Design of System for Nanoradian Angle Calibration

Military Academic Collaboration (MAC) Program

Sandia National Labs, Albuquerque, New Mexico

By C1C Kaylee Kostka, DFCE, CS-13

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Autocollimators are used in precision alignments. Sandia National Laboratories' Primary Physical Standards has an autocollimator with 0.005 arc-second (approximately 25 nanoradian) resolution. Establishing the actual accuracy of the autocollimator is challenging: 5 nanoradians is a slope of 5 nm over 1 meter span, or the angle subtended by the diameter of a hair at a distance of 20 km. The only facility that can calibrate an autocollimator with these specifications is the PTB in Germany. We are interested in developing an alternative method for achieving very high resolution angle displacements.

With the guidance of project staff and technologists, the intern will first become familiar with the lab's Elcomat HR autocollimator. The intern will learn how to set up and operate the autocollimators to see the sensitivity of the system. The intern will then design and implement tests to quantify the required stiffness or compliance of apparatus to get nanoradian-level displacements in the autocollimator system. The intern may design mechanical fixtures that can be built by Sandia's additive manufacturing capabilities, to test concepts to achieve repeatable and traceable nanoradian angle calibration systems. There is an opportunity to co-author a poster on the results.

Sandia National Laboratories

Group Picture

Metrology and the Primary Standards Lab

Metrology is the science of measurements and weights.

NIST National Institute of Standards and Technology U.S. Department of Commerce

The National Institute of Standards and Technology (NIST) is the US'S metrology lab.

- created in 1901 as the National Bureau of Standards
- Under the US Department of Commerce

Two Locations
Gaithersburg, MD
Boulder, CO

The Primary Standards Lab at Sandia National Labs NM provides calibrations for organizations within Sandia, develops reference standards for US nuclear weapons plants, and more.

"Develops and maintains primary standards traceable to national standards… [and] anticipates future measurement needs of the nuclear weapons complex."

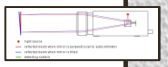
- Works collaboratively with NIST and other organizations
- Multiple labs in the PSL doing a variety of measurements
  - Pressure, AC/DC, Radiation, LMF (length, mass, force), etc.

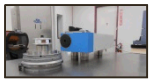
Autocollimator 101– The Key to the Project

Optical device used to measure small deviations in angles

Steps of Operation

- Emits light
- Light is reflected off a mirror
- Autocollimator receives reflected flight and measures angle between initial and reflected light





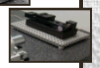
Autocollimators have two different variants: digital and visual. Both can help with a variety of applications– alignment, angle standards, monitoring, and angular movement.

Research and Development– From Paper to Prototype

Previously Developed Calibration Techniques

- Sine bar using piezo nano-positioner pusher
  - High Precision Small Angle Generator (HPSAG)
- Subdivided circles (adjusted manually or by computer)
  - Moore 1440 Precision Index Table
  - Triple-stack index table at NIST
- Bootstrap system having combination of tools

Circle Divider Moore 1440 Precision Index Table



Sine Bar HPSAG from Turkish National Metrology Laboratory

Initial Designs and Considerations

Gear Ratio Design

Reduction Ratio: 1:10
Number of required systems: 9
Reason for disqualification: Space constraints, error possibility too high

Lever Designs

Vertically Applied Weight

Displacement system: Vertically apply weights to cause rotation
Reason for disqualification: Lacked user-friendly operation, need for additional reinforcements to prevent buckling from overloading

Gauge Blocks

Initial Thinking: Have history on gauge blocks in the lab, would provide well-documented displacement

System reduction: 1:5
Reason for disqualification: Additional human element, need to remove/replace gauge blocks for various measurements

The Final Product– Autocollimator Calibration System

Final Calibration System Design

5 Lever Arm Design

Base: 330 mm x 150 mm
Lever Length: 300 mm, 250 mm, 50 mm ratio
Angle Accuracy: 3.2 nanoradians
Flexure: Cross-flex Hinge with 0.25 in outside diameter with 0.0143 $\frac{in-lb}{Degree}$
Material: 1060 Aluminum Alloy
Actuator: rounded top, similar to New Focus picomotor from Motus Mechanical

Lesson Learned– Academic and Real Life

Academic

- CSRP furthered knowledge of mechanical engineering elements, broadened my academic study
- Academy education gives broad basis of knowledge, enables you to understand general ideas on various topics
- Passion for a job, further education breeds success

Real Life

- Gained greater appreciation for airmen who work at PMEL
- As an officer, need to trust my airmen's technical skills while having an understanding of their projects
- Don't confine yourself to your desk, walk and meet people
- Work isn't just about work, but about experiences gained both on and off the job

Exploring Albuquerque, Kirtland AFB, and more!

4 National Parks in 6 Weeks!
Grand Canyon, Great Sand Dunes, Carlsbad Caverns, Guadalupe Mountains

Seeing Albuquerque with MAC interns
Climbing La Luz, exploring Old Town, watching an Isotopes Minor League baseball game

Out and About
Climbing the Highest Peak in TX, visiting White Sands NM, getting "out of this world" at Roswell

Tours of Sandia and Local Companies
Tour of Intel, Z Machine, DTRA, Explosives, and more

C1C Kaylee Kostka, Civil Engineering, Class of 2016

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