Octupole End Station for Soft X-Ray Scattering in Magnetic Dichroism (XMD)

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Abstract. This Octupole End Station is the third-generation design with substantial improvements that is used for soft X-ray scattering in magnetic dichroism (XMD) experiments. The system is mainly used for three applications: constant field for the duration of an x-ray absorption scan, point-by-point field reversal for an XMD photon energy scan, and hysteresis loop measurements. The ADC Octupole is based on earlier designs and work performed by Elke Arenholz and Soren O. Prestemon at Advanced Light Source, Lawrence Berkeley National Laboratory[1]. ADC improved on the ALS design by enlarging the chamber to allow for in vacuum goniometer and a significant increase in the number of ports that can be used for experimental design, such as cryogenic cooling. Eight conical electro magnets are equidistantly spaced about the surface of a sphere to create an omnidirectional field vector with a magnitude of 1 [T].

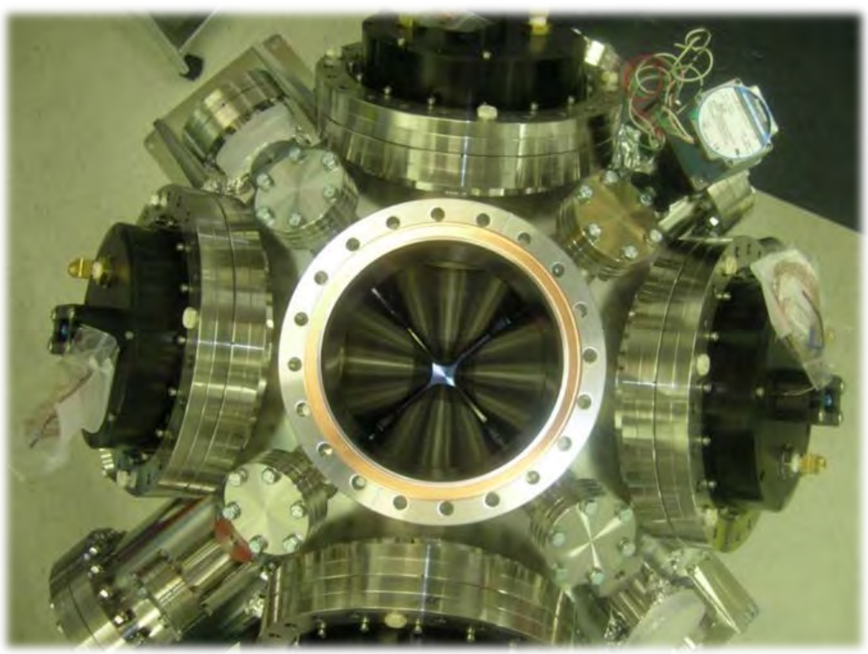

Figure 1: Looking Into the Octupole

INTRODUCTION

ADC USA, Inc. (ADC) is developing improvements in the Octupole End Station system for the University of Science and Technology of China. The design is an iteration of ADC's prior collaboration with MAX-lab. This device forms the basis of a highly adaptable end station for soft x-ray scattering experiments with the emphasis on investigating magnetism and related phenomena. Eight electromagnets, equidistantly spaced about the surface of a sphere, create an omnidirectional field vector with a peak field magnitude of 1 [T] and uniformity over the sample space of +/- 3%. The magnets protrude into an ultra high vacuum chamber with a base pressure of 5E-10 [mbar]. The chamber houses both the sample and detector apparatus. Improvements to the design include improved goniometer performance and the addition of a magnetic field return yoke to the exterior of the chamber.

DESIGN PRINCIPALS

Building on earlier instrumentation in this field[1], each magnet uses a tapered, partially hollowed iron core with a geometry optimized to cause saturation at the pole face. The windings use approximately 100 [m] and 200 turns of 12 AWG magnet wire. Power supplies capable of 100 [A] current drive each magnet. Water is injected through the hollow in the iron core then travels out into the magnet cavity through a series of radial holes and channels. The compartment containing the windings is flooded to dissipate the 4 [kW] heat load.

Various vacuum ports allow for the addition of cryogenic cooling, sample manipulation, view ports, or other equipment required for experimental design. Three DN160 CF flanges are available perpendicular to the beam axis to allow for equipment access to the sample space. The large number of available ports allow for great flexibility in future design setups.

An internal 360° goniometer allows for rotation about the 2θ axis. This allows for installation of a detector needed for XMD experiments or other X-ray diffraction experiments to measure the X-ray scattering angle.

Support Structure

The support structure, Figure 2, is constructed of 304SS to minimize its effect on the magnetic field within the chamber. A magnetically permeable structure would shunt the field relative to the sample differently at different orientations of the chamber or with a different field vector, which may also have negative effects on surrounding equipment.

Figure 2: Stainless Steel Support

Previous Test Results

The previous model was tested to verify mathematical modeling performed using Radia[2]. Calculations were done of the field both for magnitude and homogeneity as well as evaluating the cooling concept. In addition, further optimization work was carried out on the final pole piece and winding configuration to match affordable power supplies. Primarily this meant maximizing the saturation of the pole face while minimizing the total length of conductor, and secondarily considering field homogeneity etc. In practice this meant using a maximum current of 100 A with a maximum 50 V or ca. 0.5 Ohms resistance in the conductor.

In dipole tests running at 25 A, the measured peak field agreed with the models, Figure 3, to within, at most 7%, typically within 3%. There was a slight increase over the model at lower currents and a slight decrease at higher currents. We suspect that this deviation may be a result of the accuracy of the power supply display. For the cooling tests, the prototype was driven up to 150 A using a Hewlet-Packard supply provided by ADC for the purpose of the

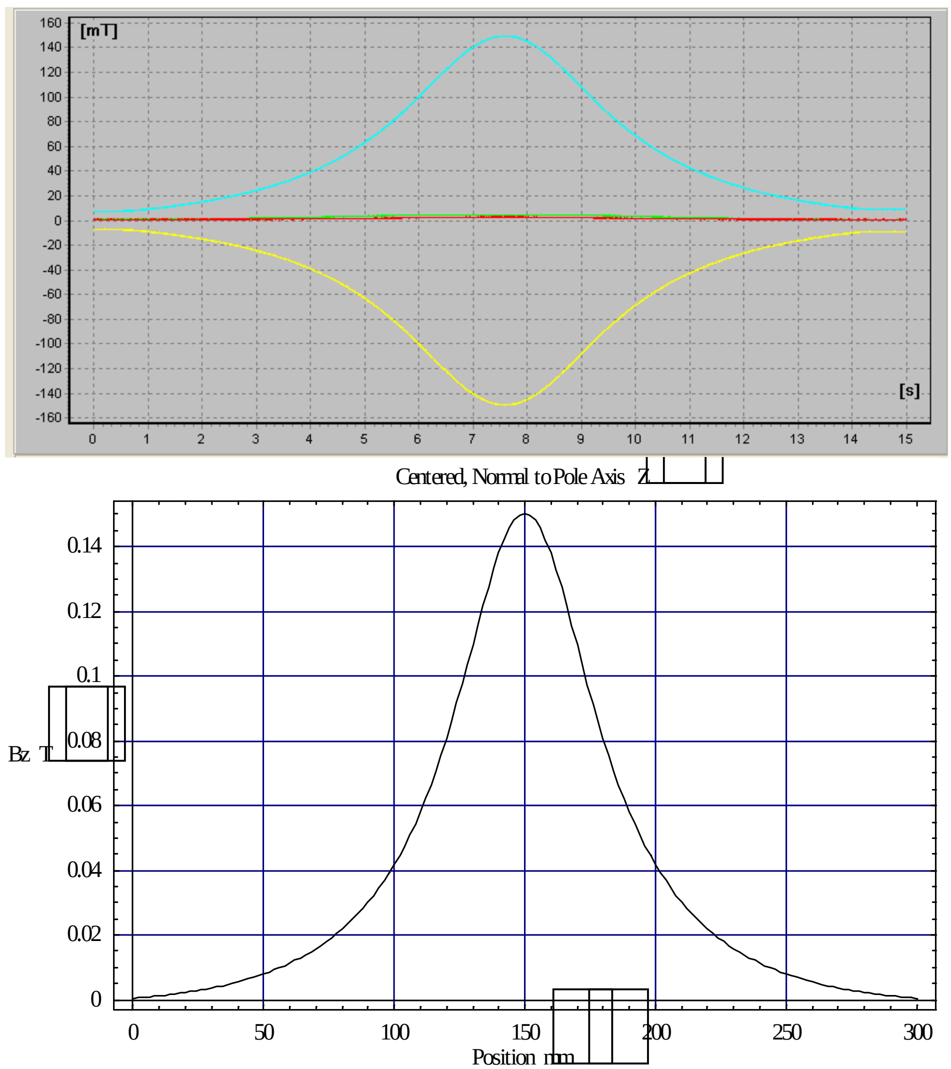

Figure 3: Top, dipole test results at 25 A running perpendicularly through pole center; note the x-axis is travel time Bottom, dipole calculations performed using Radia; note the x-axis is position

tests. Two K type thermocouples were embedded in the windings: one between the layers and one on the outer winding surface. At most we observed a 10°C difference in temperature between the two thermocouples at an operating temperature of 70 °C with a flow rate of 0.5 L/min. Increasing the flow rate to 3 L/min dropped the operating temperature to approximately 30 °C

Design Improvements

An Octuple system is currently in operation at APS from 2009, shown in Figure 4. ADC is implementing several improvements in the latest iteration including precision matching the goniometer rings, partnering with a dedicated magnet winder, increasing water flow, and testing the field increase from the addition of a yoke.

The internal goniometer is being redesigned to allow more consistent and reliable assembly. The design is a V-guide profile ring that is cut into two pieces. The previous generation relied on cutting one ring and replacing the lost material with shims. The new generation will have two rings precision matched, removing the need for the shims. Additionally, precise locating pins will be installed to ensure roundness when installed into the chamber. It is anticipated that this will result in increased accuracy and smoother operation.

ADC has developed a propriety magnet winding technique with an expert in the field for this next generation Having consistent and precisely wound wires will help get the most out of the electromagnets.

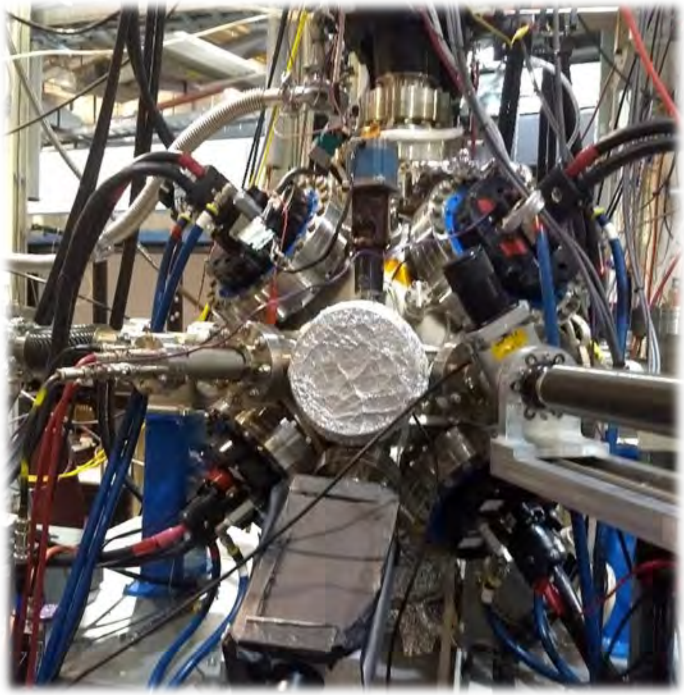

Figure 4: Octupole on APS beamline

The water flow circuit is being enlarged to increase water flow and reduce the overall pressure drop. This will also help the protective surface of the magnet core to be coated thoroughly. This will help to reduce the likelihood of exposed magnet iron and reduce the risk of oxidation occurring which will increase the service life of the system. Additionally, increased water flow will help keep the system at a lower max temperature which will increase service life.

The original Octupole design does not include a yoke to capture the magnetic return field. ADC has investigated adding a yoke external to the vacuum system and will be testing the field increase in dipole configuration. The yoke will be common to all ports, as shown to be effective in the Lawrence Berkeley design mentioned earlier. Due to the large number of ports and utilities brought in, a reduced yoke will be implemented. ADC is hoping to create a sufficient enough yoke to increase the field strength by 20%-50%, actual results will be reported after system tests.

REFERENCES

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