# HDR Image Deglaring via MTF Inversion with Enhanced Low-Frequency Characterisation

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## Introduction

The Modulation Transfer Function (MTF) characterises an imaging system's ability to reproduce different spatial frequencies [1]. Its Accurate estimation is essential for effective image restoration and deglaring. Traditional methods [2] struggle to capture low-frequency components [3], which affects the effective reconstruction of large-scale image structures. This work proposes a novel approach to HDR image deglaring that improves the characterisation of low-frequency components in the MTF. We capture a disc-shaped light source and optimise a parametric MTF model to reproduce the observed light spread pattern, offering a robust solution for image deglaring.

## Method

Figure 1 illustrates our experimental setup for camera MTF measurement, depicting a light source enclosed within a black box, with a circular aperture through which the emitted light is directly captured by the camera. Within this setup, the captured image

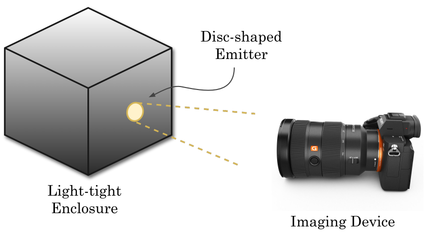


Figure 1: Diagram of the MTF capture setup.

intensity $I$ can be modelled as the convolution of the disc-shaped light source $O$ with the PSF of the camera $H$:

$$I(x,y) = O(x,y) * H(x,y) \tag{1}$$

Values of $I$ exceeding a fixed threshold are considered direct light from the source, while values below are attributed to glare. In the frequency domain, the convolution operation becomes:

$$\mathscr{F}\{I(x,y)\} = \mathscr{F}\{O(x,y)\} \cdot \mathscr{F}\{H(x,y)\} = O(\xi_x, \xi_y) \cdot M(\xi_x, \xi_y)$$

with $\xi_x$, $\xi_y$ spatial frequencies. The MTF ranges from 0 (complete attenuation) to 1 (perfect reproduction) of the spatial frequency. Finally, our prediction of the image with glare is:

$$I'(x,y) = \mathscr{F}^{-1}\{O(\xi_x, \xi_y) \cdot M(\xi_x, \xi_y)\} \tag{2}$$

In order to estimate the MTF of the camera, we use an optimisation approach, modelling the MTF as a parametric function:

$$M(\xi) = p_0 e^{-\xi^2/p_1} + p_2 e^{-\xi^2/p_3} + p_4 e^{-\xi/p_5} \tag{3}$$

where $\xi = \sqrt{\xi_x^2 + \xi_y^2}$, and $p_0$ to $p_5$ are parameters that control the amplitude and decay rate of each term. The optimisation iteratively adjusts these parameters to minimise the difference between the captured and predicted images ($I$, $I'$) from Eqn. 2. Thus we obtain the optimal set of parameters for the MTF model.

## Results

Figure 2-left compares the MTF curves obtained using the traditional slanted-edge method (blue) and ours (red). The approaches show discrepancies at low-frequencies, consistent with the slanted-edge limitations. However, both converge at higher frequencies, indicating effective high-frequency capture.

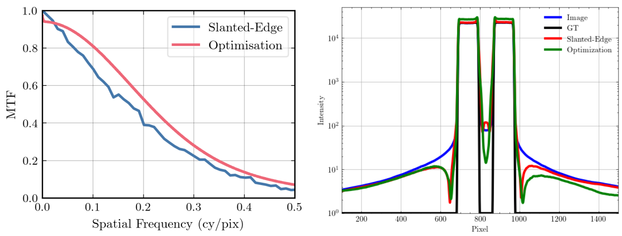


Figure 2: *Left:* MTF vs spatial frequency for slanted-edge and optimisation methods. *Right:* Pixel intensity (log) for scanline of C-shaped emitter.

Fig. 3 shows our method's effectiveness in real-world deglaring of two scenes. The left column shows the original images with glare. The center column, deglared using the slanted-edge MTF, reveals persistent glare (top) and over-correction artifacts (bottom). In contrast, our method (right column) suppresses glare without artifacts, highlighting its practical significance for accurate MTF estimation and deglaring. Finally in Fig. 2-right, where we show the pixel intensity for a scanline of the C-shaped emitter image (Fig. 3-Top). This confirms that our MTF estimation leads to a larger reduction of the glare around the emitter, in comparison with the slanted-edge estimation.

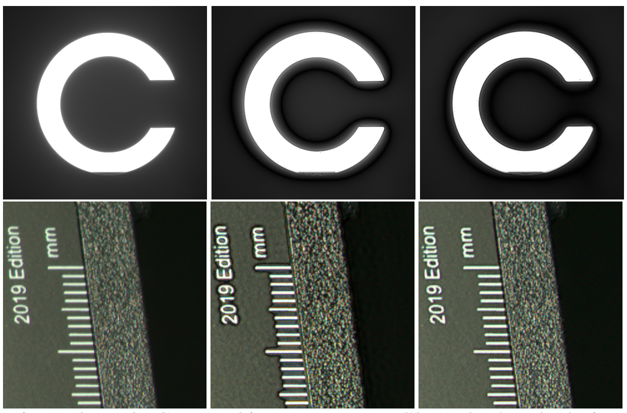


Figure 3: *Left:* Captured image. *Center:* Slanted-edge deglaring. *Right:* Optimisation deglaring (ours). *Top:* C-shaped emitter. *Bottom:* Colorchecker scene crop.

## References

[1] Glenn D Boreman. *Modulation transfer function in optical and electro-optical systems*, volume 52. SPIE press, 2001.
[2] Peter Burns. *Slanted-edge mtf for digital camera and scanner analysis.* PICS 2000.
[3] Bin Chen et al. *The effect of display capabilities on the gloss consistency between real and virtual objects.* SIGGRAPH Asia 2023.