변형 삼각간섭계에서의 위상오차에 관한 고찰

(Consideration about phase error of the MTI system)

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Abstract

We need two operation modes to obtain the complex hologram without bias and the conjugate image in the modified triangular interferometer(MTI). To solve the problem, we proposed the optimized MTI with one wave plate, which can obtain cosine and sine functions by the combination of one wave plate and one linear polarizer. In the extraction of phase term using the combination of polarization components, the phase error occurs, and we simulated such potential phase errors in the optimized MTI.

Recently, two-pupil synthesis by the MTI was reported.[1-4] A simple two-pupil interaction system was implemented by adding two wave plates and a linear polarizer to Cochran's triangular interferometer as shown in Fig. 1.

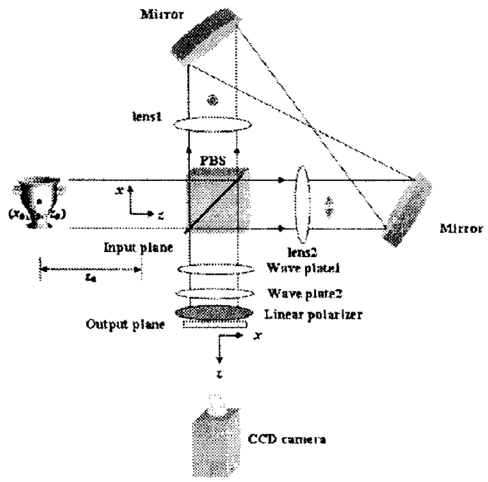

FIG. 1. Modified triangular interferometer

One can obtain the complex hologram without bias and the conjugate image using cosine and sine terms using the OTF synthesis and the complex hologram without bias and without conjugate image is described as follows.

$$H(x,y)=|P_{cw}(x,y)P_{ccw}(x,y)|[\cos\{\theta_{cw}(x,y)-\theta_{ccw}(x,y)\}\pm i\sin\{\theta_{cw}(x,y)-\theta_{ccw}(x,y)\}]$$
$$=|P_{cw}(x,y)P_{ccw}(x,y)|\exp[\pm i\{\theta_{cw}(x,y)-\theta_{ccw}(x,y)\}], \quad (1)$$

where P_{cw} and P_{ccw} denote the pupil functions of the light that travels clockwise and counterclockwise, respectively. We present the optimal MTI, which can obtain any bipolar function by combining a wave plate and a linear polarizer.

we can obtain the complex hologram without bias and without conjugate image by the combination of the phase retardation of wave plates in the MTI. However, to obtain the sine function, we use the intensity patterns obtained using the MTI that wave plate 1 is removed. That means that we need two operation modes to obtain the complex hologram without bias and conjugate image in the MTI. In other words, in obtaining the complex hologram, we use two wave plates to obtain the cosine function, and use one wave plate to obtain the sine function in the MTI. Two operation modes are inconvenient in the case of using the MTI. Accordingly, to solve the problem, we proposed the optimized MTI that wave plate 1 is removed as shown in Fig. 2.

The phase term of complex hologram in the MTI is obtained from four intensity patterns by phase-shifting technique. A phase shift or modulation in the phase-shifting techniques can be induced by moving a mirror, tilting a glass plate, moving a grating, rotating a half-wave plate or analyzer.

In MTI, a phase shift is implemented by the combination of polarization components. In the extraction of phase term using the combination of polarization components, the phase error occurs.

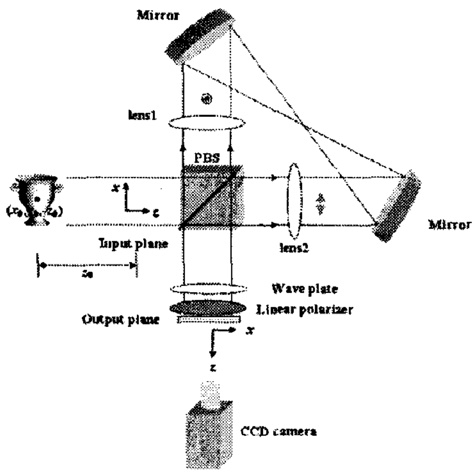

Fig. 2. Optimized triangular interferometer

Phase error due to imperfections of a wave plate is given by

$$\Delta\phi = -\frac{1}{4}\alpha^2 \sin(2\phi), \tag{2}$$

where α is the error in the relative retardation introduced by plate. Figure 3 shows phase error of Eq. (2).

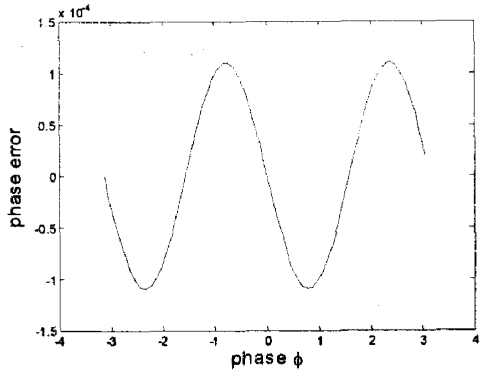

Fig. 3. Phase error by a wave plate

Phase error due to the azimuth angle error of a wave plate is given by

$$\Delta\phi = (1+\sin^2\phi - 2\cot 2\beta \sin\phi)\beta_1 - \beta_2 \cos^2\phi. \tag{3}$$

Figure 4 shows phase error of Eq. (3).

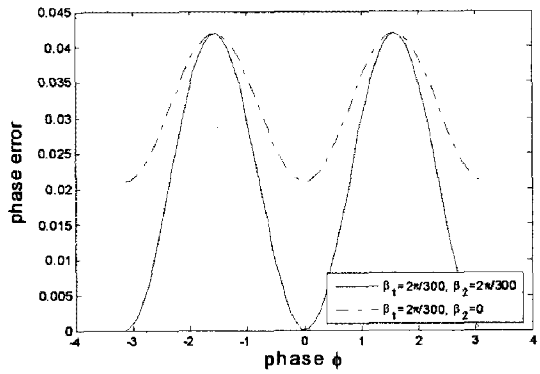

Fig. 4. Phase error due to the azimuth angle error of a wave plate

Phase error due to the azimuth angle error of a linear polarizer is given by

$$\Delta\phi = -(\gamma_2 + \gamma_3)\sin^2\phi, \tag{4}$$

Figure 5 shows phase error of Eq. (4).

Total phase error including imperfections and azimuth angle error by polarization components is written by

$$\Delta\phi = -\frac{1}{4}\alpha^2 \sin(2\phi) + (1+\sin^2\phi)\beta_1 - \beta_2\cos^2\phi - (\gamma_2+\gamma_3)\sin^2\phi \tag{5}$$

where β_1 and β_2 represent the azimuth angle errors in a wave plate, and γ_1, γ_2 and γ_3 represent the azimuth angle errors of a linear polarizer.

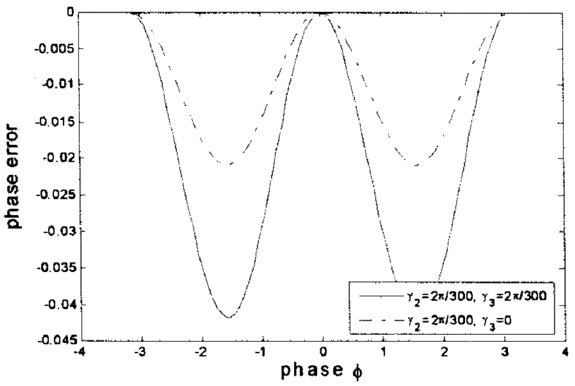

Fig. 5. Phase error due to the azimuth angle error of a linear polarizer

Figure 6 shows total phase error of Eq. (5). In solid line, azimuth angle errors of $\lambda/4$ plate and a linear polarizer were set to $\beta_1 = 2\pi/300$, $\beta_2 = 2\pi/300$ and $\gamma_2 = 2\pi/300$, $\gamma_3 = 2\pi/300$, respectively. In dashed line, azimuth angle errors of $\lambda/4$ plate were and a linear polarizer set to $\beta_1 = 2\pi/300$, $\beta_2 = 0$ and $\gamma_2 = 2\pi/300$, $\gamma_3 = 0$. In Fig. 6, phase error is minimum at $\pi/4$ and phase error is maximum at $-\pi/4$.

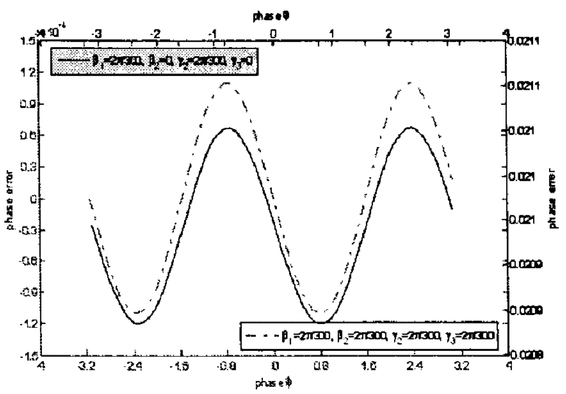

Fig. 6. Total phase error by polarization components

In the extraction of phase term using the combination of polarization components, the phase error occurs. As shown in Fig. 3, the retardation error of the commercially available wave plate makes the second-order error very small. Accordingly, we see that phase error in the optimized MTI is mainly due to the azimuth angle errors of the polarization components.

Accordingly, phase error in the optimized MTI is mainly due to the azimuth angle errors of the polarization components. The azimuth angle errors can be minimized by using a computer-controlled phase-shifting apparatus, which can accurately control the rotating angle of the polarization components.

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