Laser thermal lens measurement based on Newton ring interferometry

Lei Qi, Jinzi Huang, Shuyun Zhan, Weici Liu*, Hongjie Zhu and Yuwang Liu

Department of Electronic Information Engineering, Guangzhou College of Technology and Business, Foshan, Guangdong, 528138, China

*Corresponding author’s e-mail: liu-weici@m.scnu.edu.cn, liuweici-2002@126.com

Abstract. Thermal lens technology has attracted much attention because of its high sensitivity, low detection limit and being suitable for the analyses of minute samples. Thermal lens technology has been widely used in many fields, such as chemistry, physics, environmental monitoring, electronics, material science and life science. In this paper, the laser thermal lens measurement is studied based on Newton's ring interferometry, especially for the case of low-power laser. The application of this method in the measurement of small samples is also discussed. It is helpful to study the micro deformation of thin film and lens under low power laser at room temperature. The results are very important for the future research on the micro deformation of optical elements.

1. Introduction

Thermal lens effect is a kind of photothermal effect. The most common reason of thermal lens effect is that the laser energy is absorbed and heat is generated along the path of laser transmission in medium. As the energy distribution of laser beam is generally Gaussian, the temperature of medium changes gradiently, which leads to the transverse gradient change of medium refractive index, and lens effect occurs [1-3].

With the emergence of laser, especially high-power laser system, more and more stringent requirements are required for the properties of optical thin films, such as better optical performance, low absorption loss, and strong resistance to laser damage. Laser thermal lens technology can be used to measure the absorption characteristics of thin films. When a radially symmetric laser beam with Gaussian distribution is used as the excitation beam to irradiate the sample, the hottest spot is in the centre because the intensity of the beam at this point. A radial temperature gradient is generated in the sample, which makes the refractive index of the sample be a radial gradient distribution, thus it becomes an optical element which is similar to a Len. The thermal lens effect can be regarded as an ideal thin lens, and the corresponding thermal lens signal can be obtained by calculating the focal length of the lens. Therefore, the thermal lens effect can be used to measure the weak absorption. Chen Xiaoxiao et al. used the photothermal method on the measurement of thin film absorption by surface thermal lens technology excited by flat top beam [4].

Tianyi Jiao et al. studied the effect of small deformation of K9 glass on imaging of optical system at room temperature and medium low temperature [5]. They found that K9 glass lens produced a certain small deformation with the change of thermals and temperature, which affected the optical imaging in the experiment.

Optical thin film is a very important and vulnerable in optical system, and its absorption problem has become an important factor for the stability and service life of optical system. In recent years, with...
the development of low loss optical materials, the further maturity of process design, and the continuous improvement of coating technology, higher measurement accuracy is required for the weak absorption measurement of thin films. Laser thermal lens based on optical interferometry can effectively measure the absorption characteristics of optical thin films.

K9 glass is one of the important and commonly used components in modern optical system. When K9 glass is irradiated by low power laser, its maximum temperature changes with varying of heat source. Most of the research on K9 glass is that the damage under high temperature and high power will cause serious consequences to the optical path. Many photoelectric experiments are also carried out at room temperature and low power. The weak absorption of K9 glass can be measured by comparing the interference patterns before and after K9 glass is placed by thermal lens effect.

The laser thermal lens measurement based on Newton's ring interferometry can reduce the interference in the process of thermal lens signal measurement, and improve the signal-to-noise ratio. The optical path is simple, easy to be adjusted and has high resolution. It has a good application prospect in analyses and determinations, such as photothermal microscopy, high performance liquid chromatography (HPLC), and gel electrophoresis for protein separation.

This paper studies the thermal lens effect of low power laser based on Newton's ring interferometry. The applications of thermal lens measurement technology are discussed for the measurement of thin film, K9 glass and other small samples. These results contribute to the detection for the micro deformation of thin film or lens under low power laser at room temperature, and provide the research basis for the micro deformation research related optical element in the future.

2. Experimental principle

Newton's ring belongs to the interference phenomenon produced by the partial amplitude method, which is a typical interference fringe with equal thickness. In figure 1, $e_k$ is proportional to $r_k$, and the farther away from the center of Newton's ring, the greater the optical path difference increases. The interference image generated is shown in Fig. 2.

![Figure 1. Newton ring device diagram](image1)

![Figure 2. Newton ring Interferogram](image2)
3. Experimental device and result analysis
The experimental design based on Newton's ring is shown in 3. Through this experimental design, we can get two groups of interference fringes, one is without K9 glass, and the other is with medium K9 glass. The energy of K9 glass is absorbed by laser irradiation, and heat is generated along the transmission path.

By slightly adjusting the half reflecting plate, the interference fringe pattern can be seen. We can get the records by constantly adjusting the half reflection plate. From the figure 3 and figure 4, we can see obviously that the number of rings of the two is different. The number of rings in figure 4 is 8 and that in figure 5 is 7. By comparing the two interference fringe pattern, it can be concluded that the thermal effect is observed more clearly due to the change of the medium. It can be inferred that the thermal lens effect occurs in K9 glass medium.
4. Conclusion
In summary, based on the irregular equal thickness interference fringes produced by Newton's ring, the laser thermal lens effect is realized. As the thermal lens effect of low-power laser is difficult to be reflected, the thermal effect of low-power laser can be observed by using K9 glass with good heat absorption and high transmittance. The experimental results show that the number of bright rings is 8 without K9 glass, while the number of bright rings is 7 with K9 glass, and the ring spacing is relatively larger. The thermal lens effect of laser can be observed by adjusting the device. The device can directly display the thermal lens phenomenon and has great prospects in the study of laser thermal lens effect and medium absorption.

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