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PHOTOACOUSTIC TRANSMITTANCE MEASURMENT FOR LARGE DIAMETER LENS IN ULTRAVIOLET RAYS (193 nm)

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Abstract − The purpose of this study is establishment of the high precision transmittance measurement technology (accuracy: 0.01%) of the large diameter lens(material: CaF_2, diameter: Φ200mm) for ultraviolet rays (wavelength: 193 nm). Transmittance measurement method with photoacoustic spectroscopy[1)] is proposed. This technology depends on only photothermal spectroscopy at a local minute area and is independent of lens size. So this proposed method can be applied to large diameter lens. And measurment time at one point is extremely short. So the superiority of this new method is that the transmittance distribution in-plane can be easily measured.It was experimentally verified that this photoacoustic spectroscopy could be applicable to large diameter lens.

Keywords: Photo Acoustic Spectroscopy, Calorimetric measurement[2)], Photothermal effect

1. INTRODUCTION

In recent years, the optical product especially for ultraviolet ray became more important. Therefore, the purpose of this study is establishment of the high precision transmittance measurement technology (accuracy: 0.01%) of the large diameter lens (material: CaF_2, diameter: Φ200mm) for ultraviolet rays (wavelength: 193 nm).

Conventionally, spectrophotometer and the calorimetric measurement have been well known.

In spectrophotometer, transmittanc is measured by the light-intensity that is detected by photo multiplier. The precision of conventional spectrophotometer is around 0.3[%]. So this method can't satisfy the target accuracy because of electric noise.

The calorimetric measurement is standardized internationally and is registered into ISO(International Standard Organization)[3)]. In this method, absorbed light energy is estimated from increased temperature that is caused by photo thermal effect. Large diameter lens is illuminated by laser for long time (15 minutes or more). Calorimetric method can measure very minute absorption by accumulation of heat energy. However in the case of large diameter lens, the amount of increased temperature is extremely small because the thermal capacity is very large. So calorimetric method can be applied to very small lens whose diameter is about Φ20mm or less. Moreover, it is not the suitable for measurement of the transmittance distribution in-plane because it takes enormous time to get data at each point. Then, we propose the transmittance measurement technique using the photoacoustic effect by the photothermal effect of a minute area.

In this method, lens is illuminated by a pulse of light. Local heat expansion that is caused by minute optical absorption energy is detected as elastic wave. This phenomenon occurs in specific minute area that is illuminated by laser spot. So this proposed method can be applied irrespective of whether diameter is small or large. And measurement time is very short(several sec at each point). So transmittance distribution in-plane can be easily obtained. But this proposed method can't use accumulation of heat energy as calorimetric method. In this paper, it is experimentally verified that minute light absorption energy can be detected as elastic wave, using large diameter lens.

2. CONFIGURATION OF EXPERIMENTAL APPARATUS

Fig.1 shows the configuration of experimental apparatus.

Pulse of light whose width in 10ns illuminates a lens. The diameter of laser spot is Φ5mm. Irradiated area of lens expands by light absorption, and then contracts by heat conductivity. These expansion and contraction are spread on the whole lens as an elastic wave. This technique detects this elastic wave in high sensitivity with AE (Acoustic Emission) sensor[4)]. Transmittance is estimated from the intensity of the detected elastic wave. And absorption coefficient is estimated from transmittance.

The light which is irradiated from laser (manufacturer: TUI LASER, model: ExciStar S-200, Energy max:8mJ) branches by the half mirror. Then, reflected light is intensity measured by the photo-diode. The voltage of this photo-diode is transmitted to an oscilloscope, and it used as a trigger. On the other, the light which penetrates the half mirror arrives at power meter. Intensity of the laser power is monitored by power meter. Moreover, the elastic wave that is generated in the process of penetrating a lens is measured by AE sensor (manufacturer: NF Corporation, model:AE-900S-WB, Resonance frequency:500KHz & manufacturer:Krautkramer, model:G2KB-F, Resonance frequency:2MHz). This detected signal is amplified by low noise preamplifier. And S/N is improved by discriminator. This processed signal is indicated on an oscilloscope. Moreover, a noise filter transformer removes the noise which enters from a power supply.

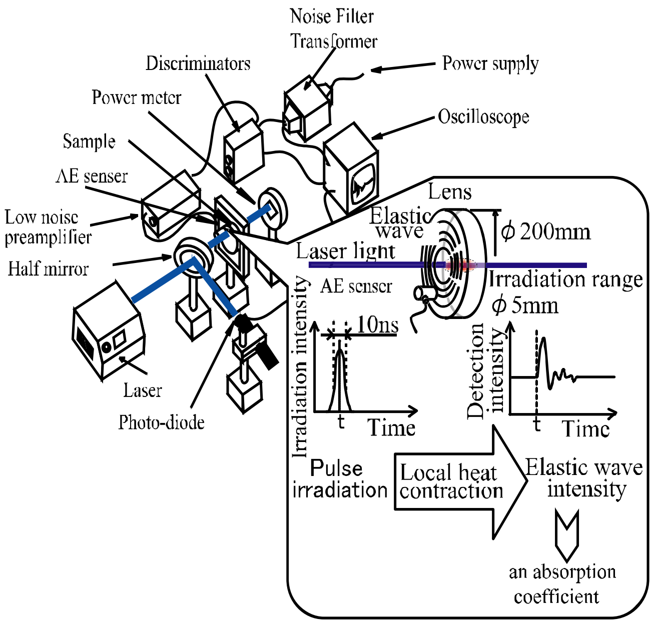

Fig. 1 Configuration of Photoacoustic transmittance measurement equipment.

3. EXPERIMENTAL

Fig.2 shows the experimental results of the relation between an absorption coefficient and an elastic wave intensity.

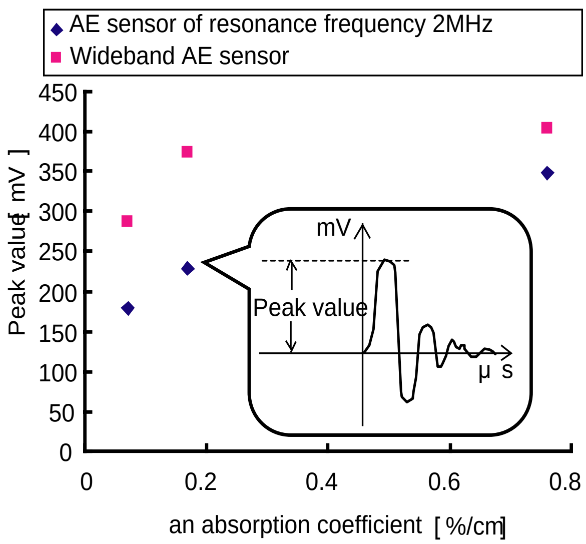

Fig. 2. Relation between an elastic wave peak value and an absorption coefficient

Horizontal axis is the measured value of spectrophotometer(manufacturer:Hitachi,Ltd, model:U-4100, accuracy:0.3%)[5]. Vertical axis shows the maximum amplitude value (peak value) of the elastic wave detected by AE sensor. Fig. 3 shows a example of the detected waveform. The diameter of this sample is 200mm and the thickness is 50mm, and absorption coefficient is 99.8%. We have confirmed that absorption coefficients and elastic wave peak values had correlation from this experimental results. This experimental results verified that minute light absorption energy can be detected an elastic wave without accumulation of heat energy. So this proposed method can be applied to large diameter lens. We are carring out experiment to insure the precision of measurement.

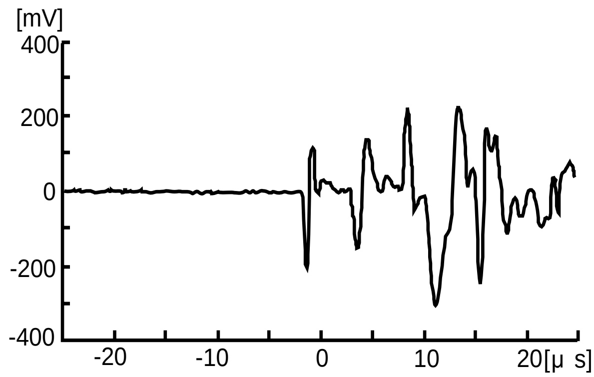

Fig. 3. Elastic waveform in the large diameter lens

Fig.4 is the waveform which measured the crystal with a thickness of 50mm. A waveform interval changes with the thickness of a crystal.

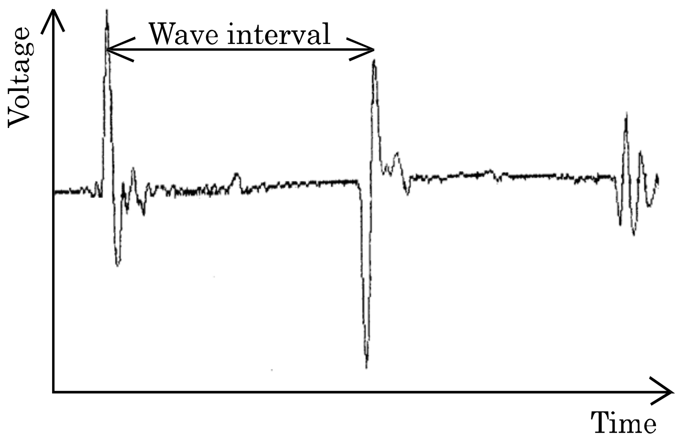

Fig.4. Measurement waveform

Fig.5 shows the relation between crystal thickness and wave interval.

Horizonal axis shows a waveform interval. Vertical axis shows a crystal thickness. The wave interval is proportional to the thickness of a crystal. It was mostly in agreement with the result calculated from the physical-properties value of a lens, and the speed of a longitudinal wave.

Fig. 6 shows the relation between a laser irradiation angle and amplitude intensity.

Horizonal axis shows a irradiation distance. Vertical axis shows a Amplitude.

If laser beam is leaned to AE sensor side, it will be measured strong amplitude. If laser beam is leaned to AE sensor other side, it will be measured weak amplitude.

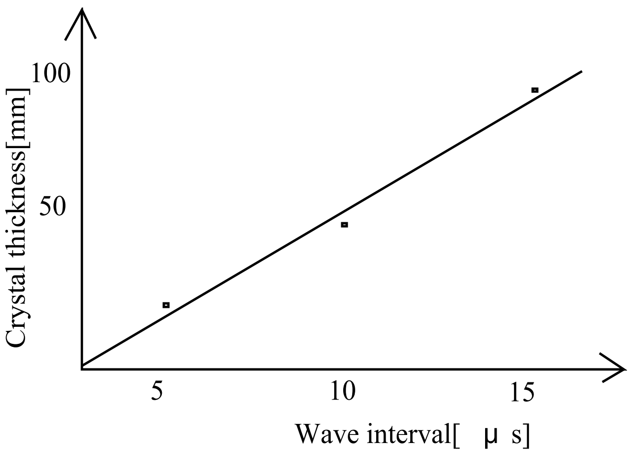

Fig.5. Crystal thickness and wave interval

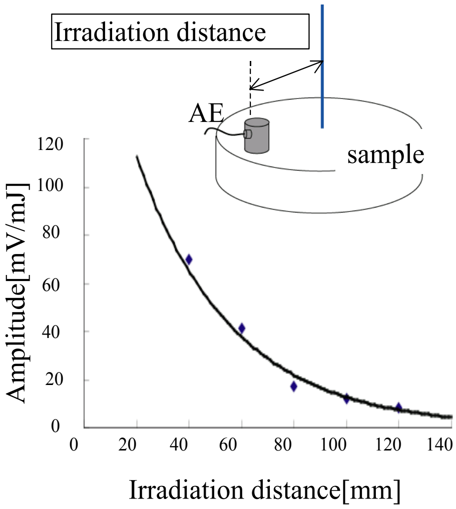

Fig.6. Amplitude and irradiation distance

When a laser beam reflects in a crystal and hits AE directly, the right measurement value cannot be obtained. Then, it installed so that a laser beam might irradiate a crystal perpendicularly. Furthermore, the laser irradiation position and the position of AE sensor were detached 55mm, and are attached.

Fig. 7 is the value which measured the absorptivity within a field.

4. CONCLUSION

The purpose of this study is to measure the transmittance of the large diameter lens (material:CaF_2,Φ200mm) for ultraviolet rays (wavelength:193nm) in high precision.

1)Photoacoustic spectroscopy method is proposed for this measurement.

2)minute light absorption energy can be detected as elastic wave.

We are carrying out experiment to insure the precision of measurement.

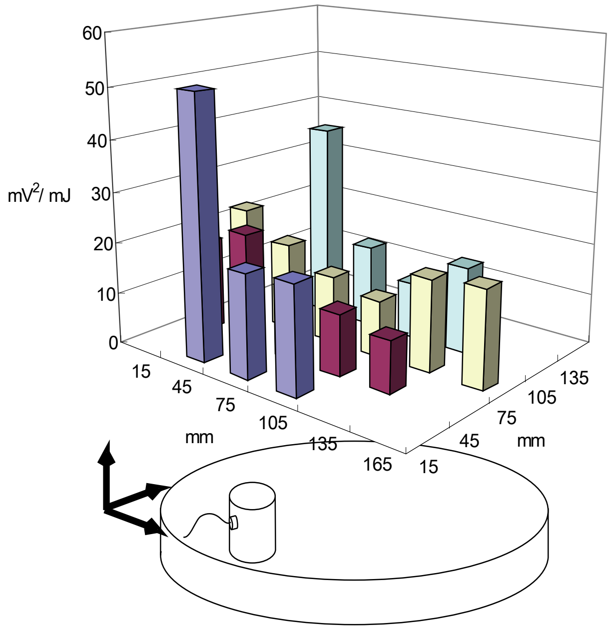

Fig.7. The absorptivity distribution within a field

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