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The Shearing Interferometry of Double Frequency Grating with Ti:Al_2O_3 Tunable Laser

INTRODUCTION

Ti:Al_2O_3 tunable laser is now emerging from the laboratory into the real world of laser application, such as spectrum analysis, atmospheric sensing, biology and other areas. Here the shearing interferometry of double frequency grating with Ti:Al_2O_3 tunable laser is proposed. In our laboratory, pulsed Ti:Al_2O_3 laser operation has been demonstrated between 663 nm and 1025 nm. Output pulse energy is about 33.5 mJ. The frequency doubling uses BBO(α-BaB_2O_4) crystal and wavelength region of Ti:Al_2O_3 laser is developed from 350 nm to 430 nm. By using this pulsed Ti:Al_2O_3 laser, the multi-wavelength and dynamic shearing interferometry is realized. It can be applied to measuring colour spherical aberration and to test complex flame temperature field. In this paper, the shearing interferograms of lens spherical aberration and temperature field by Ti:Al_2O_3 laser are given, and analysis of the shearing interferometer is described. If the performance of this Ti:Al_2O_3 tunable laser is improved, the colour hologram can be made by one Ti:Al_2O_3 tunable laser.

PRINCIPLES

A typical shearing interferometric configuration is shown in Fig. 1.

Two first diffraction wavefronts from the double frequency grating DH formed a shearing interferogram on screen K. The lateral shearing quantity is [1]

$$\Delta y = Z\lambda/d' \cos\theta, \qquad (1)$$

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where d' is the beat period of double frequency grating, θ is the average angle on the first diffraction order of DH, λ is the wavelength of light and Z is the axied distance between the double frequency grating and the observation screen K.

If there is no test object, the spacing fringes on the screen K can be written as

$$s = d'(\cos\theta + D/\cos\theta). \tag{2}$$

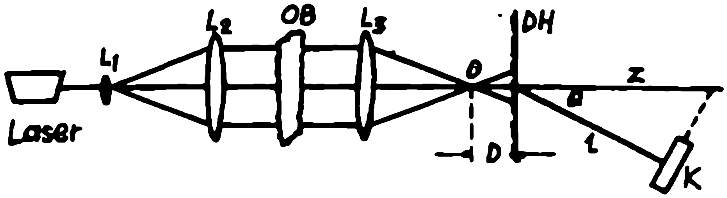


Fig. 1. Optical configuration for shearing interferometry

In the arrangement shown in Fig. 1 the phase difference of test object is

$$\Delta\phi = (2\pi/\lambda)\int_{Z_1}^{Z_2}[n(x, y+\Delta y/2, z) - n(x, y-\Delta y/2, z)]\,dz, \tag{3}$$

where Δy is the lateral shearing quantity, the experimental region is from Z_1 to Z_2, when Δy is very small, equation (3) can be expressed as

$$\Delta\phi = (2\pi/\lambda)\int_{Z_1}^{Z_2}\frac{\partial}{\partial y}[n(x,y,z)dz]\,\Delta y. \tag{4}$$

When a phase field is present, the shift quantity of shearing fringes Δs satisfies the following relation [2]:

$$\Delta s/s = \Delta\phi/2\pi = (\Delta y/\lambda)\int_{Z_1}^{Z_2}\left[\frac{\partial}{\partial y}n(x,y,z)\right]dz. \tag{5}$$

When the relative fringe shift $\Delta s/s$ is known, if we can solve the integral Eq. (5), the distribution $n(x, y, z)$ can be obtained.

The index of refraction n will vary with density ρ according to the Dale Gladstone formula

$$n = 1 + \mathrm{K}\rho, \tag{6}$$

where K is the Dale-Gladstone constant. The temperature T is obtained, from the ideal gas state equation

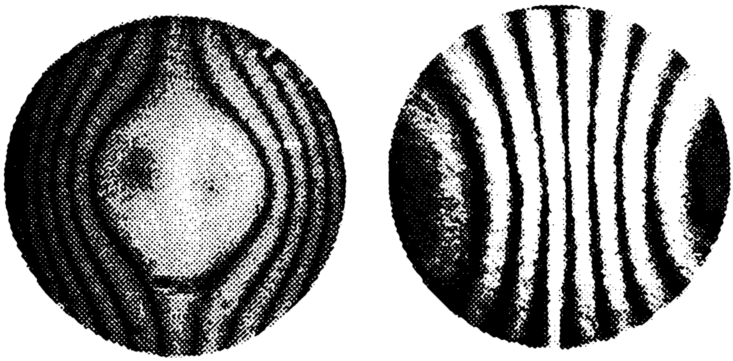
$$\rho = \mu P/RT, \tag{7}$$

where μ is molecular weight, P is gas pressure and R is general gas constant.

From Eq. (5), (6), (7) the phase field of refraction, density and temperature can be calculated.

EXPERIMENT AND RESULTS

Here a pulsed Ti:Al_2O_3 tunable laser is used as light source for dynamic shearing interferometry. The size of Ti:Al_2O_3 rod is Φ 10 $\times$ 29 mm for the π polarization. Tunable laser is designed as flat-concave cavity of 230 mm length. The reflectance of the concave mirror is over 99.5%. The Ti:Al_2O_3 laser is pumped by a Q-switch doubling Nd:YAG laser and repeating frequency of pulses is 5 Hz. The wave-lengths are tuned between 663 nm and 1025 nm by a 2F-3 prism and the frequency doubling between 350 nm and 430 nm is used BBO(β-BaB_2O_4) crystal. The diameter of tunable laser beam is usually less than 1.5 nm, just in a TEM_{oo} mode and nearly 2 mrd diverging angle. The maximum pulses energy of tunable lasers can be more than 10 mJ.



(a) (b)

Fig. 2. Shearing interferograms of lens spherical aberration

In the experiment the double frequency grating is used as a shearing interferometric element, when the double frequency grating is used, the shearing interferometer is simple, stable and easily adjusted. Precision machining and high quality optical elements are not needed. Since the angle of the two diffracted beams from the double frequency grating in the first order is very small, shearing fringe with high visibility can be observed, although the temporal coherence of this Ti:Al_2O_3 laser is not good.

The shearing interferograms of spherical aberration for the lens are shown in Fig. 2 [2]. In Fig. 2(a) the double frequency grating was placed near the paraxial focus of the lens, while for Fig. 2(b) the double frequency grating was placed near the margin of the focus. Here the wavelengths of Ti:Al_2O_3 laser are 723.4 nm and 410.9 nm, respectively. The beat period of double frequency grating is 0.318 mm, the diffraction angles at first order are 14° and 7.5°, respectively. The experiment result of spherical aberration is shown in Fig. 3. The curve (1) is obtained by

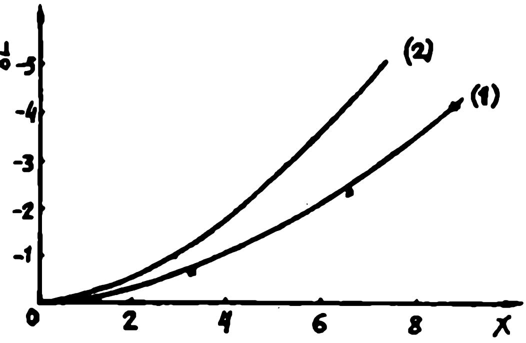


Fig. 3. Spherical aberration curve of lens with 723.4 nm and 410.9 nm wavelength, respectively

723.4 nm Ti:Al_2O_3 laser beam and curve (2) is done by 410.9 nm Ti:Al_2O_3 laser beam doubled by BBO crystal. It is shown that the curves of the color spherical aberration of lens can be given by Ti:Al_2O_3 laser shearing interferometry.

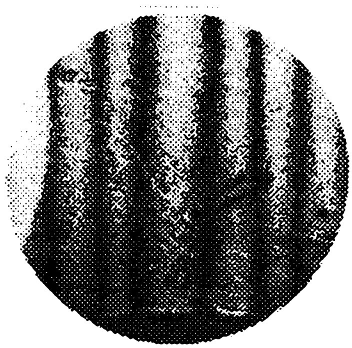


Fig. 4. Shearing interferogram of an alcohol flame with 410 nm wavelength

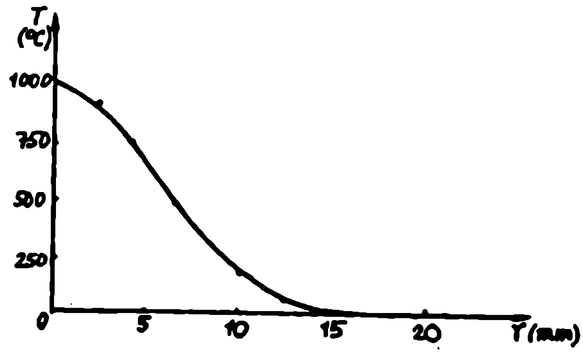


Fig. 5. The temperature T against distance r from the center of an alcohol flame

The temperature field of a flame of an alcohol lamp has been measured by this shearing interferometer. The beat period at first order of the double grating is 0.318 mm. The wavelength of Ti:Al_2O_3 laser 741.2 nm, 715.1 nm, 410 nm are used, respectively. Fig. 4 is a shearing interferogram of an alcohol lamp flame obtained by Ti:Al_2O_3 laser shearing interferometry. The wavelength 410 nm from frequency doubling Ti:Al_2O_3 laser is used and the diffraction angle at first order of double frequency grating is 7.5°. There is a small overlapping between diffractions of first order and zero order for 410 nm short wavelength. The curve of temperature T against the distance r from the center of the alcohol flame to the detected position is shown in Fig. 5. When the multi-wavelength dynamic shearing interferometry of Ti:Al_2O_3 laser is used, multi-parameters of complex flame field can be obtained by multi-interferograms.

CONCLUSION

The shearing interferometry with Ti:Al_2O_3 laser to measure flame temperature field and spherical aberration of lens is demonstrated theoretically and experimentally. Since the pulsed tunable Ti:Al_2O_3 laser is used, the color spherical aberration of lens and complex temperature field can be measured by mult-wavelength dynamic shearing interferometry.

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