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MAGSTAT V3: AN IN-VACUUM VARIABLE-GAP QUADRUPOLE WITH ROTARY PERMANENT MAGNETS

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Abstract

MAGSTAT is a quadrupole designed to magnetize samples with a variable magnetic field in flow density and in directions. Four rotary permanent magnets allow the user to specify a direction for the field and changing in situ the gap between the poles drives the field intensity. The first prototype was realized in 2016 on the SEXTANTS beamline in the framework of SOLEIL-MAXIV collaboration; a second version has been manufactured for MAXIV SoftImax beamline. This third version shows a significant evolution of the mechanical design, guaranteeing a much better stiffness in high field configurations. Samples up to Ø74mm can be placed in this quadrupole, and the tiny ones which may fit in a Ø10mm circle or smaller, can be magnetized with a 1T local field. The angle of each magnet is driven by a dedicated stepper motors with a big reduction ratio. The total gap is ensured by a single motor, and its motion is symmetrically transferred to the magnets through an Archimedean spiral. The first prototype is installed permanently at COMET endstation dedicated to the coherent scattering of soft X-ray in transmission for imaging magnetic materials via the Fourier Transform Holography or ptychography techniques.

SPECIFICATIONS

The initial specifications were:

- The quadrupole should fit in CF100 DN flange so it can be transferred to or removed from the sample through the CF100 vacuum chamber fittings.
- The horizontal magnetic field should be driven by four motorized rotating magnets, with a variable motorized gap.
- The magnetic field should reach ~1T, at minimum gap on the center of the quadrupole.
- All motorized movements should be encoded.

FIRST AND SEDOND MAGSTAT PROTOTYPES

Mechanical Description

In order to drive magnets rotations, each magnet has a dedicated UHV stepper motor and is coaxially mounted on it. The maximum field of 1T is reached only when gap of the magnets is about 12mm, with Ø26mm permanent magnets made of NdFeB. The closest motor size is Ø22mm, with the highest reduction ratio, the output torque is 1.5N.m.

Each motorized magnet block is mounted on a linear translation oriented towards the centre of the poles. To drive the four linear translations, the motorized magnets mounts are locked in a double Archimedean spiral (green part in Fig. 1) path which crosses the translation path [1].

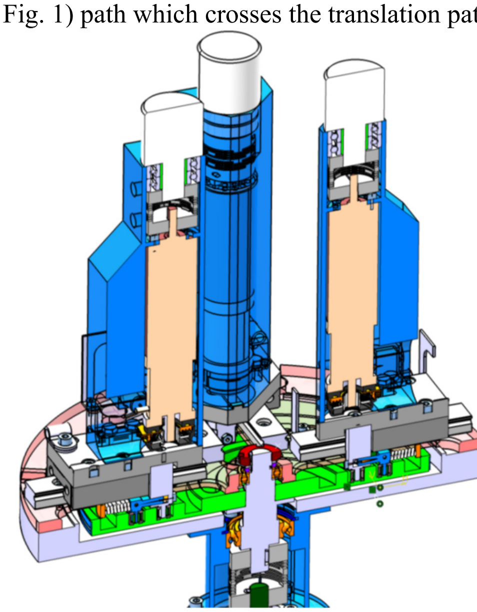

Figure 1: Section view of CAD V1 MAGSTAT prototype.

This solution ensures a great radial compactness since there is only one motor for the four symmetric linear displacements, and it is coaxially mounted with respect to the poles.

Performance

The first prototype (Fig. 2), realized in 2016 was able to achieve good performance in most field configurations and is being use on the SEXTANTS beamline.

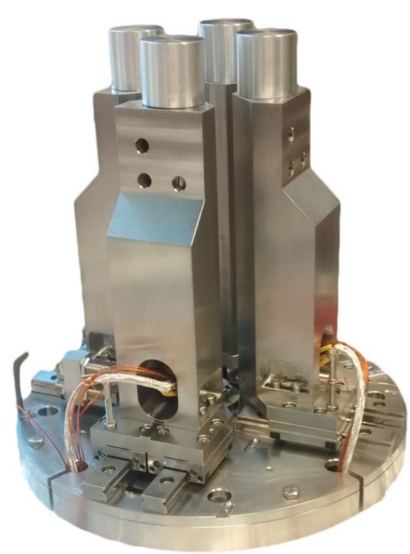

Figure 2: MAGSTAT V1 prototype main parts overview. Bottom disk diameter is less than Ø100mm.

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However, the lack of vertical stiffness for very low gap configurations tended to lock the whole system at the closest gap and disorient magnets angle. Each magnet block is mounted on a double miniature guideways which relatively low stiffness comes to be critical. Although the distance between the magnet and the guideways is reduced to the minimum, it is still significant for the lever arm. The major problem is the length of the magnets motors, with their three stages planetary gearboxes, that lead to such a lever arm.

THIRD MAGSTAT PROTOTYPE

Mechanical Description

The apparent lack of stiffness compared to the force coming from the magnets leads to a complete redesign of the four magnet blocks (magnets, motor and mounting parts), while using most of the parts of the first prototype, especially the same motors. The general gap setting system is reused as it was found efficient.

To get a better stiffness, the magnets motors are mounted horizontally, so the distance between the poles and the guideways is shorter. The mechanical driving to connect the motor output to the magnet rotation is ensured by multiple gear wheels and a worm gear. The small size requirement was a condition hard to meet with this new layout but was achievable by allowing the magnets block to be nested one within the other in close gap (Fig. 3).

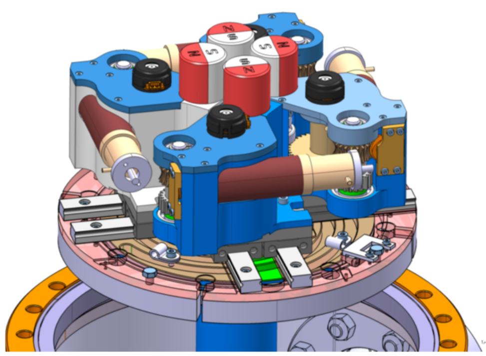

Figure 3: 3D overview of CAD V3 MAGSTAT prototype.

Expected Performance

This new design decreased the height of the motor blocks by near a third, hence guaranteeing a much better vertical stiffness.

The other improvement is about the output torque for the magnet rotations which is tenfold by the worm gear and set irreversible, preventing the motors to heat too much under vacuum with a high stop current.

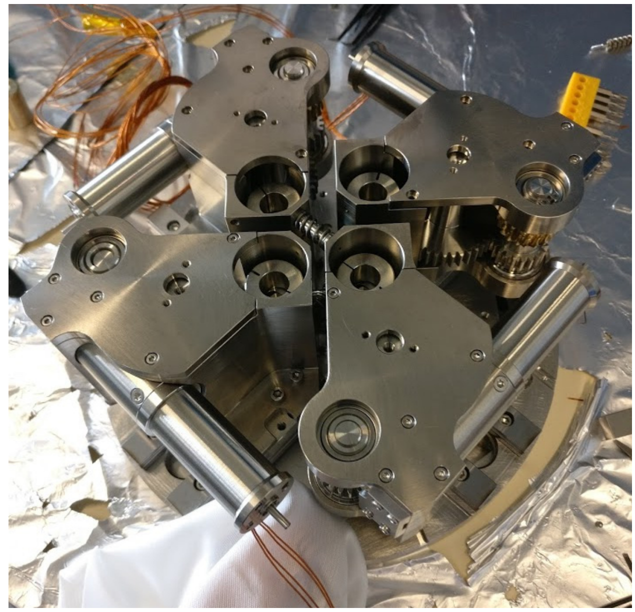

Figure 4: MAGSTAT V3 prototype main parts overview. Magnets are not mounted on the picture.

Small improvements had also been made to ensure that the magnets could not lock in a close gap position by helping the central motor with return springs mounted on several pistons (Fig. 4).

Manufacturing

All these mechanical improvements made the mounting block of each magnet much more complicated to manufacture. Due to the force magnitude and non-magnetic requirements, the motor mount is mainly machined out of a Ø100mm single titanium (TA6V) rod (Fig. 5).

Figure 5: Main magnet mounting part.

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MECHANICAL PROPERTIES

Table 1: Torque and Momentums

	V1 [N.m]	V3 [N.m]
Magnet shaft theoretical maximum torque output	1.5	11
Central shaft theoretical Maximum torque output	18.4	18.4*
Lever arm maximum parasitic momentum	36.5	24

* Central torque requirement is less in V3 since there are return springs.

PERSPECTIVES

The third MAGSTAT prototype will be mounted on COMET endstation by the end of 2018, and will allow to operate with higher magnetic field, up to 1T along with safer drive of the gap.

ACKNOWLEDGMENTS

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[1] V. Pinty, “MAGSTAT a high vacuum gap-variable permanent rotary magnets quadrupole”, in *Synchrotron SOLEIL Highlights 2016*, Gif-sur-Yvette, France, May 2016, p. 86.