

## Orange luminescence from acoustic bubbles affected by electric fields

電場下キャビテーション気泡からのオレンジ発光

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### 1. Introduction

Sonoluminescence (SL) is light emission from collapsing bubble which was generated in liquid medium exposed to intense ultrasound.<sup>[1,2]</sup> High-temperature and high-pressure conditions inside collapsing bubble are realized. The SL from water consists of the OH-radical line emission and bremsstrahlung, the spectrum of which is continuous.<sup>[3]</sup>

We have obtained extraordinary light emission from Ne-saturated water in the measurement of multi-bubble sonoluminescence (MBSL) at 1 MHz. the light was orange and its spectrum showed a broad component peaking at about 713 nm and 813 nm. The intensity of the broad component gradually decreased towards ultraviolet region.

When we obtained the orange emission, the ground electrode of the transducer was partly peeled by cavitation erosion and was exposed to the sample. We confirmed the electric field leaked from the transducer to the sample. In this study, we present the results of measuring spectrum of the orange emission and discussed the mechanism of the emission.

### 2. Experiments

**Figure 1** shows the experimental setup. The sample liquid was deionized water degassed and saturated with neon or oxygen. The electric conductivity of the sample was 0.4  $\mu\text{S/m}$ . The sample of 270 mL volume was contained in cylindrical cell made of stainless steel.

The cell was equipped with a quartz-glass window and a piezo-ceramic focusing transducer of 1.0 MHz resonant frequency on the opposite side. The ground electrode of the transducer made of silver was partly peeled by the cavitation erosion and exposed to the sample. The temperature of the sample was kept at 10°C by circulating temperature controlled water. Continuous signal from a function generator was amplified using a power amplifier and applied to the transducer through the impedance-matched transformer.

The SL was captured with a digital camera with an exposure time of 20 s and a sensitivity of ISO 25,600 through the quartz-glass window. The SL from a specific location was collected using a

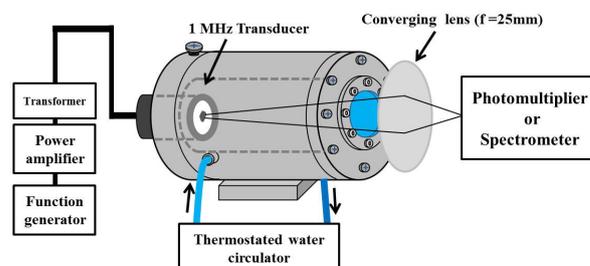


Fig. 1 Experimental setup

lens of 50 mm focal length. The SL was analyzed using the system consisting of monochromator and a cooled CCD detector with a slit width of 0.2 mm.

For measuring voltage leaked from the transducer having partly peeled ground electrode, we used a platinum-electrode probe with 1mm diameter and the oscilloscope.

### 3. Results and discussion

**Figure 2(a)** shows the front view of the transducer having a partly-peeled ground electrode. Fig. 2(b) shows the SL distribution captured with an electric power of 52 W from neon saturated water. The orange emission was observed at the central part and the normal SL was observed around of that. The shape of the orange emission in Fig. 2(b) is very similar to the peeled edge of the ground electrode shown in Fig. 2(a). It is considered that the orange emission arises from the boundary between the edge of the peeled electrode and the piezo-ceramics exposed to water.

From the measurement of the voltage leaked from this transducer, we confirmed that the electric field was leaked from the transducer into water. The

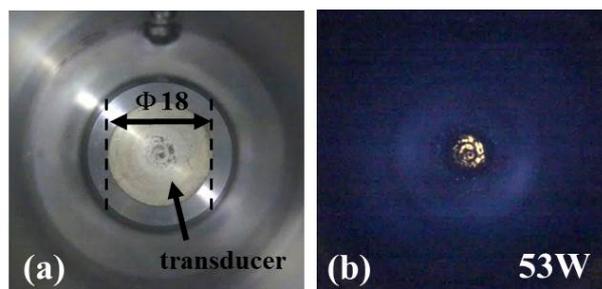


Fig. 2 SL distribution from Ne-saturated water. (a) is the front view of the transducer having partly -peeled ground electrode. (b) was captured at 53 W.

voltage leaked, in the case of the Fig. 2(b), was approximately 6.5 V at the surface of the peeled part. The leaked voltage decreased with increasing the distance from the transducer surface. The leaked voltage depended on the degree of the cavitation erosion on the transducer surface.

A probable mechanism of the orange emission is as follow. The electric fields are predicted to be large at the boundary between the peeled edge of the ground electrode and the piezo-ceramics. This affected on the cavitation bubbles which were located near the boundary. The cavitation bubbles which were affected by electric fields arose the orange emission.

**Figure 3** compare the spectrum of the orange emission. Fig. 3(a) shows spectra from Ne-saturated water with electric powers of 26 and 48 W. the spectrum consisted of two peaks about 713 nm and 813 nm and broad component which intensity gradually decreased towards ultraviolet region. The intensity of the spectra increased with increasing the applied electric power. The emission lines peculiar to neon gas were not observed. Fig. 3(b) shows spectra from oxygen-saturated water with electric powers of 20 and 47 W. The spectrum shows very similar to that from Ne-saturated water. No oxygen emission line was obtained. This suggests that the spectrum is from water molecular emission.

The bar graph in Fig. 3(c) represents vibrational levels of water molecule obtained by Kitagawa<sup>[4]</sup> from a flame emission of oxygen burning in hydrogen in the region of 550 nm-700 nm and by Gaydon<sup>[5]</sup> from oxy-hydrogen flame in the region of 700 nm-1,000 nm. The vertical scale indicates the intensity of the emission lines. The two peaks about 713 nm and 813 nm was close to the emission lines measured by Gaydon, and those lines are attributed to transitions from the vibration level (1, 3, 0), (1, 2, 1) to ground level (0, 0, 0), respectively. The levels ( $v_1, v_2, v_3$ ) indicate the three vibration modes of the water molecule that are symmetric stretch vibrations, deformation vibrations and asymmetric stretch vibrations in order. The two lines accompany vibrational-rotational transitions, which broaden the lines. The overall spectrum can be explained by the superposition of the vibration-rotational transitions which are broadened by high pressure condition at bubble collapse.

#### 4. Conclusion

We observed orange emission from water using a transducer, ground electrode of which was partly peeled. The origin of spectrum was attributed to vibrational-rotational transitions of water molecules. The emission is arose from the

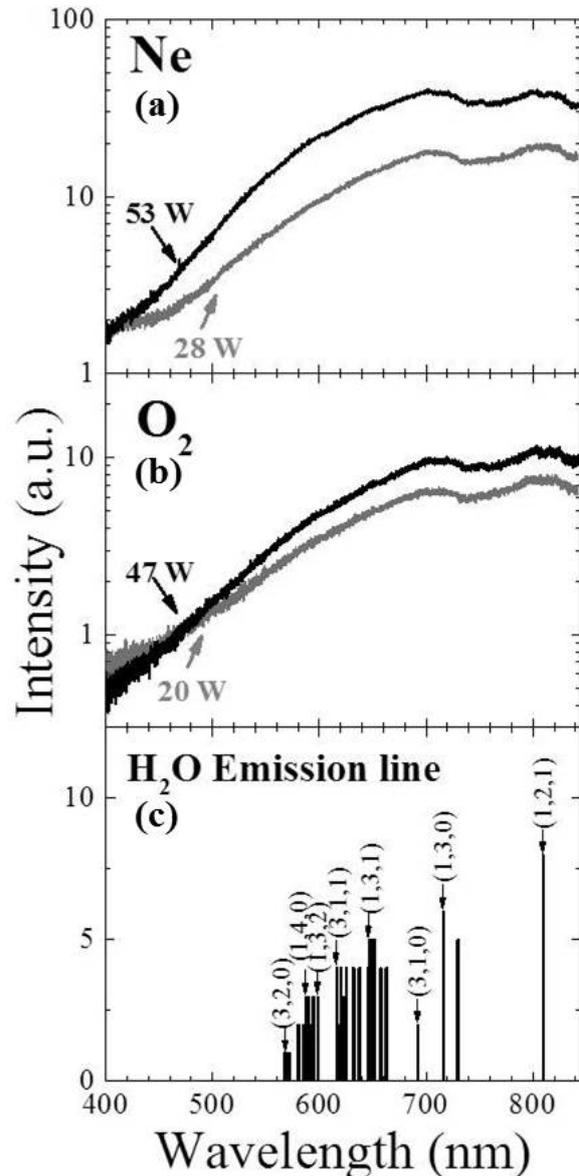


Fig. 3 Comparison of spectrum observed from Ne-saturated water (a), and from oxygen-saturated water (b) for two different input electrical powers. The bar graph in (c) shows the emission lines from a oxy-hydrogen flame measured by Kitagawa and Gaydon. Levels ( $v_1, v_2, v_3$ ) represent vibrational transition levels of water. The vertical scale indicates the intensity of the emission lines.

cavitation bubbles affected by electric fields. Additional research is needed to confirm the mechanism of the emission.

#### 4. References

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