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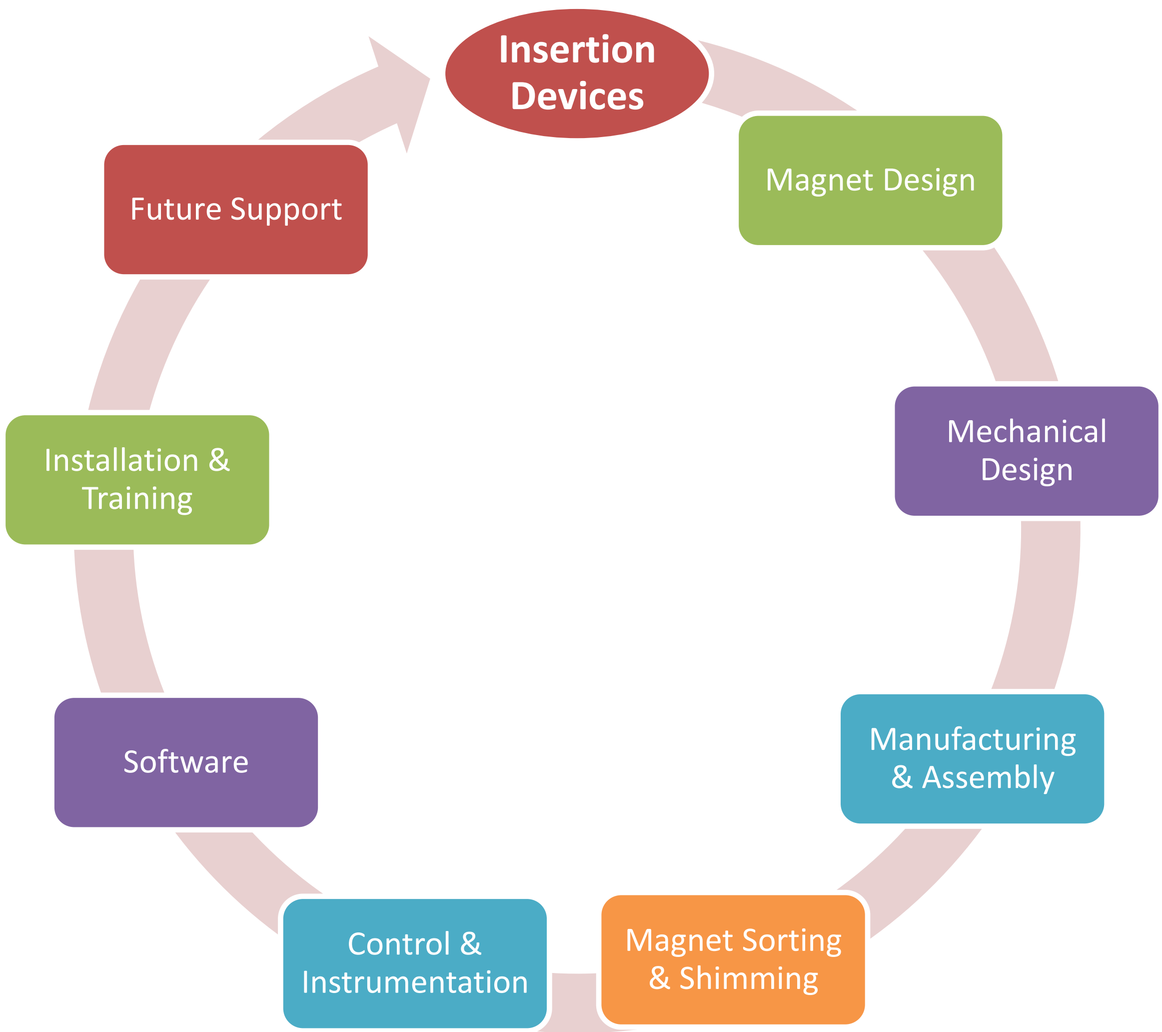
Insertion Devices

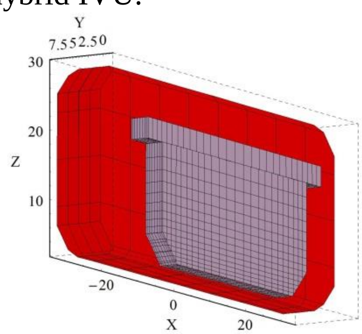
ADC USA (ISO 9001 certified), located near Cornell University in Ithaca, New York, is a leading developer and supplier of complex scientific components and instruments for large government laboratories and corporations around the world. Founded as a privately held company in 1995, ADC has grown into one of world's leading technology companies and has enjoyed years of business growth and profitability with more than 500 customers located in over 26 countries. We have developed capabilities, design, procedures and training staff to provide "Turn-Key" Insertion Devices and Magnetic Measurement Systems complete with in-house and customer site training. For more information on "ADC" please go to: http://www.adc9001.com

ADC's INSERTION DEVICE PROCESS CHART

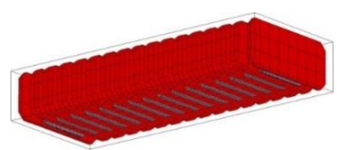


Magnet Design

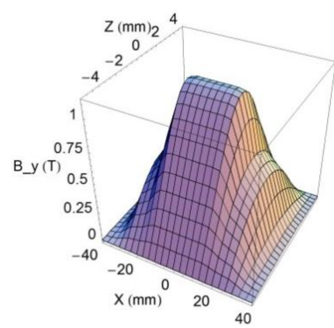
ADC is well versed in the magnetic design of undulators having delivered designs for 5 EPUs, 2 Planers, 3 IVUs, and 3 Wigglers. ADC uses RADIA which is a magnetic FEA modeling software package that runs on Mathematica. ADC interprets the customer requirements for effective peak field at min gap, effective K value, gap range, beam energy, ppm or hybrid, period, undulator length, photon spectrum and intensity, phase error, integrated fields, multipoles, and bake-out temperatures. From this data we develop a magnet model based on currently available magnet materials considering intrinsic coercivity and remanence along with the thermal effects on these parameters. Various pole materials are considered but mainly Vanadium Permendur is used. We then create an FEA model of the magnet and pole and build a representative multi-pole array which is then used to calculate end section magnet spacing and dimensions that minimize entry and exit trajectory, demagnetizing fields, bake-out temperature, electron orbit, first and second integrals, peak and effective field, and magnetic force for various gaps and modes of operation. Correction coils are also designed as required to meet integral and multipole requirements at various gaps. Figures below show samples of magnet modelling for a hybrid IVU.



Magnet and Pole FEA



Magnet Pole Layout



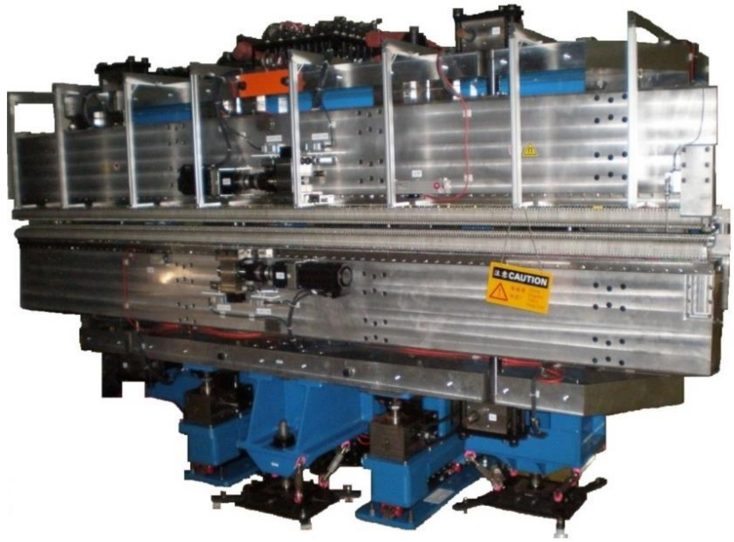
Field Distribution at Gap

Mechanical Design

Once the magnet size and magnetic forces are understood, ADC then begins the mechanical design. The fundamental type of the undulator is the main starting point. That is, the mechanical design is different depending on whether the undulator is a planer, EPU, IVU, Wiggler, or CPMU. The customer sometimes provides input for girder deflection and roll as well as requirements for beamline offset correction, taper, end sections, and site requirements such as dimensional limits inside the tunnel and floor loading. Other requirements may arise such as gap and taper encoding, drive mechanisms, and proximity of permeable materials.

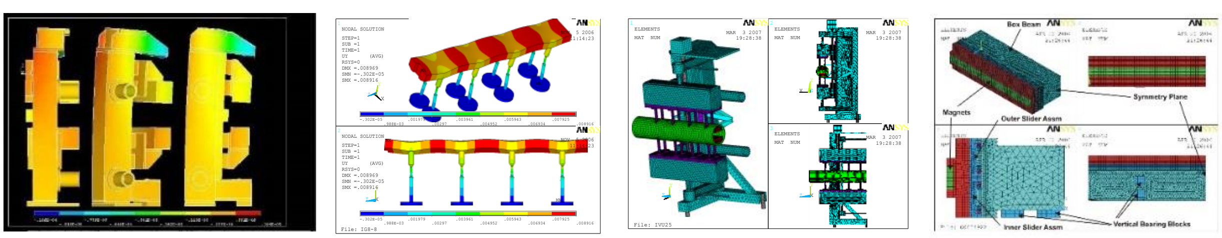
ADC typically starts with the strong back design. In our history we have successfully used vertical I-Beams that are intended for bridge construction for our strong backs. These are precision ground for critical bearing mounting surfaces and securely bolted to base and top plates. The base and top plates are very substantial, typically 8 to 12 inches thick aluminum. The vertical I-beams are stiffened longitudinally to resist the various longitudinal forces with material that is the same as the magnet girders to match thermal coefficients. If the device is an EPU, the stiffening takes the form of a box frame inside the I-Beam web. Vertical guide rails and the trucks that attach the girders to the strong back are overdesigned by orders of magnitude for stiffness and long life. The drive mechanism is based on left/right hand threaded ball screws if the gap positioning repeatability is loose as for a Wiggler or consists of a 4 motor/ball screw on each corner of the upper and lower girders if the repeatability is less than 5 ums. Sub-micron repeatability is achievable. Some frame designs are shown below.

ALBA-CELLS Wiggler

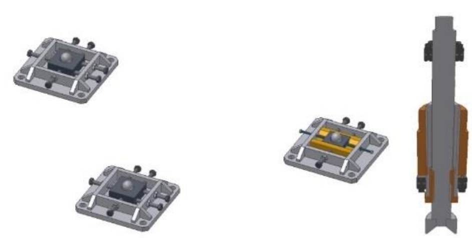


NSRRC 4m EPU

ADC supports our design with a thorough FEA of the base, top, strong back, and girders. Our goal is to minimize girder deflection, roll, and beamline offset caused by frame tit at narrow gaps. Springs are sometimes used to offset the magnet load at small gaps. We have even designed a unique bucking frame to resist the magnet load of IVUs at close gaps.



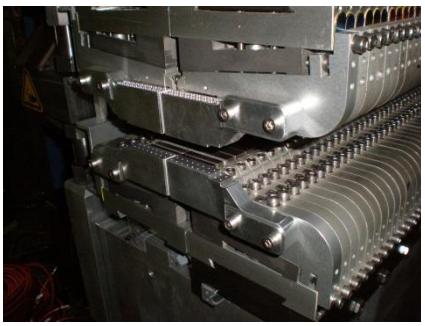
The frame base rests on 3 points. ADC has designed a set of kinematic feet that allow +/- 15 mm adjustment in X, Y, and +/- 30 mm in the vertical (Z) directions using a differential thread for very fine adjustment. The adjustable Z legs rest on a 2 inch diameter ball bearing as shown to the right. This allows the feet to be surveyed in before the undulator arrives. This ball also allows the undulator to be lifted off the ball and replaced within microns of the original position.



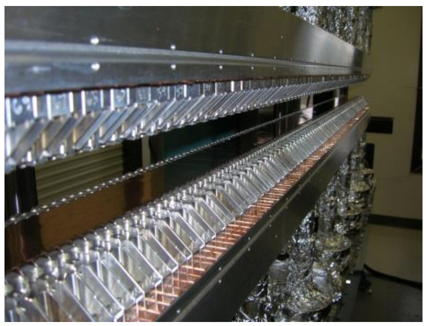
ADC's Kinematic Undulator Feet

ADC has built both types of EPU sub-girders where the magnet arrays are longitudinally guided on top of a solid girder and where the girder is split vertically and the longitudinal guides are embedded in the split girders. Both have their advantages and drawbacks.

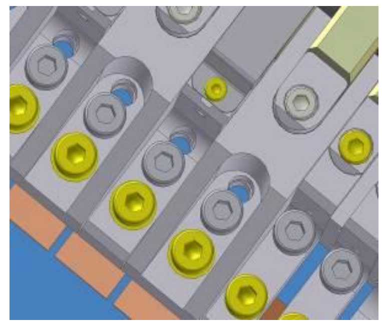
ADC has built many magnet holders and developed multiple shimming schemes using both shims and shim-less methods. For out-of-vacuum EPUs and Planers we use a wedge and screw design for infinite vertical and horizontal adjustability. For in-vacuum we use copper shims for vertical and slotted holders for horizontal. We have also developed a unique alignment method that uses a dowel pin between the holder and girder for precise period control. These methods are shown below.



NSRRC EPU Holder



PAL IVU Holder



Dowel Pin Alignment

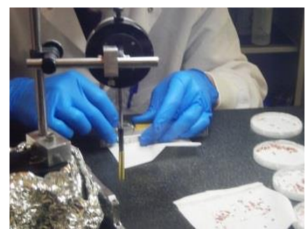
Manufacturing & Assembly

The assembly of any undulator at ADC begins on its back on the precision ground surface of the vertical I-beams. ADC uses a 10 x 20 foot granite surface plate that provides a precise surface for assembly shown to the right. The top and base are bolted to the vertical I-beams. The bolts are barred-in and marked with gliptol. The vertical rails are mounted and aligned using the girders removing any taper. Key mechanical measurements are taken and any shims that are needed are recorded. The motors and ball screws are mounted along with linear encoders and limits. The undulator is then stood up and wired to a local connector panel.

The hard stops are set and the motions verified before moving the undulator to the magnetic measurement bench. The measurement room temperature is precisely controlled to match the temperature of the ring. The undulator is allowed to soak for a few days while it is aligned to the bench. Background magnetic measurements are taken which are later subtracted from the undulator's field with magnets. In the case of an IVU the undulator chamber is assembled in a clean room, as shown on the right.

Magnet Assembly

Magnet assembly is different depending on the type of Insertion Device; however, certain requirements remain true across the board. These are: careful handling of the magnets and precise and consistent assembly to the holders. The magnet holders themselves must first be verified according to spec dimensions. ADC measures 100% of our magnet holders on our CMM machine at the right.



ADC typically builds jigs for each type of magnet assembly. In the case of an IVU the magnets are assembled in a clean room, on a granite surface plate, shown to the right. Once assembled, critical dimensions are verified using non-magnetic measurement means. If the magnets are extremely large such as for a Wiggler ADC builds a special assembly apparatus for the safe handling of these magnets. Once assembled, Wiggler magnets are stored in protective caskets as shown below.

Motion Controllers

ADC has provided a broad array of controllers for undulators ranging from a single motor for Wigglers to 8 motors for EPUs. We consider 4 motor control of the gap our specialty. We have provided facility specific motion controllers such as Allen-Bradley for Maxlab, Siemens for SSRF, Parker and Delta-Tau for BNL, Schneider-Telemechanique for ASP, and IcePAP for ALBA-CELLS. If no particular controller is required, then ADC provides Galil. Full length cables are provided and the undulator is debugged and shimmed using these cables.

We have provided mostly stepper motors but also servo motors on occasion. We have applied incremental and absolute linear and rotary encoders. A brake on all axes is standard. Limits consist of mechanical switches. For close repeatability at small gaps or near the beam pipe, ADC uses high repeatability (< 1 um) limit switches.

Software

ADC develops motion control routines using the specified motion controller for gap and phase control during shimming. We typically automate the data collection by writing specific routines to control the gap and phase as well as the hall bench and flip coil.

ADC also provides the EPICS databases for our undulators; however, full EPICS IOC software is now available on request.

Installation & Training

ADC's undulator installation plan is divided into several levels ranging from a modest check-out to a complete commissioning in the ring. These levels are described below.

Level 1

ADC provides the following as standard installation with all of our turnkey IDs. One technician is provided for 2-3 days to check out the ID after shipping.

The customer is expected to remove the ID from the truck at their dock, transport the ID to a suitable working location, and remove the crate and dispose of the crating materials. Customer is also expected to provide the required facilities such as power and cooling water as well as a technical contact. ADC personnel will perform all required safety training and conduct themselves in a safe manner.

Although the specific tasks will be different depending on the type of ID unit, the ADC technician will perform the following general tasks.

1) Check Controller and ID for any damage in shipment
2) Level the ID and center foot adjustments
3) Verify dry nitrogen shipping pressure (if IVU)
4) Verify hard stop settings
5) Situate the controller near the power drop and ID
6) Connect the cables between the controller and ID
7) Verify power connection at the controller
8) Power the system on
9) Boot or load any required software
10) Open the operator interface
11) Test motion controller communication
12) Test safety switch function
13) Verify and Test IOs
    a. Position switches
    b. Limits and Kills
    c. Flow Controls and Sensors
    d. Temperature Sensors
14) Verify encoder position at controller
15) Open and close gap 5 times
16) Read analog sensors, i.e. vacuum pressure, RTDs
17) Provide training in Operation and Maintenance of the ID

Level 2

This level (2) is performed by an engineer (not a technician) and consists of all the points in Level 1 with the addition of the following installation items. The expected time frame for this level is 1 week.

1) Assist with the movement of the ID into the ring
    a. Note the customer must provide qualified crane operators
2) Assist with the routing of the cables from the controller to the ID
3) Debug of the ID control in the ring
4) Debug of the ID operation from the control room
    a. IOC software must be ready if provided by the customer
5) Optional set-up on the customer's magnetic measurement bench

Level 3

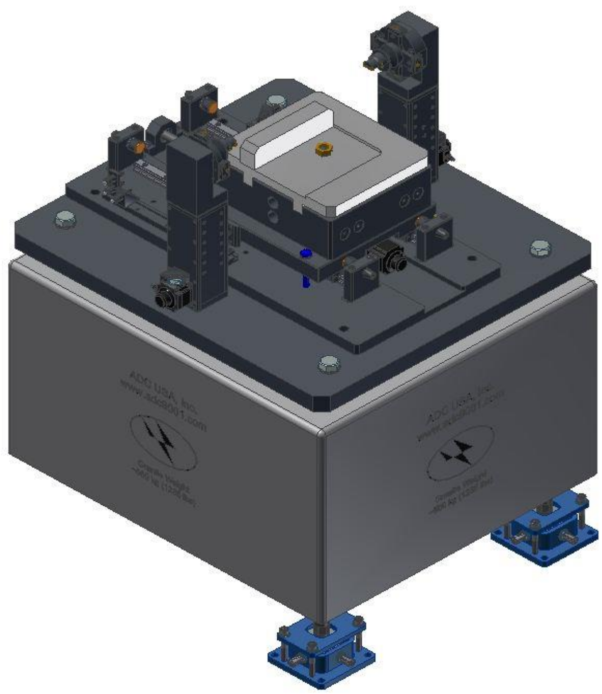
This level (3) is performed by an engineer (not a technician) and consists of all the points in Level 1 and 2 with the addition of the following commissioning items. The expected time frame for this level is 2 weeks

1) Debug of the ID with beam
2) Set up of the correction coils
3) Machine study in the ring
4) Verification of photon production

In House Capabilities

Magnet Sorting & Shimming

ADC measures the integrals of each usable magnet edge with our own sorting bench shown below. The magnets are first sorted based on manufacturer supplied Helmholtz coil data for field strength and moment. The magnets are then sorted by integral data from the sorting bench to produce the minimum integral in the undulator by matching pairs of magnets. ADC's sorting algorithm is based on a simulated annealing program that avoids false minimums. Sorting in this manner greatly reduces shimming time.

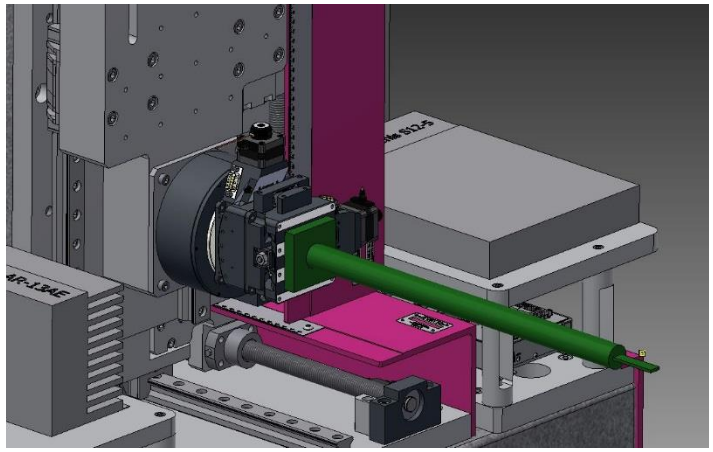


ADC Flip Coil Sorting Bench

Shimming begins with the precise location of the magnetic centerline and the precise alignment of the undulator to the measurement bench. The undulator is then shimmed for the maximum field, minimum integrals, minimum phase error, and smallest trajectory without correction coils at the working gap. When the specifications have been achieved, the undulator is then characterized by gap and the correction coils are optimized. Final machine study data can then be taken based on requirements from the customer.

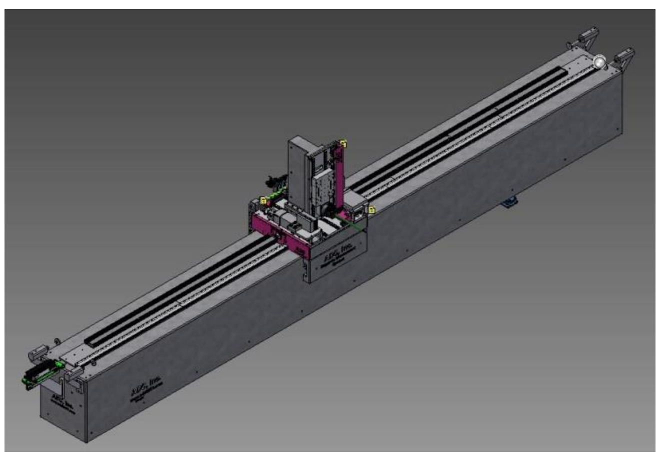
ADC typically uses B2E which runs on IGOR for most of our shimming and machine studies. Integral data is gathered and analyzed using custom routines written by ADC in IGOR.

Magnetic Measurement System (MMS-8000)



ADC's MMS-8000 represents the culmination of more than 15 years of development and design in the Magnetic Measurement System. The MMS-8000 offers new levels of performance in magnetic research. The MMS-8000 incorporates major advances in data acquisition, temperature control, and low noise magnetic field measurement with < 0.5 uT resolution, Sampling > 100 Hz and the measurement repeatability < 1 G. The MMS-8000 also provides expanded software functionality within its user-friendly graphical interface. Combining these features provides the highest level of system performance. The MMS-8000 truly represents the next generation of advanced Magnetic Measurement Systems.

ADC Magnetic Measurement System (MMS-8000) consists of two major components; **Hall Probe Mapping Bench** and **Integrated Field Measurement System**.



ADC 8m MMS and IFMS

For more information please visit us at: http://www.adc9001.com/products/

ADC's MMS rests on a concrete vault that is 10 feet wide by 20 feet long by 4 feet deep. A photo is shown below in Figure 10 of this vault under construction. The vault is cut away from the building floor and provides a common vibration isolation support for the MMS and ID undergoing shimming.

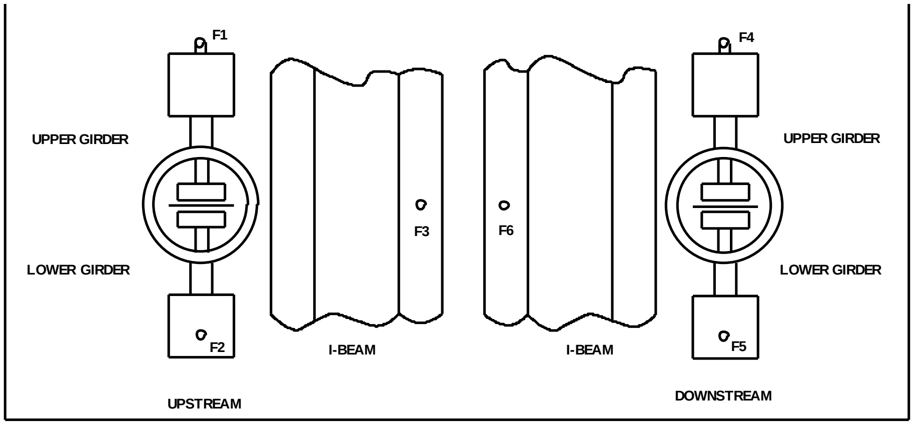
ADC Vibration Isolation Vault under Construction

Hall probe Calibration

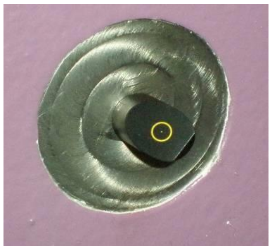
ADC has 2 large dipole magnets we use for in-house hall probe calibration. These are shown below in Figure 11. ADC has developed the fixtures to accurately locate and measure the response of Hall probes in the X, Y, and Z directions.

ADC Large Dipole Magnets

Fiducialization



As part of any ID shimming process one must perform fiducialization in order to locate the ID accurately in the ring. Fiducialization consists of a process of converting the magnetic mid-plane or beam line to an optical mid-plane which is then transferred to fiducial locations on the ID frame or girders. ADC typically supplies 4 fiducials on each end of the machine. Usually, these fiducials are transferred to fiducial locations on the back of the C frame by the customer's laser tracker and facility survey crew. ADC uses a proprietary method to precisely reference the Hall probe magnetic location to its physical location relative to an optical feature. Once this is performed then ADC uses a theodolite to transfer the magnetic mid-plane to the fiducials. The result is a map of the offsets of the fiducials to the magnetic mid-plane in the X and Y directions as shown above.



The locations of the fiducials are located on the insertion device frame such that adequate line of site is provided in the fully assembled condition for survey and alignment. Sometimes, ADC provides custom target extensions if required to accomplish this task and in some cases adjustable target seats have been provided.

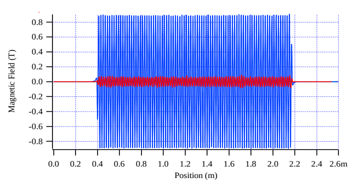
Data Collection

ADC will shim the ID to meet customer specifications. Once this is complete, data is collected at specific gaps measure the peak field, effective field, averaged electron angle, phase error, trajectory, integrated fields, and multipoles as shown in Figure 13 below. ADC uses B2E which runs under IGOR and we have written many routines to collect and analyze integrated fields and multipoles.

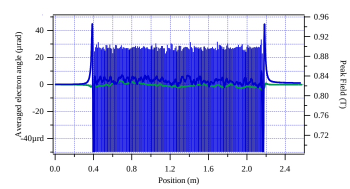
As an option to basic machine data, ADC can provide a "machine study" where we perform these measurements at multiple gaps and over a wider X and Y range. This involves the coordination of the MMS and IFMS with the ID motion controller to automate the collection of this data.

Examples of ID Data Collected by ADC

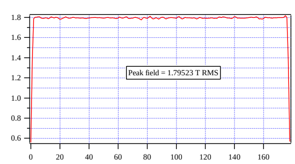
Raw Hall Probe Data



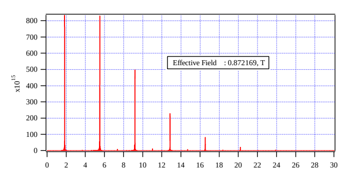
Averaged Electron Angle and Peak Field



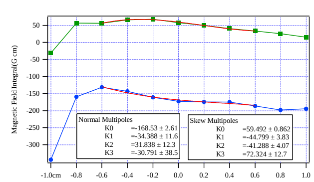
Peak Field

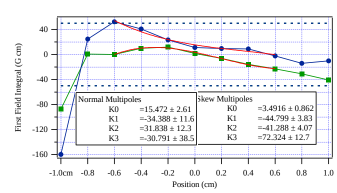


Effective Field

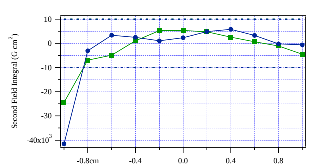


First Integrals and Multipoles Multipoles with Background Removed

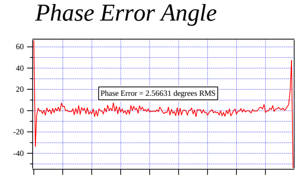




Second Normal and Skew Integrals



Phase Error Angle



ADC's Example Undulator History

CHESS Tapered Undulator

ALBA Synchrotron Wiggler

Synchrotron Radiation Center Planar Undulator

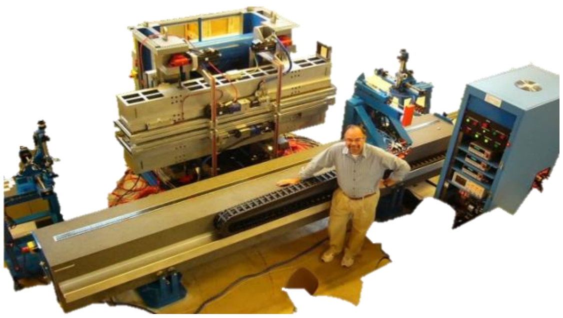
Canada Planar Undulator

Australian Synchrotron Wiggler

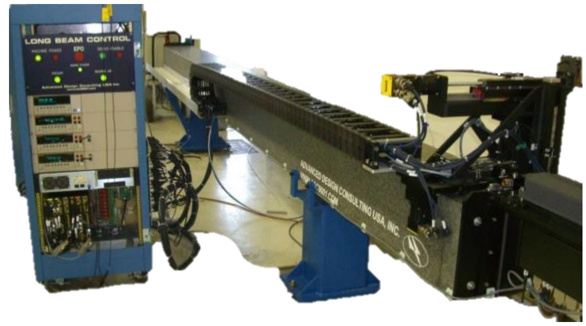
BNL Cry In-Vacuum Undulator

Find more information on undulators completed by ADC under the "Insertion Devices" Category. Or visit our website at

ADC's Example ID Measurement Systems History



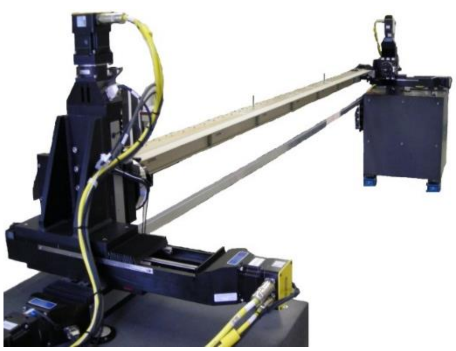
MAX Lab Magnetic Field Measurement System



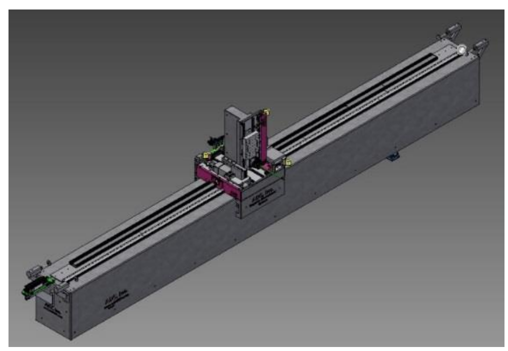
Shanghai Synchrotron Radiation Facility Magnetic Field Measurement System

ADC Old In-House Undulator Magnetic Field Measurement System

Pohang Accelerator Laboratory Magnetic Field Measurement System



National Synchrotron Light Source II Integrated Field Measurement System



ADC's New 8 Meter In-House Magnetic Measurement System

For more information please visit us at: http://www.adc9001.com/products/show_list/id/113