Supplemental Document

Optics EXPRESS

Monitoring sidewall tilting of pixelated nanogratings in 3D display: supplement

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Supplement DOI: https://doi.org/10.6084/m9.figshare.21820131

Parent Article DOI: https://doi.org/10.1364/OE.478503

Monitoring sidewall tilting of pixelated nanogratings in 3D display

1. Sample description

Figure S1 (a) shows the pixel area distribution of the measured samples. Figure S1 (b) presents a scanning electron microscope image of one of the pixel gratings. The grating region is mainly composed of three layers: the grating layer, residual adhesive layer, and substrate. The shape of a sinusoidal grating is approximated as a trapezoidal grating. The optical constants of the photoresists used are shown in the Fig. S2. Detailed model established for optical constants fitting could be found in Ref. [1]. In order to obtain the grating topography accurately, we approximate the grating topography with a multi-layer rectangle based on the strict coupled-wave model. For gratings without sidewall tilting, we use top critical dimensions (*TCD*), line heights (*H*), and sidewall angles to describe the topography. For gratings with sidewall tilting, we use top critical dimensions, line heights, and left and right sidewall angles to describe the topography. The established model is shown in Fig. S1 (c).

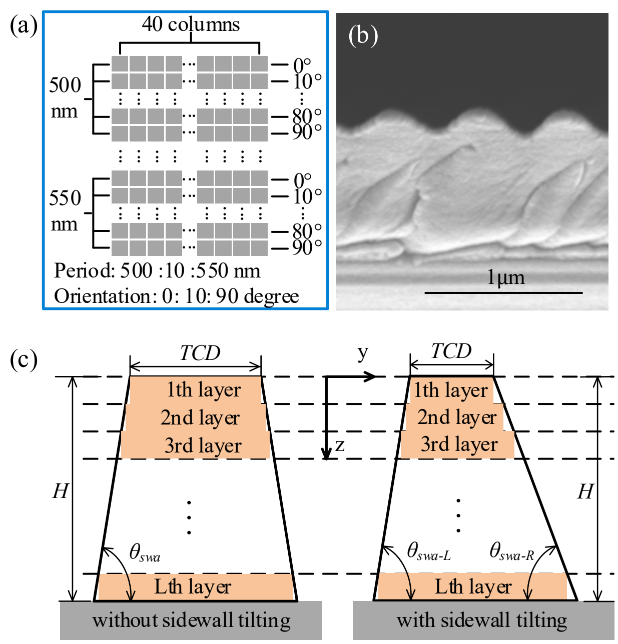

Fig. S1. (a) Schematic diagram of pixelated nanogratings; (b) the scanning electron microscope image of the pixelated nanogratings; (c) schematic diagram of rigorously coupled wave modeling for nanogratings with and without sidewall tilting.

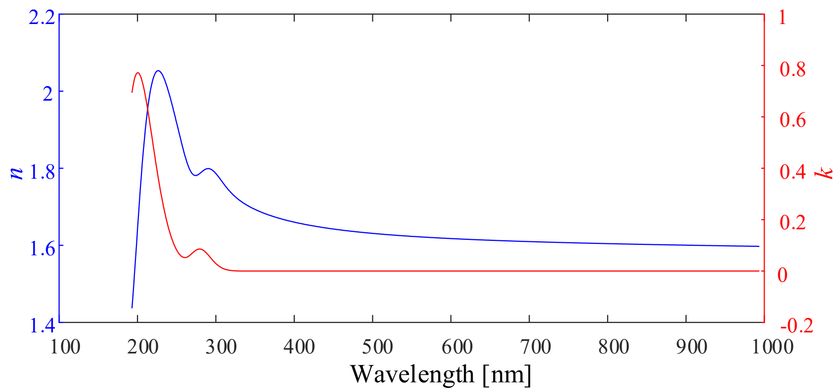

Fig. S2 Optical constants of the photoresist [1]

2. Inverse fitting results of the pixelated nanogratings

In order to verify whether the IMME measurement results are accurate, we fit the measurement spectra of some of the pixelated gratings and extract the parameters. Figure S3 shows the measurement results of the pixelated gratings with a period of 500nm at wavelengths of 450 – 700 nm. The measured incident angle was 60°. The measurement azimuths are 20° and 0°, respectively. The measured data at both azimuth angles can be accurately fitted to the model. The period is also fitted as a parameter to be solved, because when there is a difference between the period and the nominal value, it will affect the accuracy of the fitting result. Also, the left and right sidewall angles are set as two independent parameters to be fitted. We used the information at multiple wavelengths together as inputs to derive the topographical parameters of the measured structures [1]. Table S1 presents the extracted topographic parameters of the two pixelated gratings obtained by IMME from Fig. S3, and the results obtained by scanning electron microscopy. It can be seen that the results obtained by the two methods are consistent, which further illustrates the accuracy of the IMME.

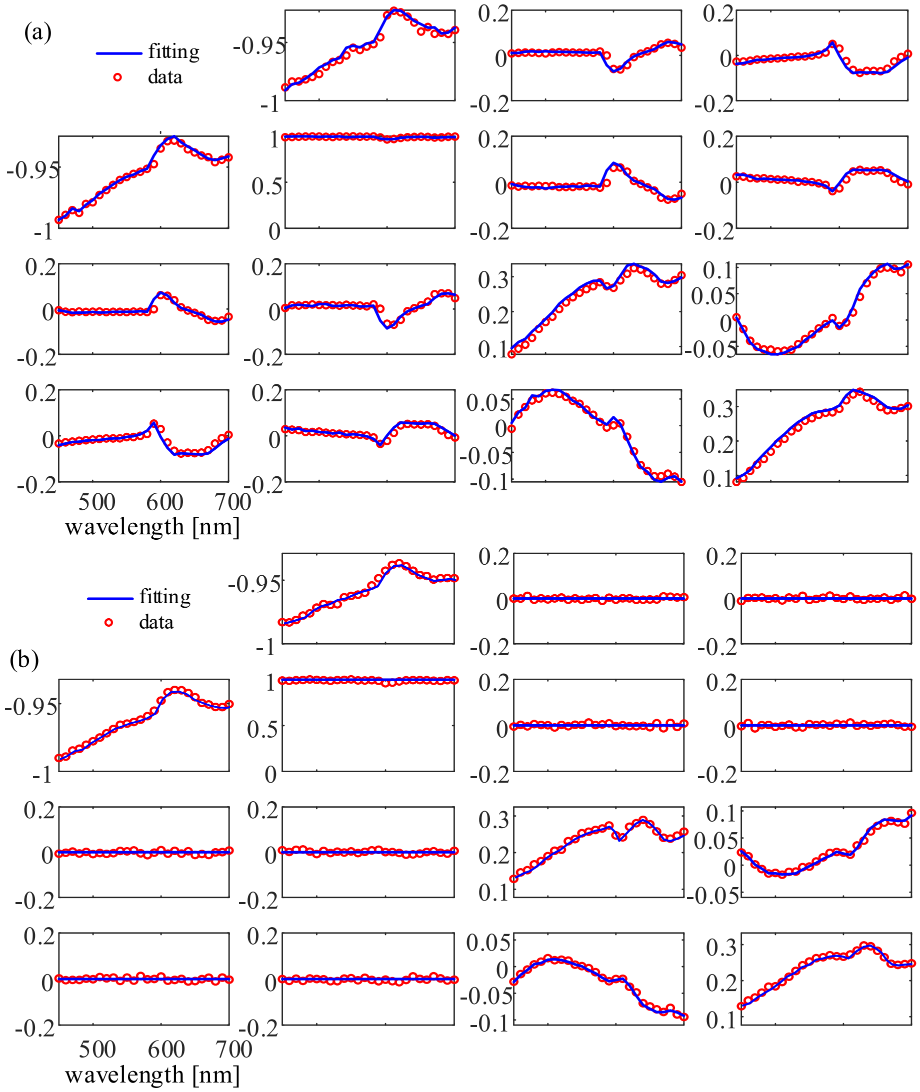

Fig. S3. Fitting results of pixelated gratings without sidewall tilting at azimuth angles of (a) 20° and (b) 0°.

Table S1. Parameter extraction results from IMME of the pixelated nanograting in Fig. S3 (95% confidence limits)

Parameters	IMME		SEM
	Azimuth-angle 20°	Azimuth-angle 0°	
Nominal Period (nm)	500	500	500
Period (nm)	498.1 ± 2.32	501.4 ± 3.58	501.1 ± 1.83
TCD (nm)	84.3 ± 0.67	85.3 ± 1.45	84.7 ± 1.15
H (nm)	180.5 ± 2.33	181.8± 3.66	183.1 ± 3.30
$\theta_{swa\text{-}L}$ (°)	53.3 ± 0.45	52.8 ± 0.77	54.0 ± 1.29
$\theta_{swa\text{-}R}$ (°)	53.4 ± 0.12	52.8 ± 0.23	53.8 ± 2.13

Taking a few data points as an example, Figs. S4-S7 show the Mueller matrix measurement and fitting results for the blue data points in Fig. 5 (b) and the red data point on the far right. It can be seen that the fitting effect is good. The extracted parameters are shown in Table S2.

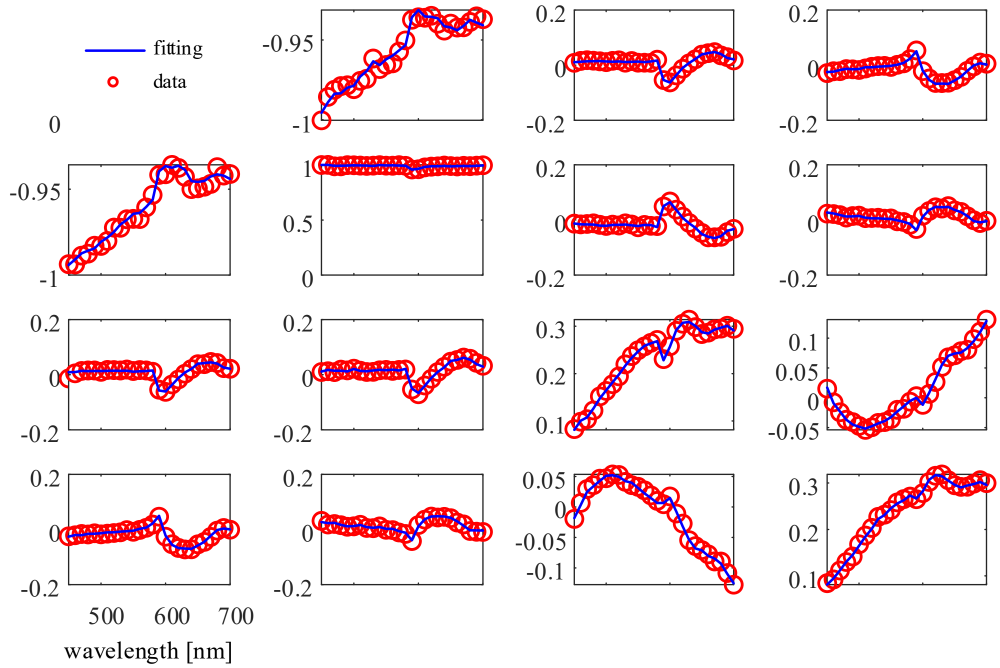

Fig. S4 Measurement and fitting results of the blue data point on the left in Fig. 5 (b).

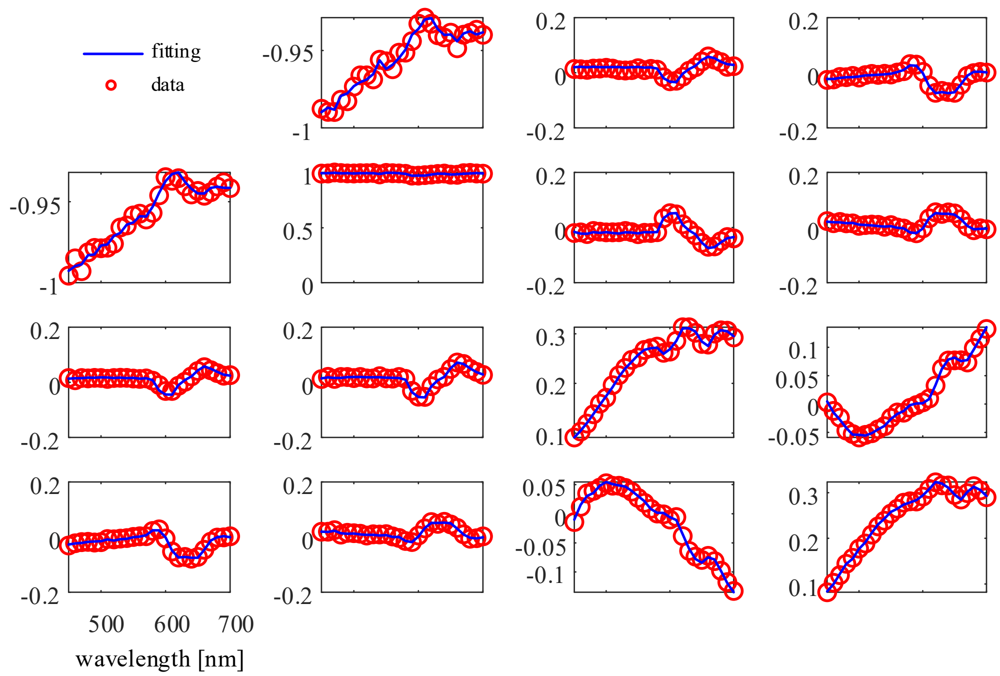

Fig. S5 Measurement and fitting results of the blue data point in the middle in Fig. 5 (b).

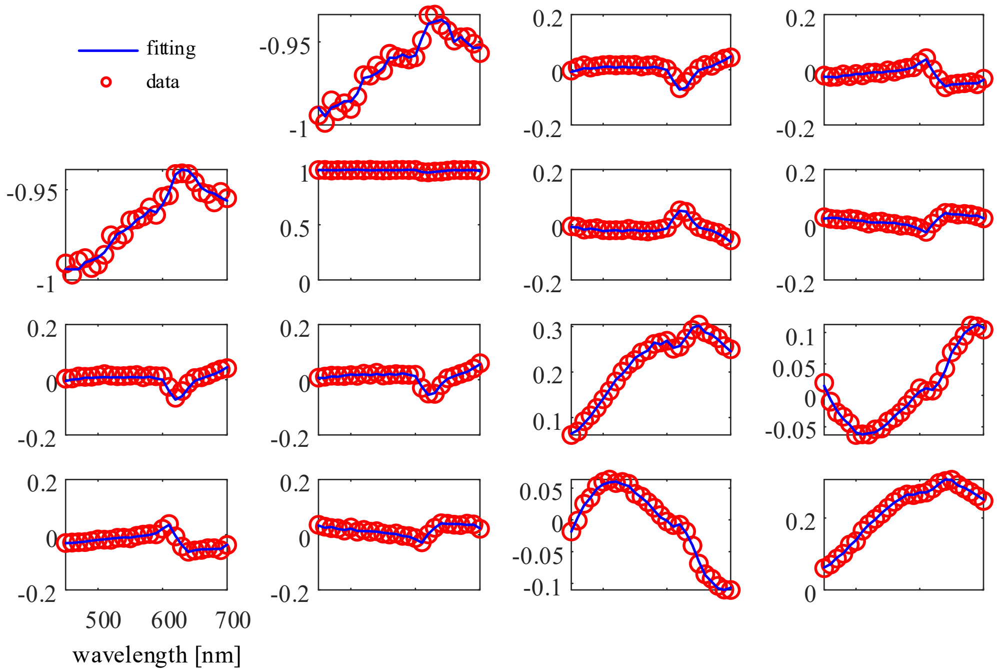

Fig. S6 Measurement and fitting results of the blue data point on the right in Fig. 5 (b).

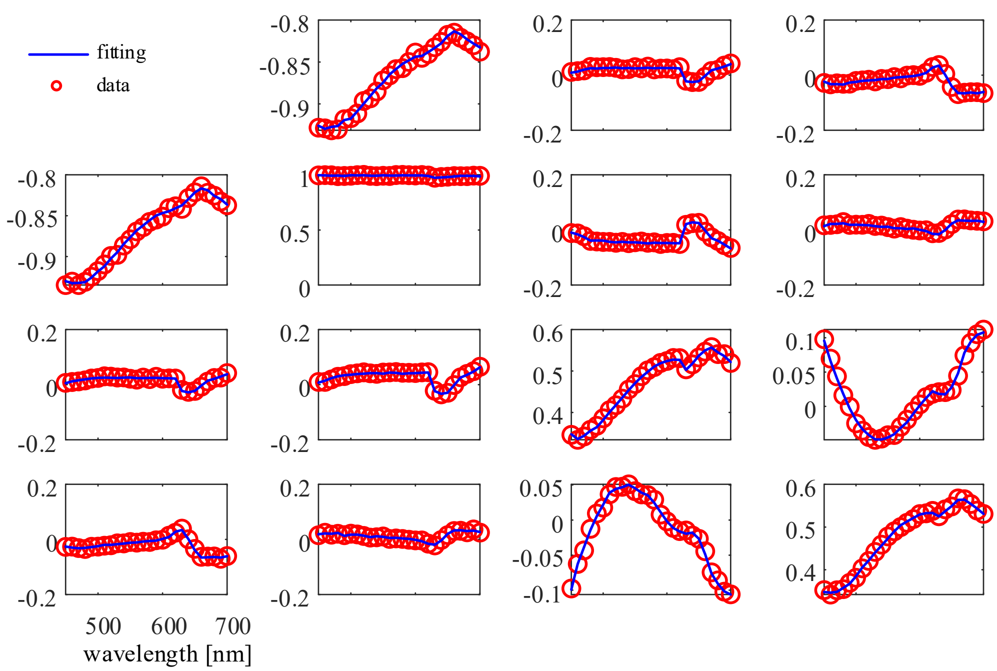

Fig. S7 Measurement and fitting results of the red data point on the right in Fig. 5 (b).

Table S2. Parameter extraction results from IMME of the pixelated nanograting in Fig. S4-S7 (95% confidence limits)

Parameters	Point			
	Point in Fig. S3	Point in Fig. S4	Point in Fig. S5	Point in Fig. S6
Nominal Period (nm)	550	550	550	550
Period (nm)	547 ± 2.44	546 ± 2.71	552 ± 2.89	551 ± 1.89
TCD (nm)	91.8 ± 0.38	92.6 ± 1.64	94.2 ± 2.40	93.5 ± 2.91
H (nm)	179.6 ± 2.74	178.8 ± 2.87	178.5 ± 1.45	183.4 ± 2.72
θ_{swa-L} (°)	50.3 ± 0.29	56.2 ± 0.42	56.7 ± 0.37	54.6 ± 0.96
θ_{swa-R} (°)	53.4 ± 0.83	52.8 ± 1.26	49.3 ± 0.87	45.5 ± 0.10

Reference

[1] C. Chen, X. Chen, Z. Xia, J. Shi, S. Sheng, W. Qiao, and S. Liu, “Characterization of pixelated nanogratings in 3D holographic display by an imaging Mueller matrix ellipsometry,” Opt. Lett. 47, 3580-3583 (2022).

[2] C. Chen, X. Chen, Y. Shi, H. Gu, H. Jiang, and S. Liu, "Metrology of nanostructures by tomographic Mueller-matrix scatterometry," Appl. Sci. **8**, 2583 (2018).