A Comparative Study on Absorbance-Modulated Interference Lithography

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Absorbance-modulated lithography is a relatively new optical patterning method where a thin layer of photochromic molecules is placed between the far-field optics and photoresist. These molecules can be made transparent or opaque by illuminating with wavelengths λ_1 or λ_2, respectively (Figure 1). By simultaneously illuminating this layer with patterns of both wavelengths it is possible to create an absorption mask capable of sub-diffraction-limit resolution.[1,2] One implementation of this method is absorbance-modulated interference lithography (AMIL) where the intensity pattern of at least one of the wavelengths is a standing wave interference pattern. The objective of AMIL is to use the photochromic absorption mask formed to compress the line-spread function (LSF) of the exposing wavelength (λ_1) enabling frequency multiplication via multiple exposures and a single development step.

AMIL comes in four basic forms as depicted in Figure 2a-d. The top two techniques involve a standing wave of one wavelength and flood illumination of the other. The bottom two techniques have standing waves of both wavelengths either with periods $P_{\lambda 1}=P_{\lambda 2}$ or $2*P_{\lambda 1}=P_{\lambda 2}$. The dashed lines in Figure 2 represent the λ_1/λ_2 power ratio, which is indicative of the absorbance grating that will be formed in the photochromic layer and, therefore, the degree the LSF will be compressed. Some of the important parameters of the four AMIL methods, derived from these power ratios, are summarized in Table 1; these can be used to estimate the potential each method has for frequency multiplication via multiple exposures. To better understand and quantify the benefits and detriments of each of these methods we have also developed a two-dimensional finite element method (FEM) model capable of simulating these four variants of AMIL.[3]

In this paper we will present the results of our FEM simulations for the four various types of AMIL. We also support these simulations with experimental results using a polymerized azobenzene derivative for the photochromic layer. In addition to the minimum linewidth and period achievable with each method we will discuss practical issues with their implementation including: tolerance to phase errors, period inequality, and fringe visibility.

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[1] T.L. Andrew, H.Y. Tsai, R. Menon, Science **324**, 917 (2009).

[2] R. Menon, H.Y. Tsai, S.W. Thomas III, Phys. Rev. Lett. **98**, 043905 (2007)

[3] J. Foulkes and R.J. Blaikie, J. Vac. Sci. Technol. B **27**, 2941 (2009).

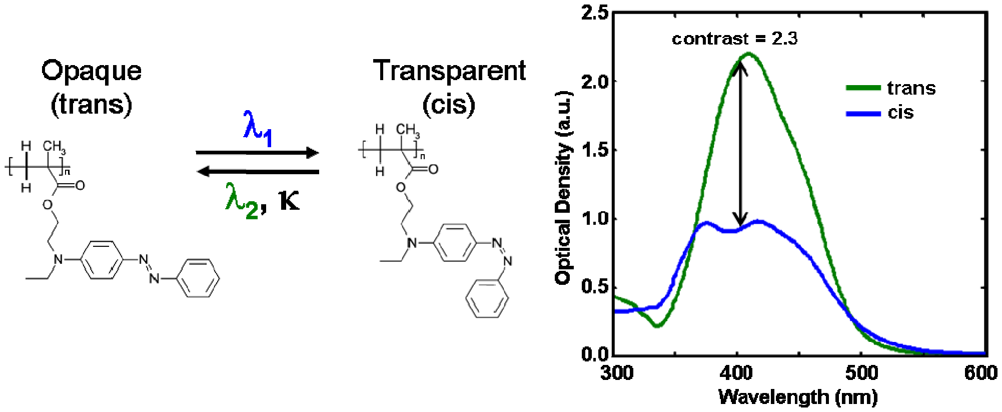

Figure 1: (left) Polymerized azobenzene molecule used for the photochromic layer. (Right) UV-vis spectrum of a 200 nm photochromic layer after exposure to $\lambda_1 = 405$ nm and $\lambda_2 = 532$ nm to excite the cis and trans isomers, respectively.

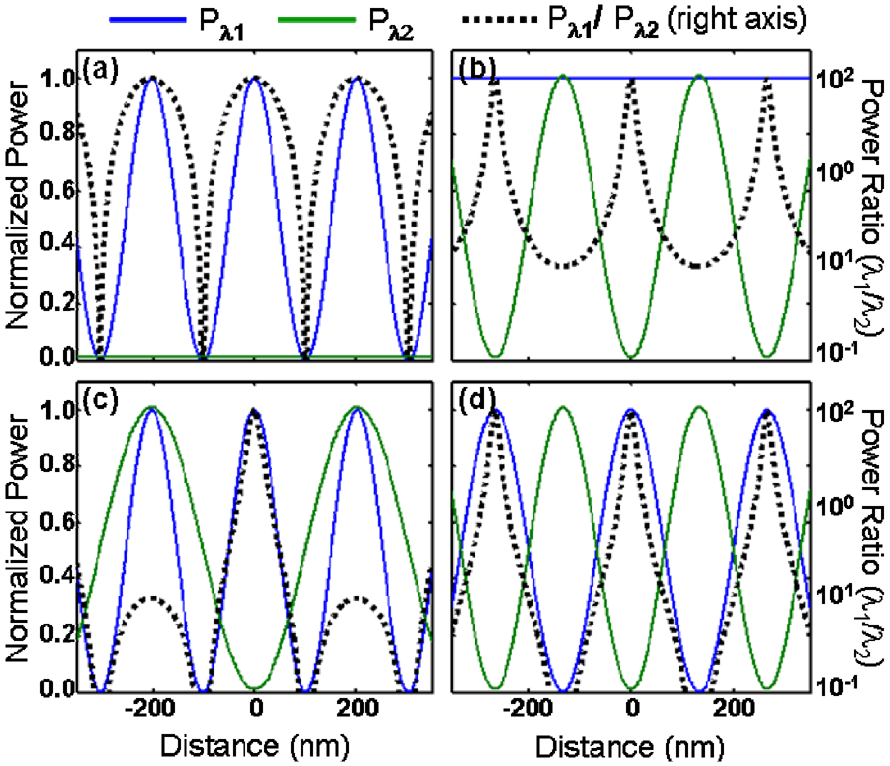

Figure 2: Normalize power distribution and power ratios for four fundamental AMIL configurations: (a) flood λ_2, (b) flood λ_1, (c) $2{*}P_{\lambda1}=P_{\lambda2}$, and (d) $P_{\lambda1}=P_{\lambda2}$.

Table 1: Theoretical minimum exposure parameters (nm) for AMIL methods[1]

Method	Period λ_1	Exposed Period	FWHM LSF λ_1	FWHM Power Ratio
a	202.5	202.5	101.25	102.0
b	--	266.0	infinite	17.5
c	202.5	405.0	101.25	25.5
d	266.0	266.0	133.00	17.0

[1] assumes $\lambda_1 = 405$ nm, $\lambda_2 = 532$ nm, and imperfect optical nulls with 1% background intensity.