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ACOUSTICAL LETTER

Sound reproduction using the photoacoustic effect

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1. Introduction

It is highly important to generate point sound sources in mid air for several applications such as virtual realty and precise acoustic measurement since most of acoustic theories are based on point sound source. One possible solution for generating point sound sources in mid air is the photoacoustic effect: energy transduction from light energy to sound energy. The photoacoustic effect generates sounds from the alternate-current components of air expansion due to the heat generated by light absorption of a material when light modulated with acoustic signal is radiated to a material [1–4]. Our research focuses on the sound reproduction by the photoacoustic effect using infrared light source since molecules of greenhouse gases absorb infrared light. Since greenhouse gases exist in mid air, it is possible to generate point sound sources in mid air by applying the photoacoustic effect to the molecules of greenhouse gases in mid air.

In this paper, in order to confirm the possibility of sound reproduction using the photoacoustic effect, experiments of the sound reproduction with the photoacoustic effect by radiating the light, produced by a halogen lamp, to charcoals that have high absorptive power are described. First, we confirm that halogen lamp can be modulated with an acoustic signal. Next, we discussed about the reproduction of sinusoidal waves and the musical sound.

2. Response speed of halogen lamp

Although a halogen lamp can produce high intensity infrared light, its response speed is slow since it is a filament light source that generates light energy from heat energy. Therefore it is required to confirm that a halogen lamp can be modulated with an acoustic signal. In order to confirm it, a halogen lamp that has 150 W power was modulated using a modulation circuit represented in Fig. 1 and observed the light received by a receive unit represented in Fig. 2. Figure 3 shows the frequency characteristic of the two observed signals when the time-stretched pulse (TSP) signal is input into the modulation circuit and no signal is input it. Because of the difference between the voltage level of TSP signal and no signal, it is confirmed that a halogen lamp can be modulated with wide-range frequency band although the characteristic of low-pass filter was observed.

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3. Sound reproduction using charcoal

In order to confirm sound reproduction using the photoacoustic effect, the experiments to reproduce a pure tone and a musical sound is performed. In order to generate louder sound, the light from the halogen lamp is focused on a charcoal, which has high absorptive power since a charcoal is black and spongy. In this experiment, the elliptical mirror is used to concentrate the light on a charcoal. Figure 4 shows the scene of this experiment.

3.1. The reproduction of sinusoidal wave

In order to confirm the reproduction of audible sound, the experiment to generate sinusoidal wave is carried out, where sinusoidal wave of 10 kHz is used as the signal input into the modulation circuit in Fig. 1 and the sound pressure level in vicinity of the charcoal is measured. Figure 5 shows that the frequency characteristics of sinusoidal sound of 10 kHz is reproduced at the charcoal.

3.2. The reproduction of musical sounds

The experiment to reproduce musical sounds was carried out, where the musical sound was used as the input of the circuit in Fig. 1 and sound in the vicinity of the charcoal was measured. Figure 6 shows sound spectrogram of them. Both sound spectrograms have the similar characteristics. This result proves that the photoacoustic effect can reproduce a musical sound.

4. Conclusions

In this paper, the experiment to confirm that the photoacoustic effect using infrared lights can reproduce audible sounds has been performed. First, the experiment of response speed of a halogen lamp was performed. It is shown that a halogen lamp can be modulated with acoustic signal although the amplitude of higher frequency components is reduced because of the response speed of halogen lamp. Next, the experiments of sound reproduction using a halogen lamp and a charcoal were performed. The results of these experiments proved that it is possible to reproduce sinusoidal sounds and a musical sound by focusing modulated light from a halogen lamp on the surface of the charcoal. For the future works, it is possible to generate point a sound source in mid air by focusing light on molecules of greenhouse gases or molecules of H_2O mist. To apply these molecules, the response speed of the light source and the high absorptive power are required. Considering these requirement, we suggest the use of a mid infrared laser diode or LED because

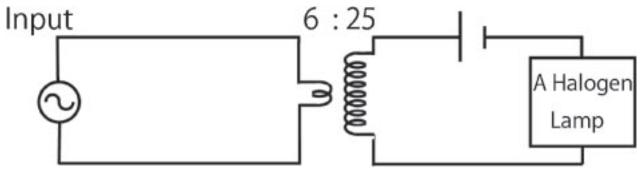

Fig. 1 Modulation circuit. The wattage of the halogen lamp is 150 W.

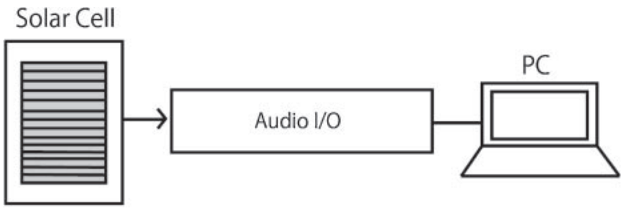

Fig. 2 Receiving unit.

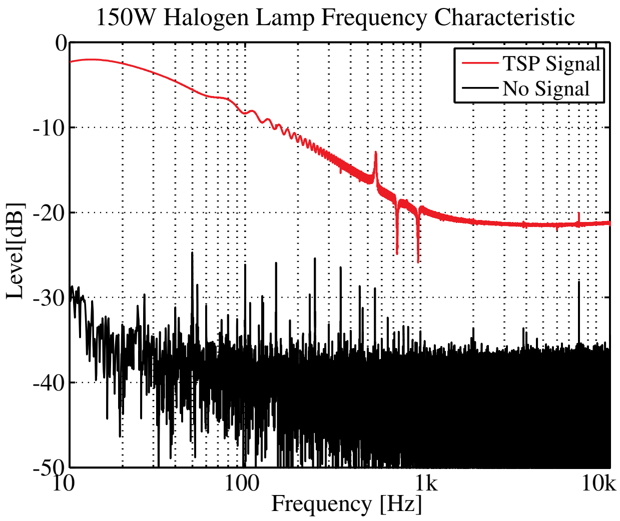

Fig. 3 Frequency characteristic of the halogen lamp. The red line is the frequency characteristic of the received signal when the input signal is the TSP signal. The black line is that of the received signal when the input signal is no signal. The frequency characteristic of TSP signal decreases about 16 dB from 10 Hz to 1 kHz. The difference of voltage level of these signals is about 15 dB at 10 kHz.

of high speed responsivity and narrow bandwidh light frequency. We will try to use these light sources and greenhouse gases to generate a point sound source in mid air in the future.

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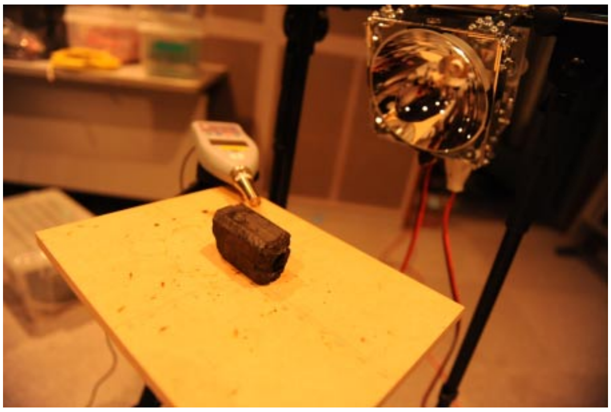
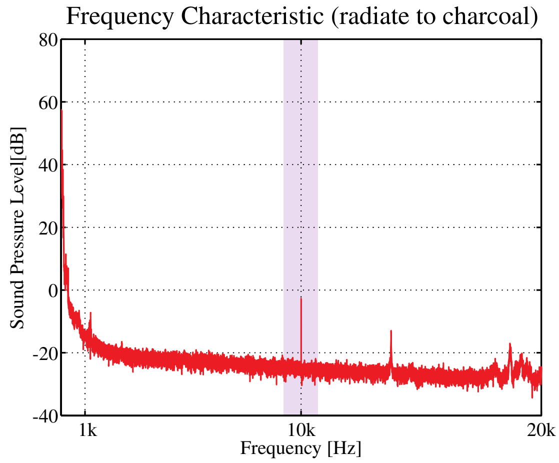
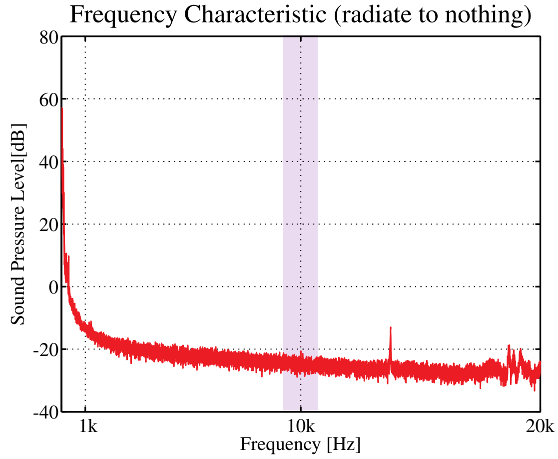


Fig. 4 Experiment Scene. The light produced by a halogen lamp is concentrated on the surface of the charcoal by the elliptical mirror. A sound-level meter is put close to the charcoal.

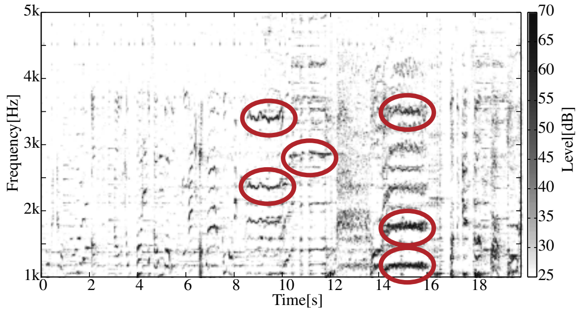


(a) Radiating to charcoal.

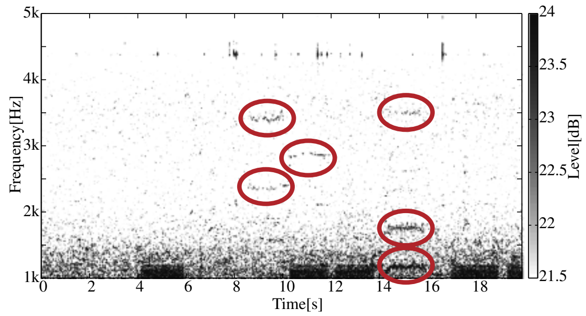


(b) Radiating to air (no charcoal).

Fig. 5 Frequency characteristics of sound in vicinity of the focal point. The input signal is sinusoidal wave of 10 kHz. (a) The frequency characteristic when the light is focused on the surface of the charcoal. (b) The frequency characteristic when the charcoal is removed and the light is focused in mid air. Since the peak at 10 kHz is shown in (a), the sinusoidal of 10 kHz wave is reproduced at the charcoal.



(a) Sound spectrogram (input signal)



(b) Sound spectrogram (reproduced by the photoacoustic effect)

Fig. 6 Spectrograms of the input signal and the measured signal in the vicinity of charcoal. (a) The spectrogram of input signal. (b) The spectrogram of measured signal. The input signal is "Matsuken Samba 2" sung by Ken Matsudaira who is a Japanese actor. To compare the marked points in Fig. 6 (red circle), it is confirmed that both signals have the same frequency components at the same time. Incidentally the result of (b) is refined by the spectral subtraction to make the sound spectrogram more visible.

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