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Measurement Results for a Hybrid Dimensional Artifact

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Research Objective

- Mesoscale metrology commonly uses video probing
- Accuracy of video systems are typically limited by calibration artifact, not resolution
  - Calibration artifact accuracy ~1μm
  - System resolution ~0.1μm

Objective: To create a calibration artifact for a video-based measurement system which can be certified to better than 0.1μm accuracy.

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Outline

- Hybrid Dimensional Artifact
  - Design
  - Manufacturing
- Edge Measurement with UMAP
- Comparison of Pitch Measurements made by CMM and Video Probes
- Discussion and Conclusions

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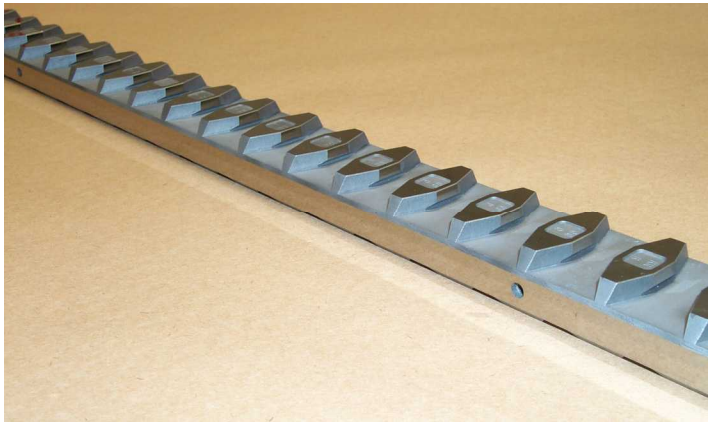
Geometric Design

- Fabricate artifact which contains miniature versions of “macro” metrology
- Step gage
  - 2D performance evaluation
- Ball plate
  - 3D performance evaluation
- Other objects for investigation



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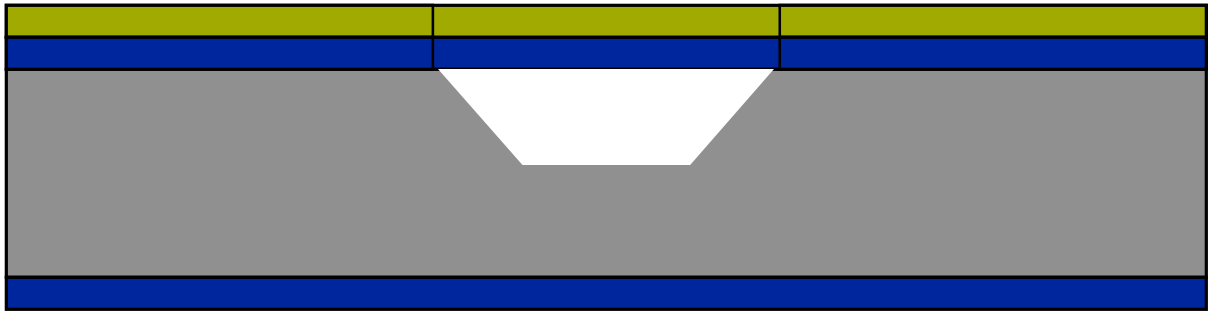
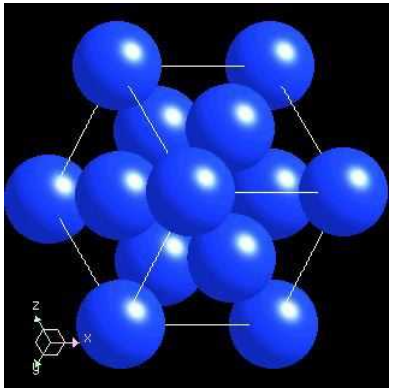
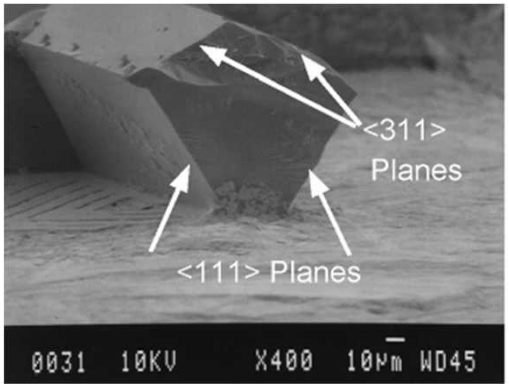
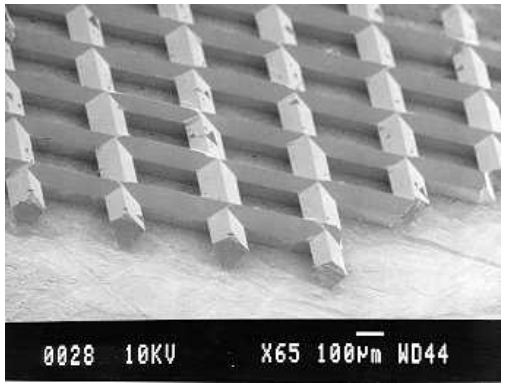
Si Bulk Micromachining









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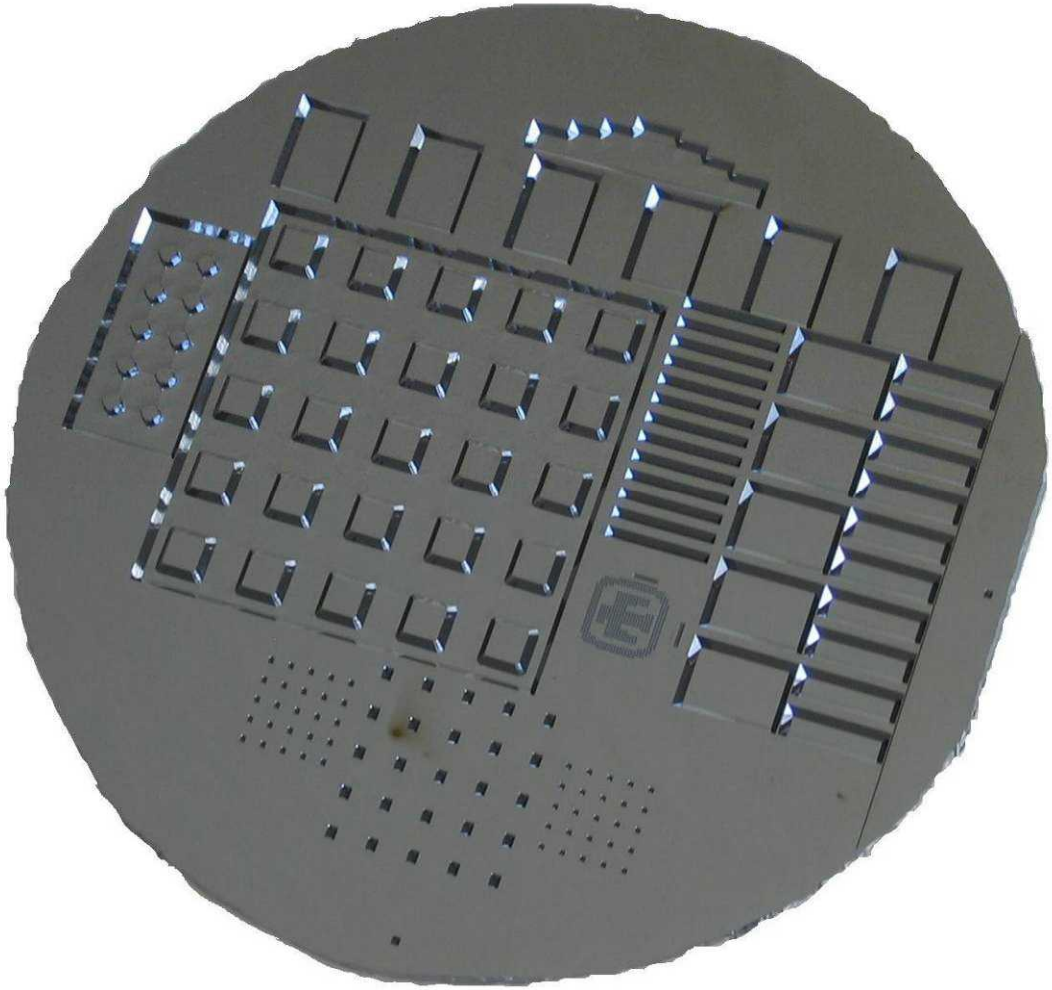
Manufacturing Design Details

- <100> silicon with KOH etchant
  - Gives sidewalls at 54.74 degrees
  - Yields etch planes flat to 50 nm
  - Edges are sharp and straight to nm level
  - Bottom of trenches not perfectly flat
- 1.5 mm thick wafer, polished on both sides
  - Flat to 50-70 nm over 20-30 mm
  - Etch depth can be varied

Artifact



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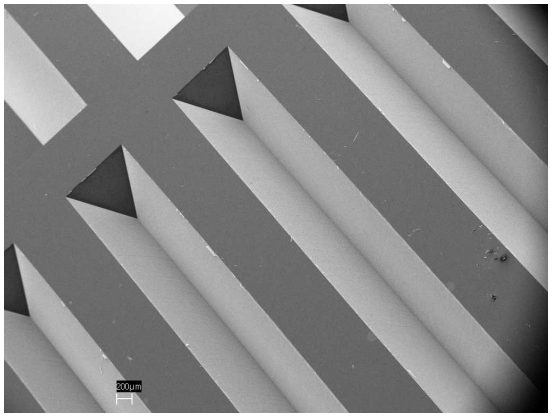
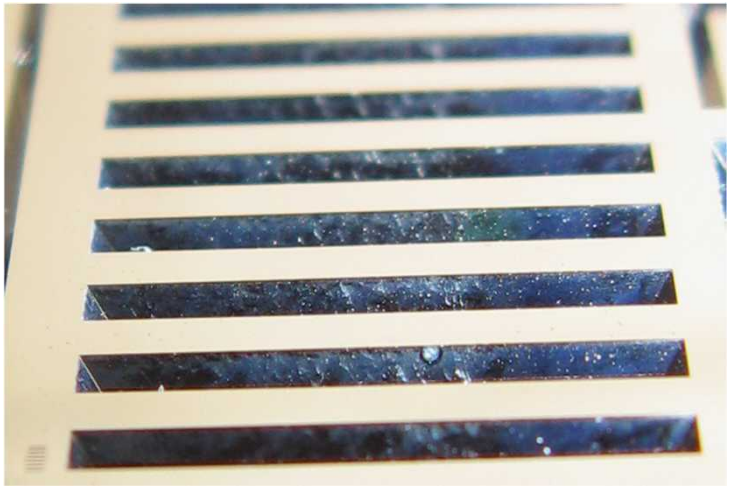
Manufacturing Issues

- Nitride removal process attacked silicon sidewalls
- Effects of alternative nitride removal processes are being studied



- Multiple crystal planes being etched



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Edge Measurement with UMAP

- Mitutoyo UMAP Ultra
- Contact measurements with probe
  - 30 μm diameter
  - 2 mm stylus length
- Accuracy

  (1.2 + 3L/1000) μm
- Repeatability

  S < 0.1 μm

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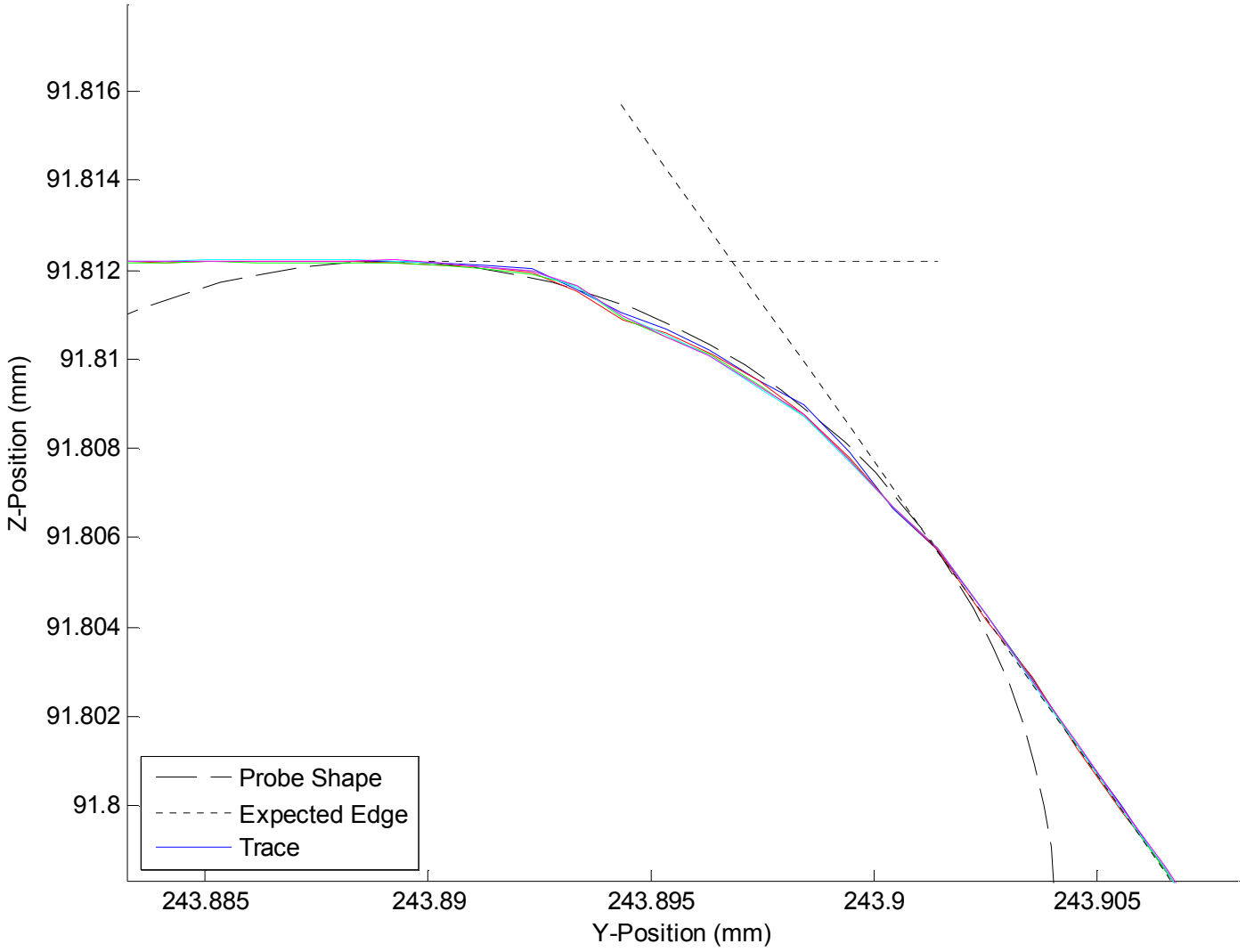
UMAP Edge Measurement



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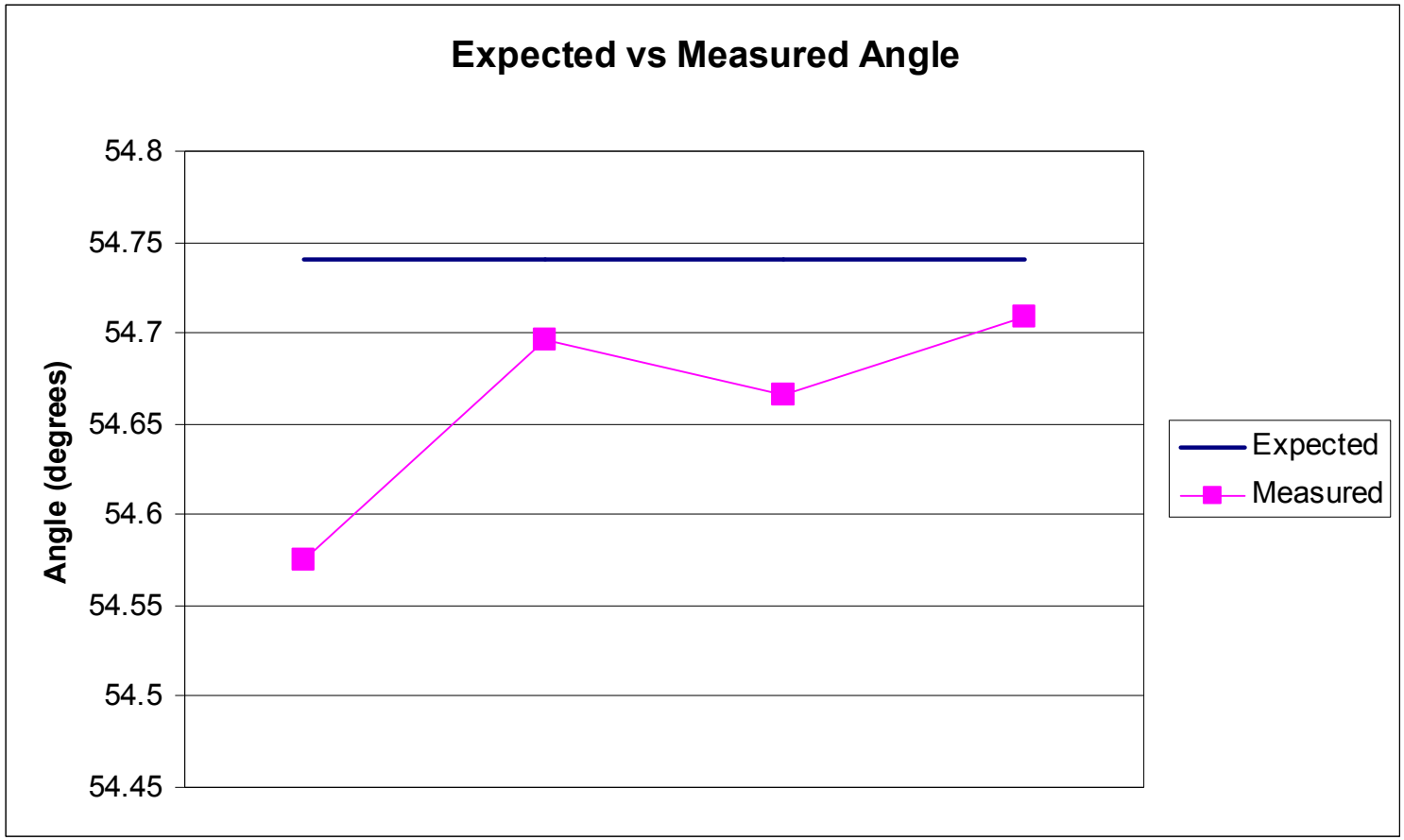
UMAP Angle Measurement



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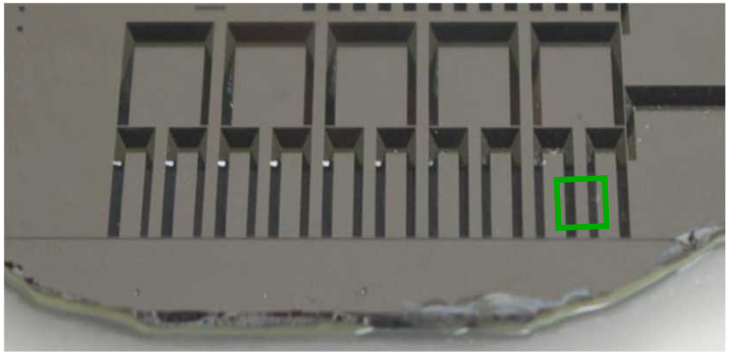
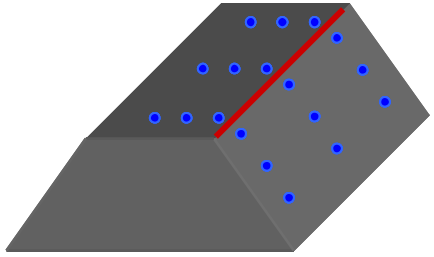
Comparison

- Compared single step bar (3mm trench, 4mm pitch)
  - Touch Probe (Moore M48)
  - Optical Probes (Werth Video-Check HA, OGP)
- CMM will probe top and etch planes and calculate intersection line
- Vision systems will locate edge formed by intersection of top and etch planes (top lighting used)





Coordinate Measurement Machine

- Moore M48 CMM
- Movomatic analog probe head
- Temperature controlled environment
- Volumetric performance 0.3 μm + L/300
- Repeatability ~15 nm

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Werth

- Video-Check HA
- High-accuracy vision measurement system
- Resolution

  0.01 μm
- XY Accuracy

  (0.5 + L/900) μm

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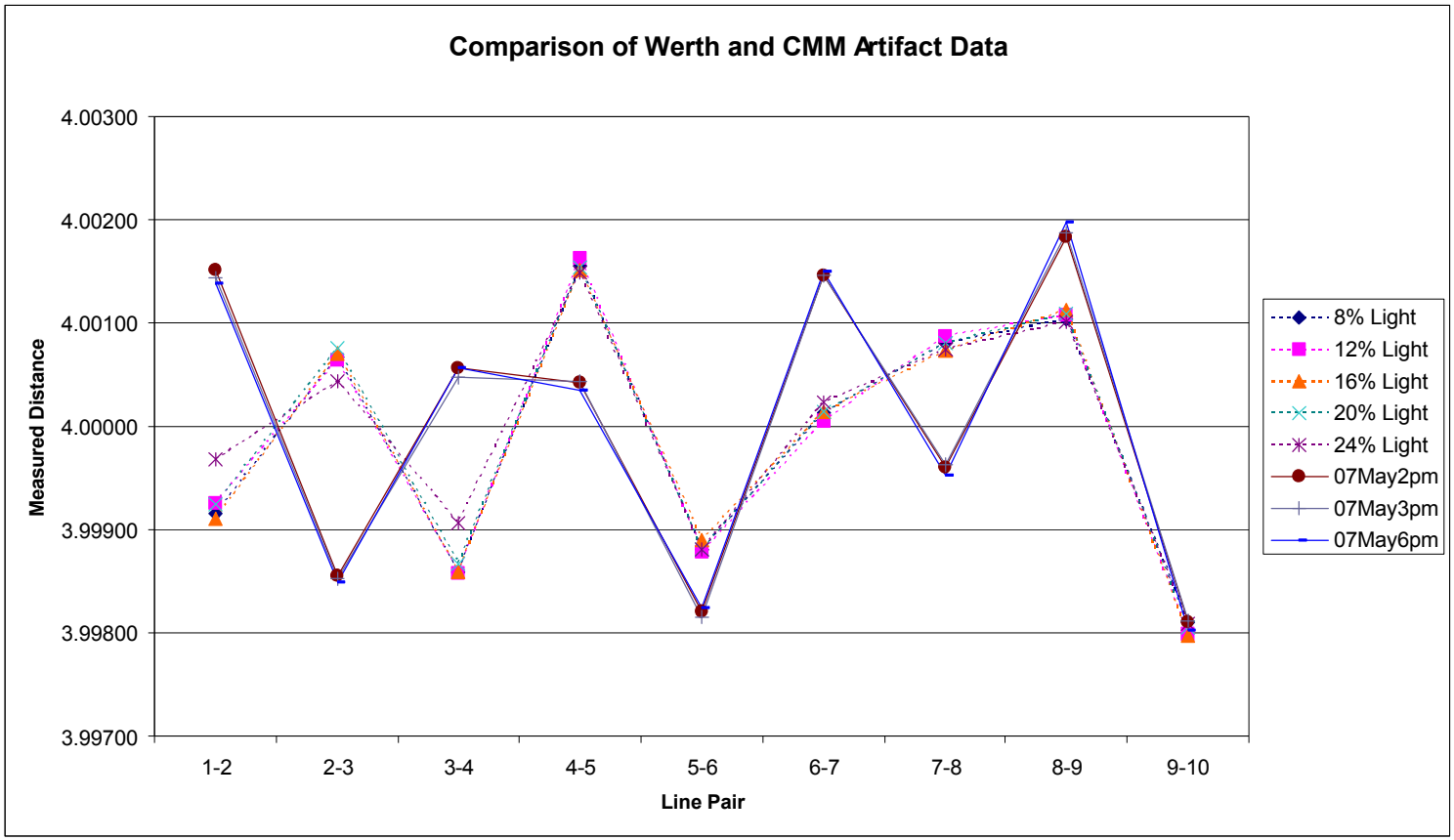
Werth Results



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OGP

- Smartscope APEX
- High-accuracy vision measurement system
- Scale Resolution

  0.10 μm
- XY Accuracy

  (1.2 + 2L/1000) μm

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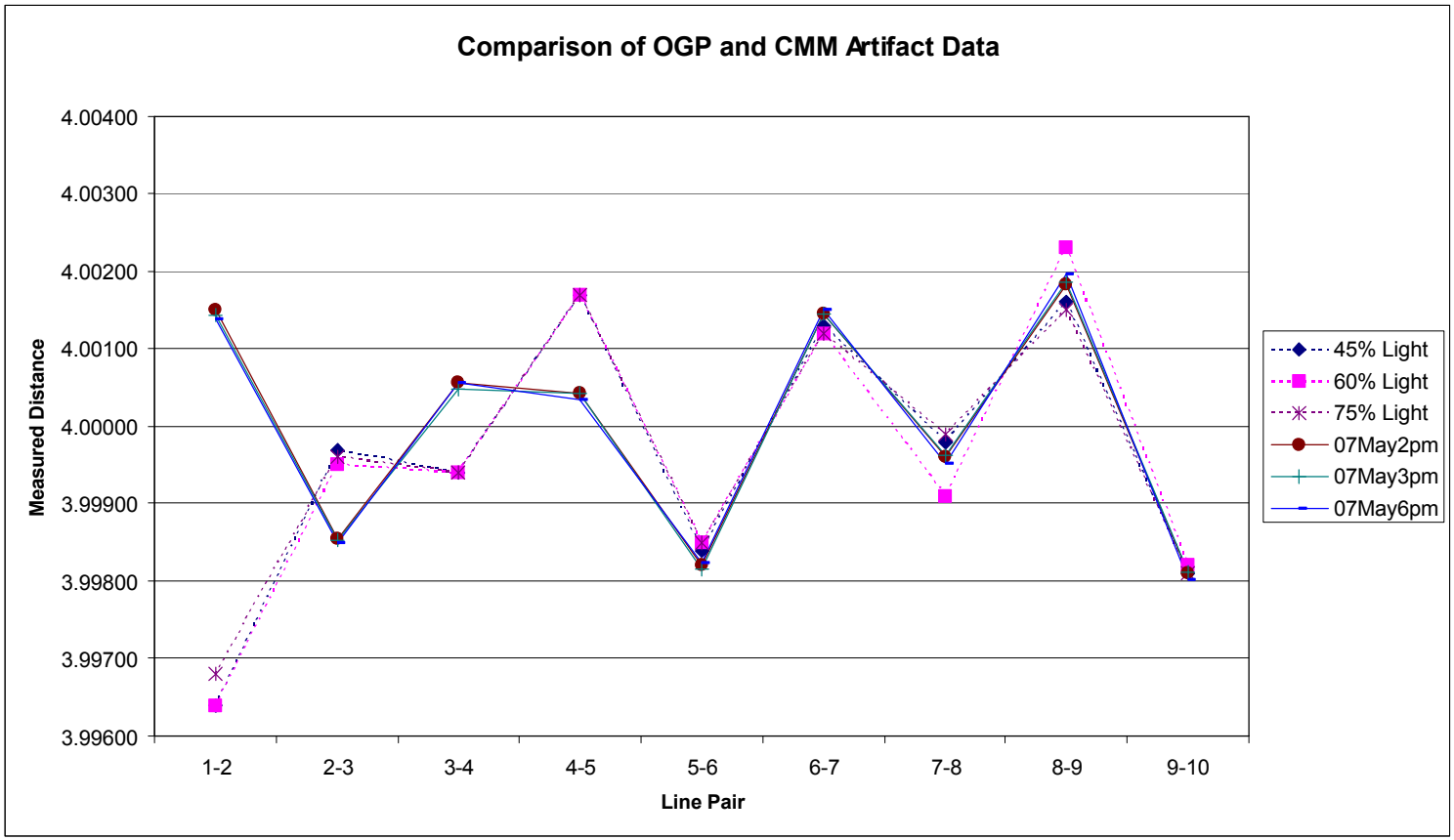
OGP Results



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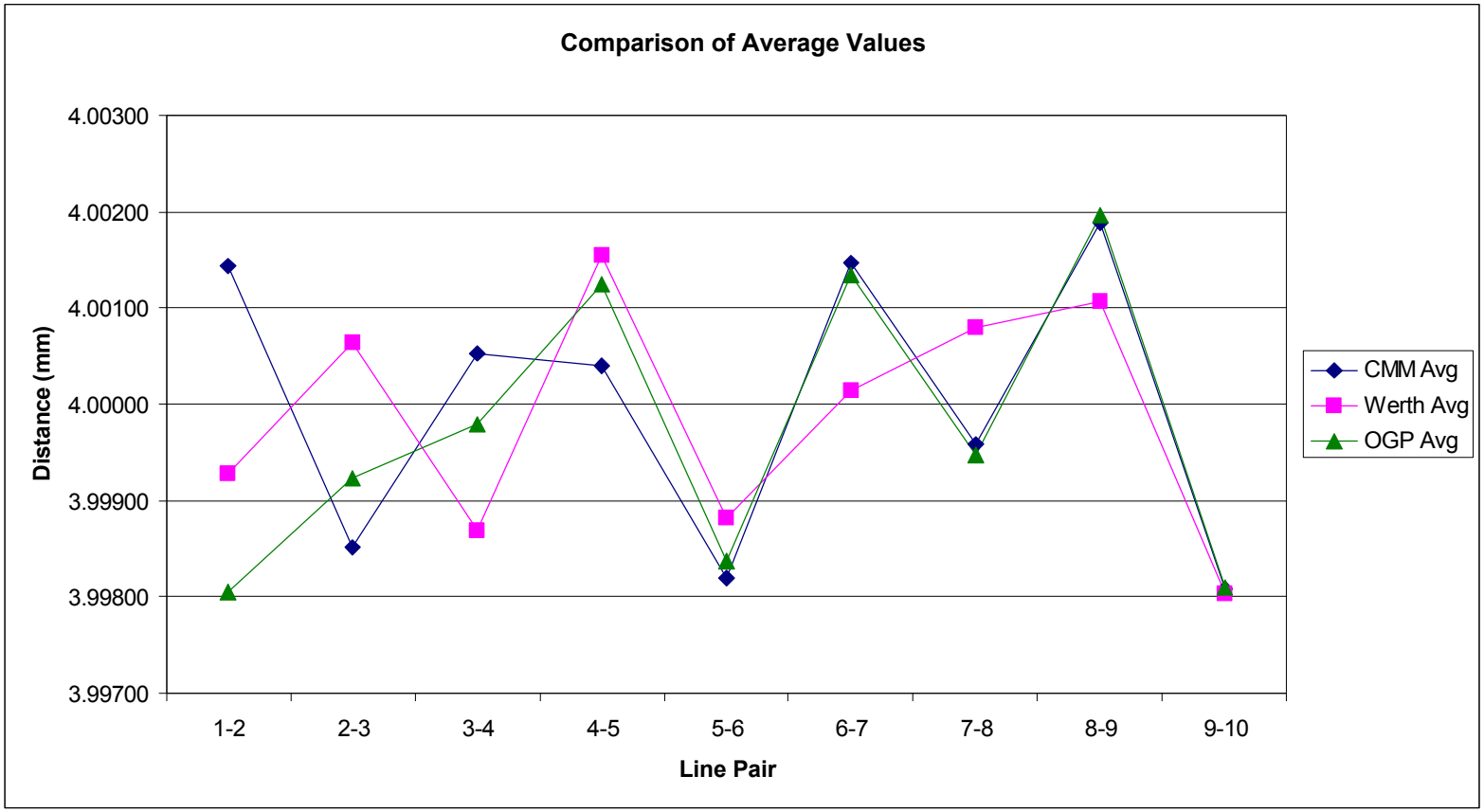
Comparison



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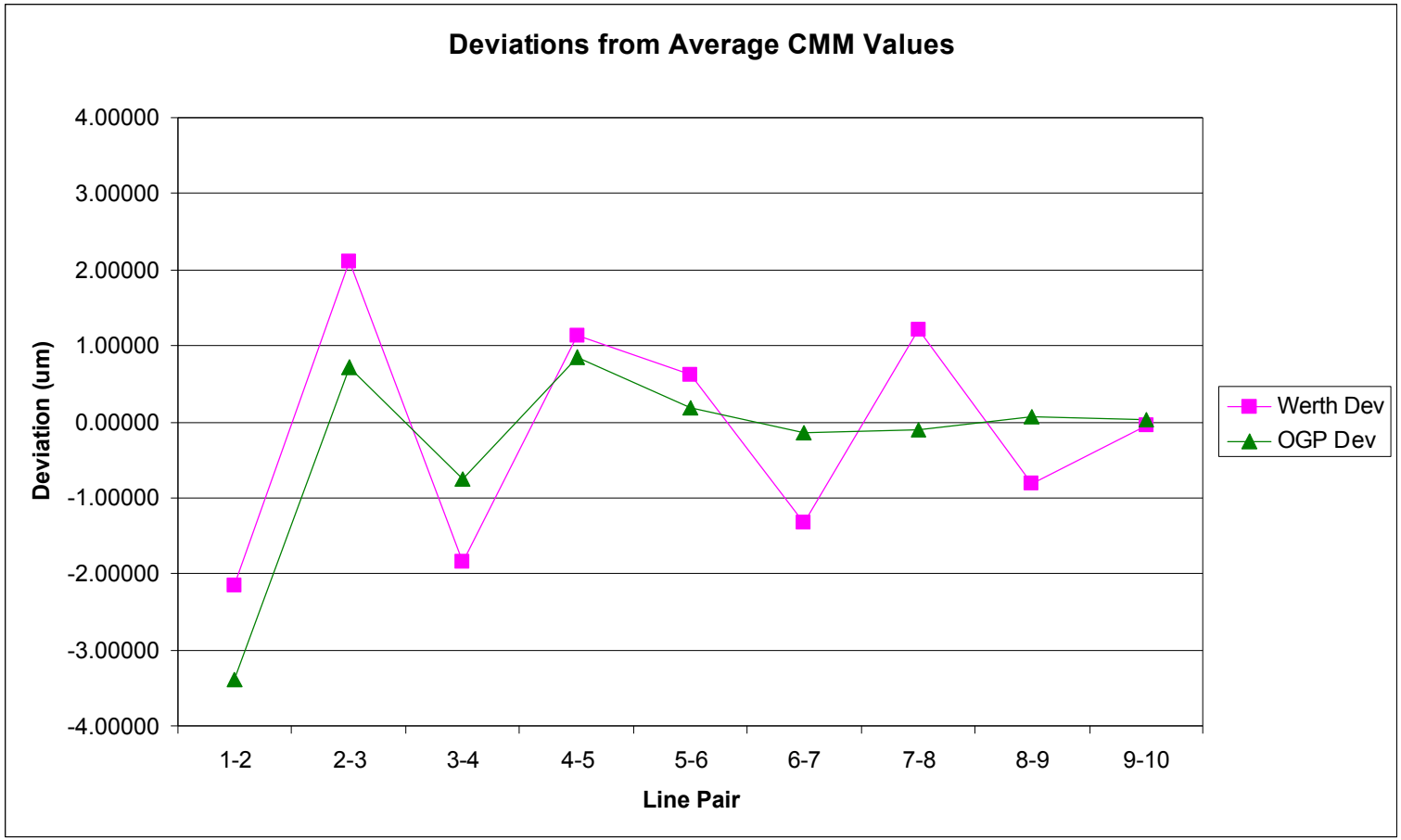
Comparison



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Discussion

- Manufacturing process needs to be studied and improved to eliminate
  - Etching on multiple planes (better alignment)
  - Roughness on sidewalls (nitride removal process optimization)
- Light level change has little effect on pitch measurement
- Multiple runs on same measurement machine are repeatable

Conclusions

- Manufacturing process requires optimization
- Artifact can be used on vision systems with little concern for lighting conditions
- Repeatability implies that the machine errors can be corrected for