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Measurement of 100-MHz SC-cut crystal resonators in liquid using laser speckle interferometer

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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 100-MHz SC-cut crystal resonator as the measurement target and clarify the vibrational state in liquid [1]. There is no record of using the laser speckle method for 100-MHz SC-cut crystal resonators. First, the C-mode of a 33-MHz SC-cut crystal resonator, which is the primary (1st) C-mode in air, was measured. Next, the results when only one side of the crystal resonator was immersed in pure water are shown. Furthermore, pure water was applied to the entire surface of the crystal resonator to clarify its vibration.

2. Measurement systems

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-10 mW, and linear polarization). Since the emission point of the LD alone 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 from ADC Corp. was placed at a position about 5 mm from the crystal resonator. A heater from Hakkosha Inc. was installed on the bottom, and the temperature range could be changed with the controller.

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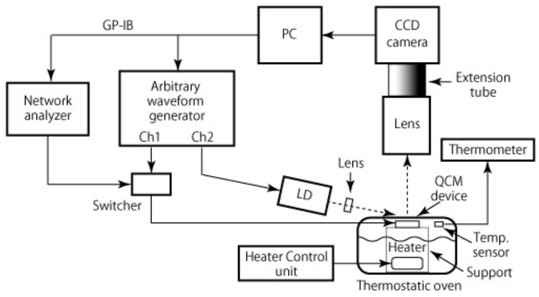


Fig. 1. Schematic of measurement system

Fig. 2 shows the system used for image processing, which uses the laser speckle-pulse method [2,3]. 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 [3]. 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.

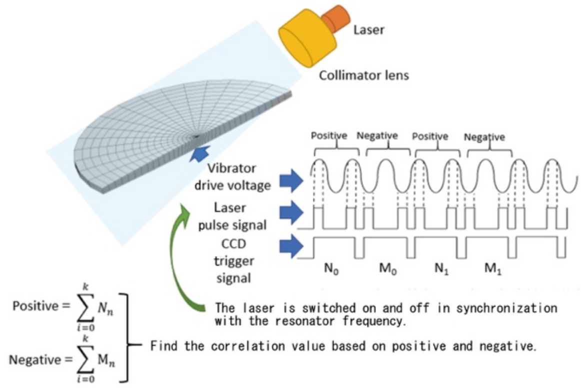
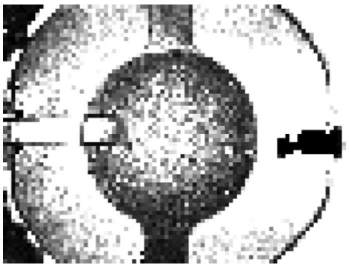
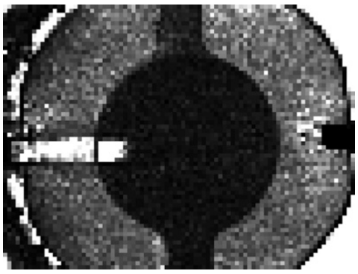


Fig. 2 Laser speckle pulse method

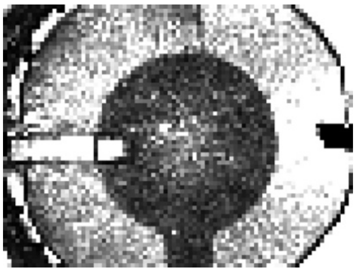


(a) 33.3 MHz (driven)

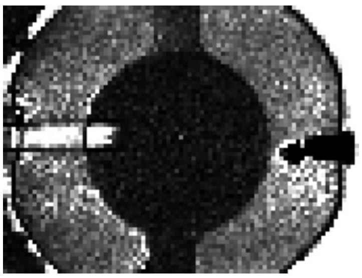


(b) 33.3 MHz (not driven)

Fig. 3. Measurement results from correlation images



(a) 100.0 MH (driven)



(b) 100.0 MHz (not driven)

Fig. 4. Measurement results from correlation images

3. Measurement results

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. 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 (the same applies hereinafter).

Furthermore, Figs. 4 (a) and (b) are measurements of the vibration displacement of the 100-MHz SC-cut crystal resonator C-mode. The drive level was slightly higher, 17 dBm | 50Ω. From this result, it can be seen that vibration displacement could be obtained even at 100 MHz.

Next, the result of only submerging the lower electrode in pure water without touching the upper electrode of the SC-cut crystal unit at 33 MHz is shown. The temperature was 25.0℃. Fig. 5 shows the result. Naturally, the resonance frequency of the crystal unit decreased. After filling pure water up to the upper electrode of the SC-cut crystal resonator, the same measurement, that is, of spurious vibration due to temperature change etc., is generally was performed.

Fig. 5. Measurement results in 33.3-MHz correlation image for pure water

4. Conclusions

As a result of measuring the C-mode of a 33-MHz SC-cut crystal resonator, which is the 1st C mode, with pure water, the main resonance mode was confirmed. In the future, we would like to confirm the same mode in an experiment that fills pure water up to the upper electrode of the 33-MHz resonator and inside a 100-MHz crystal resonator.

Acknowledgments

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References

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