Rotating optical flat for simultaneous holographic multiplexing

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A device concept is presented which enables the simultaneous multiplexing of holograms by reducing the interference visibility. This can be helpful for holographic photopolymers which show a nonlinear developing behavior. The device is capable of the complete cancellation of the visibility. This enables the simultaneous exposure of multiplexed holograms with one single coherent light source.

1 Introduction

Multiplexing in holographic photopolymers is challenging due to the nonlinear transient developing properties [1]. By simultaneous exposure, complicated exposure scheduling can be circumvented. However, parasitic structures occur due to interference between all participating waves. An economic device concept is presented which prevents for those parasitic interferences and thus, enables simultaneous multiplexing of holograms with only one single coherent light source.

2 Device concept

The concept is based on a mechano-optical modulator (MOM). The MOM, in principle, consists of a single rotating optical flat, which enables a tilt of the axis of rotation with respect to the optical axis and a tilt of the optical flats normal with respect to the axis of rotation. Figure 1 shows a realization concept for the MOM. It consists of a mount for the optical flat, which is connected to the main frame by a ball beared quill shaft. The quill shaft is driven by an electric motor via a toothed belt.

Fig. 1 *Realization concept for the modulator*

The actual MOM used for this publication is manufactured by standard components of well known shops for optical and electromechanical supply and minor additional fabrications of our in-house workshop. The total costs for such a prototype device are approximately 250 €.

3 Theoretical fundamentals

The functionality of the MOM, the visibility reduction, is based on a dynamic optical phase shift $\Delta\varphi(t)$. The phase shift is realized by a variation of the effective optical path length due to a dynamic variation of the tilt angle of the optical flat.

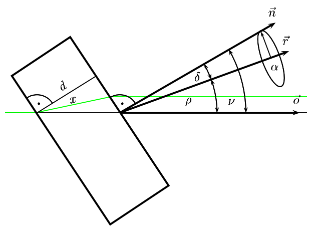

Fig. 2 *Geometric view of beam deflection by an optical flat*

This can be achieved, for a rotating optical flat, if the vector of rotation is neither collinear to the normal vector of the optical flat nor to the optical axis. Such a motion induces a dynamic periodic phase shift. This is used to reduce the unwanted interference visibility by time averaging. The spatial intensity distribution $\overline{I(x)}$ for an integration time τ can be calculated by the following formula:

$$\langle I(x,t)\rangle_t = \frac{1}{\tau}\int_0^{\tau} I_1 + I_2 + 2\sqrt{I_2 I_2} cos[ax + \Delta\varphi(t)]dt$$

And thus, the crucial parameter for hologram exposure, the interference visibility is given by:

$$\langle V\rangle_t = \frac{\overline{I(x)}_{max} - \overline{I(x)}_{min}}{\overline{I(x)}_{max} + \overline{I(x)}_{min}}$$

Detailed theoretical discussion is done in [2, 3] .

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4 Simulation and experimental verification

To confirm the applicability of the MOM, the theoretical description and simulations are verified by an experimental investigation. This is done by placing the MOM into a Mach-Zehnder-Interferometer and determining the time average interference visibility for varying parameters. The gained experimental results are in very good agreement with the numerical data, as shown in Fig. 3.

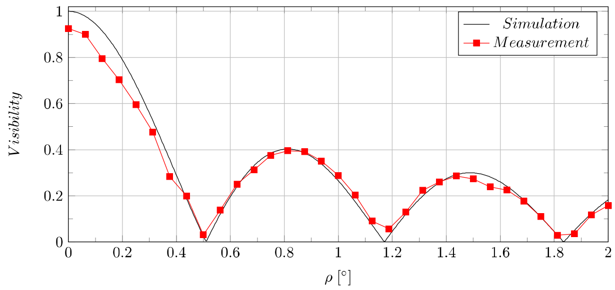

***Fig. 3** Comparison of simulated vs. experimental data*

Detailed information about the experiment can be found in [2].

5 Application: Holographic multiplexing

The MOM is inspired by a device suggested for intensity distribution homogenization for Gaussian beam illumination [4]. The concept of a rotating optical flat was adopted and applied to interference visibility reduction. Such a (visibility reduction) device is required for simultaneous multiplexing of holograms into photopolymer. Here, the application of the MOM for holographic multiplexing of two independent gratings is presented. As shown in Fig. 4 the beam of a coherent light source is split up into four beams. Each pair of beams $(A1\&A2)$ and $(B1\&B2)$ is supposed to create a grating, but the pairs among each other shell not interfere (which otherwise would create four more gratings).

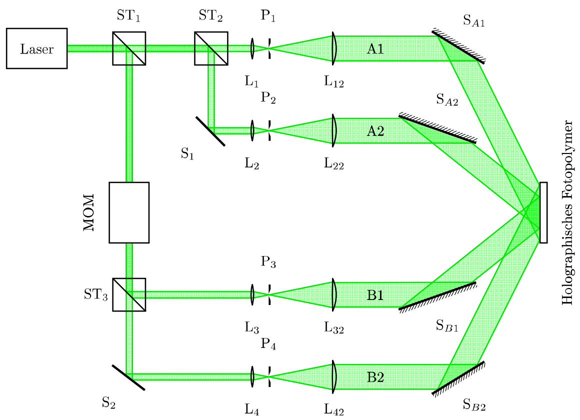

***Fig. 4** Setup for holographic multiplexing of two gratings*

Therefore, the MOM is placed into the setup in a way, that the time average visibility among the pairs is reduced sufficiently (which holds for long durations of exposure or high rotation frequencies) due to the dynamical phase shifting caused by the rotating optical flat. Fig. 5 shows the measured diffraction efficiency of the multiplexed hologram, which has been exposed simultaneously into a photopolymer film. It can be seen that both gratings have comparable diffraction efficiencies and more important, there are no parasitic gratings.

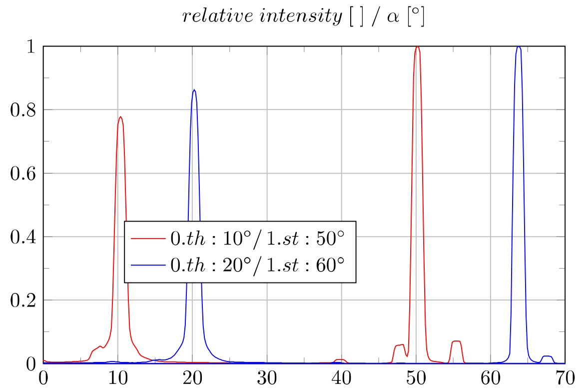

***Fig. 5** Diffraction efficiency of the multiplexed hologram*

6 Conclusion

The proposed mechano-optical modulator represents an economic and simple solution to simultaneous multiplexing problems of holograms in photopolymers. It enables the concurrent exposure of multiplex holograms with a single laser by the suppression of parasitic interferences. The presented theory and simulations are verified experimentally, which allows the design of tailored modulators for individual applications. The practicability is confirmed by successful exposure of two independent gratings into one photopolymer simultaneously.

References

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