USING THE NEW LASER TRACKER FOR EXPERIMENTS AT THE NSCL

D. P. Sanderson
Research Discussion
March 23, 2006
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: \((r, \theta, \phi)\) 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.
- $\theta$ and $\phi$ 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 $\lambda$. $D = \frac{1}{2}(m \lambda + \psi \lambda)$ where $m$ is an integer number of wavefronts and $\psi$ is the phase difference between the emitted and reflected waves. $D$ is the distance to the reflector.
- Measure the phase difference at $\lambda$, $10 \lambda$, $100 \lambda$, $1000 \lambda$, 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.