Rotating MagLev sample manipulator

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Abstract

In synchrotrons, beamline samples are measured on a positioning stage. Current systems typically use stacked stages based on piezo technology. Due to increased throughput and performance demands, MI-Partners has developed an electromagnetically actuated sample stage. Hereto, a rotating sample manipulator has been designed and built, that shows a new type of magnetic levitation, where in one rotation direction an infinite movement is possible.

For tomography in a synchrotron beamline, two typical sample scanning strategies exist:

- Continuous rotation scan. The system should make rotations around the center but also off-center. The latter is needed to perform a scan around a point that is not in the center of the sample.
- 2D scan at a fixed rotation of the stage. Hereto, the stage should hold a position at a certain angle and perform a 2D translational scan perpendicular to the beamline.

A demonstrator has been built that is capable of performing these two scanning strategies, while controlled in six degrees of freedom (DOF). Since it is magnetically levitated, no contact exists between the rotating and the fixed world, which would have caused particle generation. The system has a stroke in the X and Y (in-plane) directions of +/-1.5 mm. Also, in the vertical (Z) direction the stoke is +/-1.5 mm. In RX and RY the goal is to keep the rotor in upright position, i.e. to keep it at zero degree. No active stroke is foreseen in that direction. In RZ direction, the movement is infinite.

Layout

A schematic representation in shown in Figure 1 and a picture of the system in shown in Figure 2. The system consists of a hollow rotor on which the sample is mounted. This rotor includes the magnets of the six actuators that can apply contactless forces in the six degrees of freedom. The coils are mounted on a balance mass (BM) to reduce the effects of the reaction forces of the actuator towards the rest of the system. The rotor is positioned in six DOF towards a sensor frame (SF). This frame is suspended to the baseplate (BP) in order to reduce the influence of floor vibrations. To enable in-plane motion of the rotor +/- 1.5 mm, the sensors are placed on a movable metrology frame (MF) that is integrated into the sensor frame. This MF follows the rotor in the in-plane translational directions with a small stroke and is mounded towards the SF using three folded leafsprings. This allows to have a stiff suspension in the out-of-plane directions and obtain compliancy in the in-plane direction. Three actuators between SF and MF allow for a force in the three in-plane directions.

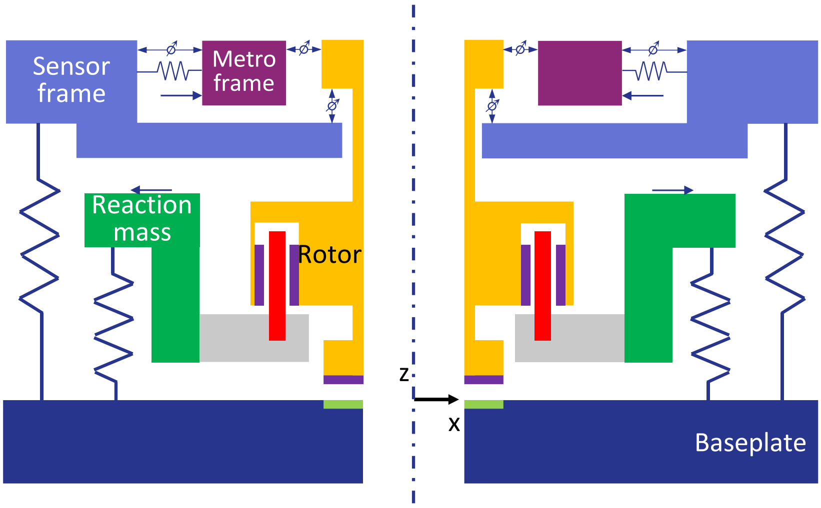

Figure 1 Schematic overview of the layout of the Maglev sample manipulator.

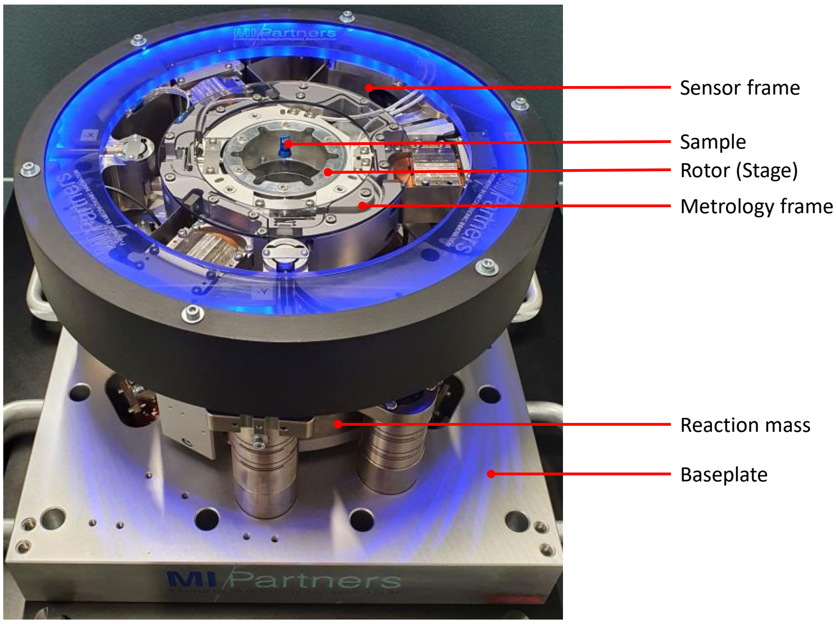

Figure 2 Picture of the Maglev sample manipulator.

Measurement principle

Measurement and control are done with respect to the sensor frame. In the out-of-plane directions, the rotor is directly measured to the sensor frame. Currently, this is done with eddy current sensors. However, to improve accuracy, these will be replaced by interferometers in the future. In the in-plane direction, no direct measurement between rotor and SF is possible, due to the stroke in X and Y direction. See Figure 3 for a schematic representation for the in-plane directions. The rotor is measured in the in-plane directions towards the metrology frame using two capacitive sensors in X and Y direction and a rotational encoder in RZ direction (MF2RO sensors in Figure 3). The metrology frame is sensed in the in-plane directions towards the sensor frame with eddy current sensors, that also will be replaced by interferometers in the future (SF2MF sensors in Figure 3). The target surface of the MF is flat such that no cross talk between motion in X and measurement and Y direction occurs and vice versa. The X and Y directions are the critical directions. Therefore, in those directions, the SF2MF sensors are placed in line with the MF2RO sensors.

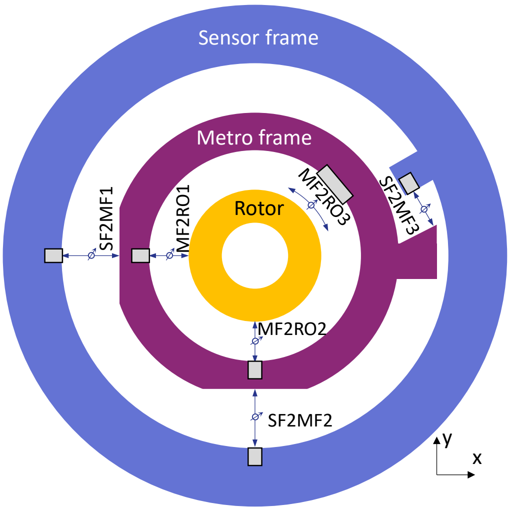

Figure 3 In-plane measurement layout.

By combining the SF2MF and MF2RO sensor signals, it is possible to control the rotor towards the sensor frame. A bandwidth of 120 Hz has been obtained. The MF is controlled in X and Y direction towards the rotor to guarantee a constant gap between the rotor and the MF. The bandwidth of the MF is of less importance than the bandwidth of the rotor control and is set to 50 Hz. Furthermore, in RZ direction, the MF is controlled towards the SF at 50 Hz. This ensures the X and Y SF2MF sensors to be aligned with the X and Y MF2RO sensors.

Conclusion

A rotating magnetically levitated sample manipulator has been built that floats contactless in 6 DOF. In RZ direction, the movement in infinite. In the translational directions, a stroke of +/- 1.5 can be made. This allows on one hand for a 2D scan at a certain rotational position. On the other hand it also allows for an infinite rotation both around the center of the stage and .off-center. In the future, the eddy current sensors will be replaced with interferometers. Then, the expected positioning performance is in the order of 20 nm (3σ). With this performance, such a system can be used in tomography in a synchrotron beamline.