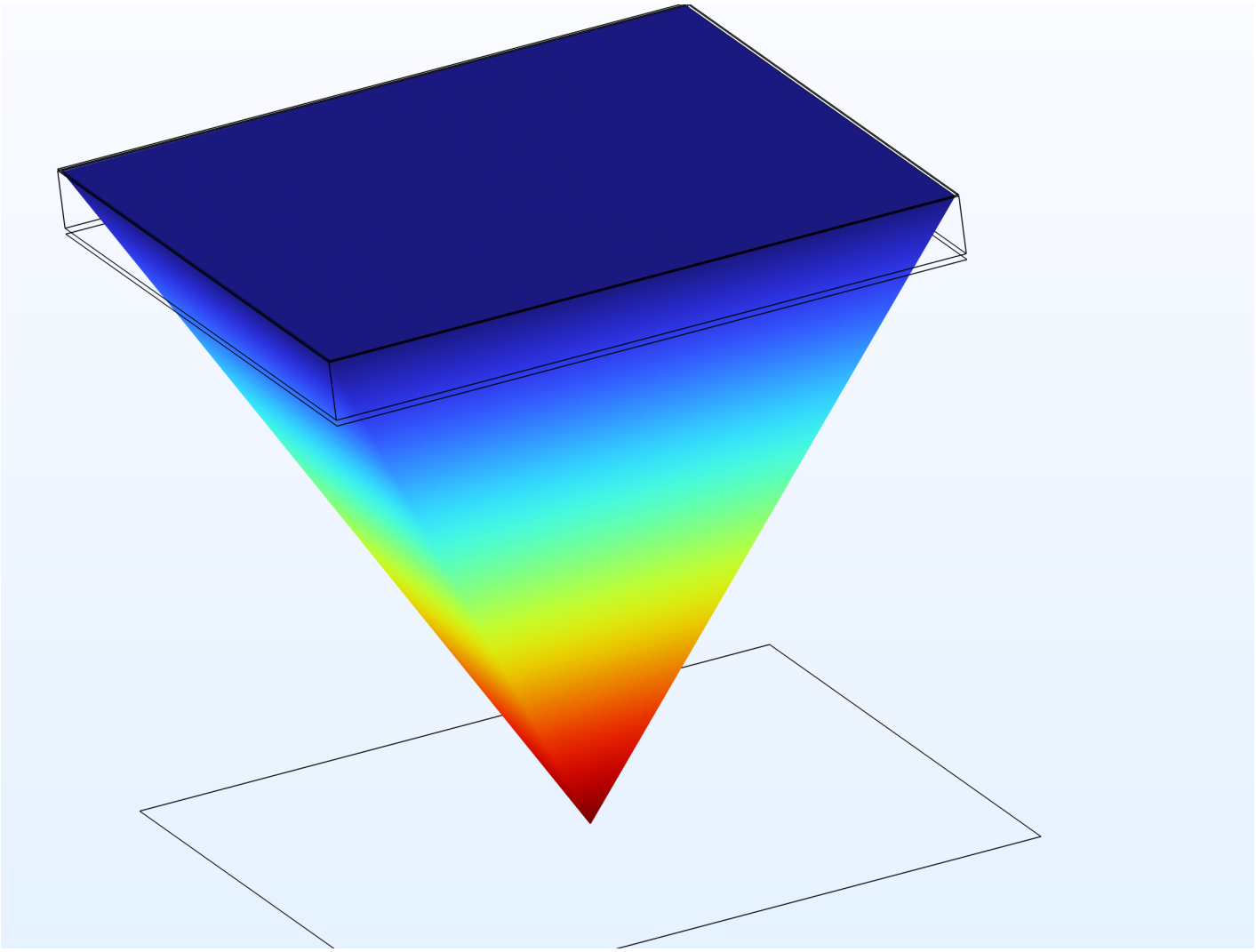
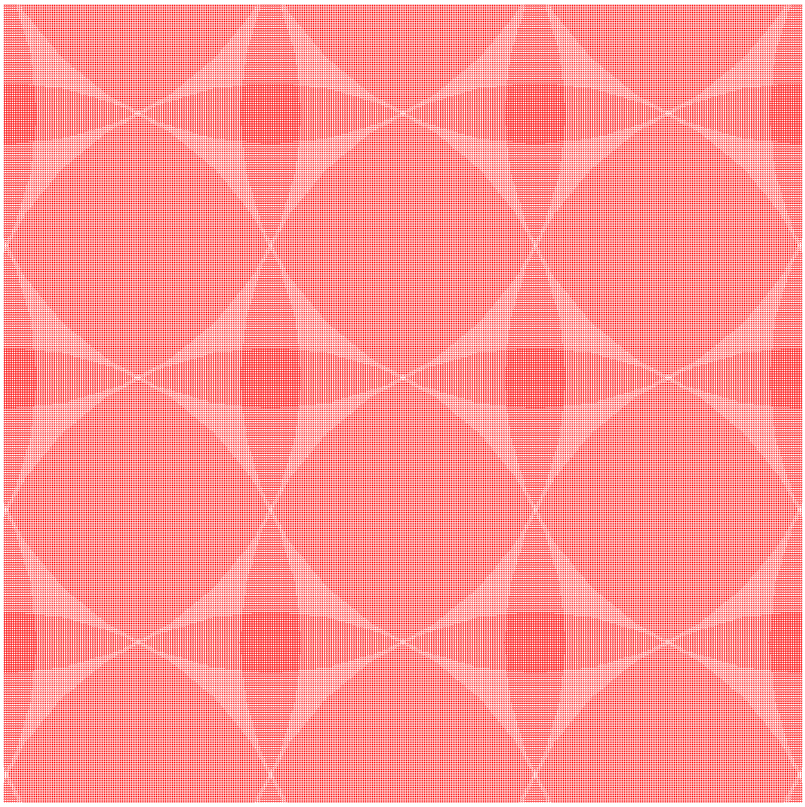


Figure 1 : Ray Trajectories for Metal Grid with Optical Window



$r_{\text{rms}} = 1.82\ \mu\text{m}$

Figure 2 : Spot Diagram for Metal Grid with Optical Window

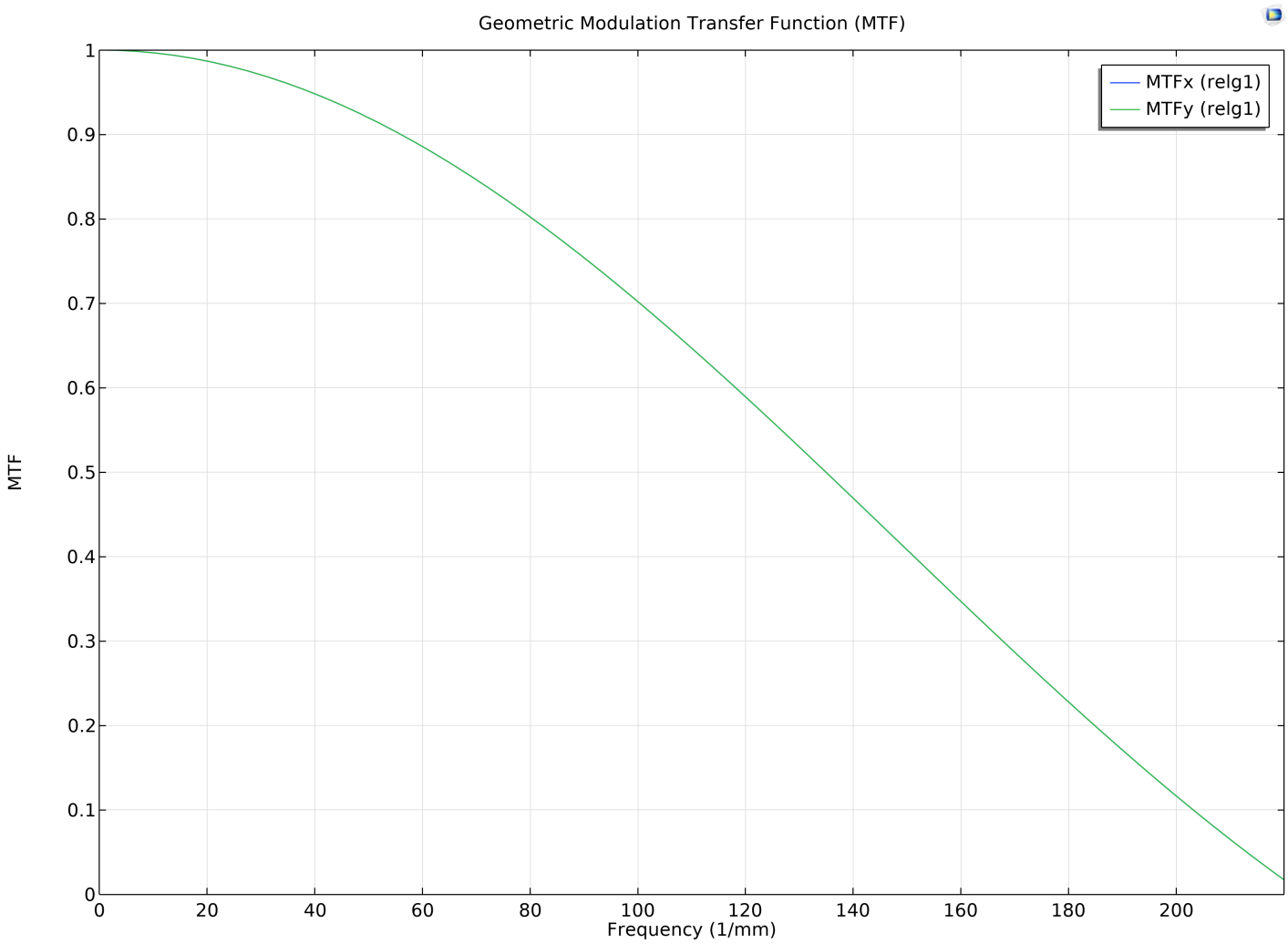


Figure 3 : MTF Chart for Metal Grid with Optical Window