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# Phase-Shifting Mask Design for Interference Exposure of Chirp Blazed Grating

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An interference exposure system using a phase-shifting mask was proposed for generating periodic sawtooth optical intensity profile with chirp in period. Multiple space-harmonic waves are launched from the mask by diffraction, and the sawtooth optical intensity is formed by interference based on Fourier synthesis after propagation through an air gap. The design concept merely utilizing positive diffraction-order harmonics with tilt illumination of an exposure light and a design algorithm based on time-reversed configuration for calculating required phase shift amount were proposed and discussed. A phase-shifting mask for a blazed grating of very high chirp rate was designed to demonstrate its potential and feasibility. The grating period changes from 2.2 to 3.1 µm gradually within 0.3 mm length. Sawtooth-like optical intensity profile was confirmed by theoretical simulation as well as preliminary experimental results.

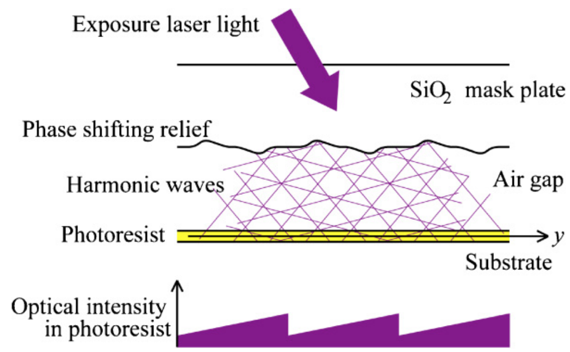


Fig. 1. Multiple-wave-interference-exposure layout using a phase-shifting mask for generating blazed grating of chirp in period.

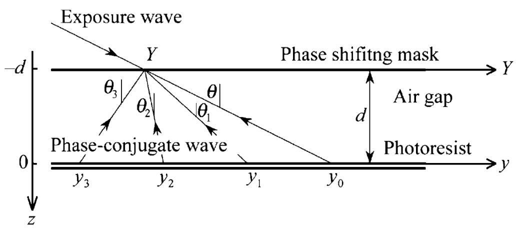


Fig. 2. Configuration of diffraction and interference points. Exposure wave diffracted by the mask surface at $Y$ reaches $y_q$ on the photoresisit. Phase shift amount for each diffraction order $q$ is calculated with respect to the required field required at $y_q$ by considering time-reversed, namely phase-conjugate wave.

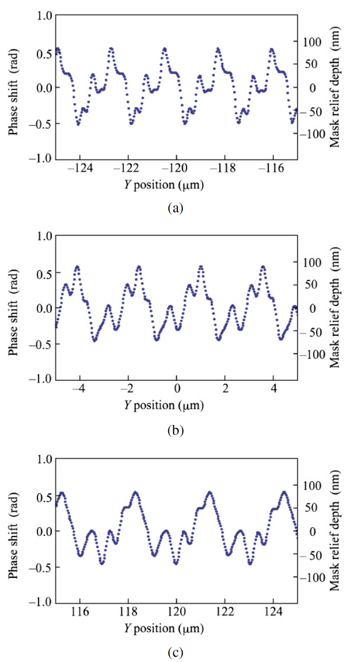


Fig. 3. Calculated example of phase shift distribution on the $Y$-axis for a case of $\Lambda_0 = 2.56$ µm at $y = 0$ mm, $m = 0.5$, $a = 0.417 \text{mm}^{-1}$, and no nonlinear chirp rates. Exposure system has exposure wavelength 488 nm, $\theta = 60^0$, and $d = 3$ µm. (a) $\Lambda = 2.21$ µm at $Y = -120$ µm, (b) $\Lambda = 2.56$ µm at $Y = 0$, and (c) $\Lambda = 3.05$ µm at $Y = 120$ µm.

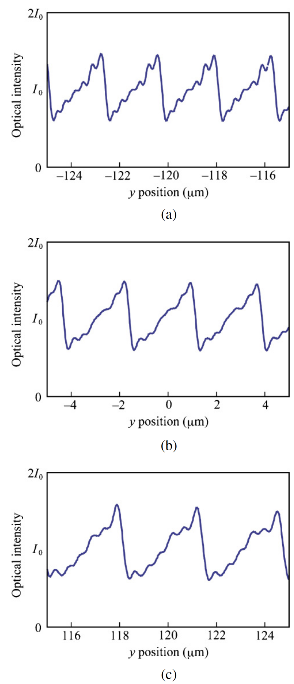


Fig. 4. Theoretically predicted interference intensity profiles: (a) $\Lambda = 2.21$ µm at $Y = -120$ µm, (b) $\Lambda = 2.56$ µm at $Y = 0$, and (c) $\Lambda = 3.05$ µm at $Y = 120$ µm.

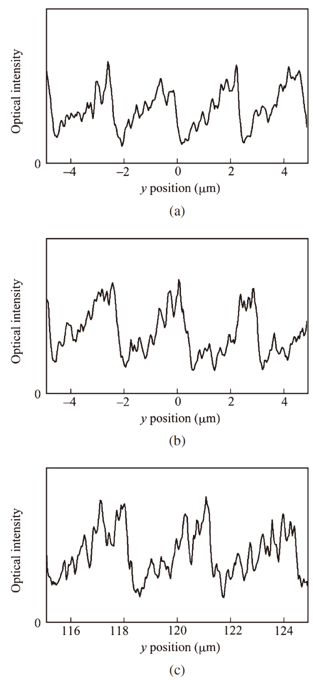


Fig. 5. Experimentally obtained optical intensity profiles: (a) $\Lambda = 2.21$ µm at $Y = -120$ µm, (b) $\Lambda = 2.56$ µm at $Y = 0$, and (c) $\Lambda = 3.05$ µm at $Y = 120$ µm.