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Measurement of vibration characteristics of quartz resonators in water

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1. Introduction

The laser speckle method is the most suitable method for measuring the vibrational state of piezoelectric resonators. Originally, it was used to measure piezoelectric resonators in air, but it has not been used for measurement in liquids, that is, using a quartz crystal microbalance (QCM). Therefore, the purpose of the experiment was to select a 33-MHz SC-cut crystal resonator as the measurement target and clarify the vibrational state in liquid [1]. Pure water was applied to the entire surface of the crystal resonator to clarify its vibration.

2. Measurement system

Fig. 1 shows the experimental system. The laser diode (LD) used for pulse modulation was from Tama Electric Inc. (wavelength: 660 nm, output power: 0.5 mW-10mW, and linear polarization). Since the optical fiber output of the ferrule is about 0.3 mm, a concave lens was used to irradiate the entire surface of the resonator with laser light, and the angle from the horizontal plane was set to 10 degrees. After capturing the crystal unit with a lens and extension tube, it was taken with a charge coupled device (CCD) camera. After performing image processing on a PC, a correlated image of laser speckle interference was obtained. A constant temperature bath was used for the container, and a temperature sensor was placed at a position about 10 mm from the crystal resonator. A heater was installed on the bottom, and the temperature range could be changed with the controller.

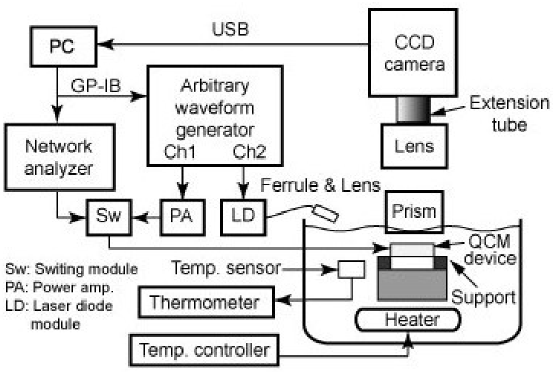

Fig. 1. Schematic of measurement system

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Fig. 2 shows the system used for image processing, which uses the laser speckle-pulse method [2]. This system calculates a correlation value by irradiating the laser when the drive voltage of the piezoelectric vibrator is positive and then irradiating the laser again when the drive voltage is negative. It is known that this correlation value has a high sensitivity of about 16 dB compared with the previously performed laser speckle-burst method [2]. The time required for measurement is about 20 seconds including correlation processing. The laser speckle pulse method and the QCM method were performed by using these experimental systems and correlation values.

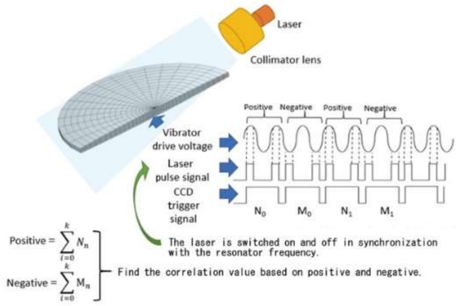
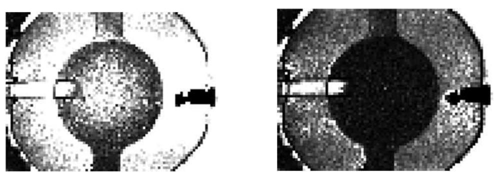


Fig. 2. Laser speckle-pulse method [2]

3. Measurement result

Figs. 3 (a) and (b) show the vibration displacement (pulse method) of the primary mode 33-MHz SC-cut crystal resonator C-mode in air [3]. The drive level was 12 dBm | 50 Ω, and it can be seen that good vibration displacement could be obtained. (a) represents the time when the resonator was driven, and (b) represents the time when it was not driven.



(a) driven (b) not driven

Fig. 3. Measurement results from correlation images of 33-MHz SC-cut crystal resonator in air [3]

In the water, an acrylic prism was used to suppress vibration from the outside. Since the Q value of the resonator decreases in water, an RF power amplifier is used, and its output is 30 dBm | 50 Ω. At the 12dBm|50Ω drive output shown in Fig. 3(b), we confirmed that there was not driven in the speckle image.

Fig. 4 shows the temperature characteristics of the resonator in water. The resonant frequency drops sharply at a temperature of 80°C, which is due to the influence of the spurious mode in the vicinity.

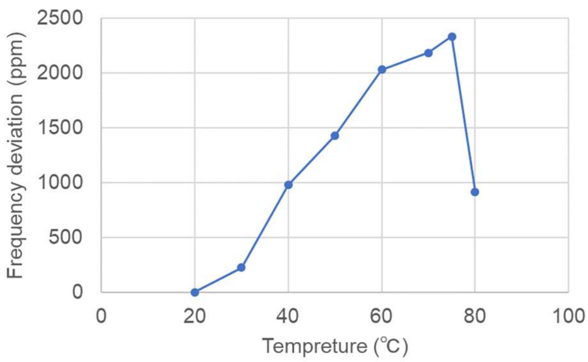


Fig. 4. Frequency deviation due to temperature change of SC-cut crystal resonator of C mode

Fig. 5 (a), (b) and (c) show the temperature characteristics at 20 °C, 75 and 80 °C, and at 20 °C they show almost the same results as in Fig. 3 (a), and at 75°C and 80 °C only the right-side resonators. This seems to be a composite of the spurious mode and the main mode.

(a) 20°C

(b) 75°C

(c) 80°C

Fig. 5. Measurement results of laser speckle pulse method: (a) 20°C, (b) 75°C and (c) 80°C

4. Conclusion and discussion

By devising a method to suppress external vibrations using an acrylic prism, it was confirmed that it was possible to perform measurements that were difficult to observe with the laser speckle pulse method. However, the ferrule and lens are in the air, and although the angle of incidence is 10 degrees, there is a reflection of the water surface, and the reflectance is about 30~40 degrees. It is predicted that this will be the error with respect to the horizontal axis.

As shown in Fig. 6, we want to waterproof the ferrule and lens and then measure again.

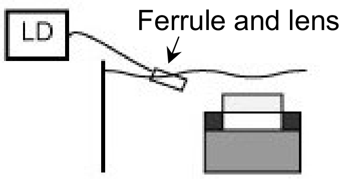


Fig. 6. Waterproof the ferrule and lens to bring it closer to the underwater QCM

Acknowledgments

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References

[1] Y. Sun et al., The 66th JSAP Spr. Meet., 2022.
[2] Y. Watanabe, et al., Jpn. J. Appl. Phys., vol. 41, pt. 1, no. 5B, pp. 3313-3315, 2002.
[3] K. Hara, et al., USE2023, 1P2-11, 2023.