Synthesis of optical transfer function and phase error analysis in the modified triangular interferometer

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In a conventional incoherent scanning or imaging system, limitations exist on image processing that are due to the resulting nonnegative intensity spread function[point-spread function(PSF)], which, in turn, imposes severe constraints on both the amplitude and the phase of the optical transfer function(OTF).(1) Such limitations can be circumvented by introducing a two-pupil system that is characterized by a great flexibility in pupil-function specification for a desired synthesized PSF.(2,3) Any bipolar impulse response can be synthesized by using two-pupil methods as long as the pupil function can be arbitrarily specified. Two-pupil systems are usually implemented by separating the responses(i.e., separating the interactive term and the noninteractive term on the basis of the spatial or temporal carriers). The pupils are created by either amplitude or wave-front divisions.

The synthesis methods divide into two important classes which are distinguished by the mathematical structure of the resultant transfer function. There are basically two kinds of syntheses possible: nonpupil interaction synthesis and pupil interaction synthesis.(1)

Recently, two-pupil synthesis by the MTI was reported.(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.

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.

$$\begin{aligned} H(x,y) &= |P_{cw}(x,y)P_{ccw}(x,y)|\left[\cos\{\theta_{cw}(x,y)-\theta_{ccw}(x,y)\} \pm i\sin\{\theta_{cw}(x,y)-\theta_{ccw}(x,y)\}\right] \\ &= |P_{cw}(x,y)P_{ccw}(x,y)|\exp\left[\pm i\{\theta_{cw}(x,y)-\theta_{ccw}(x,y)\}\right], \end{aligned} \tag{1}$$

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.

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.

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

$$\triangle\phi = -1/4\sin(2\phi)\gamma^2 + (1+\sin^2\phi - 2\cot2\beta\sin\phi)\epsilon_1 - \cos^2\phi(\epsilon_1^{'} - \epsilon_2^{'} - \epsilon_2^{''}). \tag{2}$$

where ϵ_1 and $\epsilon_1^{'}$represent the azimuth angle errors in a wave plate, $\epsilon_2^{'}$ and $\epsilon_2^{''}$ represent the azimuth angle errors in a linear polarizer

In the extraction of phase term using the combination of polarization components, the phase error occurs. The retardation error of the commercially available phase plate make the second-order error very small. 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.

REFERENCES

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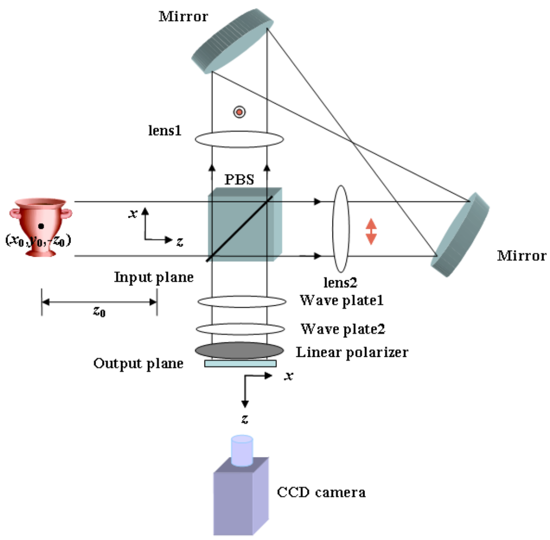

FIG. 1. Modified triangular interferometer.