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Development of Customized High Precision Optical Table for X-ray Imaging Application in Material & Life Sciences

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Abstract. The design of a high precision optical table for the IMAGE beamline at the synchrotron radiation source ANKA by the Institute for Synchrotron Radiation, ISS,at the Forschungszentrum Karlsruhe will be presented. The IMAGE beamline will be devoted to x-ray imaging applications in material and life sciences. This experimental station for micro-tomography is planned to be installed which requires one suited customized optical table with specific characteristics. Table dimensions: Length (1) 2000 mm; Width (w) 800mm; Height (h) 900mm. Over the last fourteen years ADC has developed many high precision motion systems in collaboration with major synchrotron and neutron facilities around the world. [1,2]

Keywords: Optical, table, beamline, exchanger, precision, micro-tomography, spectrometer
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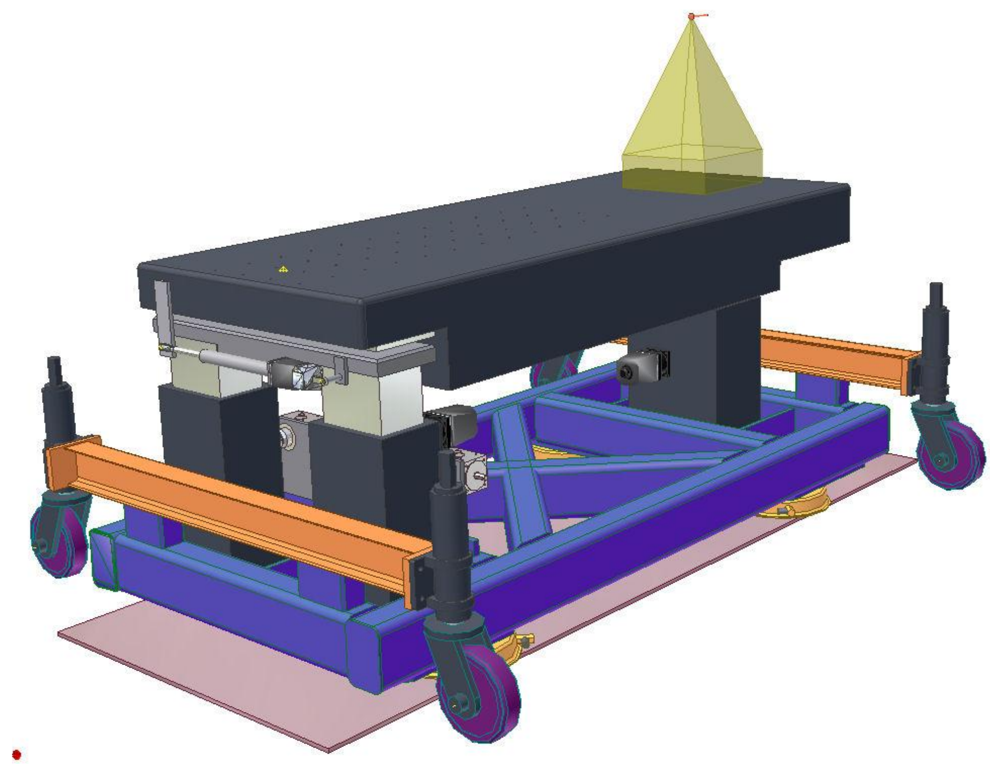

FIGURE 1. Customized High Precision Optical Table

INTRODUCTION

Design

The table in Figure 1 consists of a large, black granite top, with working surface measuring 2000 mm by 800 mm, flat within .1 mm, and containing a grid of M6 holes for mounting required items. The granite is 254 mm thick and weighs 1200 kg, thus providing a highly stable platform for sample stages, detector, 205 kg detector translation system, and the fast sample exchange system. Total loading on the table will be up to 1500 kg. It must remain stable within 1μm for up to 3 hours. Removable jacking casters are provided for transporting the system from receiving areas to test and acceptance areas and then to the final destination. Within the hutch, the table will be periodically moved off line when other kinds of experiments are scheduled. For this purpose, air bearing supports are provided under the frame for ease of movement on the smooth marble floor. In order to avoid the need to survey the table back in parallel to the beam when it is returned to operation, motorized yaw adjustment of +/- 3 degrees is provided. The yaw motion is centered on the nominal sample position. Transverse location of the sample is accomplished within the stack of sample stages. Additional requirements for table movements to accommodate various experiments include motorized vertical movement of 200 mm with a resolution of 0.01 mm, and 2 degrees of pitch movement with a resolution of 0.005 degrees. The center of pitch rotation is directly below the sample. Under the sample is a single jack with capacity of 25 kN and interfacing the table with a spherical plain bearing. At the downstream end there are two jacks with capacity of 10 kN each and tied together with a common drive motor. The interface to the table consists of a line of ball transfer units, ensuring that the table is level transverse the beam.

All axes are motorized, use encoders and equipped with mechanical limit switches. The display resolution of the encoder surpasses the positioning resolution of the corresponding motion. All the other characteristics are listed in Table 1 below.

TABLE 1. System Specification

Stability	1 μm/3hours in all directions		Surface flatness	< 0.1 mm over the whole surface
Surface material	Single granite block		Mounting holes	M6 screwing holes on 100 mm grid
Damping	Passive damping system		Maximum load	1500 kg

Height movement (Tz) ±100 mm around the nominal height Resolution: < 0.01mm Repeatability: < 0.1mm Speed: 0.5 mm/s	Pitch (Ry) & Yaw (Rz) ± 3 degree around the nominal zero position Resolution: < 0.005 degree Repeatability: < 0.01 degree Speed: 0.5 degree/s

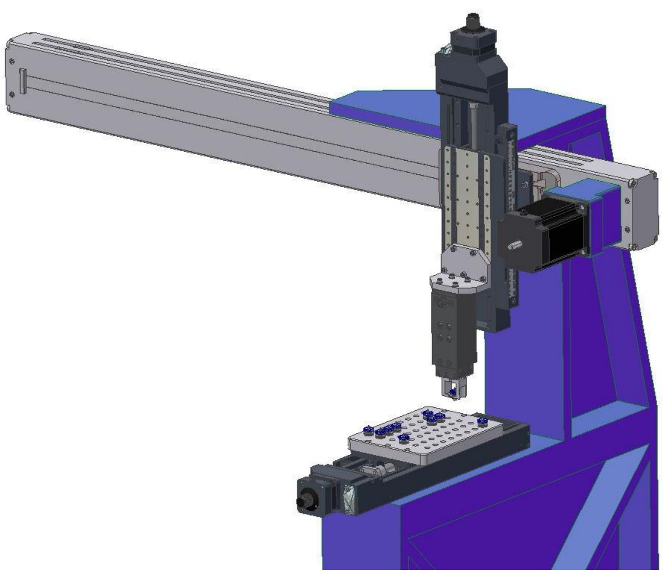

FIGURE 2. Sample Exchanger

Tomography experiments require the sample, shown in Figure 2, to be rotated in the beam while data is taken. It is important for the sample to be located on the center line of the rotation so each sample must be adjusted within its holder. This is a time consuming function so it is not done during beam time. ADC provides sample holders with a spherical locating feature that features light friction during adjustment and then is securely clamped. A sample tray with an array of up to 49 samples may be preset for measurements. During beam time, the ADC fast sample exchange system moves individual samples from the sample tray to the measurement location which is on top of a stack of translation, tilt, and rotation stages, and then back again. See Figure 3 below. The exchange system can load samples in a predetermined sequence and it is triggered by the measuring system, while also providing TTL signals to indicate completion of its tasks. The gripper is activated by a pulse to an electromagnet and remains gripped until another pulse releases it. Vertical motion is accomplished by a standard ADC slide, which is driven by a stepper motor and can accommodate samples of various heights. Transverse motion is approximately 500mm by stepper motor. The sample tray is mounted to a standard ADC slide to present various rows of samples of the sample tray to the gripper. Total cycle time to exchange a sample is in the order of 7 seconds.

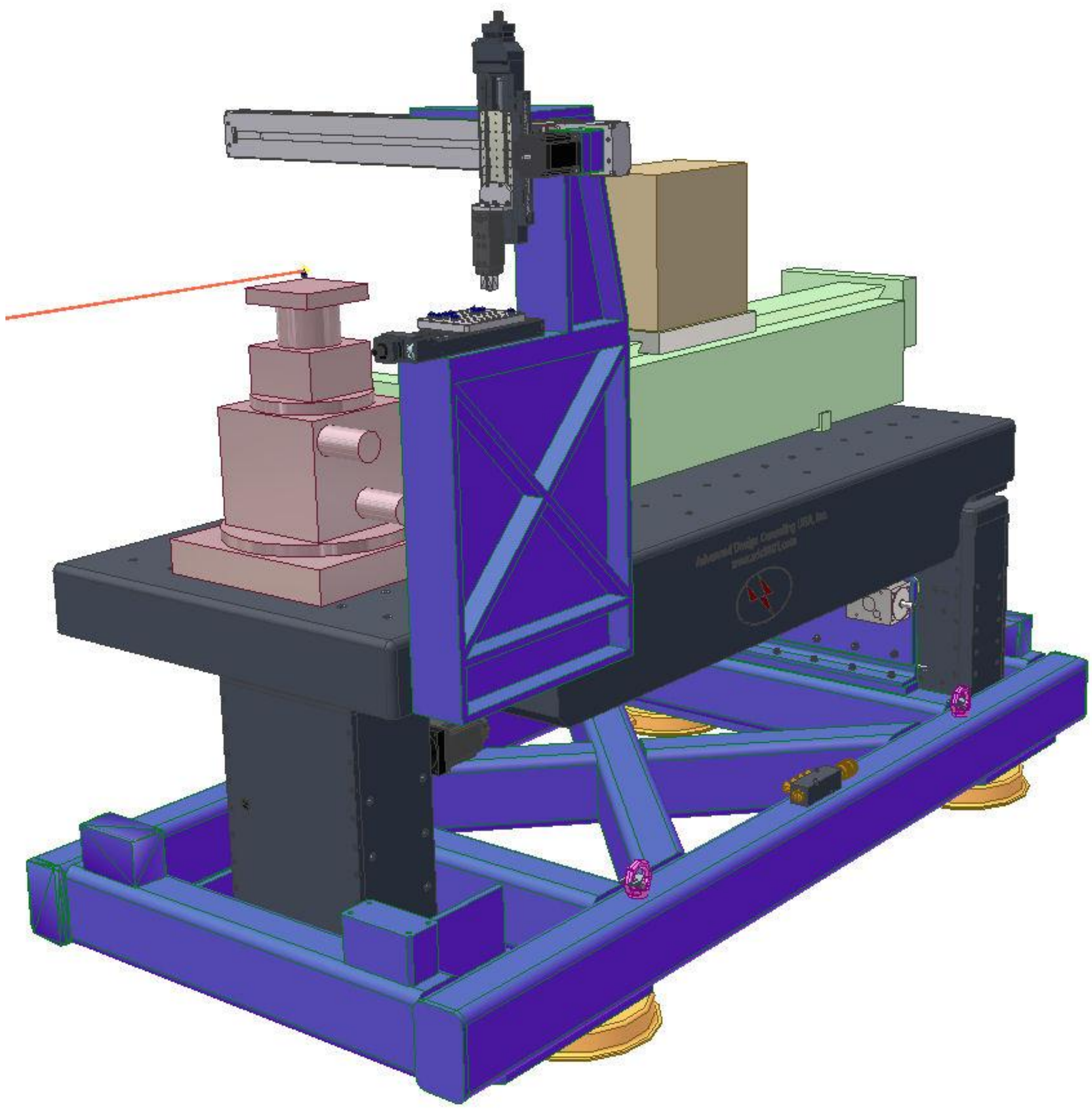

FIGURE 3. Sample Exchanger Mounted on a Table

The brakes used by the jacks are manufactured from Inertia Dynamics, LLC and are electric powered spring applied brakes. The MPC series brake used on the jacks is a power-off brake module with an output shaft. The unit mounts on a C-Face motor and the output can be coupled to a C-Face gear reducer. Ideal for creating brake-motor packages on stepper frame motors. The brake comes in a variety of voltage outputs with the ADC standard being 24VDC.

Numerik Jena's miniaturized encoder is a high-performance linear encoder scanning head that uses chip-on-glass technology allowing it to only measure 6 mm high and has max sensor speed of 10 m/sec. Combined with the Numerik Jena tape scale, it produces a very high-accuracy linear encoder. The digital unit provides A-quad-B output with resolution of 0.5 µm. The signals generated by the measuring module are automatically corrected within the sensor without following error over the entire velocity range. This measure not only increases the accuracy, but also the reliability of the encoder. Manufactured from stainless steel, the linear encoder has grating periods of 20 µm, accuracies from ±1 µm, and measuring lengths up to 30 m.

ADC uses a bipolar 2-phase stepper motor manufactured by Lin Engineering. These steppers motors are known for their high torque and great repeatability. A stepper motor is a brushless, synchronous electric motor that can divide a full rotation into a large number of steps. The motor's position can be controlled precisely, without any feedback mechanism i.e. open-loop. ADC uses a Lin Engineering 5718 series high toque bipolar stepper motor in a NEMA 23 package.

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