Magnetic Levitation Based Nanopositioner

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Nanopositioning and nanomanipulation stages have been in high demands in the last decade. The manufacture of nanoscale devices and their manipulation is essential for the development of the next-generation nanotechnology [1]. The miniaturization of existing manufacturing technologies requires a high-precision positioning stage for the manipulation and fabrication of nano-sized objects. The stage must be able to travel in all directions, and position and orient the object at the desired position with minimum error. This requires high accuracy, large travel range, and simultaneous generation of multi-DOF motions and high control bandwidth.

Figure 1 is a photograph of the maglev system we developed. This magnetic levitator has the minimum number of actuators necessary and sufficient for 6-DOF motion generation. Its specifications and dynamic performances include 0.212-kg moving-part mass, 2-nm precision in horizontal motion, 300-μm travel range, 3-*g* acceleration, maximum payload mass of 400 g, higher than 90-Hz control bandwidth, and 15-mW power consumption per horizontal actuator in steady state.

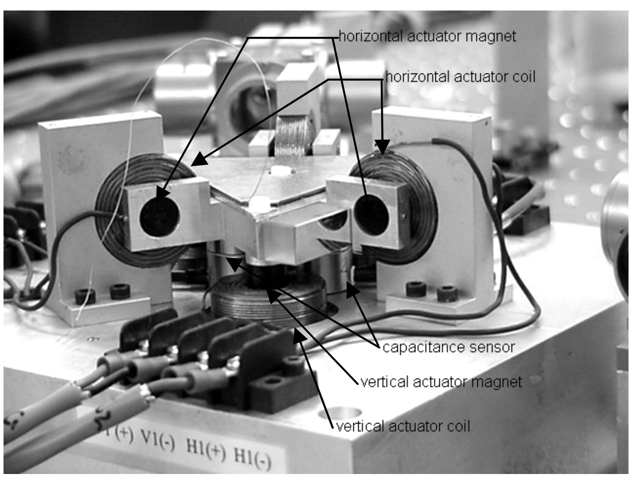

Figure 1. The 6-DOF maglev stage

The triangular part in the center is the platen that is levitated with the help of 3 vertical linear actuators. Maintaining the stiffness high, the mass of the platen was reduced by pocket milling, leaving ribs on the edges and center. On the top surface of the platen there is a viscoeleastic passive damping layer covered by a constraint layer to damp the vibration from resonance. There are 3 sets of protrusions on the sides of triangular platen to hold six magnets for 3 horizontal actuators. These magnets are surrounded by 3 horizontal coils to complete the horizontal actuation scheme of x-y translation and rotation about z. On the three corners of the triangle on the bottom side there are three magnets attached with spacers. These magnets are surrounded by three vertical coils that are attached to base plate with coil holders. This set of coil and magnet forms three actuators and generates motion in the vertical direction. The bottom surface of the platen is used as the target of the capacitance gap sensors, so it has been ground to a surface roughness of 2.54 μm. Three plane mirrors are fixed on the sides of the platen by a 127 μm thick double-sided tape.

Figure 2 shows a 3D trajectory followed by the platen layer by layer in the way as desired for microstereolithography (μSTL) to prove this maglev stage's positioning capability in micromanufacturing. The generated shape is of an impeller that has an outer radius of 25 μm and inner radius of 10 μm. The maglev stage was made to follow this whole 3D motion trajectory in only 18 s, although the platen would need to be moved much slower in an actual μSTL process to allow sufficient time for the photopolymer to cure. These experimental results demonstrate the microscale 3D motion-generation capability of the maglev stage.

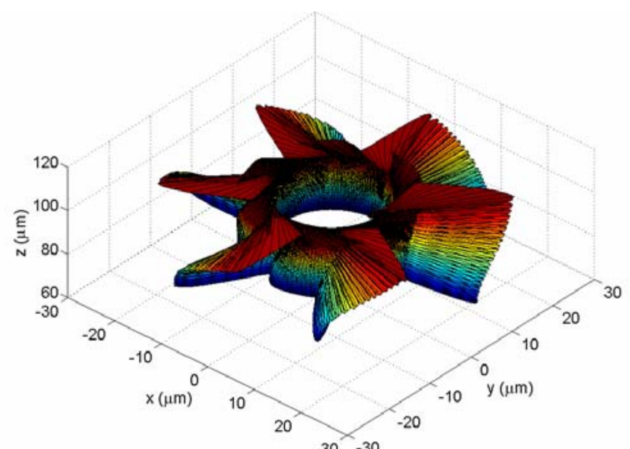

Figure 2. A 3D impeller shape traversed by the platen

Acknowledgements
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References

[1] C. Bauer, A. Bugacov, B. E. Koel, A. Madhukar, N. Montoya, T. R. Ramachandran, A. A. G. Requicha, R. Resch, and P. Will, "Nanoparticle Manipulation by Mechanical Pushing: Underlying Phenomena and Real-Time Monitoring," *Nanotechnology*, vol. 9, pp. 360–364, 1999.