IC/88/68
INTERNAL REPORT
(Limited distribution)

International Atomic Energy Agency
and
United Nations Educational Scientific and Cultural Organization

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

SEMICONDUCTOR LASER SHEARING INTERFEROMETER *

Ming Hai **
International Centre for Theoretical Physics, Trieste, Italy,

Li Ming, Chen Nong and Xie Jiaping
Department of Physics, University of Science and Technology of China,
Hefei, Anhui, People's Republic of China.

ABSTRACT

The application of semiconductor laser on grating shearing interferometry is studied experimentally in the present paper. The method measuring the coherence of semiconductor laser beam by ion etching double frequency grating is proposed. The experimental result of lens aberration with semiconductor laser shearing interferometer is given. Talbot shearing interferometry of semiconductor laser is also described.

MIRAMARE – TRIESTE
March 1988

* Submitted for publication.

** Permanent address: Department of Physics, University of Science and Technology of China, Hefei, Anhui, People's Republic of China.

1. INTRODUCTION

Comparing He-Ne laser with the semiconductor laser has some advantages: small, compact, high efficiency and long life. It is installed conveniently for instrumentation and more useful to the metrology. Now the semiconductor laser has been applied to heterodyne interferometry and position sensor device. In our laboratory the semiconductor laser is used as light source of shearing interferometry, holography and speckle techniques. Here the semiconductor laser shearing interferometer is only proposed.

2. OPTICAL CHARACTER OF SEMICONDUCTOR LASER

When the semiconductor laser interferometry is performed its optical coherence must be discussed at first. The two types of semiconductor laser used in our experiments are: (1) HLP1400 type single mode semiconductor laser (P = 15mw, λ =8200Å), (2)TOLD100 type multimode visible semiconductor laser (P = 5mw, λ = 7800Å) The characteristic curves of HLP1400 semiconductor laser are shown in Fig.1, Fig.2 and Fig.3. Fig.1 shows the curve of laser diode

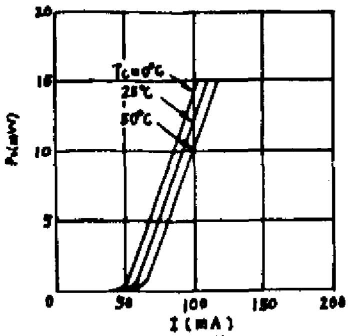

Fig.1 LD output power vs. input current.

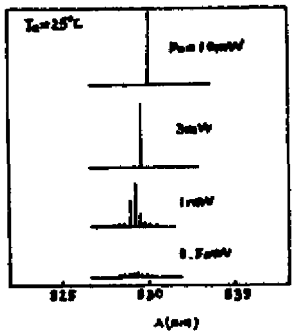

Fig.2 Axial mode vs. output power for HLP1400 LD.

output power against input current in different temperature conditions. The relation of axial mode and output power HLP1400 type semiconductor laser is shown in Fig.2. Fig.3 shows the far-field patterns in different output condition. It is clear that the spectrum of the semiconductor laser is changed with light output power and the laser diode output power is changed with temperature. In order to keep axial mode stability of the semiconductor laser the APC (automatic power control) circuit and ATC (automatic temperature control) circuit are used. Generally the semiconductor laser with single transmode is selected for interferometry.

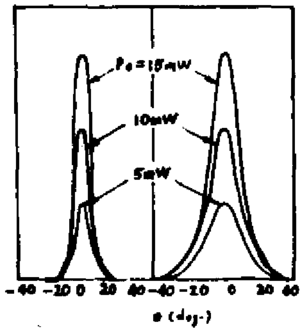

Fig.3 Far-field patterns of HLP1400 LD.

3. EXPERIMENTAL SETUP

The experimental arrangement for semiconductor laser shearing interferometer with double frequency grating is shown in Fig.4. This setup is very simple. The semiconductor laser LD beam collimated by lens L is illuminating the holographic double frequency grating DH through the test phase object.

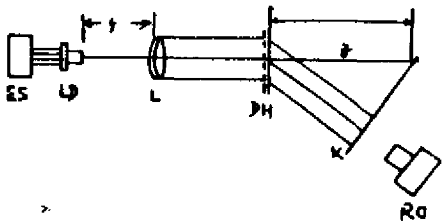

Fig.4 Experimental arrangement.

The observation screen K is set on 1st diffraction direction. RO is infrared scope for observation of invisible semiconductor laser beam. In our experiment the holographic double frequency grating DH is made with two exposure and ion etching techniques[1]. This grating is stable, durable and dustproof, and it has high diffraction efficiency for two reconstructed images with a small different diffraction angle.

4. OPTICAL COHERENCE MEASUREMENT

For multimode semiconductor laser the temporal coherent length is shorter. The temporal coherent length is very important in the interferometry. For the uniform slit source the visibility of fringes is given as follows:

$$V(z) = \mathrm{Sinc}\,(az/d'f)\,\exp\langle -\sigma^2/2\,(2\pi z/d'd)^2 \rangle$$

where a is the slit width, d and d' are average and beat period respectively. z the axial distance between observation screen k and double grating DH, f is the focus length of lens L.

When the position of observation is satisfied with the following relation

$$az/d'f = n \qquad (n = 1,2,3...)$$

the visibility V (z) = 0, the fringe disappears and spatial coherence of the optical source can be measured. But in the shearing interferometal experiment of semiconductor laser luminescent area of the semiconductor laser is very small (about 1×10μm). So it has good spatial coherence. When the axial distance z is very long ($z = d'f/a = 5.2\times10^4$ mm) the shearing fringe disappears.

According to resolution criterion when

$$\exp < -\sigma^2/2(2\pi z/d'd)^2 > = 0.1$$

the fringe disappears. If the spectrum is of the Gaussian type, then $\Delta\lambda = 2\times1.177\sigma$. By using the setup in Fig.1, when TOLD100 type semiconductor laser is used as light source, the shearing fringe disappearing point can be measured and z = 2160mm, according to the above formula the semiconductor laser spectrum width can be measured, $\Delta\lambda$ = 6A. Fig.5 shows TOLD100 semiconductor laser spectrum made by WDG-30 monochromator and the profile width of the spectrum is about 6.3Å. The method of shearing interferometry is convenient also for measuring temporal coherence of multimode semiconductor laser in the metrology real time.

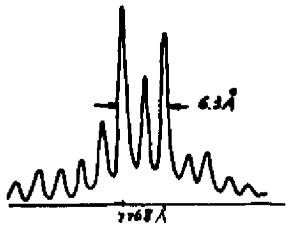

Fig.5 TOLD100 semiconductor laser spectrum made by WDG-30 monochromator.

5. LENS ABERRATION MEASUREMENT

The optical configuration for lens aberration measurement is shown in Fig.6. The semiconductor laser beam imaged by lens L illuminates the double frequency grating DH. The lens L aberration shearing interferogram can be seen on the observation screen K. Fig.7 shows two interferogram, which is obtained by the double frequency diffraction grating interferometer with semiconductor laser illumination, to test a lens having spherical aberration. For Fig.7a the grating was

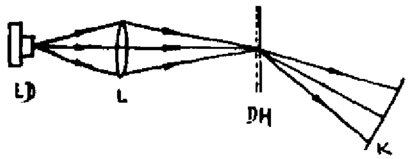

Fig.6 Optical configuration of lens aberration measurement.

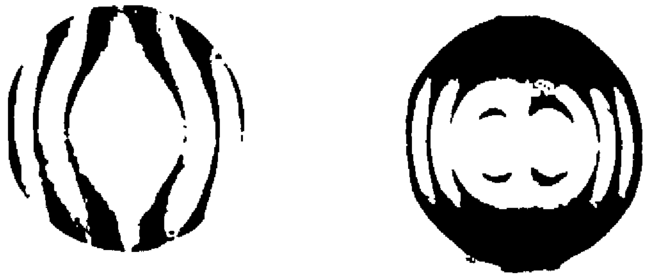

Fig.7a,7b Interferogram of lens spherical aberration

placed near the paraxial focus of lens, while for Fig.7b the grating was placed near the margin of focus. The experimental result curves are shown in Fig.8. The aberration curve a is in the case illuminated by semiconductor laser (7800A°) and the aberration curve b is in the case illuminated by the He-Ne laser. The difference between the two curves shows the achromatic aberration of this lens.

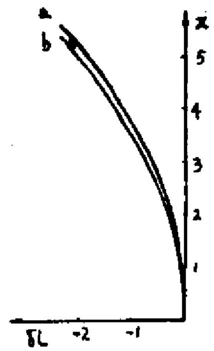

Fig.8 Spherical aberration curves.

Semiconductor laser shearing interferometer can also be used for the determination of lens focus. When the double grating is placed at the focus of a lens, one fringe will cover the pupil. The measurement accuracy is determinated by following formula

$$F = 2f/d'D$$

where D/f is lens relative aperture. This method can be used for waveguide coupling.

6. TALBOT SHEARING INTERFEROMETER

Talbot shearing interferometer illuminated by semiconductor laser is shown in Fig.9. The semiconductor laser beam collimated by lens L is illuminated by the grating G_1. The same grating G_1 and G_2 have a Talbot distance Z = $2nd^2/\lambda$. The shearing quantity of Talbot interferometer is $\Delta = z\lambda/d$. The Talbot shearing interferometer with semiconductor laser illumination has good fringe and the setup is small and simple. It can also be used for testing phase object and lens.

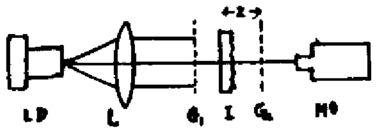

Fig.9 Talbot shearing interferometer configuration.

7. CONCLUSION

The shearing interferometry with semiconductor laser illumination is demonstrated experimentally, and its applications are proposed as well.

ACKNOWLEDGMENTS

One of the authors (M.H.) would like to thank Professor Abdus Salam, the International Atomic Energy Agency and UNESCO for hospitality at the International Centre for Theoretical Physics, Trieste. The authors wish to thank Professor T. Tada, Tokyo University, for his kind assistance in the experiment.

REFERENCES

1. Ming Hai et al. "Shearing Interferometer with Ion Etching gratting Using Noncoherent Illumination and Nonlinear Treatment", SPIE Proceedings 814-83, 1987.8.
2. M. Born, E. Wolf, Principle of Optics, Pergamon Press, Ch. 10, 1975.

Stampato in proprio nella tipografia
del Centro Internazionale di Fisica Teorica