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Analytical evaluation of normalization criteria for the diffraction efficiency of blazed gratings on LCoS devices

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Through analytical expressions, three experimental-based normalizations are evaluated for the diffraction efficiency of blazed gratings on LCoS devices. We find that non-inclusion of the fill factor, usually the case, leads to wrong conclusions.

1. Introduction

Parallel-aligned liquid-crystal on silicon (PA-LCoS) microdisplays are used in many modern photonics applications[1,2], and in particular in programmable diffractive optics[3,4]. In this paper we focus on the application of LCoS microdisplays to beam steering[3], which is typically done by displaying blazed gratings. Most of LCoS devices exhibit absorbent interpixel gaps, thus their fill factor is smaller than one[4]. We show that this modifies not only the global efficiency of the LCoS but it also affects the general expressions for the diffracted field by the programmable phase element. The latter is not usually considered; thus, it may lead to a bad assessment of the results in experiments.

In Fig. 1 we show the diagram for a multilevel blazed grating on the LCoS microdisplay: d is the pixel pitch, W is the width of the clear aperture of the pixel, M is the number of levels for the blazed grating, N is the total number of pixels across the whole grating aperture, c_r is a constant factor which incorporates the losses due to reflection in the interfaces, residual absorption in the different layers of the LCoS structure and non-unit reflectance of the pixel mirror electrodes. The fill factor is usually defined in areal terms as $(W/d)^2$. Recently, we developed original analytical expressions for the diffracted field spatial profile and for the diffraction efficiency at the different orders, combining the fill factor and the flicker together with phase depth ϕ_0 and the number of quantization levels[4].

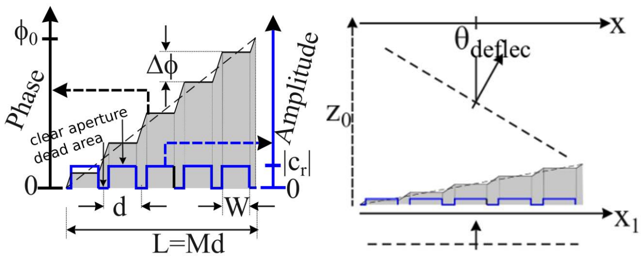

Figure 1: Diagram of the multilevel blazed grating and the parameters involved (from [4]).

To make the expressions operative it is necessary to normalize them according to the experimental procedure followed in the measurements. Three different normalizations are possible[4]. We consider unit incident intensity, i.e. unit amplitude of the incident electric field. Normalization 1 considers the total incident power over the illuminated area of the grating and produces $P_{norm1} = (Nd)^4$. Normalization 2 considers the power diffracted to the zero diffraction order when no image is addressed onto the pixelated device: $P_{norm2} = |c_r|^2 (NW)^4$. And normalization 3 considers the total diffracted power, i.e. the addition of the power at all the diffraction orders: $P_{norm3} = |c_r|^2 N^4 (Wd)^2$. The corresponding normalized expressions for the diffraction efficiency for each diffracted order n of the blazed grating,

$$\eta_{norm1}(n) = |c_r|^2 \left(\frac{1}{Md}\right)^2 \left(\frac{W}{d}\right)^2 \left|\frac{\sin\left(\pi n \frac{W}{Md}\right)}{\pi n \frac{1}{Md}}\right|^2 \left|\frac{\sin\left(\frac{1}{2}(\phi_0 - 2\pi n)\right)}{\sin\left(\frac{1}{2M}(\phi_0 - 2\pi n)\right)}\right|^2 \qquad (1)$$

$$\eta_{norm2}(n) = \left(\frac{1}{MW}\right)^2 \left|\frac{\sin\left(\pi n \frac{W}{Md}\right)}{\pi n \frac{1}{Md}}\right|^2 \left|\frac{\sin\left(\frac{1}{2}(\phi_0 - 2\pi n)\right)}{\sin\left(\frac{1}{2M}(\phi_0 - 2\pi n)\right)}\right|^2 \qquad (2)$$

$$\eta_{norm3}(n) = \left(\frac{1}{Md}\right)^2 \left|\frac{\sin\left(\pi n \frac{W}{Md}\right)}{\pi n \frac{1}{Md}}\right|^2 \left|\frac{\sin\left(\frac{1}{2}(\phi_0 - 2\pi n)\right)}{\sin\left(\frac{1}{2M}(\phi_0 - 2\pi n)\right)}\right|^2 . \qquad (3)$$

In Fig. 2(a)-(c) we show respectively for normalization 1, 2 and 3 the diffracted intensity to the first order $n = 1$ as a function of the number of quantization levels and for three different values of W. We see, especially for normalizations 1 and 3, the deviation in the predicted results when the fill factor is smaller than one.

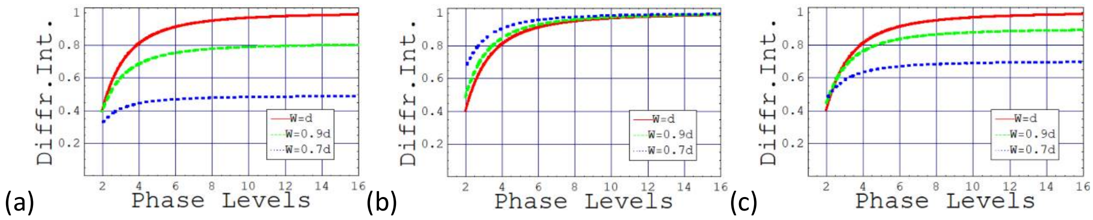

Figure 2: For normalizations 1, 2 and 3 respectively in (a), (b) and (c), intensity diffracted to the first grating order n=1 as a function of M : phase-depth of 2π radians and no flicker. In the legend, the three values for the pixel aperture W. (from [4])

2. Conclusions

Applying the diffraction integral we recently obtained the diffracted field for blazed gratings displayed onto pixelated devices[4]. In most of the literature dealing with LCoS devices, the conventional expressions used are the ones that were derived for micro-optics where no fill factor parameter is needed. We have demonstrated that for the three experimental-based normalizations it is necessary to include the fill factor to produce the correct results.

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[1] G. Lazarev, P.-J. Chen, J. Strauss, N. Fontaine, A. Forbes, Opt. Express **27**, 16206–16249 (2019).

[2] A. Márquez, A. Lizana, Appl. Sci. **9**, 3049 (2019).

[3] L. Wu, X. Wang, C. Xiong, Z. Huang, Q. Tan, M. Li, Opt. Eng. **55**(11), 116115 (2016)

[4] A. Márquez, F. J. Martínez-Guardiola, J. Francés, M. G. Ramírez, E. M. Calzado, M. Morales-Vidal, S. Gallego, I. Pascual, Opt. Eng. **59**(4), 041208 (2020).