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Simultaneous Achievement for X, Y Movement and Θ Rotation of Stage with Straight-Move Ultrasonic Vibrators ― Application to Microscope ―

直線動作振動子によるステージの X、Y 移動とΘ回転の同時実現― 顕微鏡への応用 ―

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1. Introduction

In this paper, taking stage of optical microscope as an example, we have proposed a novel ultrasonic motor to achieve both X- and Y-directional movements and Θ-angle rotation simultaneously. Shapes and cut angles of piezoelectric materials and directions of driving electric fields have been investigated to design various movements and rotations in conventional ultrasonic motors. Our proposed motor has a new basic structure constructed with straight-move shafts attached to vibrators. We have also developed peripheral circuits which supply driving voltages with arbitrary amplitudes and phases. Combining above structure and the circuits, small circular / elliptic vibrations for tips of shafts were achieved, which drive the stage to move and rotate simultaneously.

Straight-movement of back and forth can be achieved by a shaft attached to bimorph. One unit consists of three *x*-, *y*- and *z*-directional shafts connected perpendicularly to one another. Arbitrary circular / elliptic / straight micro-movements can be synthesized by controlling amplitudes and phases of driving voltages for bimorph vibrators. Three units are arranged at apexes of an equilateral triangle with 120 degree apart to one another. Discrete circuit technique is used to generate driving voltages in the experiment, because each driving voltage should be controlled independently.

Proposed motor is constructed with three units and a transparent stage is put on them for convenience. Framework of each unit was made by 3D printer. X, Y movements of the stage were achieved by applying voltages with different amplitudes and phases to all bimorphs. Θ rotation of the stage was achieved by applying voltages with same amplitude and phase to all *x*- and *y*-bimorphs, while different voltages were applied to *z*-bimorphs. Very clear rotation of the stage was observed. The technology can be applied to more complicated machines.

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2. Fundamental structure of proposed motor

2.1 Required X, Y movement and Θ rotation

As shown in Fig. 1, an optical microscope requires not only X-, Y-directional movements but also Θ-angle rotations for the stage. Our ultrasonic motor aims at achieving these movements and rotations simultaneously.

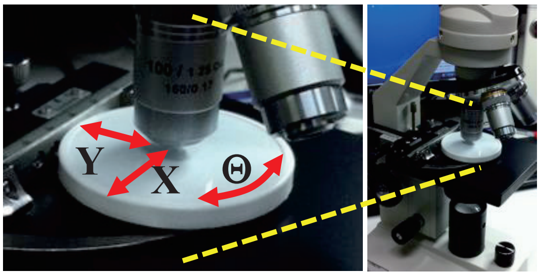
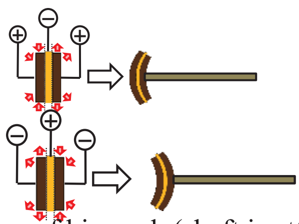
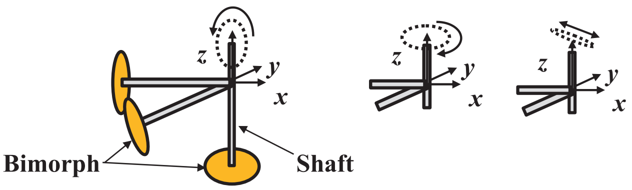


Fig. 1 Required X-, Y-directional movements and Θ-angle rotations by optical microscope.

2.2 Generation of micro-motions to shaft tips



(a) Vibration of bimorph (shaft is attached to it).



(b) Micro-motions of shaft tip (circular, elliptic and straight).

Fig. 2 One unit consisting of three perpendicularly connected shafts with bimorphs.

A shaft is attached to bimorph which forms convex / concave deformations (Fig. 2(a)). Three shafts are connected perpendicularly to make circular / elliptic / straight micro-motions by controlling amplitudes / phases of driving voltages to bimorphs (Fig. 2(b)), which forms one unit.

2.3 Motor constructed with three units

Three units are arranged at apexes of an equilateral triangle to support a movable stage illustrated in Fig. 3. The shaft tip of each unit can provide micro-motion independently. The stage can move and rotate in any direction by three independent micro-motions. Each unit was made by 3D printer (right of Fig. 3).

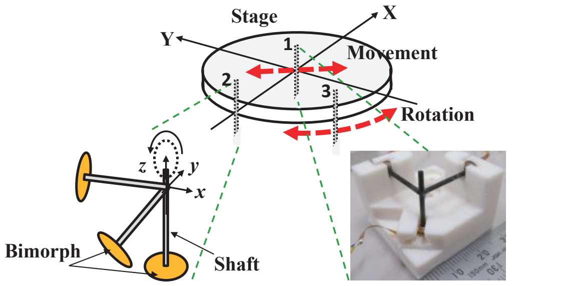


Fig. 3 Stage supported by three units: each unit is made by 3D printer (right).

3. Experimental setup and driving voltages

Experimental setup is shown in Fig. 4. To obtain Fig. 2(b)'s circular / elliptic / straight micro-motions of the shaft tips, amplitudes and phases of driving voltages were synthesized. Advances in peripheral circuit technology have been remarkable, which makes it possible to provide IC-type driving circuits in near future. But in the experiments, we used rather primitive discrete circuit technique to obtain combinations of any amplitude levels and any phase values.

Examples of driving signals at 70 kHz to achieve micro-motions of shaft tips at two dimensional x-y plane are shown in Fig. 5. In the figure, 4 synthesized phases, 0°, 90°, 180° and 270° are illustrated compared with 0°-standard signal. Exactly 90° mutually shifted signals are obtained. Phase differences of 0° and 180° correspond to staight motion of shaft tips. Those of 90° and 270° correspond to CW and CCW circular motions. We can achieve not only phases but also amplitudes, which can't be illustrated due to space.

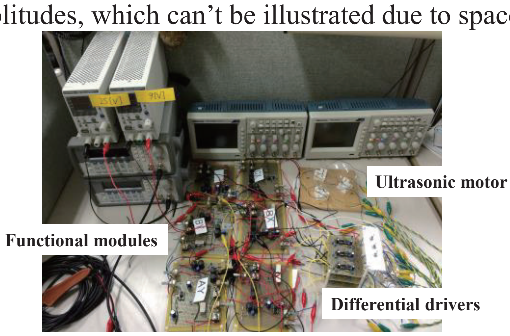


Fig. 4 Experimental setup to achieve X, Y movement and Θ rotation.

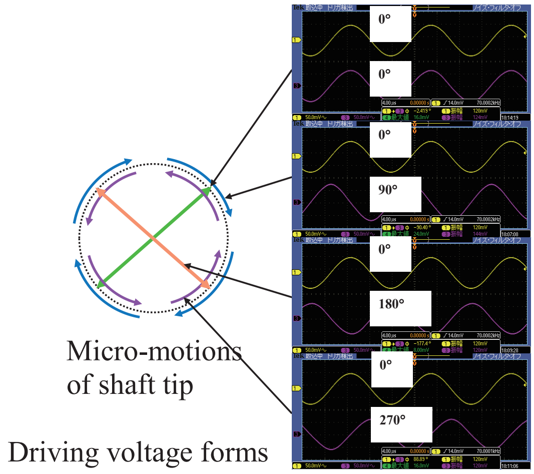
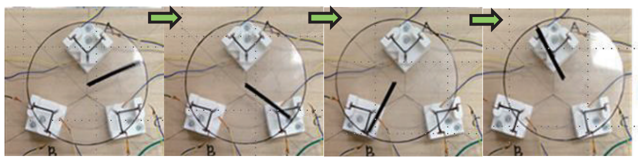


Fig. 5 Examples of driving voltages (phases) for micro-motions of shaft tip at x-y plane.

4. Fundamental experiments

In order to verify the proposed X-, Y-directional movements and simultaneous Θ-angle rotations, we conducted a basic experiment using Fig. 4's setup. We introduced a transparent stage for experimental convenience. X- and Y-directional movements are shown in Fig. 6(a) and (b) respectively. A slight bit of rotation occurred during X-directional movement. On the contrary, ideal Θ rotations are obtained as shown in Fig.6(c). These results show the possibility of simultaneous movement and rotation.

(a) X movement (b) Y movement



(c) Θ rotation

Fig. 6 Experimental results for movements and rotations.

5. Conclusion

We have proposed novel ultrasonic motor with X, Y movements and simultaneous Θ rotations. Feasibility check based on fundamental experiments using three pairs of perpendicularly connected shafts showed possibility of proposal.

References

1. T. Sakayachi, Y. Nagira and M. Hikita, in Proc. of USE Vol.35, pp.97-98, 2014.