

***AUTOMATION GROUP***

***Fiber Automation Division***

***Michael K. Formica – General Manager***

# **Fiber Automation 101**

***Fiberoptic Automation Exp /  
Assembly Tech Expo 2001***

- **Agenda**
  - *Pop Quiz*
  - *Resolution*
  - *Step Size*
  - *Repeatability*
  - *Error Sources*
    - Thermal
    - Abbe

**1) What is (typically) the most critical performance specification in photonics alignment?**

- a) *Accuracy*
- b) *Repeatability*
- c) *Resolution*
- d) *Step Size*

**1) What is (typically) the most critical performance specification in photonics alignment?**

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**2) What is (typically) the most commonly specified performance specification in photonics alignment?**

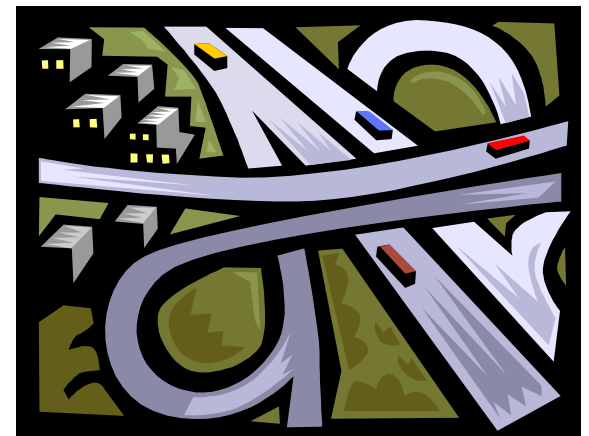
- a) *Accuracy*
- b) *Repeatability*
- c) *Resolution*
- d) *Step Size*

**2) What is (typically) the most commonly specified performance specification in photonics alignment?**

- a) *Accuracy*
- b) *Repeatability*
- c) *Resolution*
- d) *Step Size*

- **Resolution** - the minimum *theoretical* distance that can be measured by a closed-loop feedback device
- **Step Size** – the minimum distance that can *actually* be moved by a positioning device

- **Driving the streets of Pittsburgh with a GPS**
  - *You may know where you are...*
  - *You may know where you want to go...*
  - *That doesn't mean that you can get there*





*In a perfect world...*

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- **Engineers would get paid like pro athletes**

- **Ideal System**

- *Infinite resolution*
- *Frictionless*
- *Feedback at work height*
- *No backlash*

- **It exists...**

- *Wafer steppers have*
  - Air bearings, linear motors, laser interferometers
  - Big price tag
  - Poor form factor (for fiber optics)
  - Insufficient axes (for fiber optics)

# The world is not a frictionless surface...

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- **In a real system**

- *Open-loop*

- Backlash / hysteresis unaccountable
- All distances are assumed

- *Closed-loop servo dither*

- Theoretical minimum =  $\pm 1$  count
- Well-designed systems can be approx. 2-3 counts
  - Function of servo gains, amplifier, system noise, etc.

- *Friction*

- Can lead to inconsistent step sizes as friction varies

- *Compliance between drive system and feedback device*

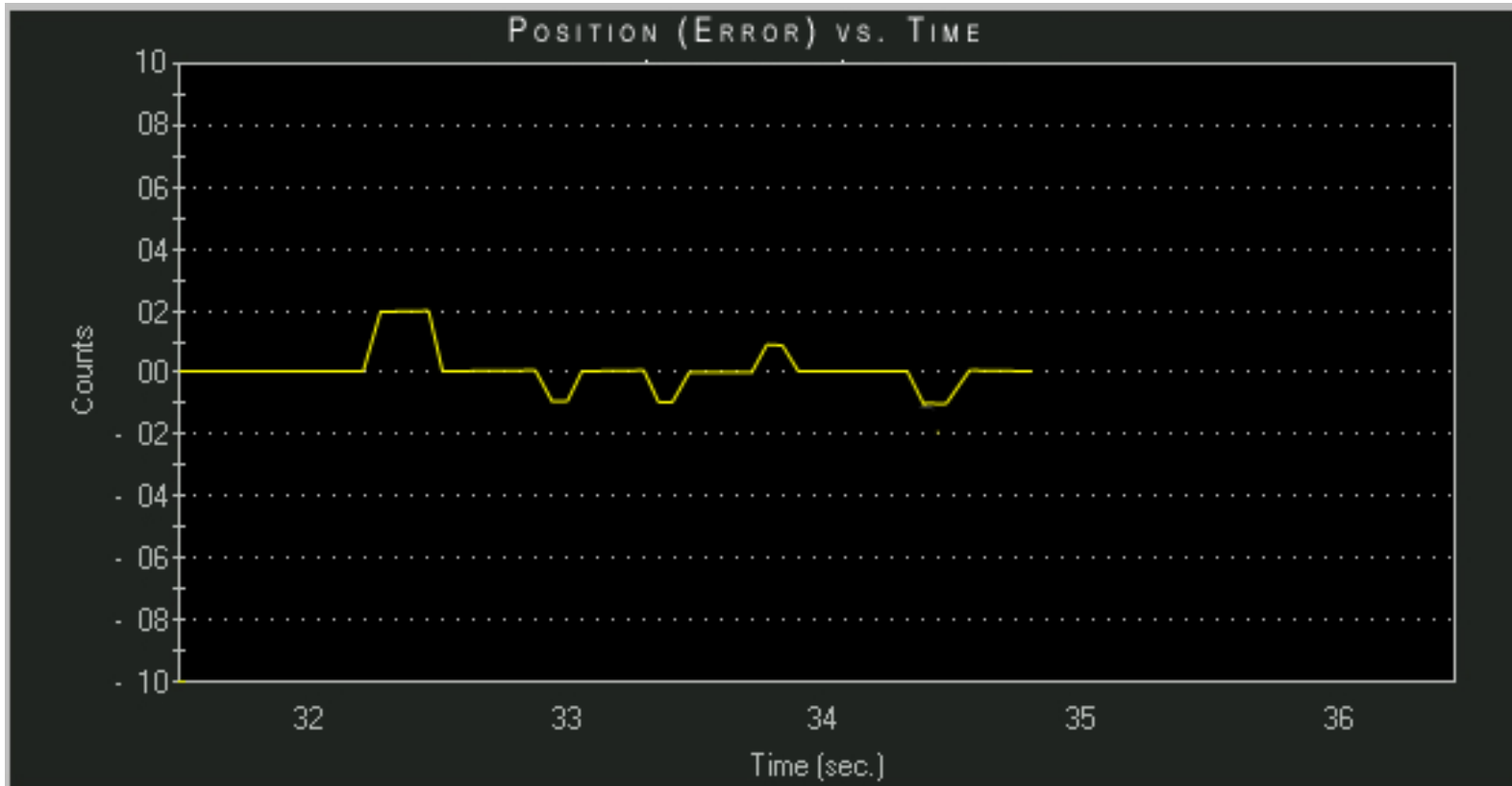
- Impractical to place feedback at work piece

- *Backlash / hysteresis*

- Near zero with direct drive (linear motor, voice coil) mechanisms
- Significantly worse for alternate drive mechanisms (screw, piezo)

## Proof is in the plots

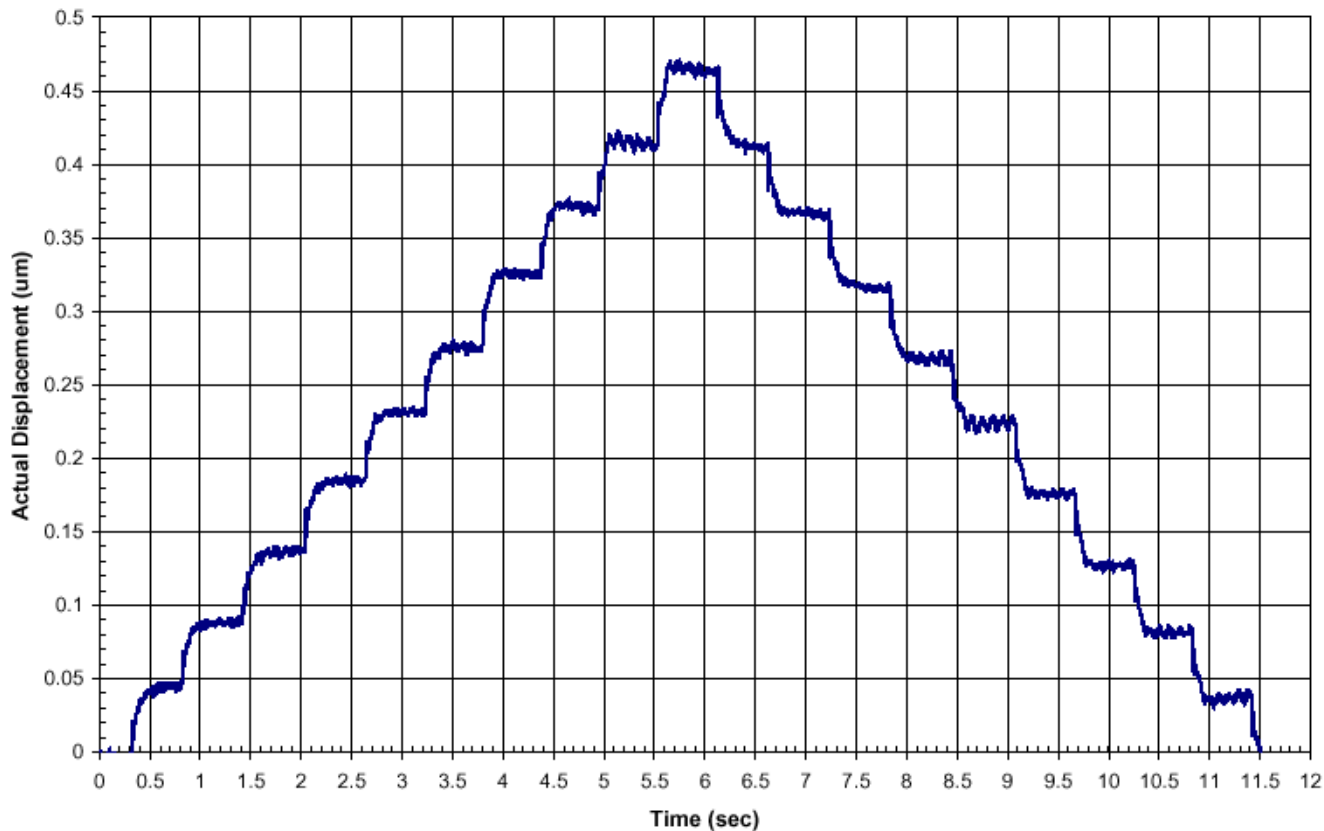
- **Closed loop servo performance**
  - *Only measures what encoder sees*



# Proof is in the plots

- **Interferometer measurement**
  - *Indicative of what device does*
  - *Takes into account geometrics also*

0.05um moves, 500msec dwell, 10nm resolution, 5lb load



- **What to look for**

- *High precision requires closed loop servos*
  - High resolution
  - Good servo tuning / analysis tools
- *Friction*
  - High-quality bearing system
  - Non-contact drivetrain (linear motor / voice coil)
- *Compliance between drive system and feedback device*
  - Directly coupled feedback
  - Avoid complex drivetrains (rotary motors, couplings, ballscrew/nut)
- *Backlash*
  - Non-contact drivetrain (linear motor / voice coil)
  - Avoid complex drivetrains (rotary motors, couplings, ballscrew/nut)

➤ **Step Size > Resolution**

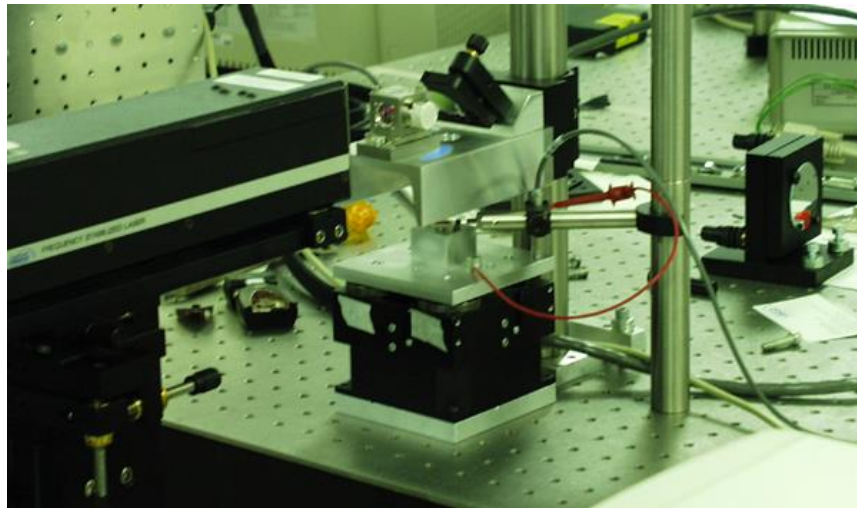
- **Repeatability** - the ability of a system to return to a given point over *many attempts*
  - *Uni-directional* – only when approaching from a single direction (ignores backlash / hysteresis)
  - *Bi-directional* – when approaching from either direction



- **I can prove that I can hit a 30-foot jumpshot with my eyes closed.**
  - *A day of videotaping...*
  - *A day of missed shots...*
  - *Eventually one of them will go in...*
  - *That's the clip you show*
  - *Doing it once out of a hundred tries doesn't mean you can do it.*

- **Plot of system repeatability**

- *Measures actual vs. commanded position along the axis of travel*
- *In this case, bi-directional*
- *The difference between forward and reverse is the repeatability*

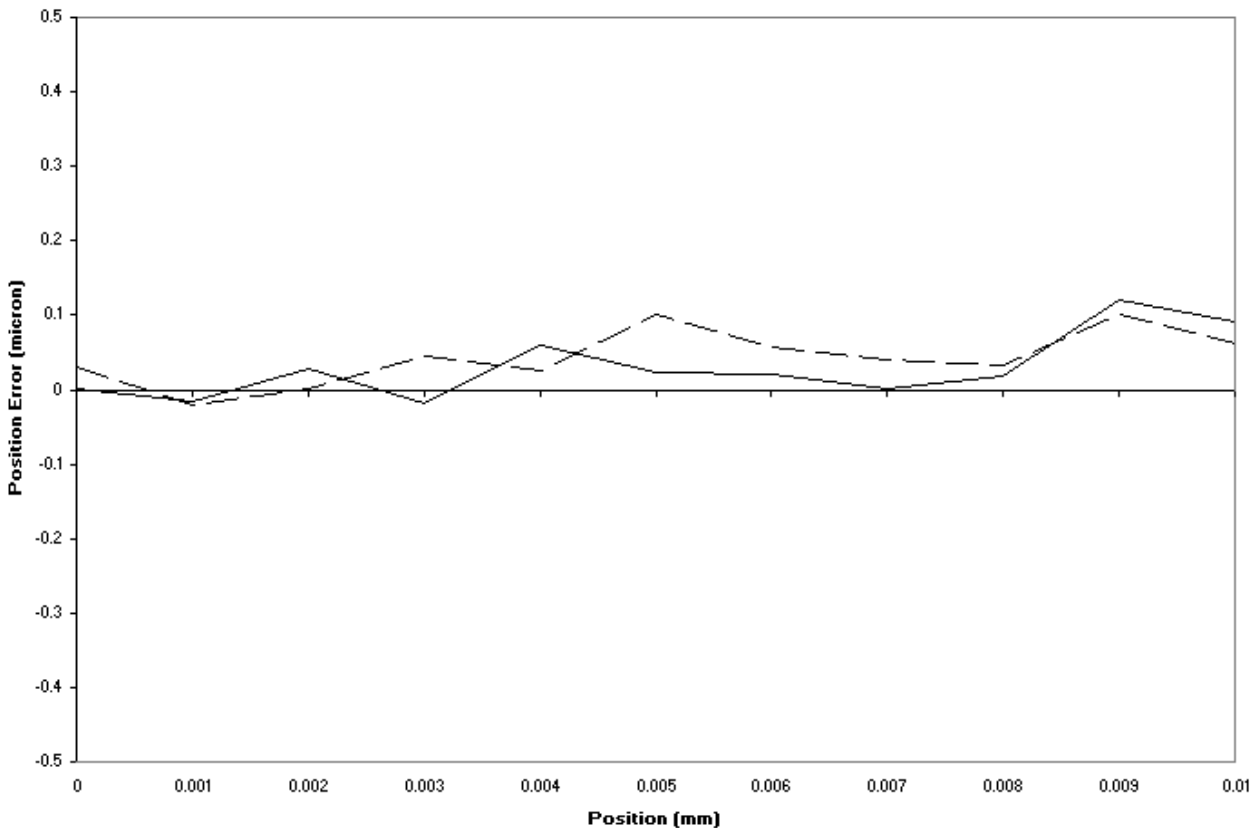


*Axsys FAST6 positioner undergoing automated calibration with laser interferometer*

# Proof is in the plots

- **Plot of system repeatability**
  - *Looks pretty good, but...*

Linear Accuracy - Bi-Directional

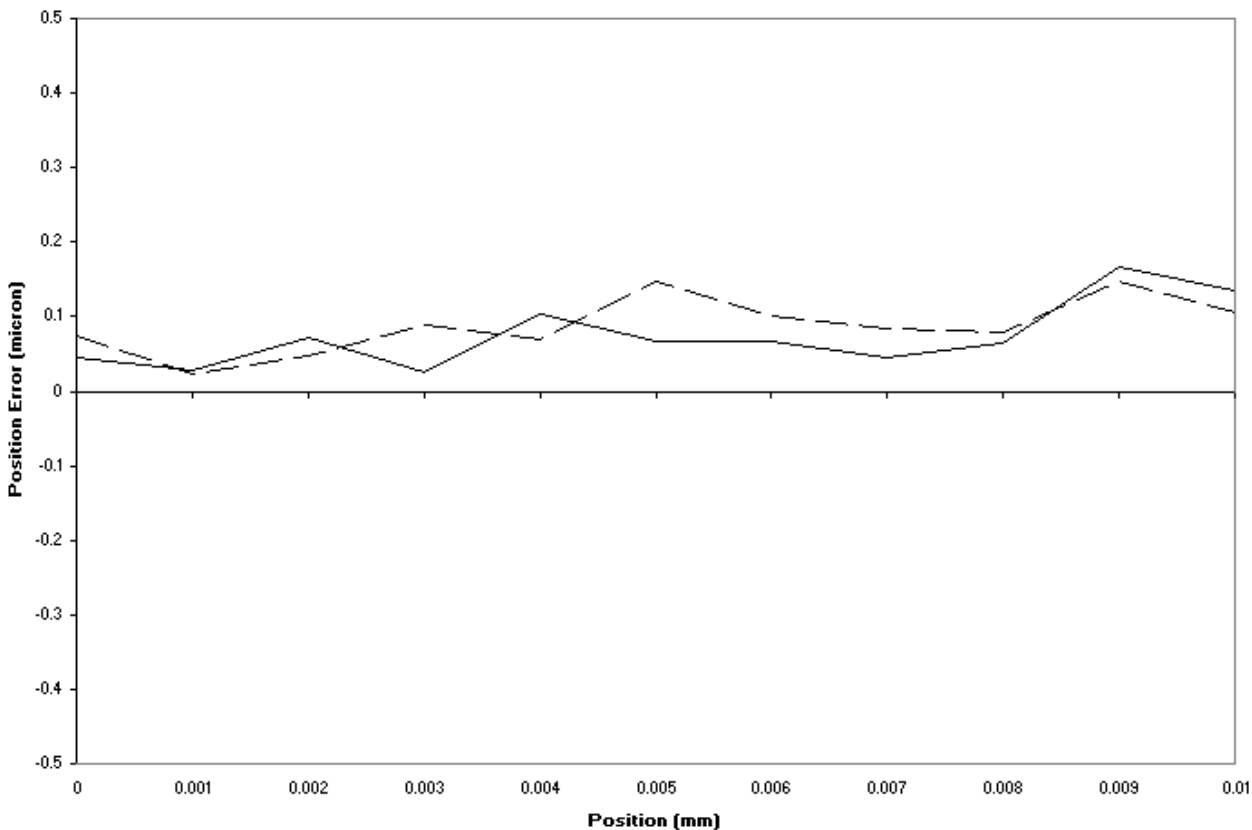


# Proof is in the plots

- **Plot of system repeatability**

- *...now it hasn't been normalized to zero...and...*

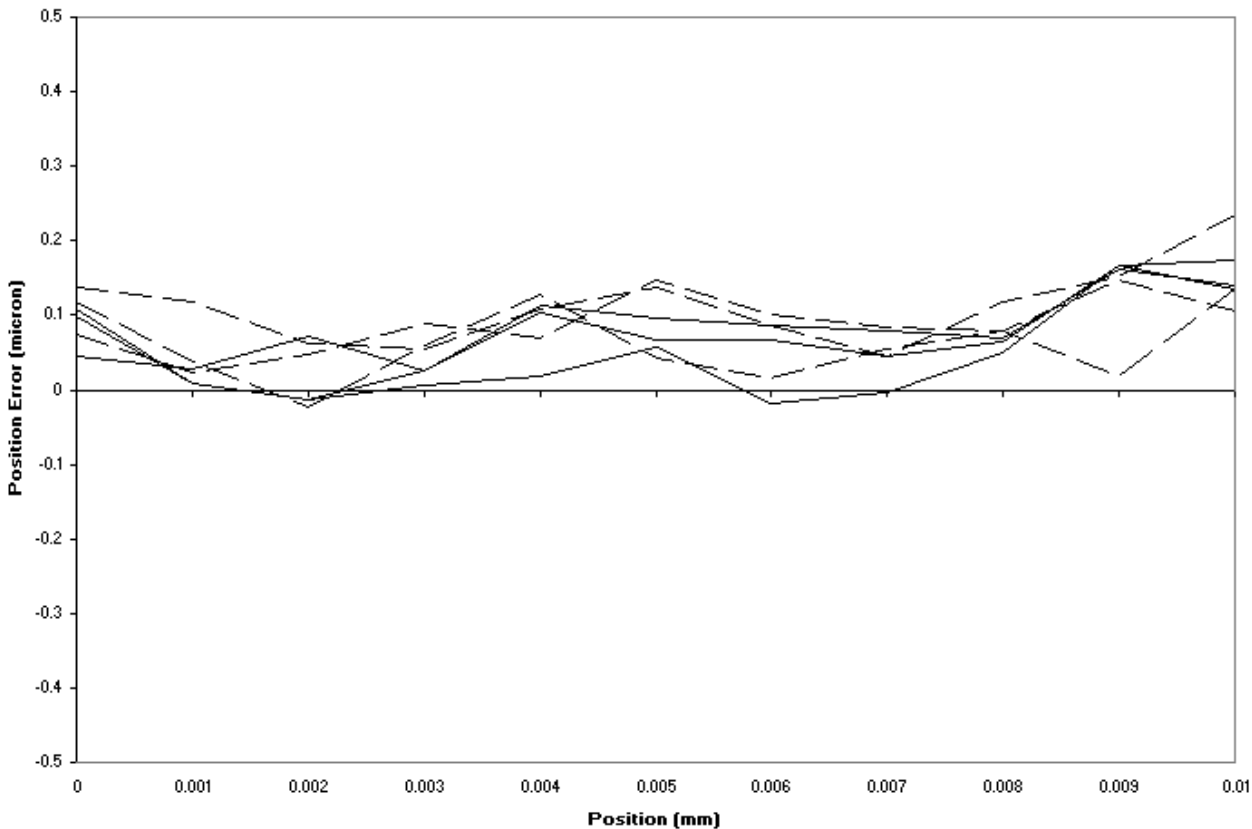
Linear Accuracy - Bi-Directional



# Proof is in the plots

- **Plot of system repeatability**
  - *...now it shows multiple attempts, indicating true 'repeatability'*

Linear Accuracy - Bi-Directional



- **What to look for**

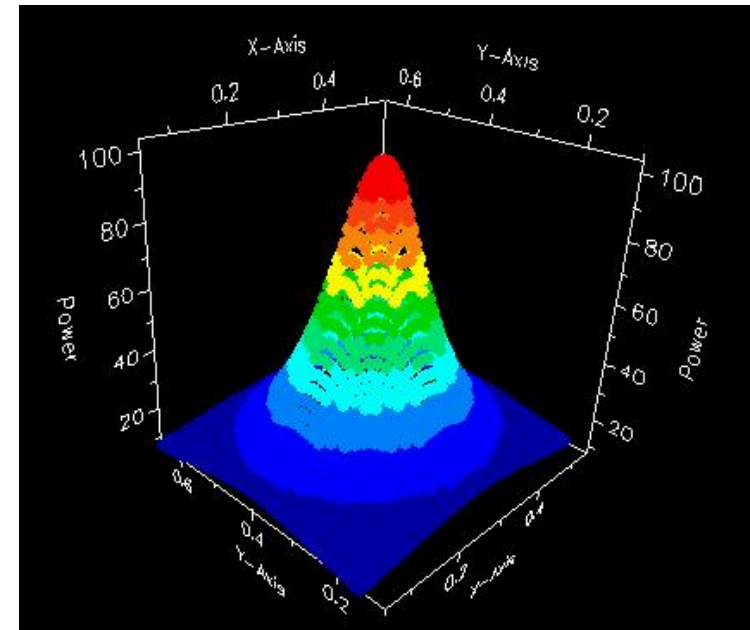
- *Actual performance plots of repeatability*
- *Several runs of data*
- *As measured as a system at work height*
  - Ref: Abbe errors
- *Not always practical to perform 3sigma testing on all products, however, should exist as a baseline*
- *Be wary of claims of repeatability equaling  $\pm$  resolution*
  - This is an electrical spec and ignores mechanical and step size effects

- **Repeatability > Step Size**
- **Step Size > Resolution**

- **Accuracy** - the ability of a system to go to a given point in space against an absolute reference
  - *Very commonly misused term*
  - *Pure accuracy not typically required in photonics applications that peak about optical signal*



- **Peaking optical power**
  - *Start with first light (typically use vision)*
  - *Peaking algorithm to find optical center*
    - Typically small distances from start
    - Decision to move or stay based on power not position
    - Therefore accuracy not applicable

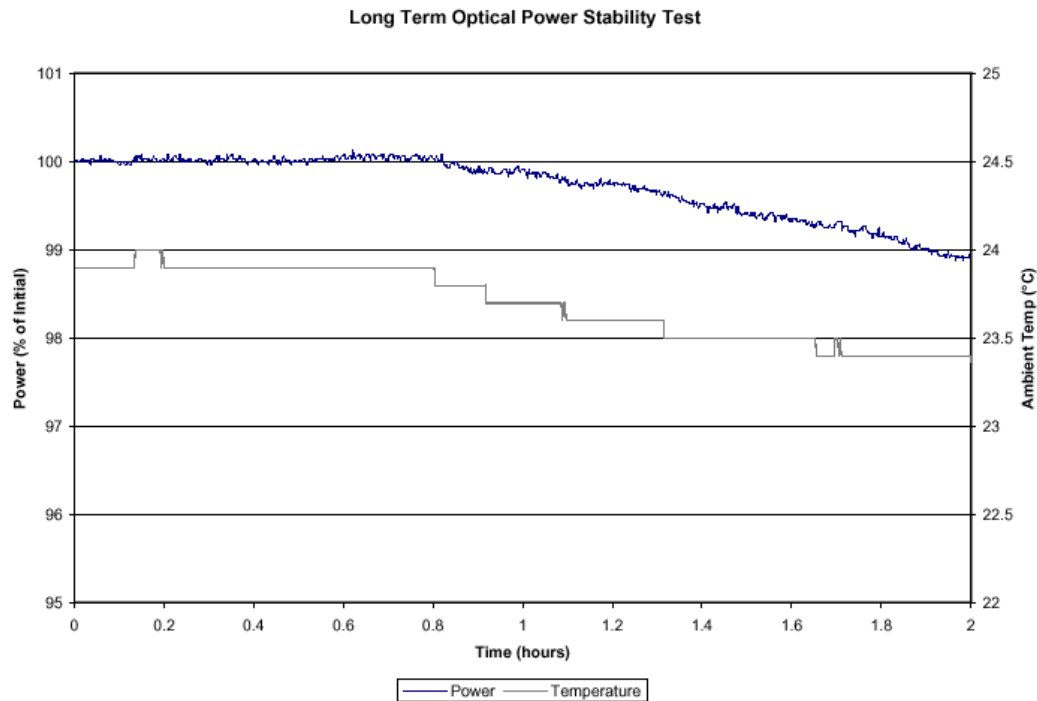


- **Accuracy > Repeatability**
- **Repeatability > Step Size**
- **Step Size > Resolution**

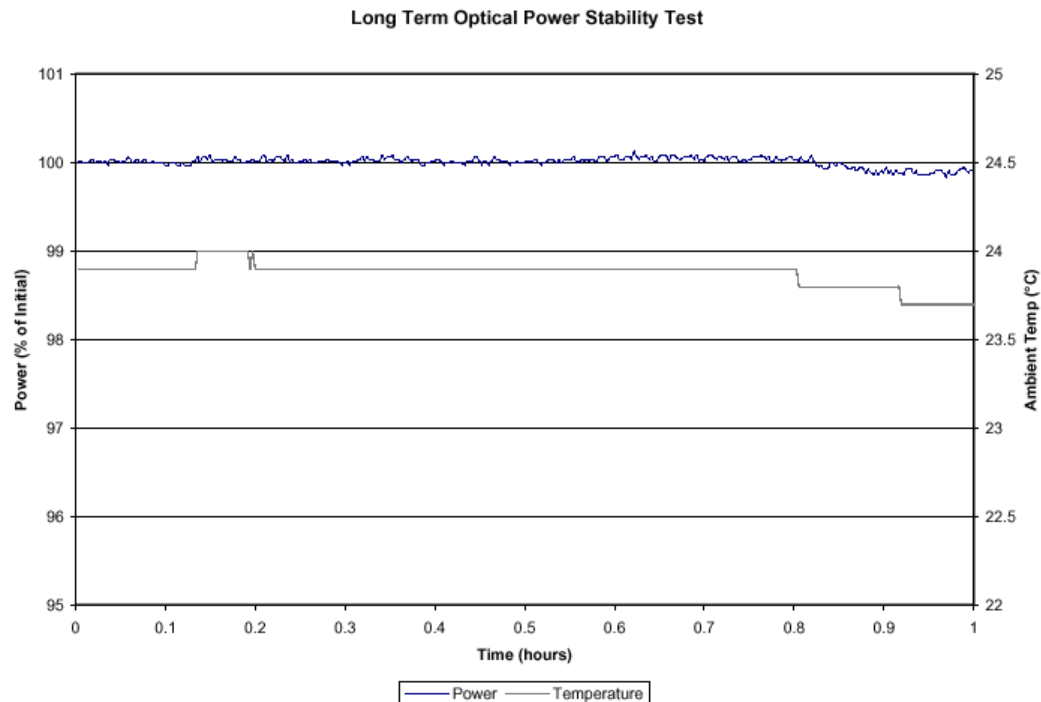
- **Thermal Stability**

- *Axsys utilizes glass scale (8ppm /°C) encoders to minimize thermal expansion*
- *Steel 'tape' encoders stretch with their substrate, typically aluminum, resulting in much poorer thermal stability*
- *Systems without linear encoders are more susceptible to thermal expansion induced errors*
  
- *Common material expansion coefficients:*
  - Al – 23.4ppm /°C
  - Stainless – 17.3ppm /°C
  - Granite – 6.3ppm /°C

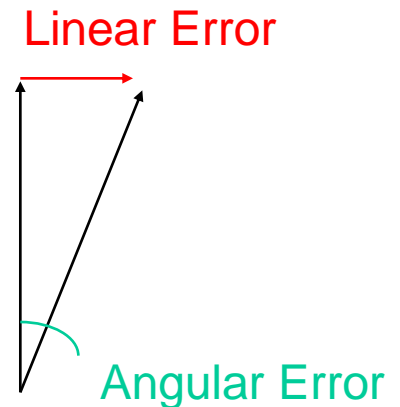
- **Power Stability vs. Thermal**
  - *When temperature varies, so does power*



- **Power Stability vs. Thermal**
  - *When temperature is stable, so is power*



- **Abbe Error – Linear error caused by angular deviations**
  - *Mounting surface*
    - Must be flat and clean
  - *External loading forces*
  - *Friction in system 'kicks' or 'holds' motion*
  - *Entry/exit of balls in recirculating ways*
  - *Worse the further away feedback is from device*
  - *Stacking errors – pitch / straightness / etc. of lower stacks contribute*
- **Highlights importance of system level calibration / testing**



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**Thank You!**