2Pa2-4

Measurement of polished surface vibration displacement of piezoelectric resonators in laser speckle interferometers
レーザスペックル干渉計における圧電振動子の鏡面振動変位の絶体測定

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1. Introduction

Various techniques use the laser speckle interference method to visualize the surface of a piezoelectric device[1)]. In recent years, piezoelectric devices with mirror-finished surfaces have enabled portable devices to operate at higher frequencies. For example, the interference method is used to test the polished surface of a quartz crystal resonator for unevenness.

In previous research, laser speckle interference was obtained by incidence at a 16-degree incidence angle, and a red laser (λ = 630 nm) was used to accurately measure a polished surface[2)]. However, the incidence angle cannot be made horizontal in order to measure in-plane vibrations. A technique is still needed to accurately measure the absolute vibrational displacement of laser speckles during laser speckle interference.

In this study, we attempted to measure the absolute displacement of a polished surface using a laser Doppler vibrometer and measure the surface for laser speckle interference with an external ceramic resonator. A 456-nm violet laser was used as the laser speckle interferometer.

The results verified that the laser Doppler vibrometer and the laser speckle interferometer are related through image correlations and the absolute displacement of the piezoelectric resonators was obtained.

2. Experimental system

Fig. 1 shows a block diagram of our proposed measurement system with a 456-nm violet laser[3)]. A glass-paneled device is installed as a substitute for piezoelectric material, and the center of the device is measured by a laser Doppler vibrometer. A vibration device is observed by a CCD camera. After the device vibrates, the vibrations are multiplied by on and off frequencies and then treated as an image correlation value. The image correlation

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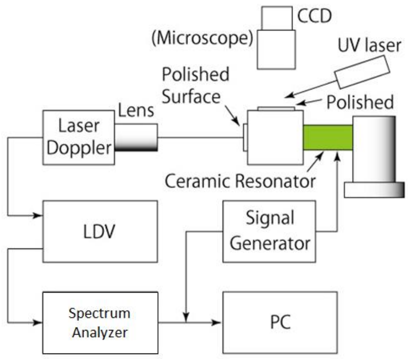

Fig.1. Laser Doppler vibration meter system and Laser Speckle interferometer [5)]

value is obtained by the following equation (1) and **Fig. 2** shows an example of the image correlation[4)].

The image takes the inverse $(1/\rho(i_0,j_0))$ of the correlative value. The white parts contain the largest vibration displacements, while the black parts contain minimal vibration displacements.

$$\rho(i_0,j_0)= \frac{\sqrt{\sum_{i=i_0-(M/2)}^{i_0+(M/2)}\sum_{j_0-(N/2)}^{j_0+(N/2)}\left|a_{i,j}-\overline{a}\right|^2\sum_{i=i_0-(M/2)}^{i_0+(M/2)}\sum_{j_0-(N/2)}^{j_0+(N/2)}\left|b_{i+l,j+m}-\overline{b}\right|^2}}{\sum_{i=i_0-(M/2)}^{i_0+(M/2)}\sum_{j_0-(N/2)}^{j_0+(N/2)}\left(a_{i,j}-\overline{a}\right)\left(b_{i+l,j+m}-\overline{b}\right)} \qquad (1)$$

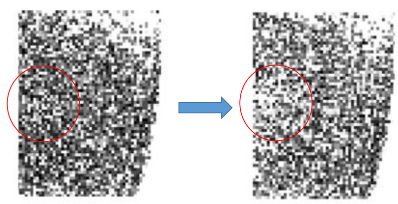

Fig. 2. Example of correlative image of speckle pattern.

Fig. 3 shows an outline of the laser speckle interferometer based on equation (1) and Fig. 2. This system uses a laser pulse method and is able to measure the entire surface in approximately 20 seconds.

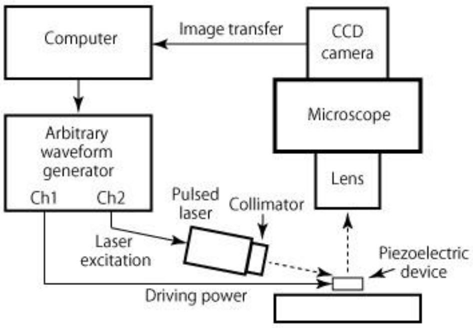

Fig.3. Laser Speckle interferometer system

3. Experimental results

Fig. 4 shows the measurement results of the mirror surface in Fig. 2[4]. The incident angle was 10.5 degrees due to the reflection from speckle interference. The surface was measured 400 times and the results were averaged. **Fig. 5** shows the laser speckle interferometer measurement based on Fig. 2. The measurement is indicated by the inverse of the correlative value to an axis of abscissas with displacement in the axis of ordinates.

Fig. 6 shows the quartz crystal resonator of 4 MHz AT-cut using the laser speckle interferometer shown in Fig. 3[5]. When the inverse number of the correlation is in the center part of the quartz crystal resonator, a maximum 1.2 value is obtained at 0 dBm drive power. The maximum absolute displacement was determined to be about 10 nm.

4. Conclusion

We clarified the absolute displacement of the piezoelectric (quartz crystal) resonator by combining the laser speckle interferometer with laser Doppler measurement. The measured maximum absolute displacement value was about 10 nm.

Acknowledgment

I would like to express my deepest gratitude to Prof. Tagawa who offered to the laser Doppler vibrometer. This work was supported by Grant-in-Aid for Scientific Research 17k06466 in the Ministry of Education, Culture, Sports, Science and Technology.

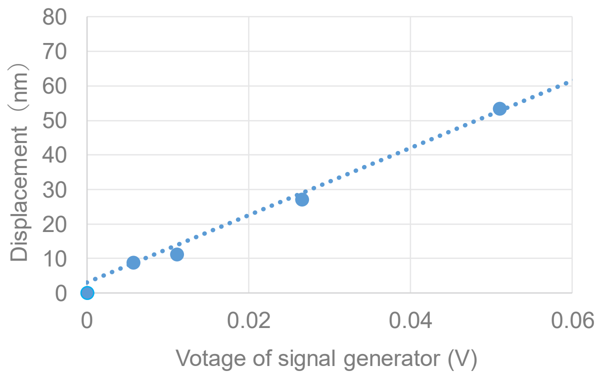

Fig. 4. Measured results of laser Doppler vibration meter for Fig. 1.

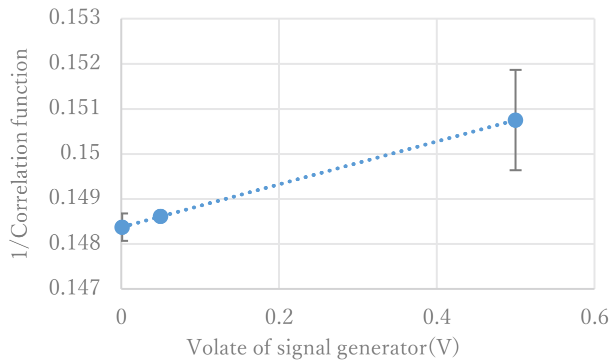

Fig. 5. Laser speckle interferometer measurement based on Fig. 2.

Fig 6. AT-cut 4 MHz quartz crystal resonator using laser speckle interferometer.

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