Improving measurement system of laser speckle pulse method for observing vibrational modes in pure water

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1. Introduction

Laser speckle pulse method exists as a technique for observing high-frequency vibrations[1-7]. This method utilizes the scattering of laser light on the surface of the resonator, making it possible to easily observe the vibration mode. However, with the pulse method, the detection sensitivity changes significantly as the measurement conditions change. In this study, the optimal measurement conditions for the pulse method were determined by relative evaluation of detection sensitivity.

In addition, to examine the change in the vibration mode due to the change in the resonance frequency in water, we attempted to observe the vibration of the crystal resonator in water using the pulse method[8-10]. This time, we would like to report that we have devised a method to realize our ideas in the Laser Speckle method in water.

2. Measurement principle

In the laser speckle method, vibration is observed from the correlation of speckle patterns in two states. **Fig. 1** shows a correlation image obtained by the laser speckle method, and vibration modes can be observed from this image. The white area of the image is the area where the correlation of speckle patterns of the two states are low and vibration are observed.

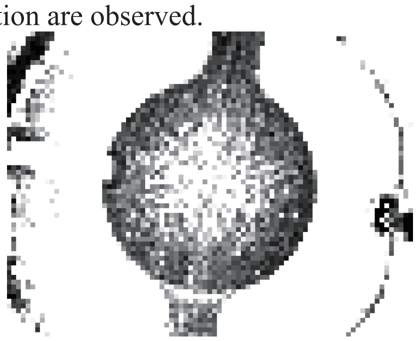

Fig. 1 Correlation image in air

Fig. 2 shows the pulse method. In the pulse method, the resonator is constantly driven. The pulse laser is irradiated at a certain phase of the resonator's driving voltage and at a phase 180° offset from that phase. Laser scattering occurs on the resonator surface and speckles are observed. The speckle pattern changes as the irradiation surface changes. The vibration was observed from the correlation of speckle pattern images obtained from these two phases.

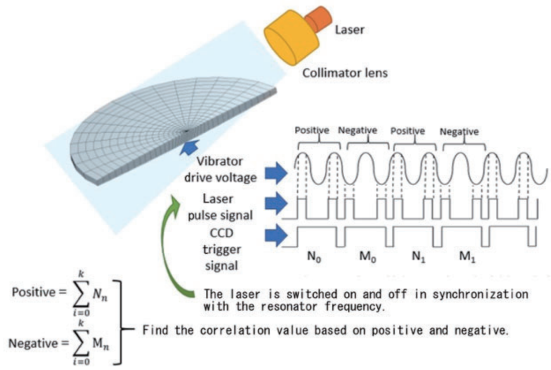

Fig. 2 Laser speckle pulse method

When creating a correlation image, the reciprocal of the correlation value is used, and this value was used for the relative evaluation of detection sensitivity in this study.

3. Measurement system

Fig. 3 shows the system used to obtain the results of the measurements.

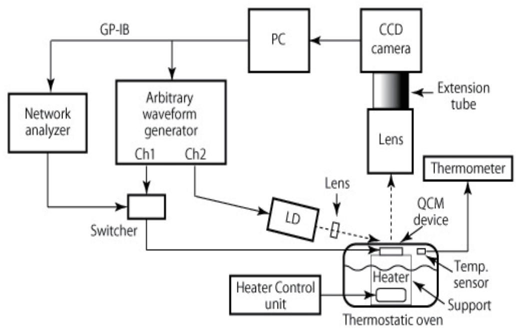

Fig. 3 Measurement system of pulse method

A SC-cut crystal resonator was used, the resonance frequency was about 33.35 MHz, and the drive voltage was 15 dBm in air and 17 dBm in water. Thickness-shear vibration was observed. Due to its nature, the central area of the resonator vibrates the most. The detection sensitivity was evaluated by comparing the average value of the reciprocal of correlation value within the central 50×50 pixels of

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a 512×680 pixel correlation image obtained for each measurement condition.

4. Measurement results

Fig. 4 shows the changes in the reciprocal of the correlation value as the phase angle of the laser pulse, relative to the resonator drive voltage, is changed. **Fig. 5** shows the detection sensitivity changes when the duty ratio of the laser pulse is changed at the phase angle where the reciprocal of the correlation value is the highest during the measurement as the phase angle is changed.

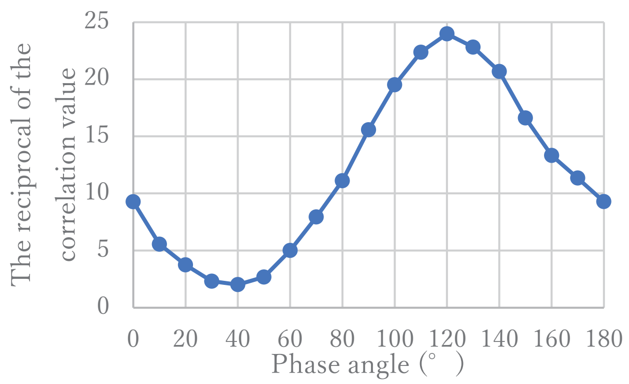

Fig. 4 Rreciprocal of correlation value with pulse method, phase angle: 0~180°

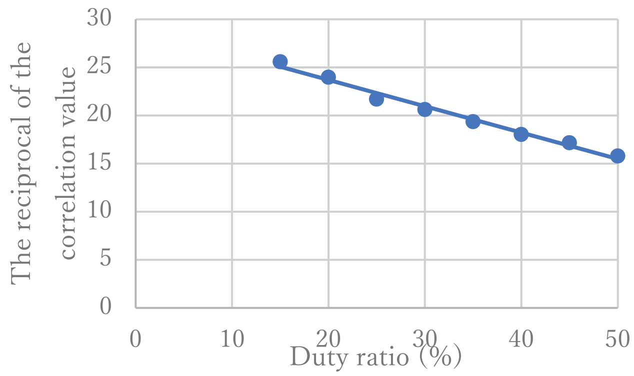

Fig. 5 Rreciprocal of correlation value with pulse method, duty ratio: 15~50%

In the pulse method, the detection sensitivity changes greatly by changing the phase angle, so it is necessary to conduct measurement at the optimum phase angle. When measuring at the optimum phase angle, it was found that lowering the duty ratio increases the detection sensitivity.

Based on these measurement results, we determined the optimum measurement conditions for the phase angle and duty ratio, and tried to measure the vibration of the oscillator in water. When the vibrator was immersed in water, it became difficult to obtain laser speckles, and the vibration could not be observed.

5. Conclusions

Based on these measurement results, we improved the location of the transducer and the laser oscillator. We are planning to try the vibration observation again by further improving the measurement system such as **Fig. 6**.

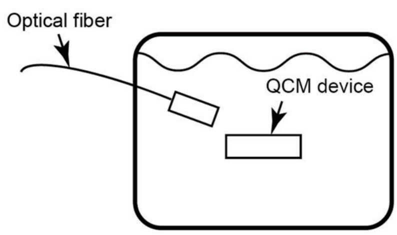

Fig. 6 Improve the measurement system

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