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Soft X-Ray Scattering Octupole End Station

The Octupole End Station is used for soft X-ray scattering in magnetic dichroism (XMD) experiments. The system is mainly used for three applications, i.e., 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, Berkeley, Ca. ADC improved on the ALS design and has performed several design improvement iterations (see chart below)

Eight conical electro magnets (coils) are equidistantly spaced about the surface of a sphere to create an omnidirectional field vector with a magnitude of 1 [T]. The magnets protrude into an ultra high vacuum chamber with a base pressure of 5E-10 [mbar] that houses both the sample and detector apparatus. The entire system is then capable of tilt rotation vertically about the beam axis +/- 45^{O}. The 1T field is achieved by the combination of fields from 2 or more coils.

Technical Specification Base System:

- Peak field magnitude of 1T
- Field uniformity of 5% over 10mm cube
- Field vector rotatable in any direction
- 8 magnet coils
- Water cooling for 8 coils
- Base frame, kinematic, adjustable, 304 SS,
- Detector 360^{O} rotation goniometer
- Top sample access
- Sample rotation axis
- UHV operation @ 5E-10mbar
- RGA Analysis
- Water flow sensors
- Ports for sample, pumping, detector, observation, beamline, vacuum gage, spare

Each magnet uses a tapered, partially hollowed iron core with a geometry optimized to cause saturation at the pole face. The windings use approximately 200 [m] and 400 turns of polyurethane insulated 12 AWG magnet wire yielding 0.5 ohms. Power supplies capable of 100 [A] nominal current (120 [A] maximum) drive each magnet. Water is injected through the hollow in the iron core, then travels out into the magnet coil cavity through a series of radial holes and channels. The compartment containing the windings is flooded to dissipate the 8-10 [kW] heat load. A triple build is used on the wire to eliminate shorts between coils and to the cover. An aluminum core can replace the iron core but the peak field drops to < 0.5T; however, the field can be controlled to a finer degree. The beam enters from the side at the bearing mount

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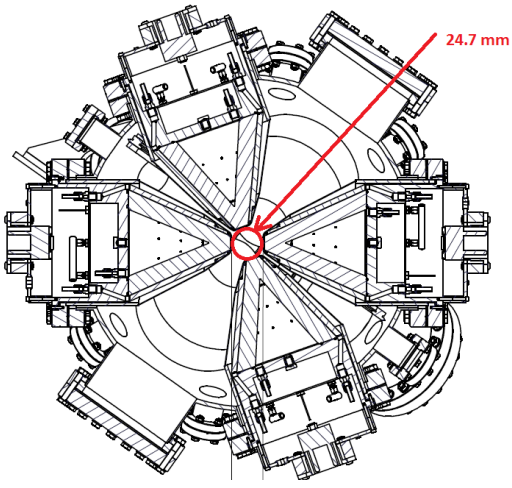
for the 90^{O} tilt rotation. The sample is placed through a port on the top – the access path is a cylinder with a 24.7 mm aperture. All motions, sample and detector, are driven by stepper motors external to vacuum. At minimum each Octupole provides ports for roughing/turo pump (x1), ion pump (x1), sample access ports (x3), observation ports (x3), beamline ports (x2), magnet ports (x8), vacuum gage (x2), detector wiring ports (x2), spare (x3), Thermocouple ports (x1)

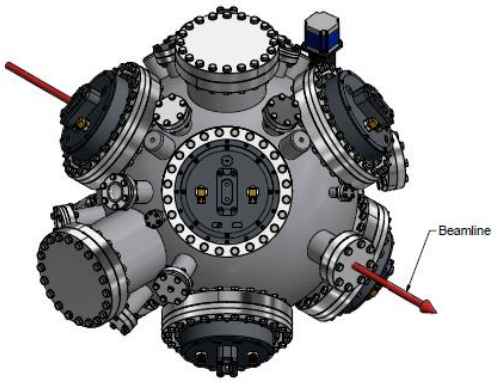
Comparison of ADC and ALS Octupoles

Table 1	ALS Octupole	ADC Gen 1	ADC Gen 2
Peak Field	0.9 T Any direction	1 T Between pole pairs	1 T Any direction
Vacuum Chamber	Sample and Access	Solid Sphere	Split Sphere
Sample Motions	Ø Rotation	Ø Rotation	X,Y,Z,Ø
Detector Motion	Fixed	360^{O}	360^{o}
Detector Position Repeat	Fixed	30 arc min Open loop	2.0 arc sec With encoder
Tilt Motion	No	+/- 45^{O}	+/- 445^{O}
Load Lock	No	Yes	Yes
Cryo Sample	No	Yes	Yes
Coil Wire Insulation	Single Build	Double Build	Triple Build
Water Cooling	Limited Copper Tubing	Limited Direct Water	Significantly Improved Direct Water

The beamline entry is shown in the figure below. It is up to the user how to attach the Octupole to their beamline. ADC will provide a kinematic support to align the Octupole to the beam.

The electromagnet coil layout is also shown below. This figure also shows the 24.7 mm access cylinder for the sample. This can be specified to access from the top, bottom or side. Each coil requires a 100 amp bi-polar power supply – eight (8) power supplies are required.





All coils work in concert to produce a 1T field vector. Two coils alone cannot achieve 1T because the adjacent coils are not in saturation and in effect "steal" field from the primary direction. Also, peak current is not necessary to achieve 1T if the adjacent coils are also used to produce the field. For this reason a spread sheet formula is provided that determines the optimum coil currents for any particular direction.

General System Layout

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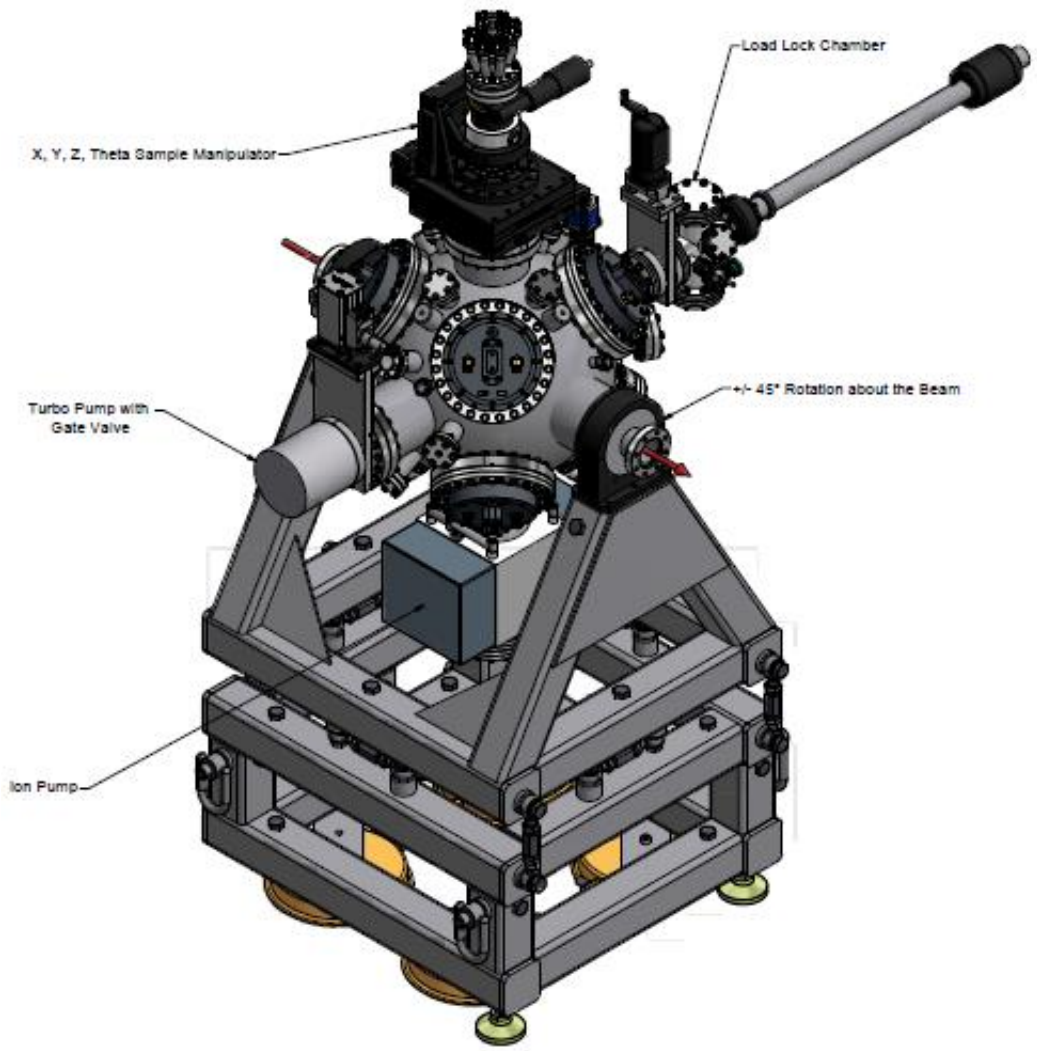

Testing

ADC performs the following operations and tests on each Octupole

1) Dimensional and weld inspections
2) Individual coil water flow rate
3) UHV cleaning and bake-out
4) Vacuum base pressure
5) Vacuum leak rate through rate of rise
6) Leak check using a Pfeiffer helium leak checker
7) Full range of motion on each axis
8) Limit switch actuation and hard stop on each axis
9) Position repeatability on each axis

Magnetic field test on 4 coil pairs

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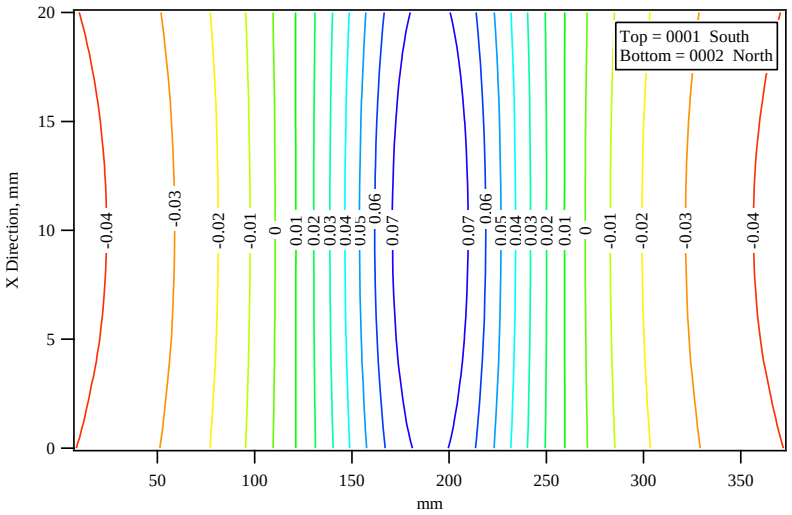
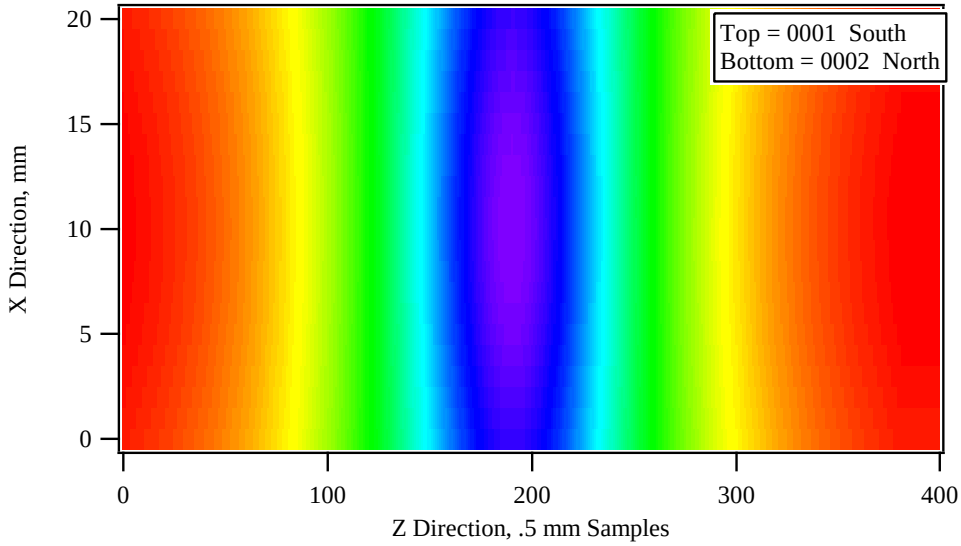
ADC performs a magnetic field test for homogeneity and field at 25 amps. Two coils are mounted in a fixture so they face one another as shown below. An XY map of the field is made using a 1D Hall probe at the center point between the coil tips and plotted as shown below.





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Optional Features
ADC can provide the following optional features as specified by the customer.

Optional tilt rotatable from +/- 45^{O} about beam axis
The entire Octupole can be made to rotate 90^{O} (+/- 45^{O}) about the beamline axis allowing the sample to be exposed to horizontal or vertical sections of the beam. The Octupole pivots on bearing rings at each connection to the base support. This motion is manual and can be locked. An additional option provides motor for this motion.

Optional Ion pumps and controller
ADC can optionally provide an ion pump and controller of the type specified by the customer.

Optional Roughing and turbo pumps
ADC can provide roughing and turbo pumps with a gate valve for switch-over with controller of the type specified by the customer.

Optional Vacuum Gage
ADC can mount and test a vacuum gage of the type specified by the customer.

Optional X,Y,Z Sample Manipulator
ADC can provide an X,Y,Z sample manipulator. This is mounted on the top. The sample is mounted to a rod that extends down into the Octupole and the rod is manipulated outside the vacuum chamber. See image below. This assembly is in addition to the theta rotation motion provide in the base system.

Sample Manipulator		
X-Axis	Travel	10 mm
	Resolution	0.17 um
	Repeatability	2.5 um
Y-Axis	Travel	10 mm
	Resolution	0.17 um
	Repeatability	2.5 um
Z-Axis	Travel	50 mm
	Resolution	0.17 um
	Repeatability	3 um
Theta Rotation	Travel	360°
	Resolution	0.015°
	Repeatability	0.15°

Optional load lock chamber
ADC can provide a load lock that allows sample exchange without breaking the vacuum. This can be provided on top or side sample access, with or without the sample manipulator.

Optional 8 programmable power bi-polar supplies with 0-60V, 0-100A
ADC can provide a power supply system that consists of two commercial AC/DC power supplies to provide raw DC for eight DC/DC bipolar power converters capable of 0-60 VDC at 100 Amps Power Input required: two 400/480 VAC 3 phase inputs, at 50 amps.

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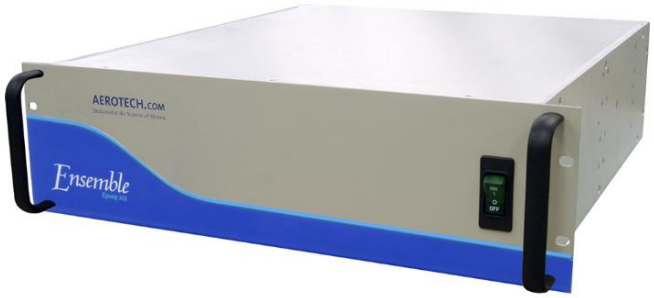
Optional aluminum core
An aluminum core can be provided in place of the iron core. This produces lower field (< 0.5 T) but better incremental field control for experiments that need this type of control.

Optional Detector Ring Encoder
ADC can provide a Renishaw absolute or incremental encoder, in-vacuum, with a resolution of 0.1 microns per count. The drive motor also requires a gear reducer to achieve +/- 1 um positioning repeatability.

Optional motion controller
ADC can provide a 2, 4, 6, or 8 axis motion controller. This consists of an Aerotech Ensemble controller which is capable of controlling stepper motors open-loop or with encoder position feedback. EPICS drivers are free from Aerotech.

For 2-4 axis motion, ADC will provide the Aerotech Ensemble-LAB which is a 4 axis motion controller shown at left below. For 6 or 8 axis motion, ADC will provide the Aerotech Ensemble Epaq MR motion controller which is shown at right below.



Both controllers are capable of the following:

- Controller architecture capable of coordinating motion of up to five independent tasks
- Capable of driving and controlling linear or rotary brushless, DC brush servo, and micro-stepping motors
- Complete motion capabilities include: point-to-point, linear and circular interpolation, electronic gearing, velocity profiling
- Program in AeroBasic with the IDE, Microsoft .NET including C#, VB.NET, C++/CLI, LabVIEW, and MATLAB
- Remote ASCII interface provided for Windows or non-Windows programs (including Linux) to command the Epaq through standard Ethernet, RS-232 port, and optional IEEE-488
- Advanced Windows-based remote diagnostics, tuning, and programming interface software
- Front panel display and control pad for convenient menu-driven axis control and status checking
- Axis jogging/control with optional joystick
- Fully compatible with EPICS set of software tools and applications, making Ensemble ideal for use in synchrotron and general laboratory facilities.