USING THE *NEW* LASER TRACKER FOR EXPERIMENTS AT THE NSCL

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Research Discussion

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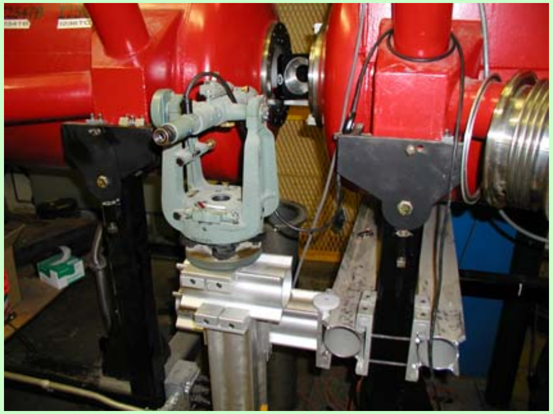
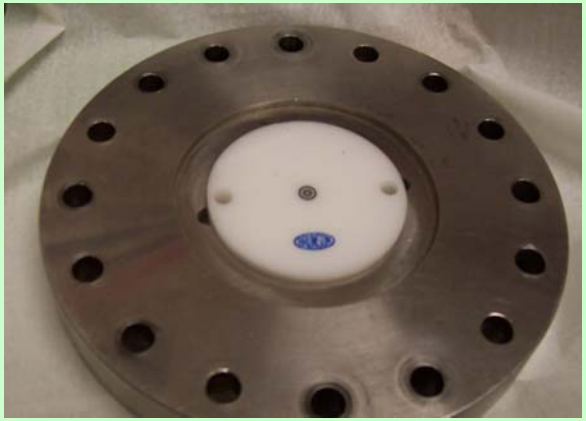
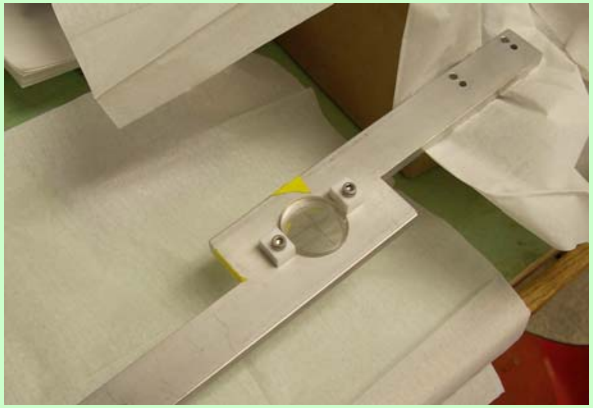
Present Technology

- Optical telescope on the beam axis.
  - Transit on beam axis via mirror in S-800.
  - Beamline flanges with alignment targets.
  - Detector mount with built-in glass targets.

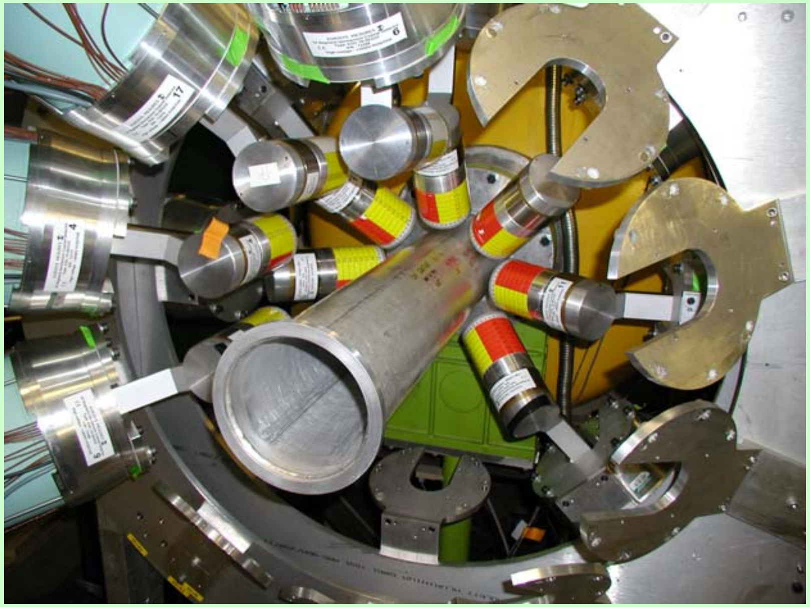






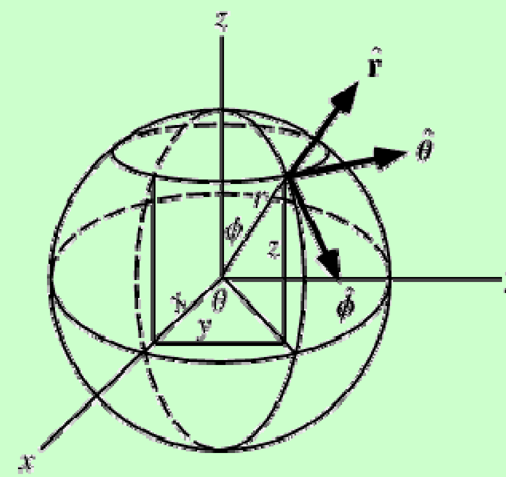
Present Technology

- 3-D Coordinate measurement via twin-theodolites: SEGA detector array.



What is a Laser Tracker?

- 3-D Coordinate Measurement Machine (CMM)
- Raw data: (r, θ, ϕ) position of a Spherically Mounted Retroreflector (SMR).



Who uses them?

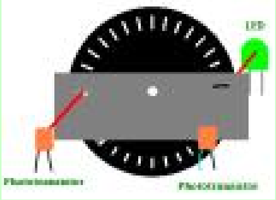
- National Nuclear/Particle Physics Laboratories: TJNAF, FNAL, SLAC, CERN, GSI.
- Synchrotron Light Sources: APS, SLAC, Spring-8, Diamond, ESRF, PSI.

Results of a Measurement

- Software + multiple measurements = (X, Y, Z) and graphic primitives (circle, line, cylinder, plane, etc.) in a user specified coordinate system.
- Results can be compared to a CAD model of the item.

How does a Laser Tracker work?

- The reflected light from the SMR is used in a feedback loop to keep the instrument pointed at the target using stepping motors.
- θ and ϕ are given by angle encoders mounted to the two rotation axes.



- R is given by the Absolute Distance Measurement (ADM).

ADM (Absolute Distance Measurement)

- Laser light is modulated at wavelength λ. $D=1/2(m \lambda + \psi \lambda)$ where m is an integer number of wavefronts and ψ is the phase difference between the emitted and reflected waves. D is the distance to the reflector.
- Measure the phase difference at λ, 10 λ, 100 λ, 1000 λ, etc. Each measurement, combined with the others gives another significant digit to the result.
- Limitations: At short wavelengths, it becomes difficult to measure the phase difference. This limits the absolute accuracy.
- Hardware/electronics constraints set the total range of modulation wavelengths.
- Temperature, humidity, return signal strength, and air currents limit the accuracy at long distances.
- Our tracker: Range: 0-35 meters Accuracy: +/- 0.025 mm at 2 m.
- Encoder angular resolution: 0.02 arcseconds (10**-7 radians).

Graphical Primitives Measured

- Infinite plane, level plane.
- Points, 2-D lines, 3-D lines.
- 2-D circles and ellipses, infinitely long cylinders, arcs.
- Cones, slots, spheres, toroids.
- Surfaces, extrusions.

Graphical Primitives Constructed

•Lines, circles, ellipses, points, cones, cylinders, etc.

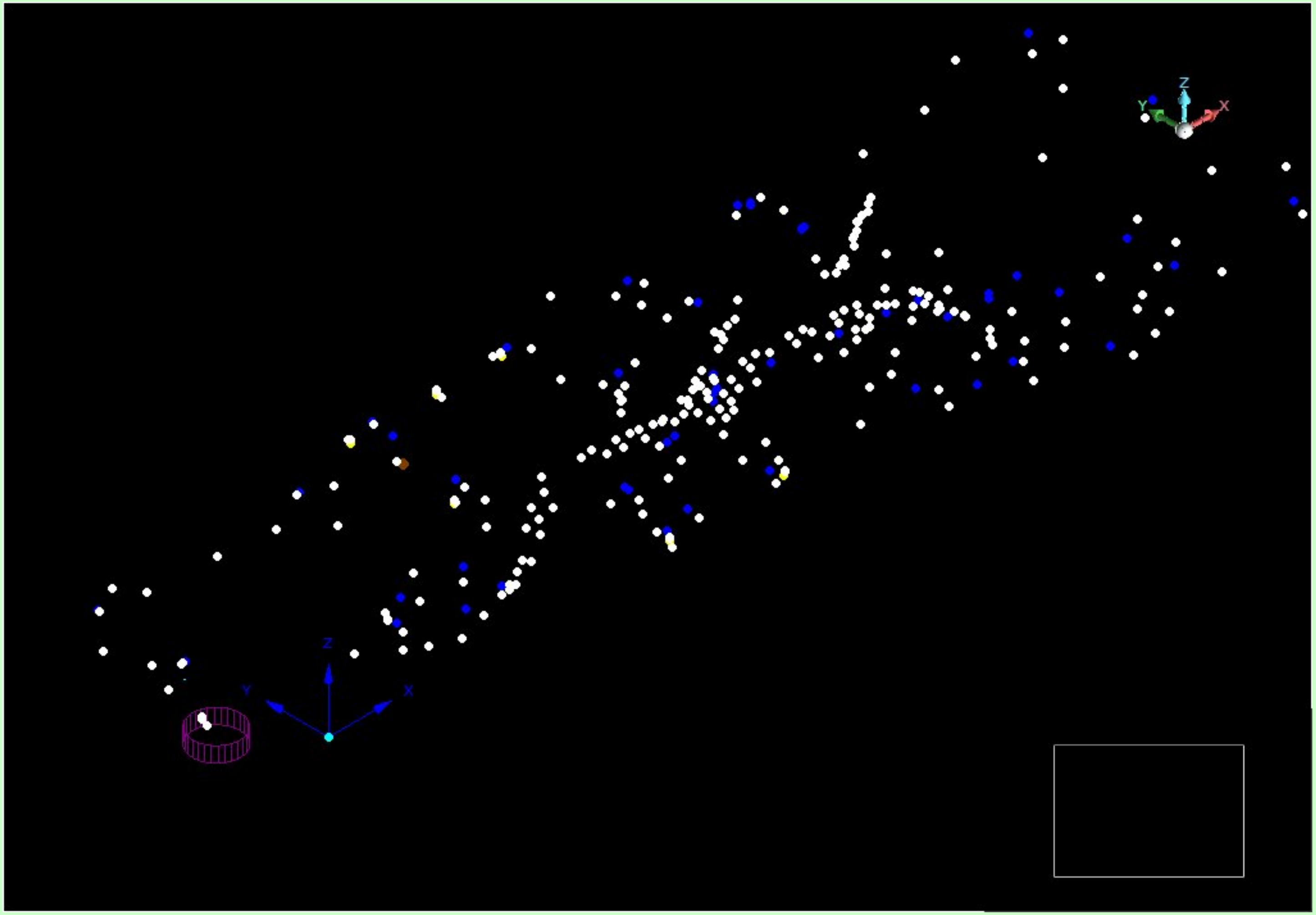
•Planes, intersections, tubing.

•Coordinate systems, alignments to CAD drawings.

How will we use the Tracker on the beamlines?

- A grid of calibrated floor and wall monuments has been created.
- Beamline straightness.
- CAD vs. As-Built. (Export measurements to the CAD drawing of the laboratory).
- How much did the magnet move since installation?
- How much does the floor move over time?

Calibrated Laboratory Monuments



Monuments

- Floor:

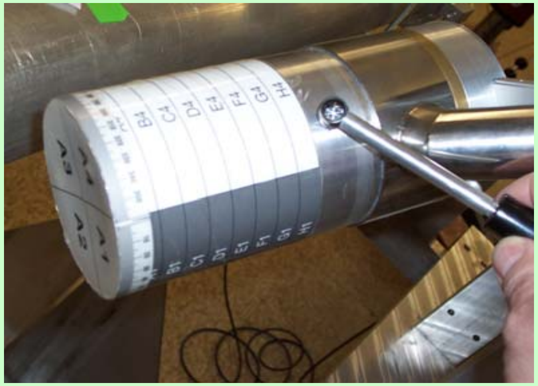
- Wall:

Using a Tracker on an Experiment

- Measure the position of the apparatus relative to the laboratory coordinate system.
- Measurement of the edges of a detector as graphics primitives: planes, lines, circles, etc.
- Comparison to CAD model of the apparatus
- Fabricated mount for an SMR at a known position on the detector.
- “Scanning” a surface, producing position data points across a virtual grid on the device.

Example: SEGA Detector

- Measure a cylinder.



- Measure a plane.

- Measure 2-D lines.

Summary

- The laser tracker is a high precision 3-D coordinate measurement instrument.
- The use of it in experimental setups requires either custom SMR target holders or surfaces and features in the apparatus that are easily described by simple graphic shapes.
- Getting useful information out of the raw data will often require comparisons with CAD models for the experiment.