

Ultra-Precision x-y-Stage on AMBs

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Abstract: This paper presents concept and design of a magnetically levitated x-y-z stage combining high precision and large displacement strokes (up to the cm order). The platform, uses inductive sensors for coarse positioning and interferometers for the fine sensing, ultimately at sub-nm resolution . It is not yet operational, but preliminary measurement results will be shown at the symposium. Possible applications include usage as a sample stage for scanning probe metrology.

1. Introduction

High-precision x-y–supports on flexure hinges suffer from limited stroke. In many microengineering applications such as instrumentation, metrology, steppers as well as for machining and manufacturing, a combination of precise, back-lash–free motion with large strokes in at least the two horizontal degrees of freedom is necessary. In addition, this should be combined with significant movements in vertical (z–) direction and at least some limited angular freedoms. A magnetically levitated platform is ideally suited to meet all these requirements. Such platforms have been proposed in [1] and built for special purposes by several companies.

The mechanical design of the x-y ultra-precision platform presented here allows significant freedom of movement in all six degrees of freedom. Relatively large (cm order) strokes are possible in x- and y-direction. Angular motion strokes cover a few degrees and motion-stroke in z-direction is in the order of millimeters.

At present it uses inductive sensors for coarse motion. Laser interferometry combines sub-nanometer resolution and accuracy with long range measurements.

Heterodyne laser interferometers [2], [3] have therefore been designed for x–y–z– displacement measurement. Optical tilt detection with four-segment photodiodes is performed with the same laser beams. All this optical sensing is now in the process of being put into operation in hard– and software step by step.

One possible application in perspective at our Institute is use as a scanning probe microscope sample stage for metrology. An AFM operating in non-contact mode with a PZT cantilever [4] is currently being built.

Once the AFM is operating on a sample placed on the magnetically levitated platform, it is conceivable to include the AFM signals [1] in the control of the sample stage position, e.g. to realize an ultra-flat x-y motion platform.

Thermal drift is reduced by careful placement of the coils of the magnets far away from the sample being scanned. The coils below the sample stage are only for stabilization during transients, they need not to be considered as heat sources as their operating point is at $i=0$.

Figure 1 shows the setup of the optical path and the actuator magnets suspending the platform. A precisely machined glass cube near the sample carrier with polished mirror surfaces reflects the laser beams of the interferometers.

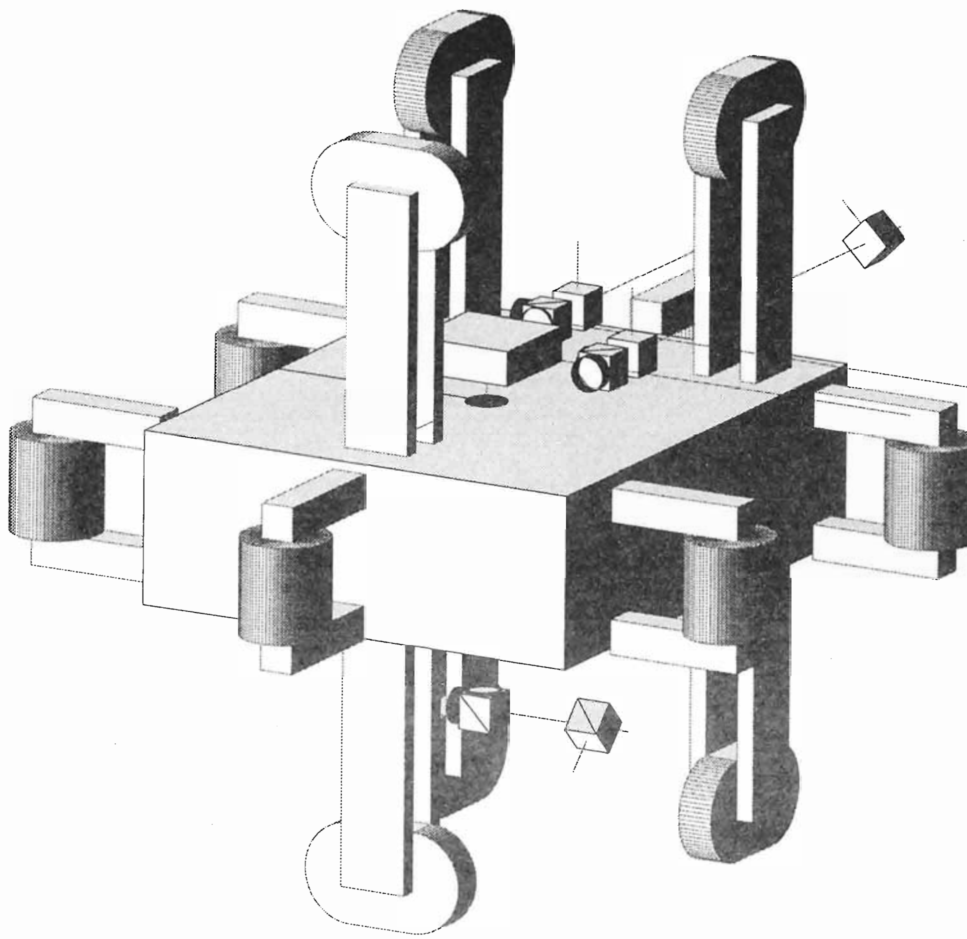

Figure 1. Setup of the magnetically suspended platform with laser interferometry position sensing. The yokes of the electromagnets are long in order to keep heat sources far away from the plateform. The magnets below are only active during transients.

2. Position and angle sensors

The six inductive sensors measuring x, y_a, y_b, z_a, z_b and z_c (fig. 1), are used as preliminary and coarse sensors. The optical system directly measures tilt angles and displacements of an accurately machined and polished glass cube near the sample carrier, above the center of gravity. The angles are obtained by sensing the reflected laser beams with 4-segment photodiodes. This is much more accurate than the values computed from the inductive sensors, but the angular range is smaller.

For linear displacement x_p, y_p and z_p (fig. 1), heterodyne laser interferometers are used. Light source and fringe interpolation technique is the same as Yamada et al [2]. The resolution of this sensor was about 0.1 nm in 1kHz bandwidth. However, our environment is not as good as that of [2], so we may not obtain such a high resolution. The so-called balanced-detection technique [2], [3], is used to reduce cyclic non-linear detection error. The system has two heterodyne laser sources (He-Ne, 633 nm), one for the x-y-direction and one for the z-direction.

The alignment technique of the three dimensional configuration of the interferometer is the same as Fujii et al [5]. The interferometer is a relative displacement sensor and is not used to stabilize the platform at startup. It is used only in conjunction with the coarse sensor.

3. Control structure

The control plant consists of the platform and the magnetic actuators along with the voltage–to–current amplifiers.

A digital controller is used to stabilized and control the motion of the platform. It has been designed on Matlab/Simulink™ and implemented on a C40 DSP using dSpace™ real-time interface.

At the input of the ADC, there are the six inductive sensors-, three four-segment photo–diodes and three interferometry- signals. The inductive sensors are used to stabilize the platform at start-up and for coarse positioning. The optical sensors are used during operation to obtain a higher accuracy. The control structure is decentral with PID algorithms at the core.

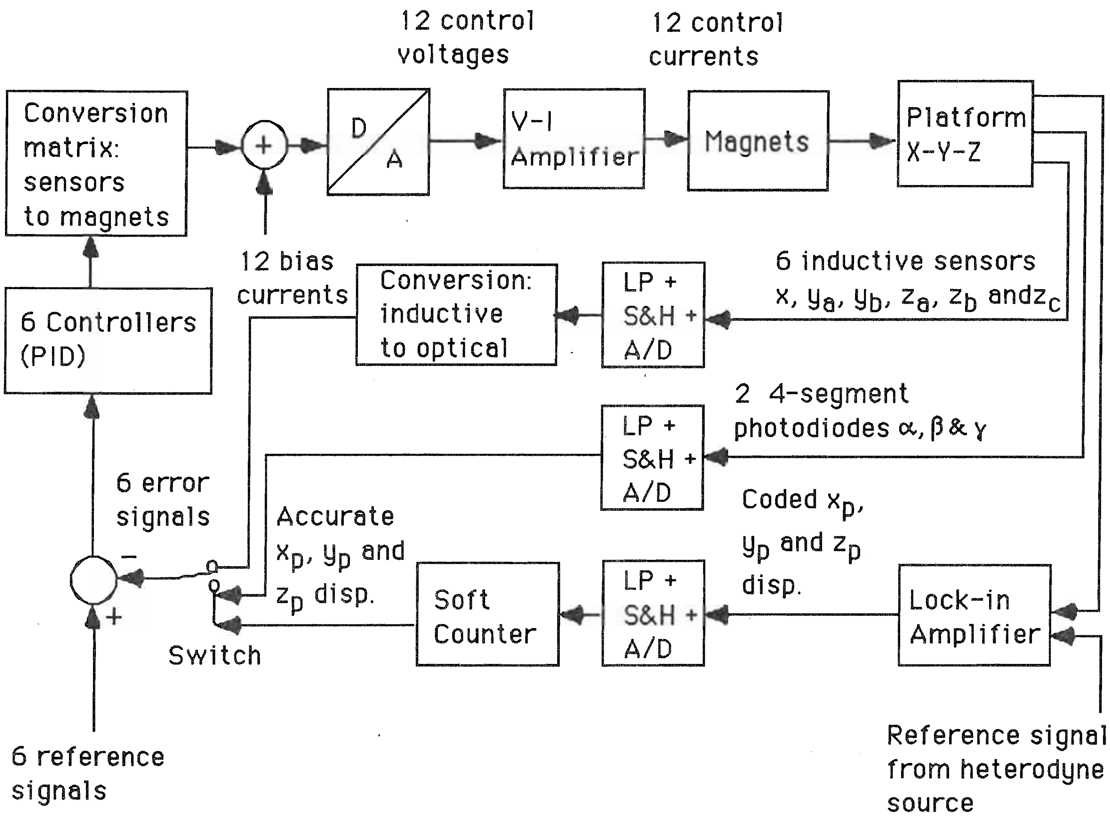

Figure 2. Control schematics of the 6D Magnetic Bearing

4. Present status

The plateform is not yet operational. The components have been manufactured and partially tested. The switching of an AMB from inductive to interferometric sensing is now being tested on a one-degree op freedom system. We hope to present first measurement results at the symposium.

Acknowledgments

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