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Study of Mirror Device Using Piezoelectric Bending Vibrators

圧電横振動子を用いたミラーデバイスの検討

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1. Introduction

Recently, the mirror device for optical deflection used for a mobile projector etc. has attracted attention. The some constructions are proposed as such a device, the problem that the deflection angle of a mirror is small is pointed out.[1)] The authors have advanced research about the acceleration sensor using the frequency change of a bending vibrator by axial force.[2-9)] In this vibrator, the vibration displacements at both ends are very small.[10,11)] For this reason the vibrator has high quality factor and large vibration amplitude because the leakage of vibration energy from the supported portion becomes very small. If such a vibrator is used as an actuator for driving the mirror of the device, a coupling phenomenon is not observed between two vibrators and the constructed device will become more stable for support.

In this research, the example of one-axis construction of such a mirror device is proposed, and the device is designed using the finite-element analysis. Moreover, the possibility of realization as a mirror device is investigated.

2. Structure and Vibration Mode of Vibrator

Fig. 1 shows a bending vibrator and its vibration mode used for a mirror device. The first or second out-of-plane mode which vibrates to the z axis direction of the vibrator is used in this device. The first mode is shown as an example in the figure. In the vibrator, the ratio u_z/u_{z0} of the displacement u_z of both ends to the maximum value u_{z0} of the z axis direction at the center portion of the central arm is designed so as to become about 10^{-4}.

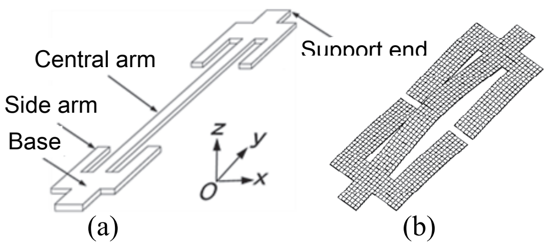

Fig. 1 Structure and vibration mode of vibrator.

3. Construction of One-Axis Mirror Device

Fig. 2 shows an example of one-axis construction of the mirror device. In this construction, two bending vibrators shown in Fig. 1 are used and the mirror is connected by connecting bars at the center portion of the central arm of the vibrator as shown in the figure. The vibrators vibrating with out-of-phase mode result in a rotation angle of the mirror around the y axis. Because the vibrator with very small displacements at both ends is used, the displacements at the support portion of the device also become small after construction of the device and the coupling phenomenon between the two resonators are hardly observed. Here, the device is made of stainless steel (SUS304), and its external dimensions are about 29×21.8×0.5 mm^3.

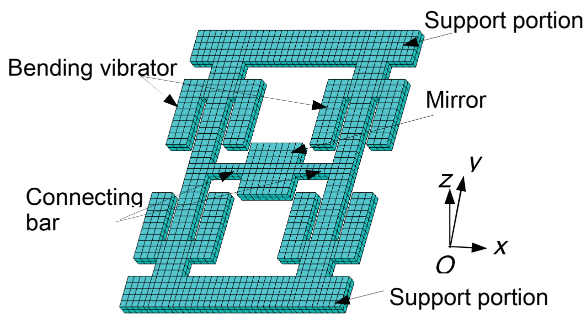

Fig. 2 Construction of one-axis mirror device.

4. Drive by Piezoelectric Ceramics

The device in Fig. 2 is driven by bonding piezoelectric ceramics to the upper surface of the vibrator. The design of the device should be realized in consideration of the influence of the bonded ceramics. First, the maximum displacement ratio u_z/u_{z0} of the both ends of the metal vibrator is designed so as to become about 10^{-4} before construction of the device independently. Next, the metal device in Fig. 2 is constructed using these two vibrators. As a result, the displacement ratio at the support portion of the device increases slightly, so the ratio is designed to the value of about 10^{-4} by adjusting the side-arm length of the vibrator.

Fig. 3 shows a connection diagram for the piezoelectric drive of the device shown in Fig. 2. As shown in the same figure, two small ceramics (5.2×2.0×0.2 mm^3) are bonded at a time to the upper surface of each vibrator. The ceramics are bonded inversely on either side of the vibrator to change the

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direction of a polarization as shown in the figure. As a result, the two vibrators are mutually vibrated with out-of-phase.

Moreover, Fig. 4 shows the analyzed result of a lengthwise strain characteristic on the upper vibrator surface. The length and bonding position of ceramics were determined from the result of Fig. 4. The device is inserted into a self-oscillation circuit, and used by controlling of the vibration amplitude.

On the other hand, the displacements at the support portion increases by bonding the ceramics. Then, the displacements at the support portion were decreased again so as to become about 10^{-4} by adjusting the side-arm length of the vibrator.

Fig. 5 shows the operation principle of the device of deflecting light on the mirror. Moreover, Fig. 6 shows an example of the device of trial production. The resonance frequency of the device is about 11.0 kHz.

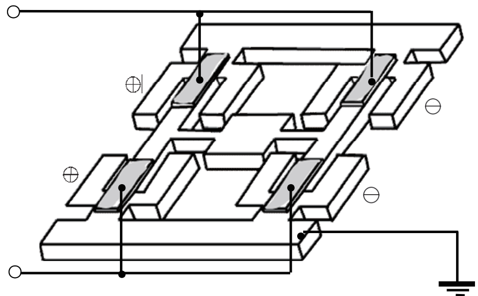

Fig. 3 Connection diagram for piezoelectric drive.

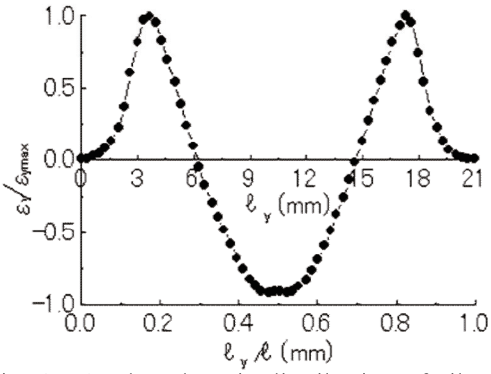

Fig. 4 Analyzed strain distribution of vibrator.

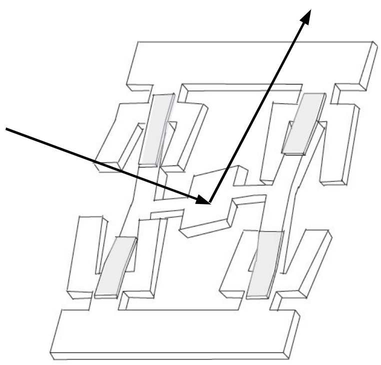

Fig. 5 Deflection of light by mirror device.

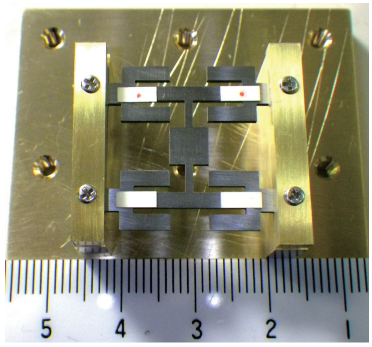

Fig. 6 Example of device of trial production.

5. Conclusions

A new mirror device was proposed using the bending vibrator which is used to the frequency-change-type acceleration sensor, and investigated by the finite element method. The obtained results are summarized as follows.

(1) As the displacement ratio at the support portion of the device increases in comparison with the ratio of the bending vibrator itself, the ratio can be decreased by adjusting the side-arm length of the vibrator.

(2) As the displacement ratio at the support portion of the device increases by bonding piezoelectric ceramics, the ratio can be decreased similarly by adjusting the side-arm length.

(3) The proposed mirror device having the merit that the displacement at the support portion becomes very small and therefore a coupling between two vibrators is not observed can be constructed.

The device for enlarging a mirror angle is considered now. Moreover, the knowledge acquired here is utilized and also the construction of two-axis device is considered.

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