PRECISION TO THE NTH DEGREE™

Automation in the Development Phase
OIDA – June 19, 2002

Mike Formica – General Manager
mformica@axsys.com

Axsys Technologies
Fiber Automation Division

Who is Axsys?

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- **Axsys manufactures photonics automation equipment, including:**
  - Alignment stages
  - Development systems
  - Semi-automated test & attach systems
  - Fully automated test & attach systems
  - Photonics lab development services
  - Custom machine design
- **For photonic components:**
  - Planar (AWG, Modulator, VOA, etc.)
  - Active (Diodes, Pumps, etc.)
  - Hybrid devices, discrete optics, etc.

- **Philosophy**
  - Understand the current and emerging needs of our customers by soliciting input and feedback in everything we do
    - You can't improve what you can't measure
  - Employ Lean operating principles to deliver better products faster and at lowest possible cost
    - More than a statement, it is a way of life
  - Incorporate 6 Sigma Philosophies at all levels of the business
    - SPC – leads to *Superior* Process Control
  - Measure our success by the success of our customers. Make our customers successful by understanding and working in concert with their needs
    - Help them help themselves by engaging them at every level of development

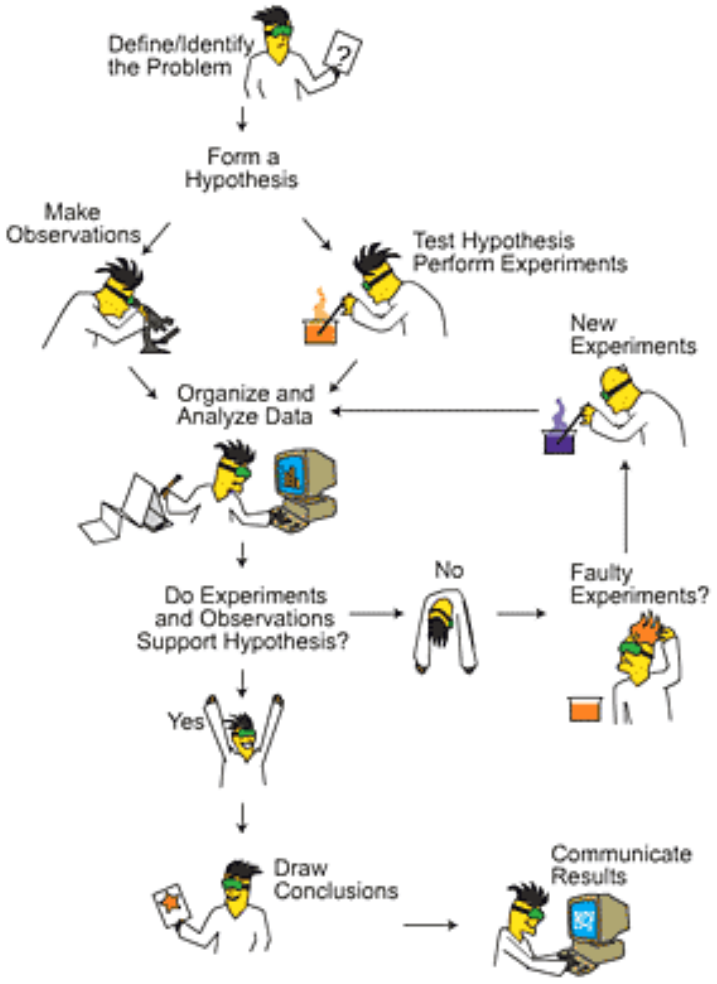
- **What's wrong with this picture?**
  - Everyone knows the problem, most know the solution, it is just a matter of time
    - "Those who don't learn from history are doomed to repeat it."
  - Automation benefits are widely understood
    - Increases throughput
    - Improves yield and quality
    - Reduce component unit costs
    - Reduces scrap
    - Doesn't require unmanageable staffing
    - Infinitely more scaleable
    - Companies must automate their manufacturing to survive the upturn

Typical photonics manufacturing plant circa 1999.

- **What's wrong with this picture?**
  - Automation in the lab is just as critical
    - Increases accuracy and repeatability
    - Improves time to market
    - Decreases development time
    - Reduces errors

Prince Andrew at BU Photonics Center circa 1999.

- **Scientific Method**
  - Objectivity of approach
  - Acceptability of results



- **Scientific Method**
  - Objectivity of approach
    - Attempt to observe things as they are without swaying observations to accord with preconceived view
    - Automation eliminates the 'human factor' and is exceptionally objective
  - Acceptability of results

Even the most disciplined researchers can inadvertently steer an experiment towards an expected outcome.

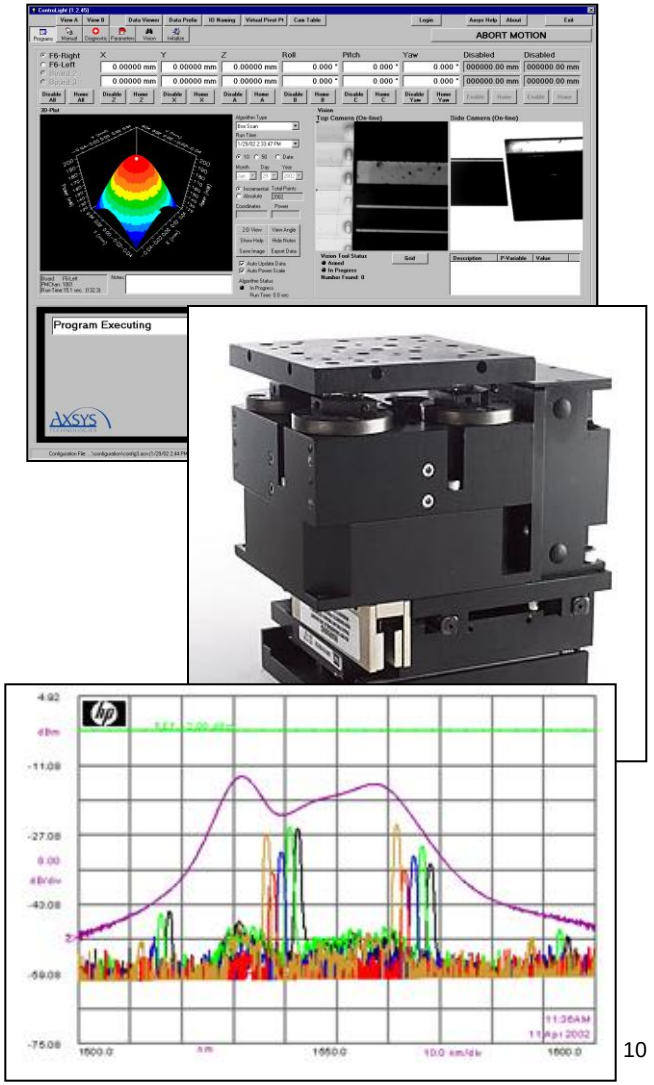
- **Scientific Method**
  - Objectivity of approach
  - Acceptability of results
    - Degree to which observations and experimentations can be reproduced

Anyone remember Ponds & Fleischman?

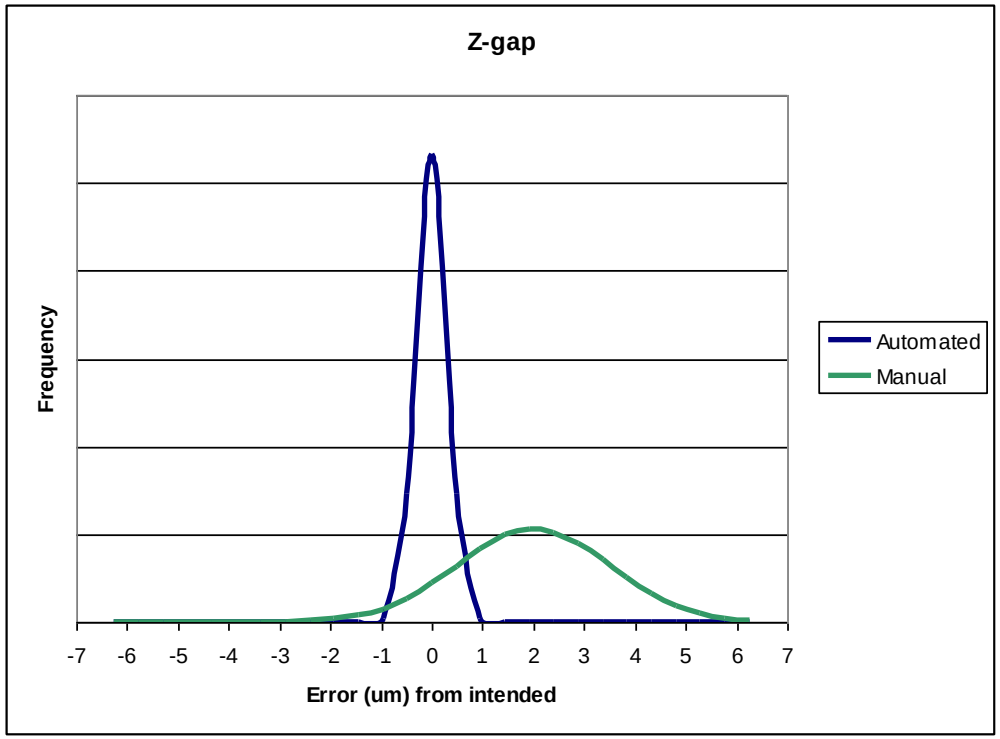
- **Manual Methods**
  - Pros:
    - Simple, easy method to get quick results
    - Inexpensive
  - Cons:
    - Poor repeatability
      - Leads to additional error sources
      - Results vary based on operator, procedure, etc.
    - May hide potential problems as 'level of river is lowered' (examples to come later)
    - Labor intensive
    - Inconsistent measurement standard – meters, etc. are calibrated for a reason

ThorLabs XYZ manual positioner

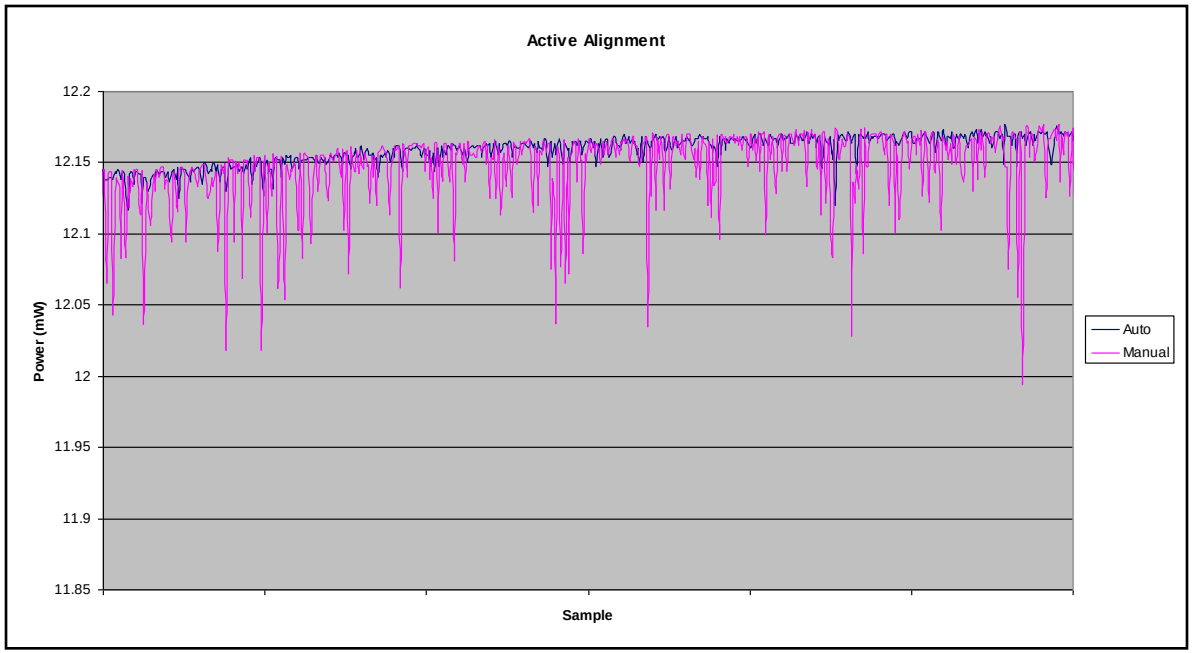
- **Automated Methods**
  - Pros:
    - High repeatability
    - Convenient data logging and analysis
    - Eliminates variables and ensures consistency of measurement
    - As devices progress, manual methods will be unable to be prototyped manually
      - Not all devices can be tested manually
    - Certain complex motions impossible manually
      - 6-axis with virtual pivot
      - On-the-fly data capture
  - Cons:
    - Requires initial investment in time and money (no impulse buying)



- **Alignment Comparison**
  - Task: Set the optical z-distance prior to performing XY alignments
  - Manually with microscope
  - Automated with machine vision



- **Alignment Comparison**
  - Task: Peak in XY axes with fixed Z setting
  - Manual search for peak
  - Automated alignment algorithm



- **Automation Benefits**
  - Improves suitability for production
    - Difficult to Design For Manufacturing when core methodology (manual lab vs. auto mfg) is fundamentally different
    - DFM issues understood at earlier stage when costs to make changes are the least
      - Costs increase exponentially as time progresses
      - Changes such as adding fiducials are trivial during design phase
      - Not having them can be devastating to either add or implement without during production

More Reasons to Automate

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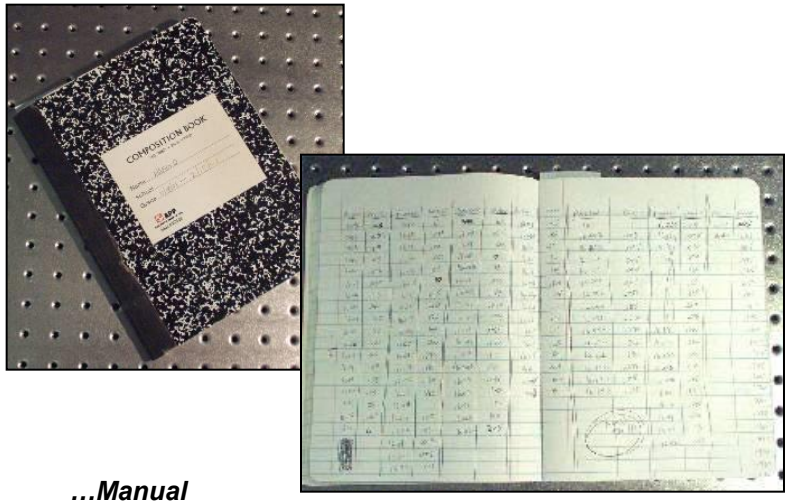
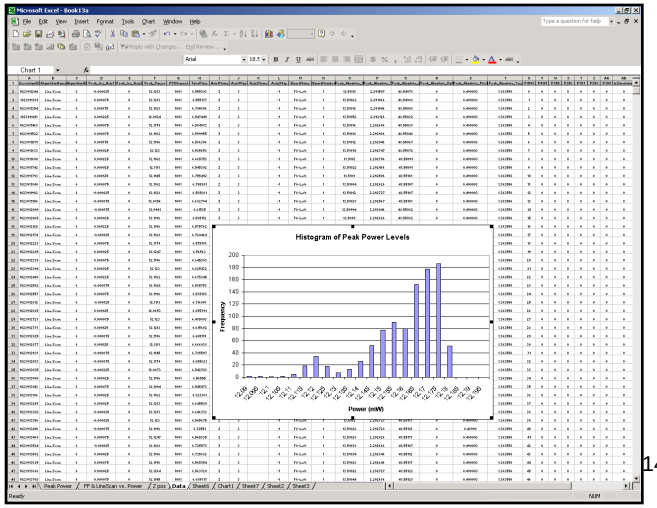
- **Automation Benefits**
  - Speed of testing
    - Reduces time to test
    - Increases ability to test larger lots
    - Enables collection and analysis of greater amount of data



…Manual

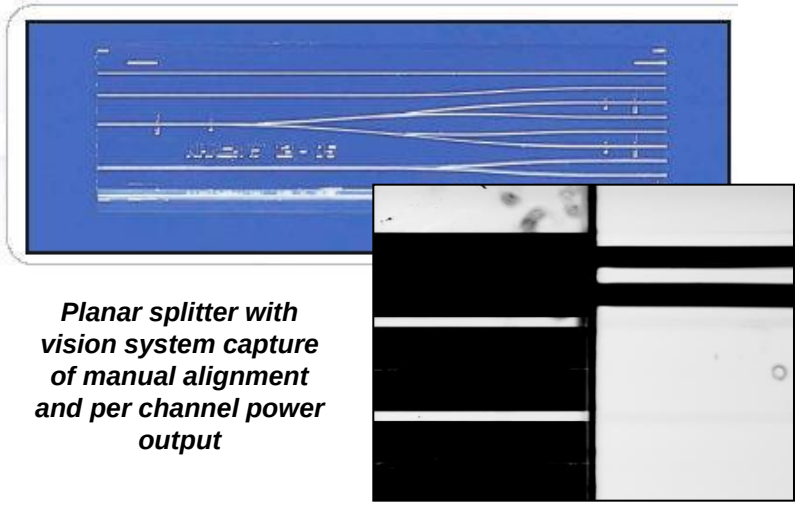
vs.

Automated…

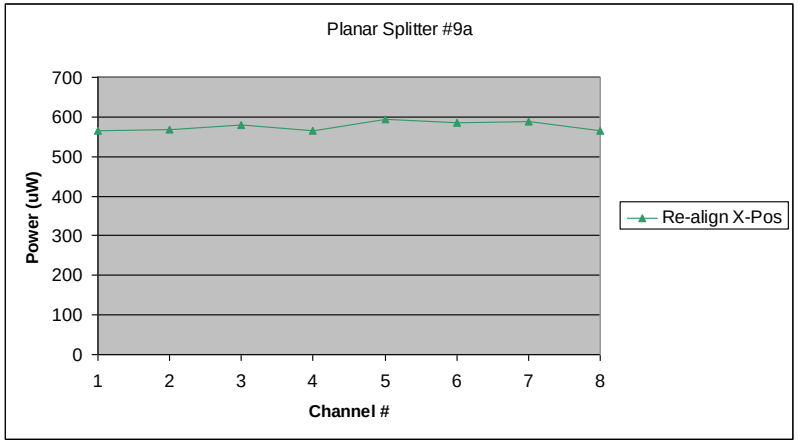


- **Automation Benefits**
  - Quicker transfer to production
    - Avoid 'Automate this *(manual process)*' mentality
    - Instead 'Migrate this *(well thought out development effort)* to the factory'
    - Result is
      - Quicker time to production
      - Quicker time to market introduction
      - Quicker time to market penetration
      - Quicker time to . . . . .

- **Case Study – Planar Waveguide**
  - Planar Waveguide splitters – single chip with multiple devices
  - Operators manually aligning to each output channel (single fiber)
  - Achieved acceptable coupling efficiencies on a per channel basis
  - Channel spacing confirmed visually

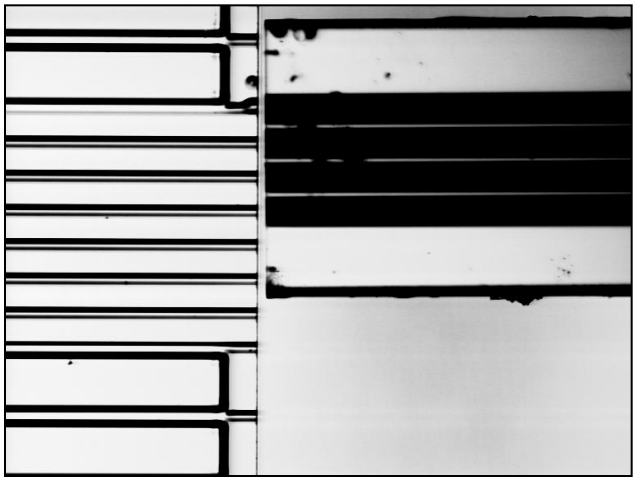


Planar splitter with vision system capture of manual alignment and per channel power output

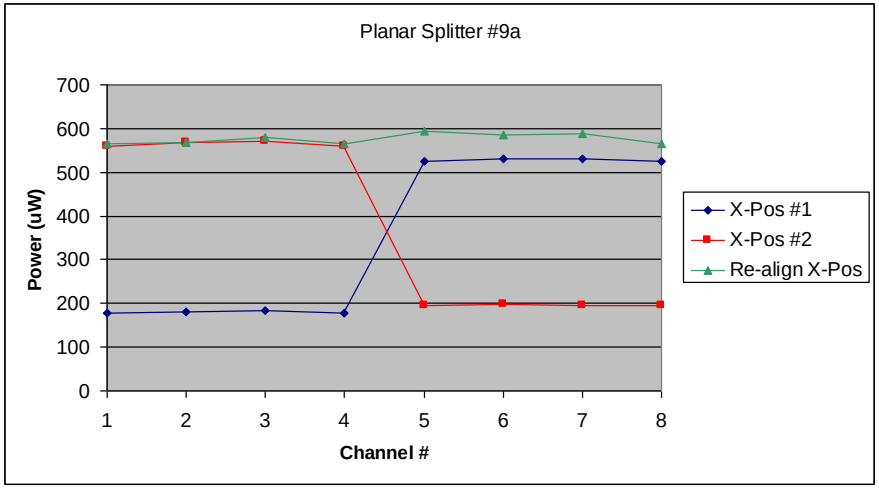


- **Case Study – Planar Waveguide**
  - Problem:
    - Upon transfer to production, manufacturing began to attach fiber arrays
    - Customer was unable to achieve consistent coupling efficiencies over all channels

- **Case Study – Planar Waveguide**
  - Cause:
    - In actuality half the channels biased +3um in x, half -3um in x
    - Impossible to get high coupling efficiency due to inherent mispacing of *optical* centers



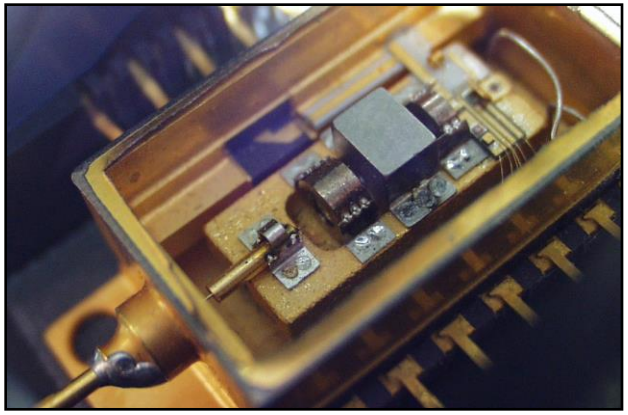
Vision system capture of automated multi-channel alignment



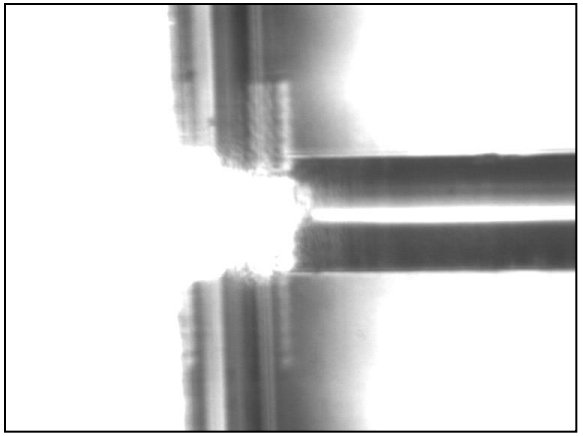
Per channel power output for multi-channel array align and single channel fiber align

- **Case Study – Planar Waveguide**
  - Contributing Factors:
    - Visual inspection of physical channel spacing did not account for optical center errors
    - Inadequate measurement accuracy in manual stages, therefore, 3um error not seen as operators re-aligned
    - Very difficult to create true angular motion (roll) manually, therefore, shortcut was to use single fiber which hid this problem

- **Case Study – Laser Diode**
  - Prototype edge emitting laser diode
  - Procedure
    - Manually align fiber
    - Run numerous tests taking data manually
    - Re-align prior to each new set of tests
  - Achieved good consistent power results in lab



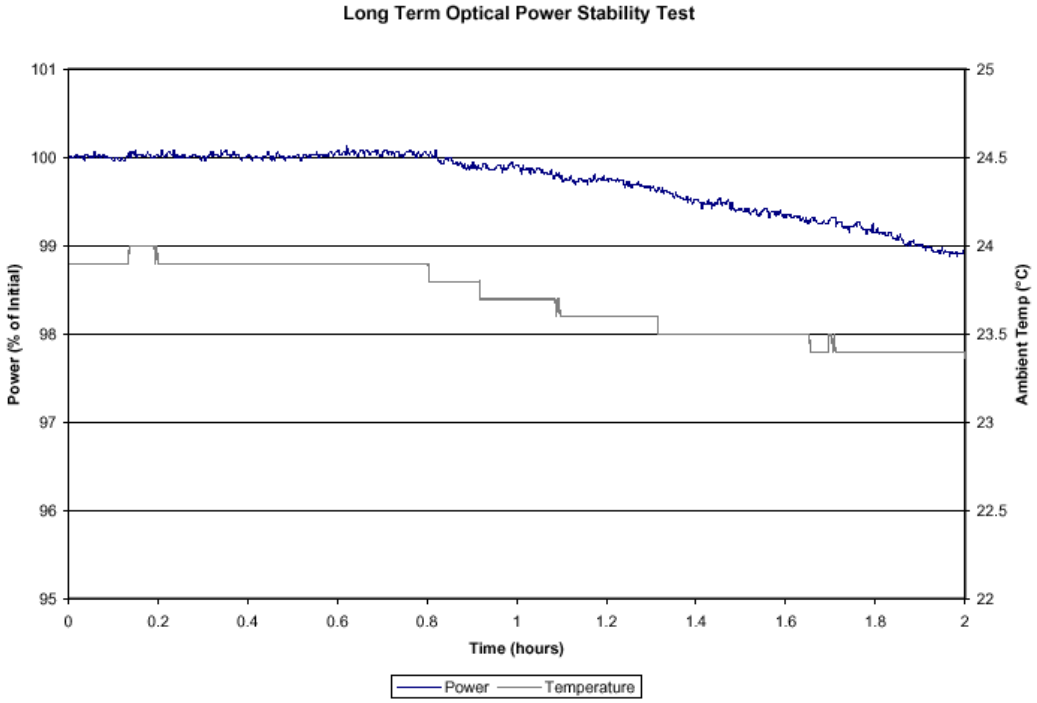
Packaged and attached laser diode



Aligned fiber as seen through vision system

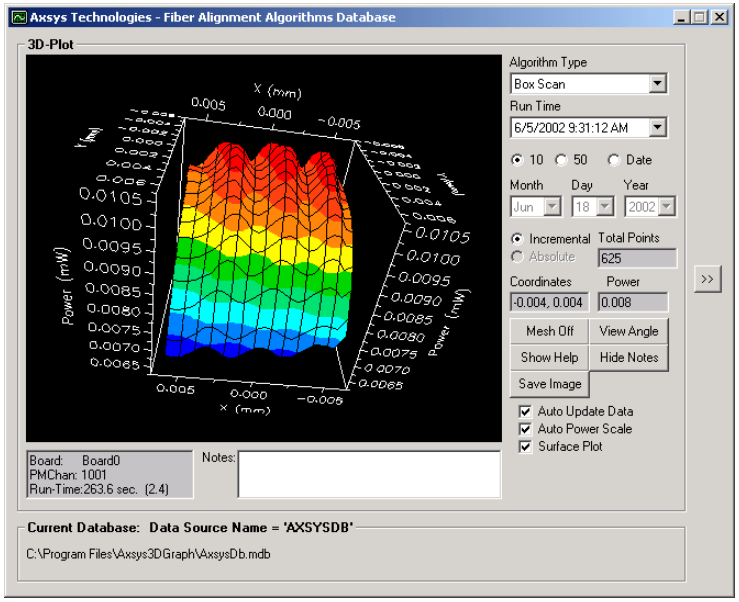
- **Case Study – Laser Diode**
  - Problem:
    - Upon transfer to attach process, power output varied significantly

- **Case Study – Laser Diode**
  - Cause:
    - After thoroughly evaluating attach process…
      - New device determined to be highly sensitive to thermal changes



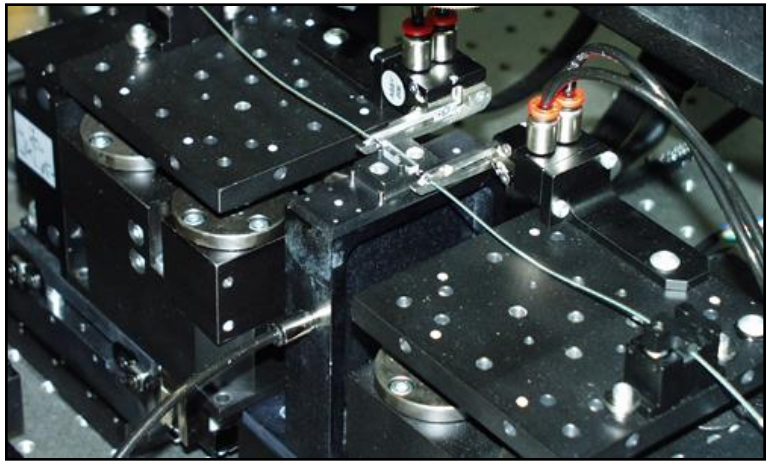
- **Case Study – Laser Diode**
  - Contributing Factors:
    - Operator was re-aligning fiber to achieve most recent power thereby masking temperature effects
    - Inability to run tests automatically resulted in longer test time and more human intervention than necessary

- **Selecting an automated system for the lab**
  - Ease of use – software is key
    - Windows based, canned routines for typical tasks (vision, active align, etc.), ability to write own routines (data logging, unique align, remote triggering)
    - Integrated automation tools – machine vision
      - Vision tools are useful to measure parts, angles, gaps, etc (i.e. setting up input fiber to modulator requires fixed angular offset)
    - Data logging – ability to crunch, coordinate large amounts of data saves time
  - Compatibility – able to interface with wide range of instruments
    - National Instruments has created an entire product line (LabVIEW) around this concept
    - Want to be able to use wide range of best in class instruments - avoid systems that are limited to proprietary interfaces and instruments
      - i.e. integration of temperature sensor from laser diode case study was critical to analysis



Power profile from automated scan – manual operator would be unable to differentiate local peaks

- **Selecting an automated system for the lab**
  - Flexibility
    - Needs will change as product develop, can equipment be reconfigured?
      - Quick change fixturing to accommodate range of fibers, device and array sizes (i.e. waveguide case study)
      - Easily adjustable components (vision camera locations, align stages, device fixtures)
    - May find unique requirements in lab (peak off of data register not power meter)
  - Scalability
    - Ensure equipment will be suitable to production in the long run, otherwise investment is not adequately leveraged



Alignment system with quick change fixtures for fiber arrays (1-64 channel)

Thank you for your time!