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Improvement of laser-pulse methods in piezoelectric device analyses using laser speckle interferences

Laser Speckle 干渉を用いた圧電デバイス振動子解析におけるレーザパルス法の改善

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1. Introduction

Quartz crystal oscillators are used in various electronic devices such as smartphones and PCs. A laser speckle method is used for irradiating the oscillator with a laser and observing the state of vibration from the speckle[1-5]. The pulse method is used to accurately acquire a correlation image of the speckle pattern using a laser pulse proportional to the drive voltage of the crystal unit[4]. However, there are many unclear points regarding this method, such as the optimum phase angle of the laser pulse with respect to the drive voltage of the crystal unit.

Through experiments, we obtained the optimum phase angle of the laser pulse with respect to the drive voltage of crystal resonators to obtain data that are the basis of the pulse method.

2. Measuring principle

In contrast to the burst method, in which the surface of the oscillator is irradiated with a laser and the state of vibration is observed from the correlation between the laser speckles when the oscillator is driven and not driven, the pulse method shows that the oscillator is constant. The speckle pattern is observed by irradiating the laser at the point where the amplitude of the drive voltage is maximum and the point where the drive voltage is the minimum and determining the correlation of the laser speckle.

By acquiring an image when the vibration displacement becomes maximum, it was possible to observe the vibration with a very high detection sensitivity compared with the burst method, as shown in Fig. 1.

3. Measuring system

The measurement was conducted using the system shown in Fig. 2. To evaluate the detection sensitivity, the speckle pattern on the surface of the vibrator was acquired with a charge coupled devises (CCD) camera, and the acquired image was correlated by the reciprocal of the correlation function to obtain a correlated image.

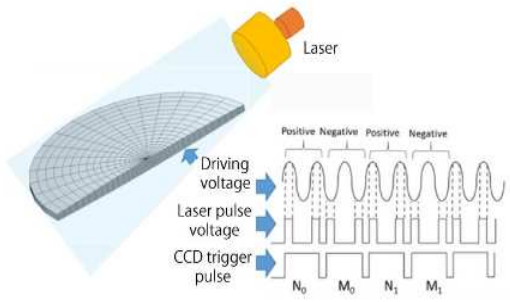

Fig.1 Principle of pulse method of laser speckle interference.

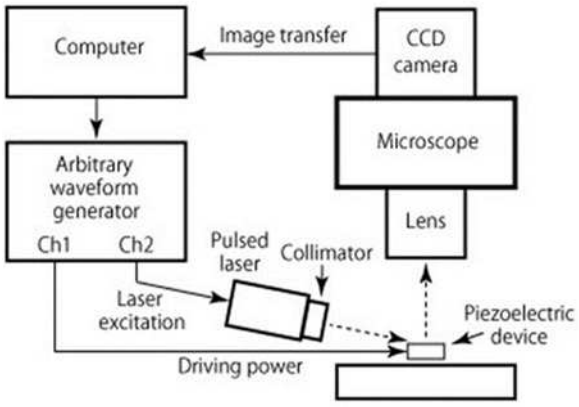

Fig.2 Schematic diagram of measurement system[5,6].

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Figure 3 is a correlation image of the speckle pattern acquired with the pulse method, and the high-luminance point is the portion where the vibration was observed.

This evaluation was conducted by comparing the average 1/correlation in the region with the central part 50x50 pixel of the correlation image which has 512 x 680 pixels. The 1/correlation is from 1 to ∞, and if it is large, the observed vibration displacement is also large and the detection sensitivity is high. The phase angle at which this value is maximized was taken as the optimum phase angle.

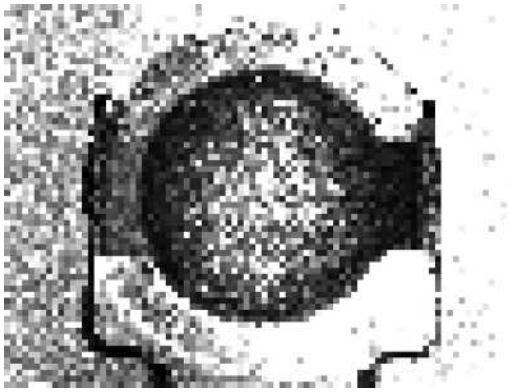

Fig.3 Correlation image with pulse method.

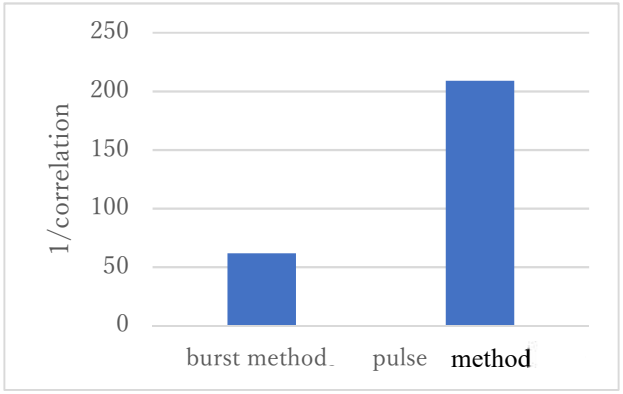

Fig.4 1/correlation of pulse and burst methods.

4. Measuring results

Figure 4 compares the detection sensitivities of the pulse and burst methods at a phase angle of 90°. There was a difference of about 4 times in the average 1/correlation. This confirms that the pulse method has higher detection sensitivity than the burst method. The phase angle of the laser was also changed in steps of 10° from 0 to 180° with the pulse method for measurement.

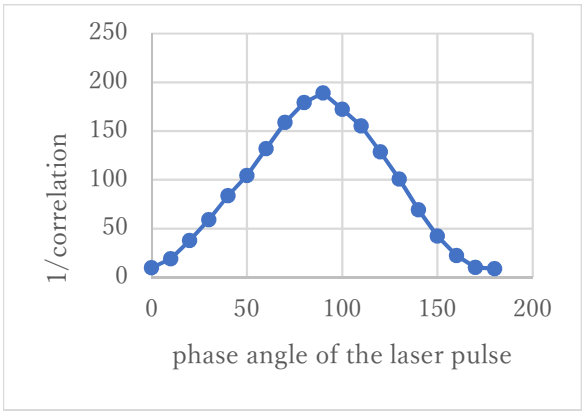

Fig.5 1/correlation with pulse method, phase different: 0~180°

Figure 5 shows that the phase angle of 90° is the optimum phase angle with the highest average 1/correlation. We determined the optimum phase angle by changing it from 0 to 180° with the pulse method.

5. Conclusion

We determined the importance of measuring at the optimum phase angle from the difference in detection sensitivity between the optimum and non-optimal phase angles. However, the optimum phase angle changes due to slight changes in conditions, so further research is needed.

Acknowledgement

This work was supported by JSPS Grants-in-Aid for Scientific Research Grant Number 17K06466.

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