Phase Mask [Stitching-Error]

Digital Twin Specification

Twin Code:	`CF-PMST01`
Twin Name:	Phase Mask [Stitching-Error]
Category:	Component
Type:	Function-Based
Version:	1.0
Package:	Grating Package
Last Updated:	`2026-03-19`

Description

The fabrication of a linear grating with period d can be affected by positional errors when writing successive grating rows. This results in stripes of height h with slight horizontal displacements, described by a stitching error parameter s, where $-s_{\max} \leq s \leq +s_{\max}$. The Stitching-Error Phase Mask is positioned directly behind a nominal grating component (without stitching error) to model this effect, as illustrated in Fig. 1.

Simulation Model

The simulation model is based on the detour phase principle[1, 2]. A horizontal displacement s of a grating stripe results in a constant phase shift in its response. This detour phase ϕ_s is given by

$$\phi_s = \frac{2\pi s}{d}. \tag{1}$$

The incident field from the grating is decomposed according to the stripe structure of height h. Each subfield is then assigned a random stitching error s (drawn uniformly from the range $-s_{\max} \leq s \leq +s_{\max}$), and the corresponding detour phase ϕ_s is applied, thereby simulating the stitching error.

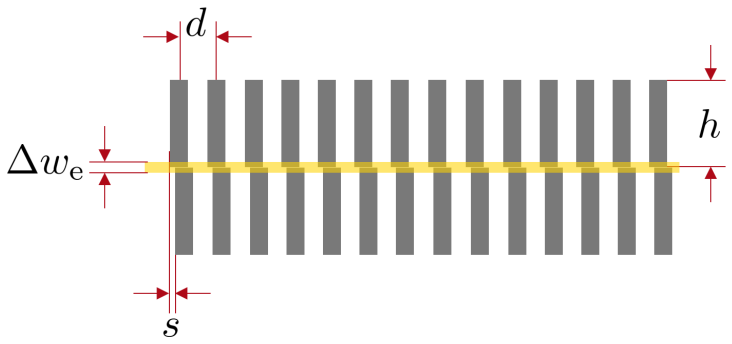

Figure 1: Illustration of parameters for simulating stitching errors in grating fabrication.

In VirtualLab Fusion, the field decomposition uses smooth edges of width Δw_e between subfields. This ensures proper numerical sampling and allows control over the physical sharpness of the edges to accurately model diffraction effects.

Model Parameters

- **Period:** d of the linear grating.
- **Height:** h of the grating rows (without stitching error).
- **Maximum Stitching Error:** $s_{\max}$, expressed in meters ($[s_{\max}] = \mathrm{m}$).
- **Beam Diameter:** D of the incident beam; this information is used for proper field decomposition.
- **Seed:** $a \in \mathbb{Z}$ determines the random number generation for the stitching error distribution.
  - $a > 0$: A single, initially generated random distribution is reused for all simulations, ensuring reproducibility.
  - $a < 0$: A new random distribution is generated for each simulation run.
- **Edge Width:** Δw_{e}, specified as a percentage of h (default: $\Delta w_{\mathrm{e}} = 5\%$).

Channel Information

The digital twin is function-based and defined on a single plane. Light can strike the plane from either side and be either transmitted or reflected. Consequently, four channels must be specified:

Channel $+/+$ In this channel, the intended functionality is provided.

Channel $+/-$ Not activated.

Channel $-/-$ This channel can be selected, but it does not alter the incident light.

Channel $-/+$ Not activated.

Recommended Usage

The stripe pattern with height h is aligned along the component's x-axis. By rotating the component relative to the grating, the stripes can be aligned orthogonally to the grating grooves.

The beam diameter can be initially determined by the Beam Size Detector. Select a larger beam size if you are unsure about the actual beam size.

The edge width Δw_{e} is given as a percentage of the height h. Reducing Δw_{e} allows for more accurate modeling of diffraction effects in the y-direction but requires a higher spatial sampling rate, which increases computational cost. For faster simulations, the edge width can be increased. Adjust this parameter carefully to balance accuracy and performance.

References

[1] A. Lohmann and B. P. Paris. "Binary Fraunhofer holograms generated by computer". In: *Appl. Opt.* 6.10 (1967), pp. 1739–1748.

[2] J. Bucklew and N. C. Gallagher Jr. "Comprehensive error models and a comparative study of some detour-phase holograms". In: *Appl. Opt.* 18.16 (1979), pp. 2861–2869.

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Related Twins: CF-PHMC01, CF-PHMV01, CF-PPUD01, CS-GRRO01