Direct detection of acoustic waves by laser light diffraction and proposals of the optophone

Y. Sonoda

School of Engineering, Kyushu Tokai University, 9-1-1 Toroku, Kumamoto 862, JAPAN

Abstract: The application of the Fraunhofer diffraction method, which has been developed in the nuclear fusion research, to the acoustic waves was experimentally examined. It is demonstrated that the waves with a wavelength longer than 85 mm can be detected by using a visible laser, which is extremely longer than the standard value measurable by the conventional light diffraction method. Furthermore, as a new technique with no diaphragm, the optical microphone (or the optophone) is proposed and its property and possibility are shortly discussed, which is expected to stimulate the development of the opto-acoustic engineering.

INTRODUCTION

As a standard technique to detect the acoustic waves, the microphone has been developed and used over one hundred years. It, however, always uses a diaphragm or any vibrating object and has many restrictions on the practical applications. On the other hand, the light diffraction is very effective and has been used to the measurement of refractive-index waves, including the ultrasonic wave and the plasma wave. But the conventional light diffraction method cannot be applied to the measurement of the acoustic waves with a long-wavelength, where the diffracted optical waves propagate in the penetrating optical beam and cannot be measured because of the disturbance by the latter. The aim of this study is to establish the optical technique to measure the extremely long wavelength, which has not ever been treated. In the present study, the Fraunhofer diffraction method, which was developed as a new means to detect the electromagnetic radiation scattered within the penetrating laser beam in the plasma nuclear fusion research, are applied to the measurement of the audible sound waves. And the possibility of measuring the audible sound waves by a visible laser light are experimentally investigated. Furthermore, the optophone of various types are proposed as a new acoustic detection method.

PRINCIPLE AND EXPERIMENTAL

The fundamental setup of the Fraunhofer diffraction method is shown in Fig. 1, where a He-Ne laser (632.8 nm) of 5 mW is used and the spot size is about 2 mm. When an incident laser beam crosses any refractive-index waves or acoustic waves, the diffracted light waves are generated and propagate with or within the penetrating beam and reach an optical detector. The acoustic waves or the ultra-

![Figure 1. Experimental setup.](image1)

![Figure 2. Relation between the sound pressure and the optical signal intensity (f = 1 kHz).](image2)
Sonic waves are transmitted from a speaker or an ultrasonic transducer. In the receiving optics, the Fourier optical system composed of three lenses is adopted. The detector is the 32-channel photodiode array and the size of one element is 0.585 mm × 1.3 mm. The output signal from the photodiode is amplified, input into and analyzed in a digital oscilloscope. The sound pressure is monitored by an electrostatic microphone system or a sound-level meter.

The fundamental characteristics, as shown below, of the laser-optic method or the optophone were experimentally examined: (1) Spatial profile of light diffraction, (2) Relation between the sound pressure and the optical signal intensity, (3) Relation between the laser power and the optical signal intensity, (4) Dependence of the sensitivity on the sound frequency, (5) Detectable sound pressure by the present system, (6) Directivity of the one-dimensional laser beam microphone, and so on.

Relation between the sound pressure and the diffraction signal intensity: In order to examine the relation, the experiment was carried out by keeping the sound frequency constant and changing the sound pressure. The experimental result is indicated in Fig. 2. The optical signal intensity is found to be linearly proportional to the sound pressure under the present condition. The details of other results are to be reported in the conference.

PROPOSAL OF THE OPTOPHONE AND ADVANTAGES

Based on the above principle, we can construct the optical microphones of various types, an example of which is shown in Fig. 3, which do not need any diaphragms and can detect acoustic waves optically and directly and have many advantages as followed:

Merits of the optophone: (1) It is applicable to measurements under such special conditions as the high electric and/or magnetic fields, where the conventional microphone cannot be applied to. It can also measure sounds in the airtight chamber, if an optical window exists. (2) Any lasers from visible to near-infrared wavelengths can be used. In accordance with needs, the visible or invisible laser microphone can be constructed. (3) The receiving part or laser beam of the optophone can be constructed in one to three-dimensions, by which we can offer various directivities and various sizes (the compact or ultra-large sound antenna type). (4) The sound signal could be optically amplified and transmitted by an optical fiber without the disturbance of the electromagnetic noise.

CONCLUSION

It was experimentally shown that the acoustic waves of a long wavelength longer than 8.5 mm could be measured by the Fraunhofer diffraction method. Utilizing the principle, the optical microphone was proposed and the basic characteristics as an sound-antenna were examined. Further studies are to be carried out to know whether this method could be practically useful in the acoustic engineering field.

ACKNOWLEDGEMENT

This work was supported in part by a grant from The Sound Technology Promotion Foundation in Japan and The Kyushu Industrial Technology Center Foundation.

REFERENCES