Careers In Optics

Exceptional service in the national interest

Sandia National Laboratories

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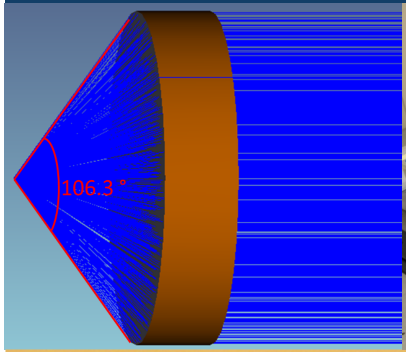
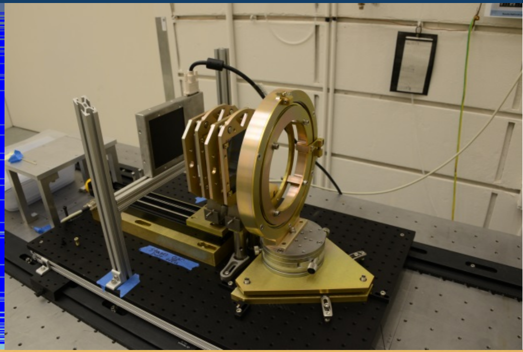
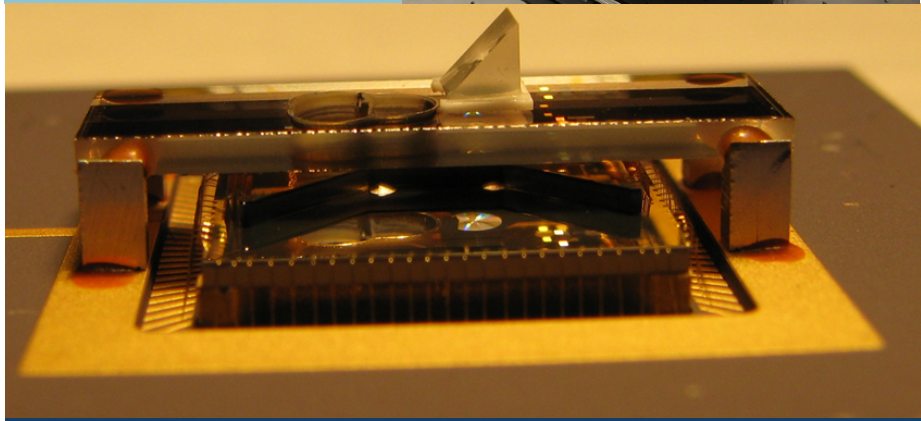
Optics & Photonics Winter School
Tucson, AZ
January 7, 2016







U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND No. 2011–XXXXP.

A Career~~s~~ In Optics

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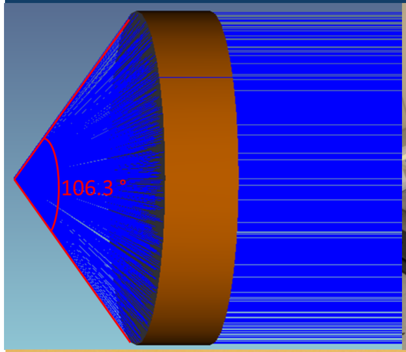

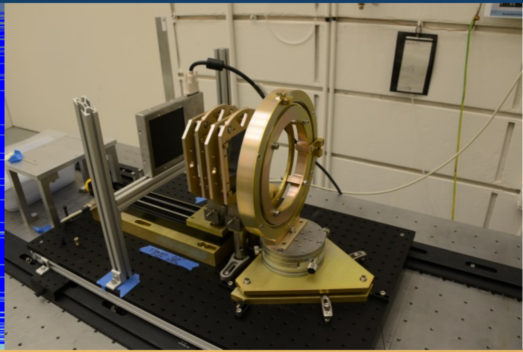

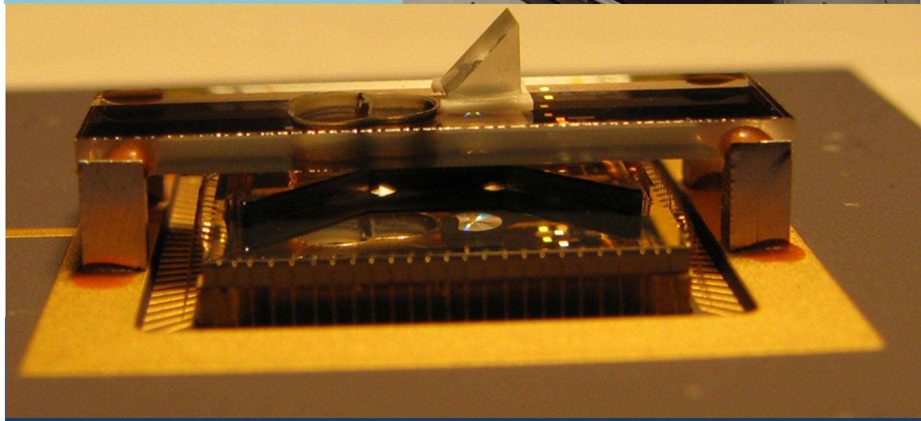

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Sandia National Laboratories

- Origin
  - WWII Manhattan Project.
  - Originated as a single-mission engineering organization for the non-nuclear components of nuclear weapons
- Today
  - Multidisciplinary national lab and federally funded research and development center (FFRDC)
  - GoCo: Government owned/Contractor operated
  - Multiprogram laboratory engaging in research supporting a broad spectrum of national security issues
- Sandia's highest goal is to become the laboratory that the U.S. turns to first for innovative, science-based, systems-engineering solutions to the most challenging problems that threaten peace and freedom for our nation and the globe

Sandia Mission Areas

Sandia National Laboratories

- Primary mission: ensuring the U.S. nuclear arsenal is safe, secure, and reliable
  - Highly complex technical challenges require a multi-disciplinary approach of systems engineering supported by deep science
  - Sandia's foundation is science-based engineering, in which fundamental science, computer models, and unique experimental facilities come together so researchers can understand, predict, and verify weapon systems performance
- Defense Systems and Assessment
- International, Homeland, and National Security
- Energy and Climate

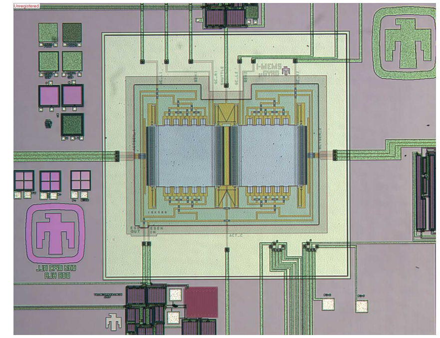
Sandia Mission Areas

- Committed to science with the mission in mind
  - create innovative, science-based, systems-engineering solutions to our nation's most challenging national security problems
- Sandia collaborates with external partners to bring emerging technologies to the marketplace
  - Commercial
  - Academic

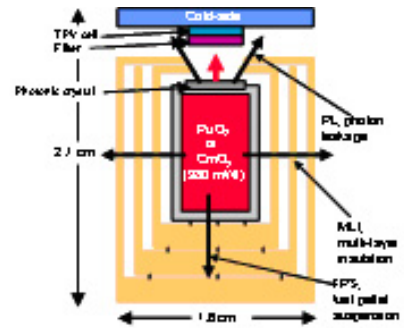
Hybrid Microsystems

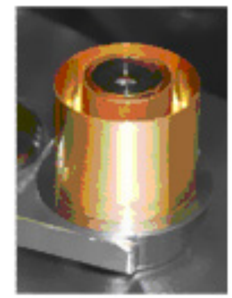
Sandia National Laboratories

- Micro-optical-electro-mechanical systems
- Micro optics
- Opto-electronics
- Optical computing
- Optical communications
- Optical sensors
- Energy
- Bioapplications
- Silicon photonics, on-chip architectures
- Wafer scale 3D nanostructures
- Functional coatings
- Waveguide writing
- Microelectronics
- Nanotechnology
- Metamaterials

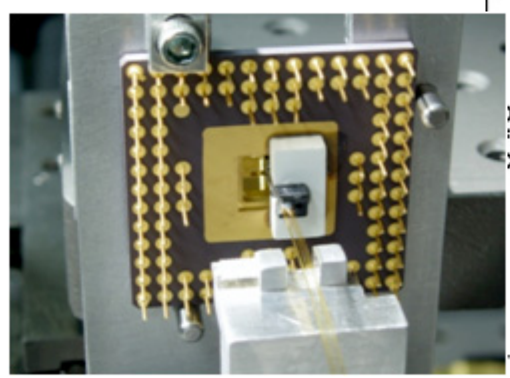


Vibratory gyroscope

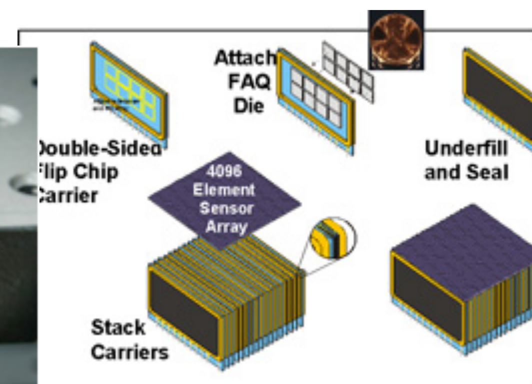




Micro-scale power sources



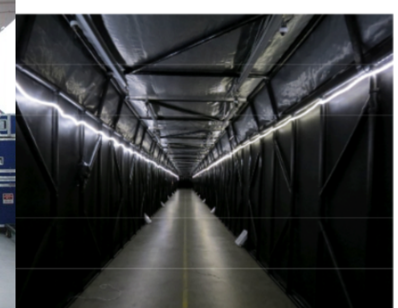
MEMS ion trap package with integrated optics



3D packaging

Facilities

- Microsystems, Engineering, Science, & Applications (MESA)
  - 400,000 ft2 complex, 60,000 ft2 of clean room
  - Silicon fabrication, compound semiconductor fabrication, system integration
- Test chambers: Salt fog, humidity, smoke, aerosols, dust
  - World's largest controlled fog chamber 180' x 11' x 10'
  - Create fog with known and controlled particle sizes and distributions
  - Measure optical desnity, persistence, air speed, temperature
- Super computers
- Robotics Range
- Z-machine

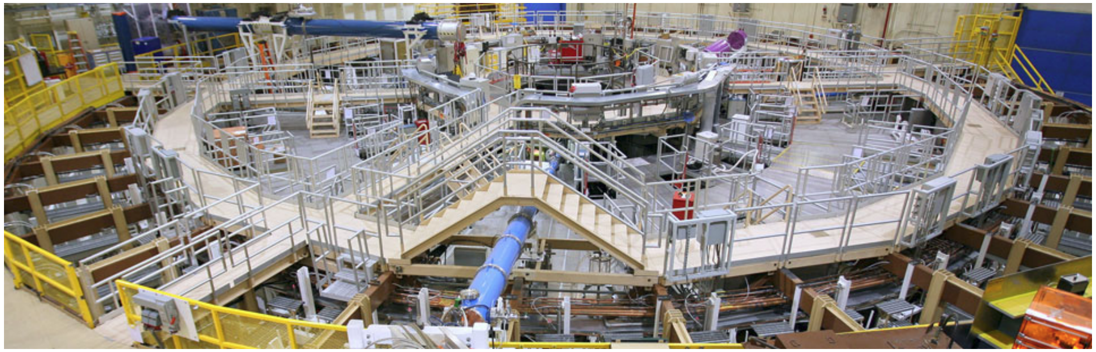


SNL fog tunnel

Light fog generation

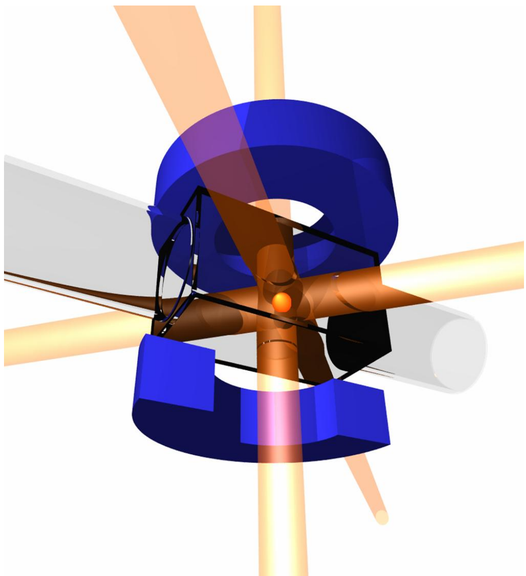
Technical Work

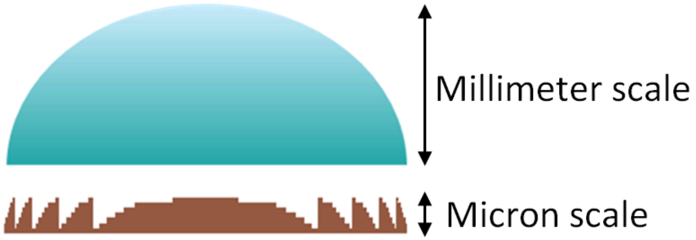
- Quantum Information Science (neutral atoms, ions)
  - Diffractive optical design, integration, new materials
- X-ray Phase Contrast Imaging
- Non-conventional imaging
  - 3D imaging
  - Fiber interferometer - Imaging vibrometry
  - 3D optics – object detection
  - Magnetoencephalography
- Grating design:
  - Z-machine
  - XPCI
  - optical alignment
- Hyperspectral imaging – thin film design

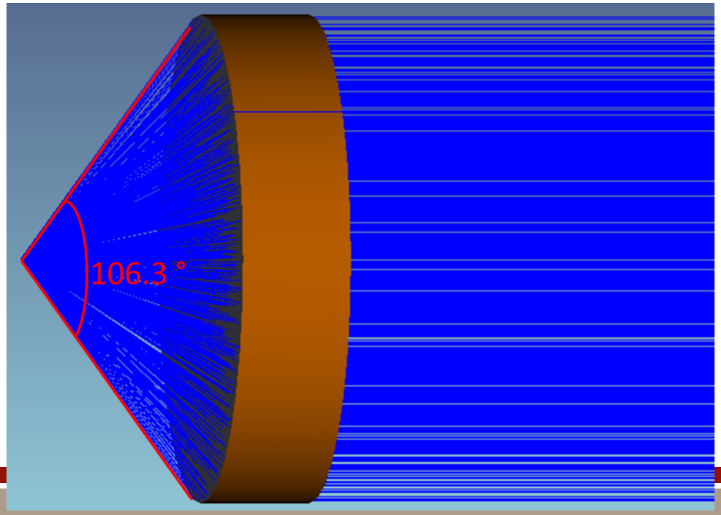


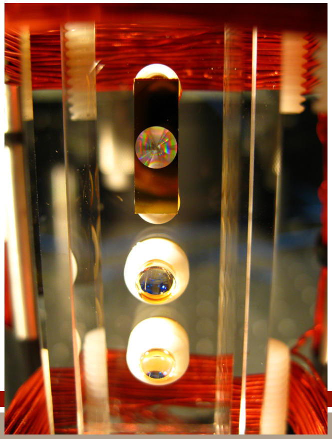
Neutral atoms for quantum information processing

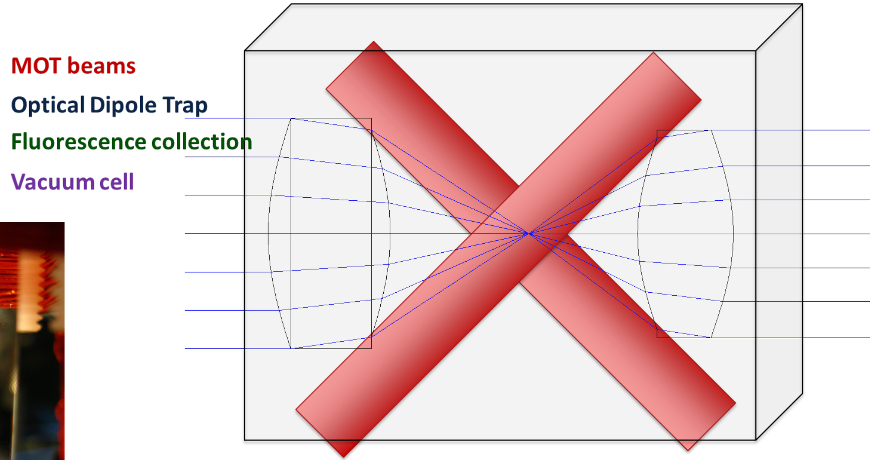
- 3D magneto-optical trap cools a cloud of neutral cesium atoms in a vacuum cell
- A single atom is trapped in a tightly focused optical dipole trap
- Rydberg laser excites atoms to Rydberg states







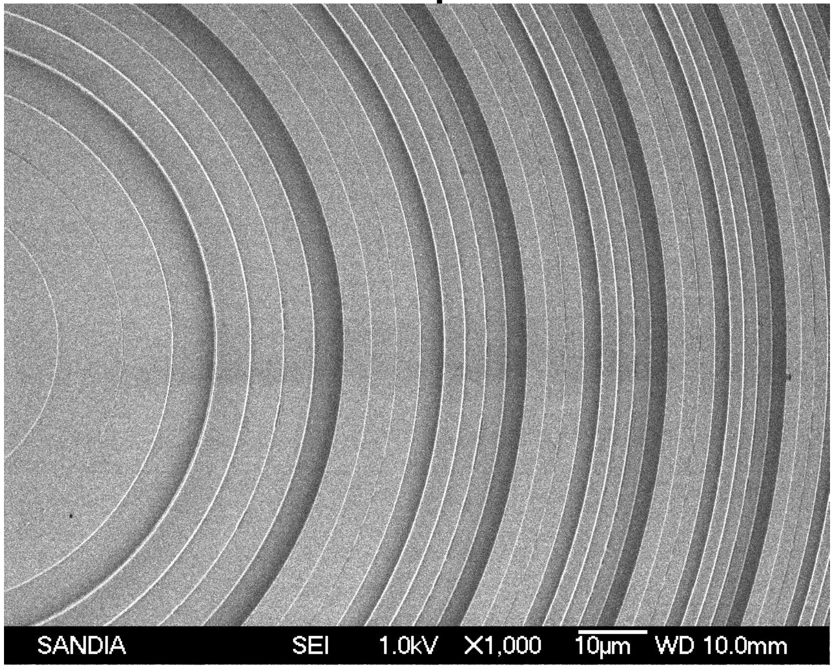




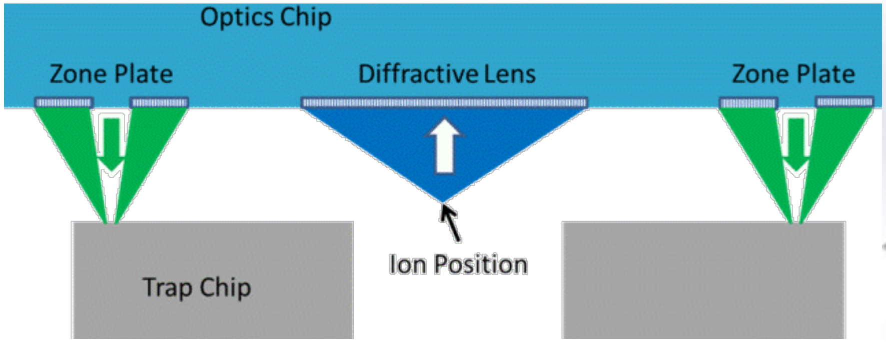
Top Right Figure: http://saaubi.people.wm.edu/ResearchGroup/Research/UltraCold_Research/Apparatus_UltraCold/Apparatus_UltraCold.html

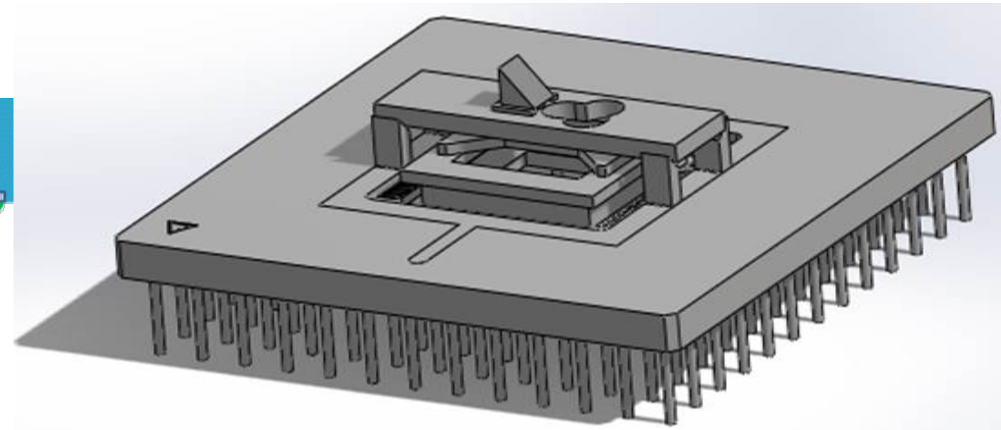
Diffractive Optics Enable Scaling

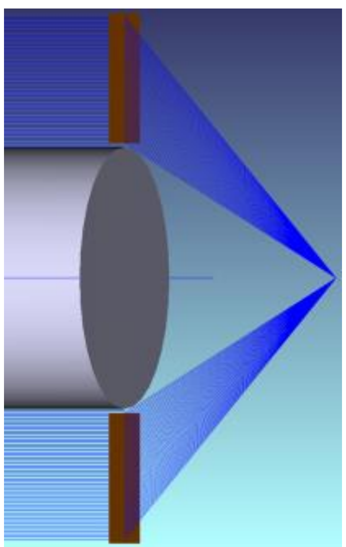
- Diffractive Optics are an enabling technology in the scalability to large numbers of qubits in neutral atom based quantum computing
- Vacuum compatible
- Small physical profiles
  - High optical access
  - Enables shorter distance to atoms
- Specifically tailored to the optical field
- High collection efficiency
  - An NA of 0.55 represents photon collection from 8.2% of the sphere whereas at an NA of 0.8, photons from 20.3% of the atom's radiating sphere are collected

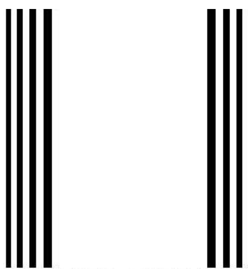


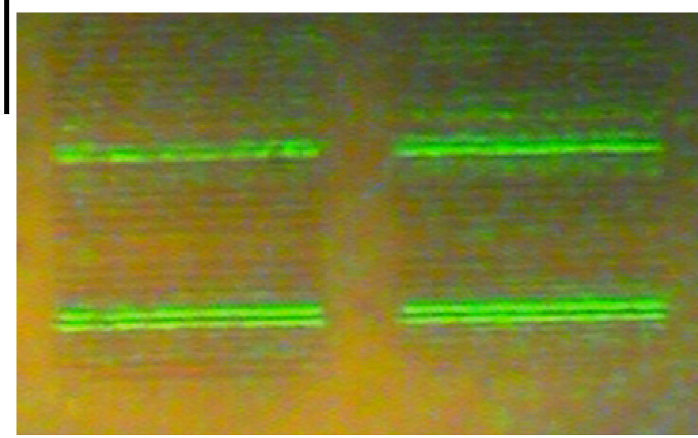
Precision alignment of integrated optics in surface electrode ion traps for quantum information processing

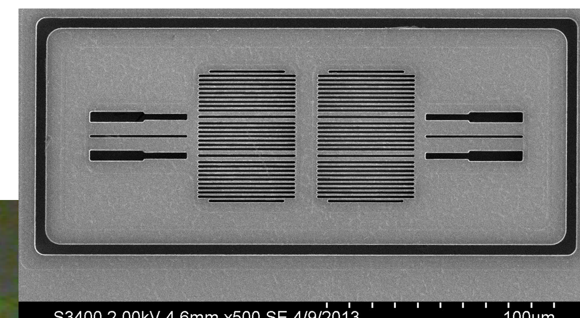


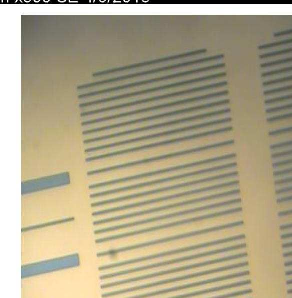




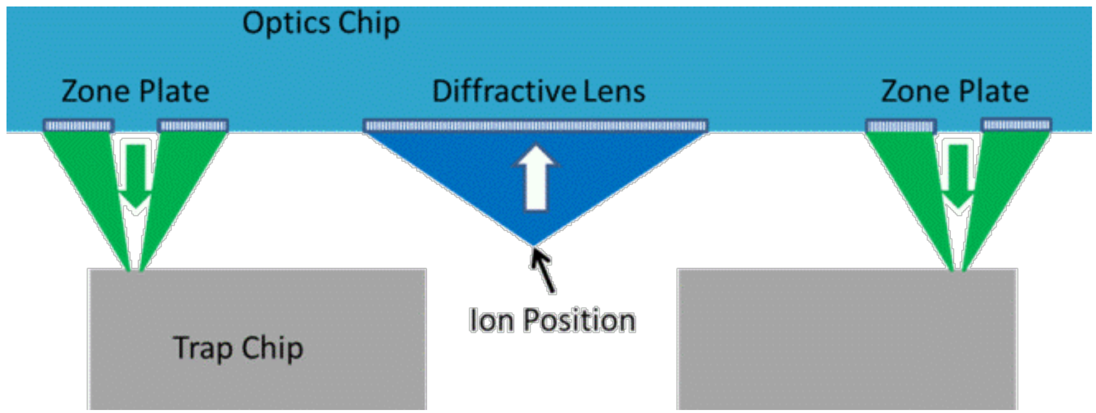


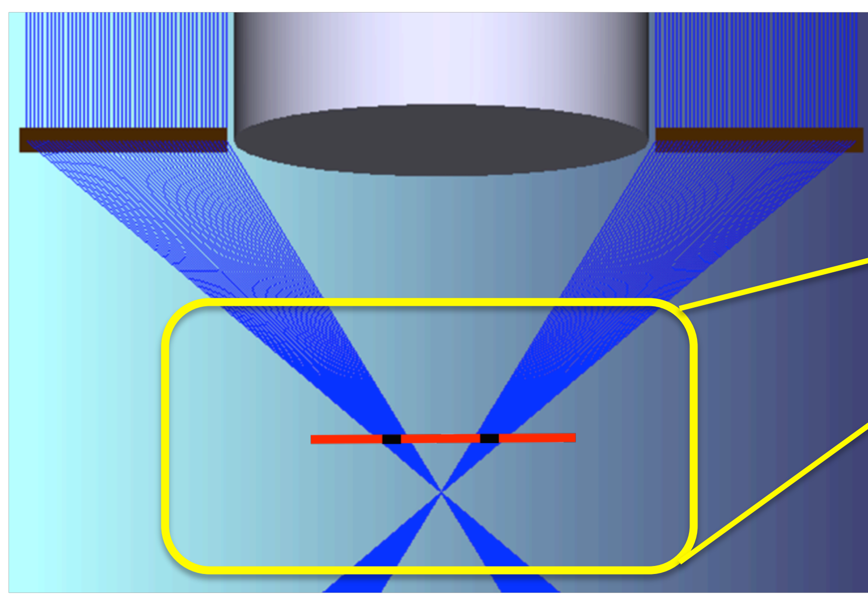






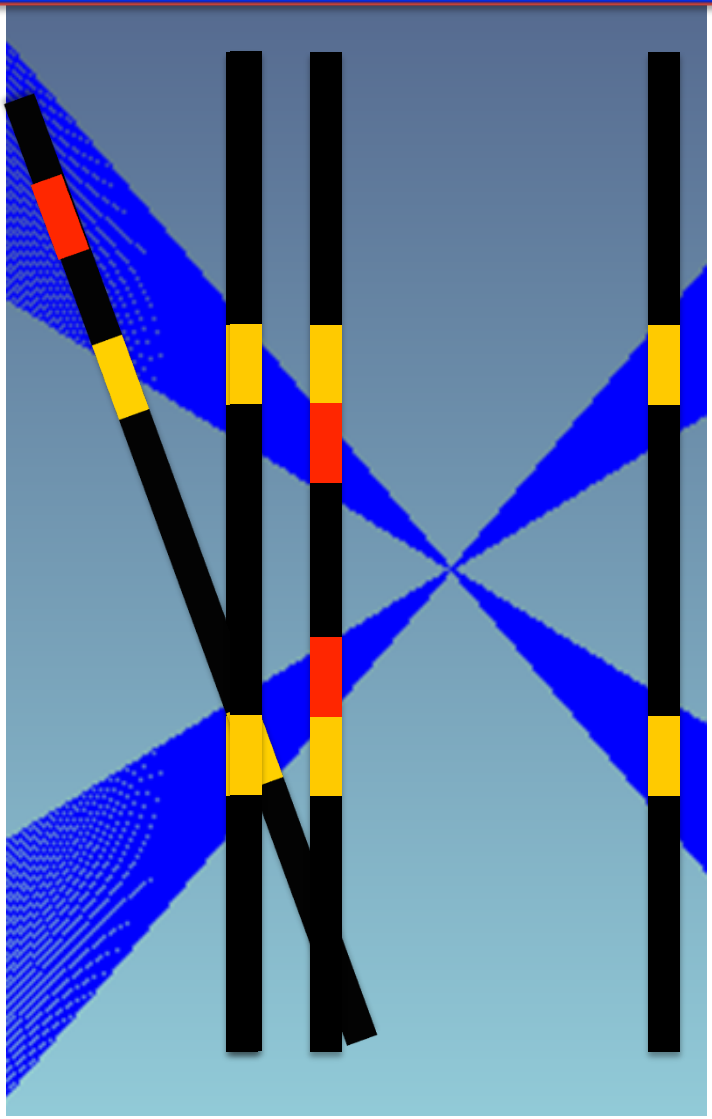
Converging Line Foci for Alignment

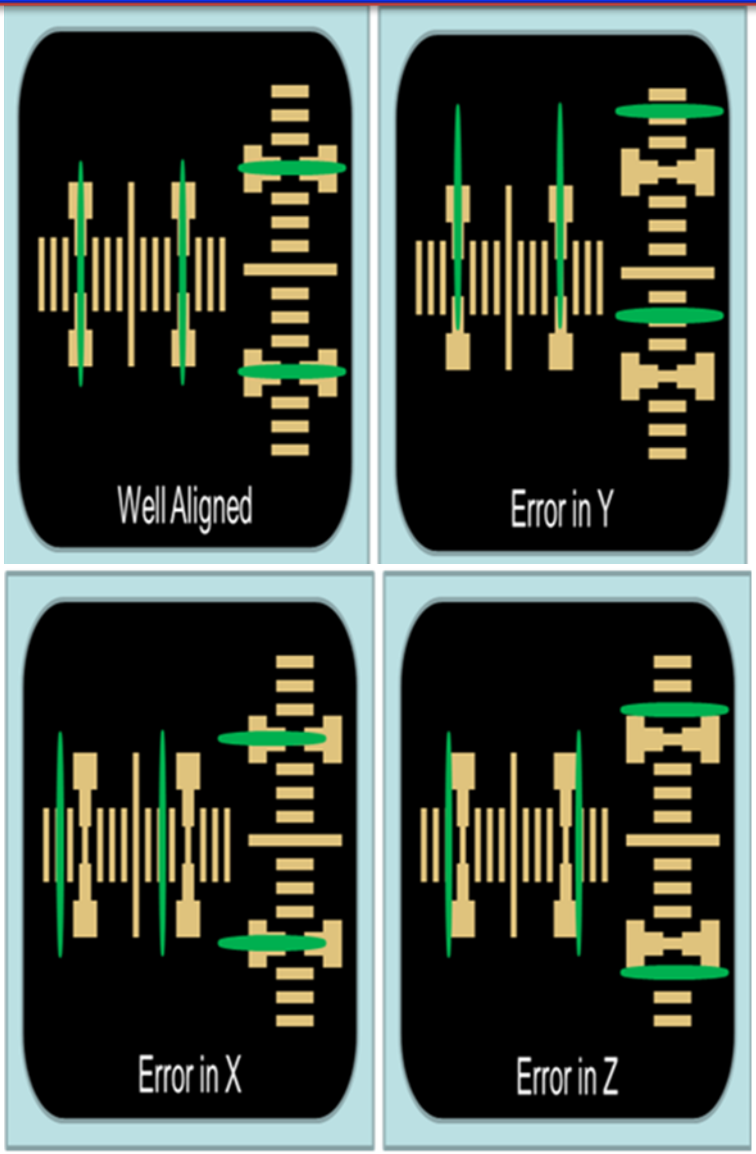




Zoom-in (and rotate)

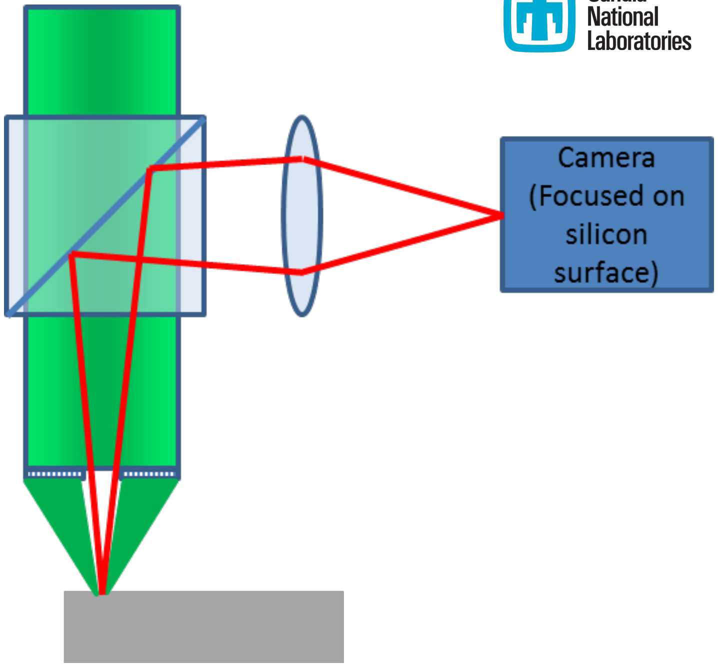
Converging Line Foci for Alignment

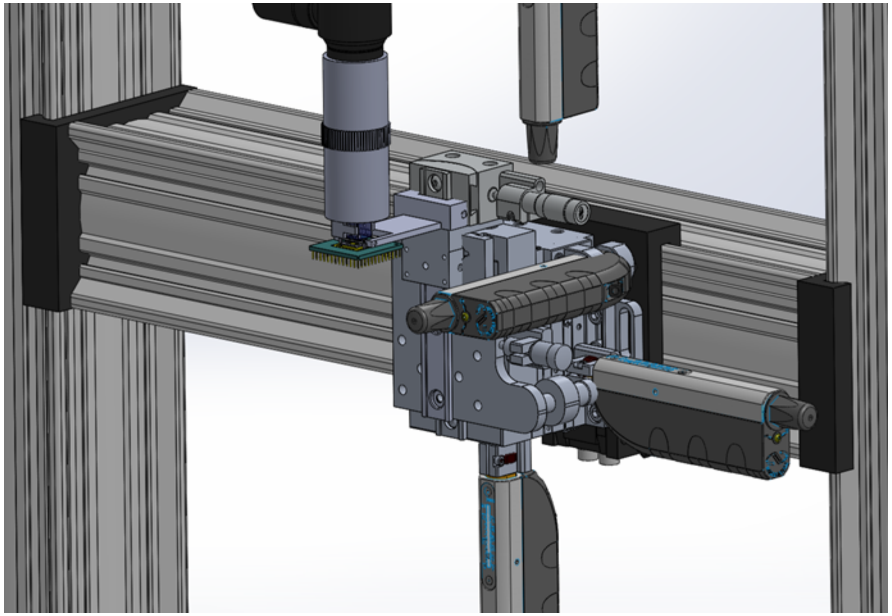


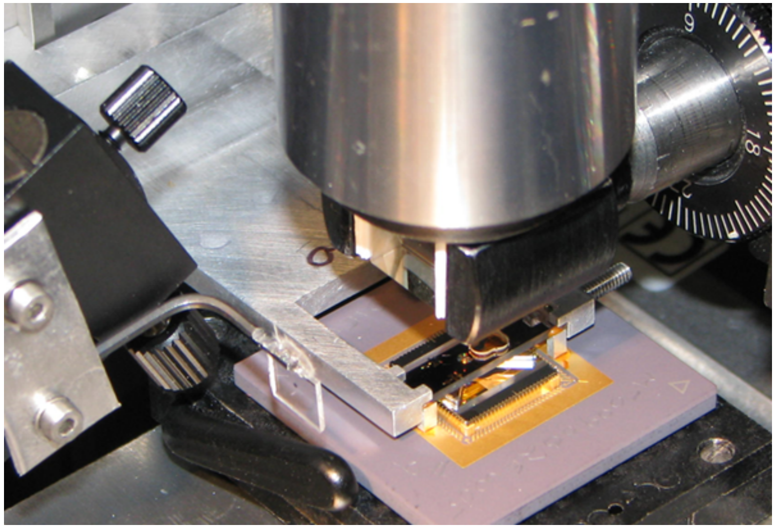


Alignment System

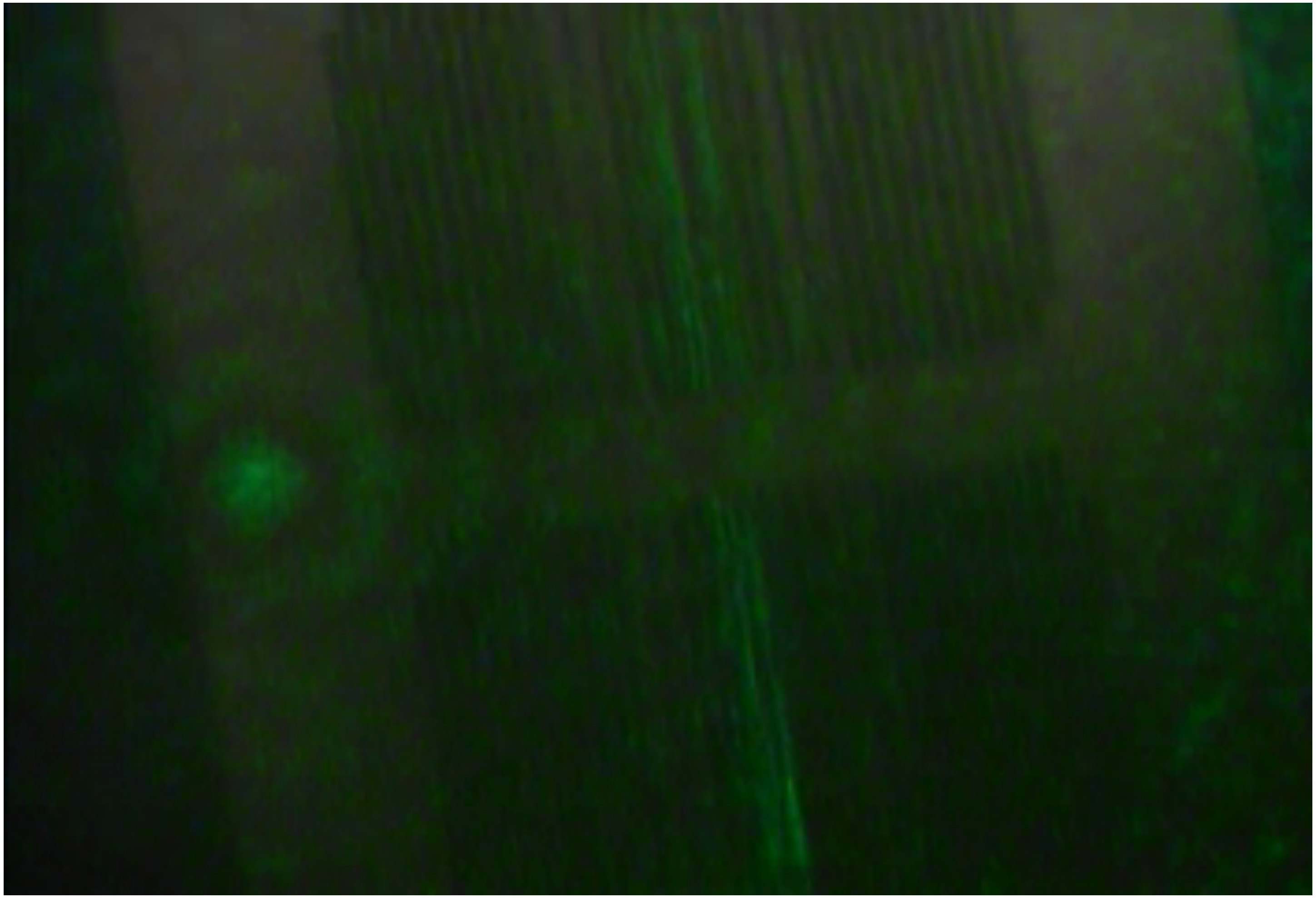
- Illumination source
  - Uniform, well-collimated, normal to OAFZPs
- Obscuration
- 6 DOF movement of optics chip
- Iterate between OAFZPs





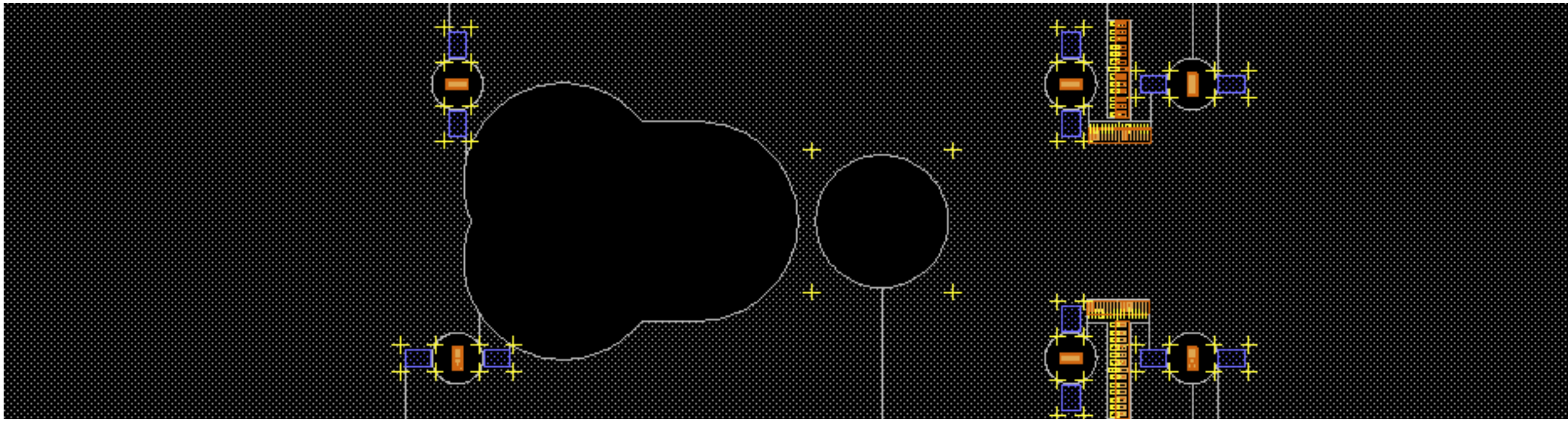


Execution of Alignment



Benefits of OAFZPs for alignment of hybrid microsystems

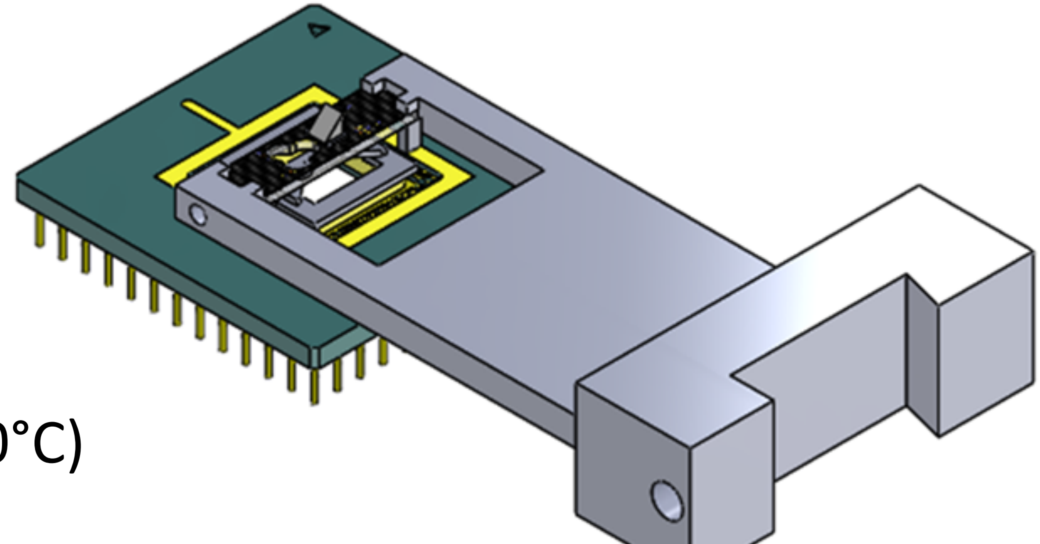
- No contact or interference with microsystem package
- Small binary element
  - Fast, easy fabrication, flat element
- Small real estate on chip
- Design for illumination at any convenient wavelength
- Single image plane
- Quantify alignment error

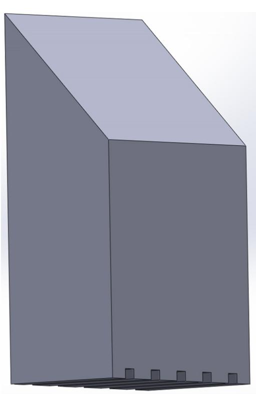


Bonding: Mechanical + Adhesive

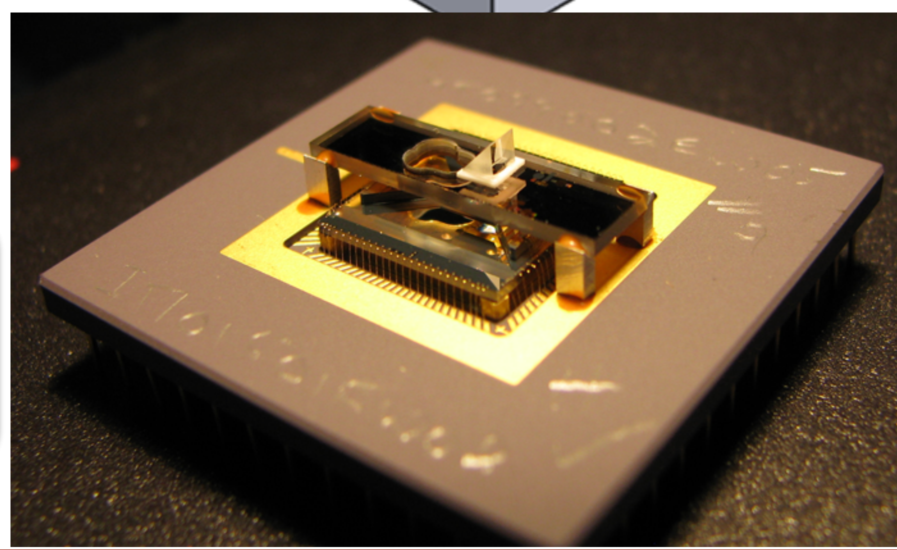
No interference with system operation or performance

- Mounting mechanism
- Adhesive
- No stress or strain
- CTE
- High temperatures (150°C)
- UHV compatible
- Epoxy outgassing, material loss





Aluminum wedge
+
Masterbond EP21TCHT-1



Rectification of Projected Images Using Piecewise Homographies

Sandia National Laboratories

Perspective changes cause projected images to become warped.

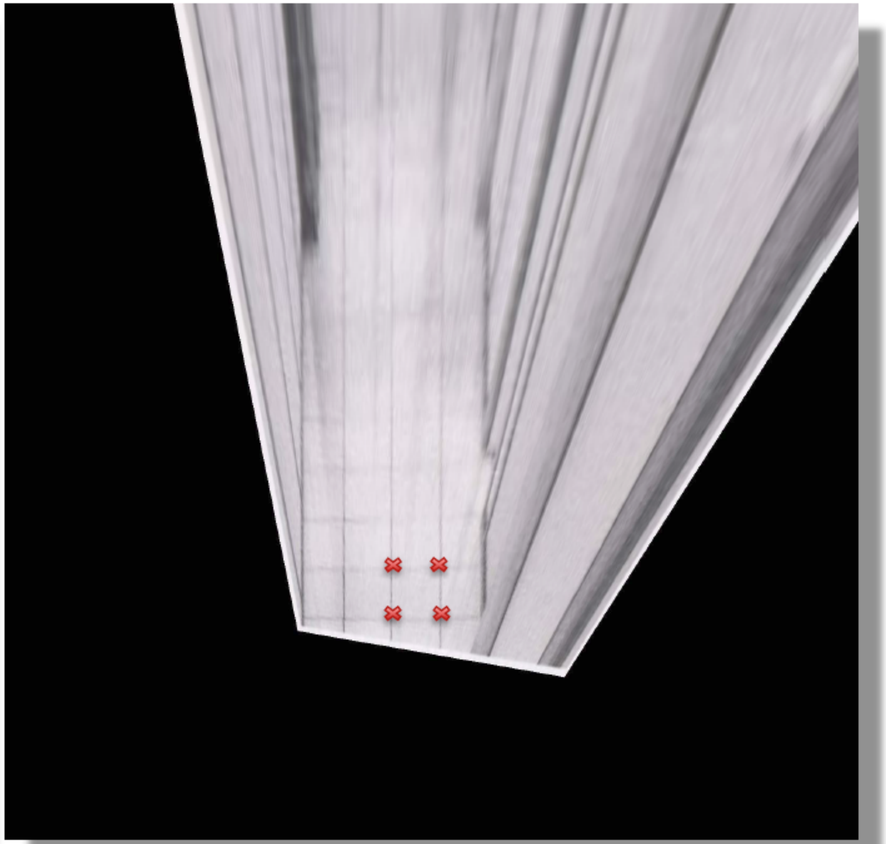
Original Image

Image skewed by projection

Perspective Correction: Warping

Original Scene

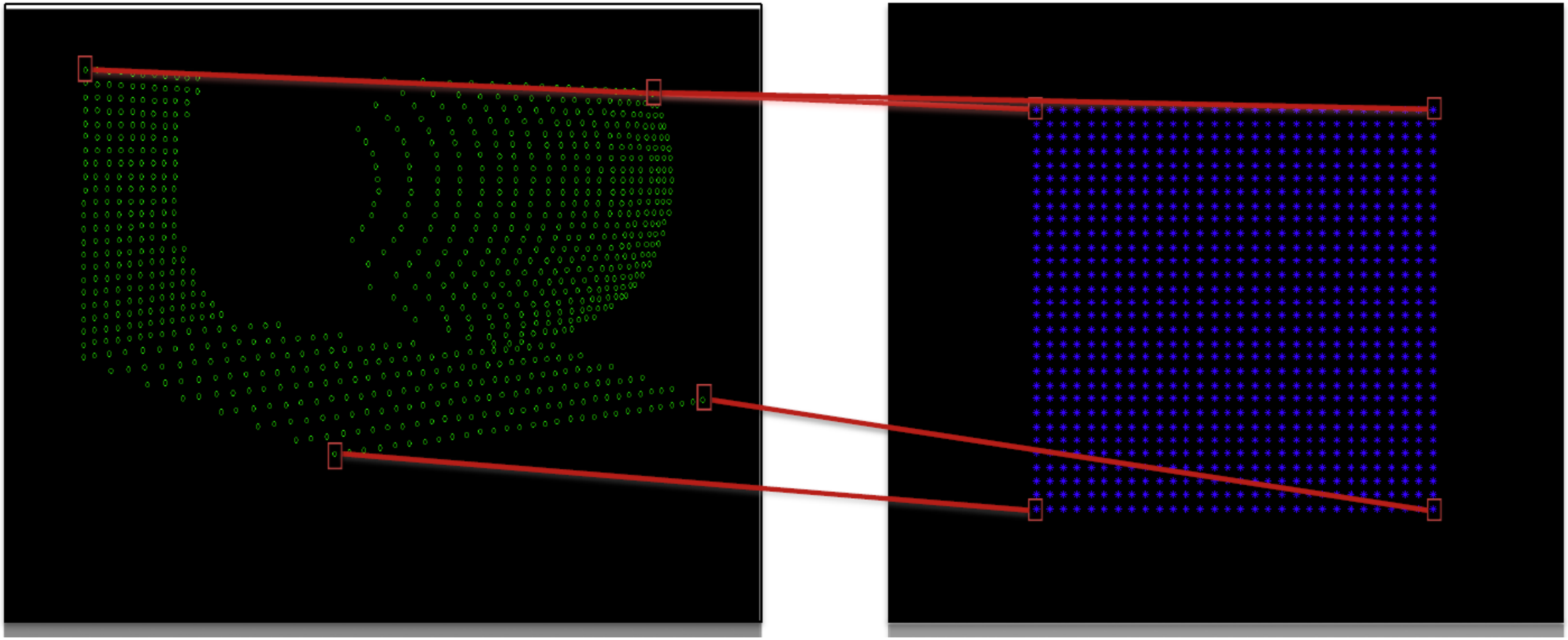
Post-Rectification



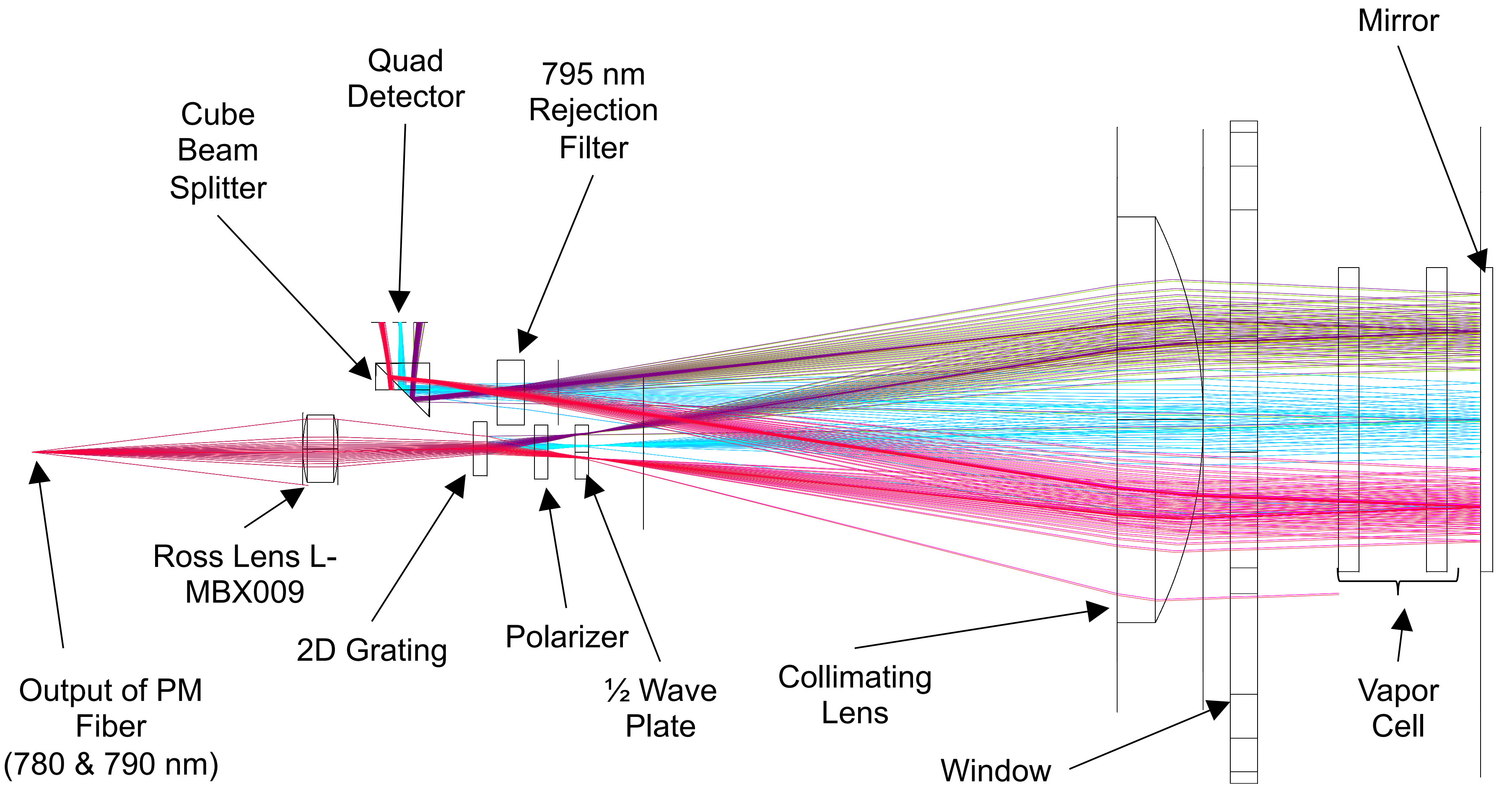
Wu, Steven Rectification of hallway [Photograph] Retrieved from https://inst.eecs.berkeley.edu/~cs194-26/fa14/upload/files/proj7A/cs194-do/rectify0/sample1.jpg

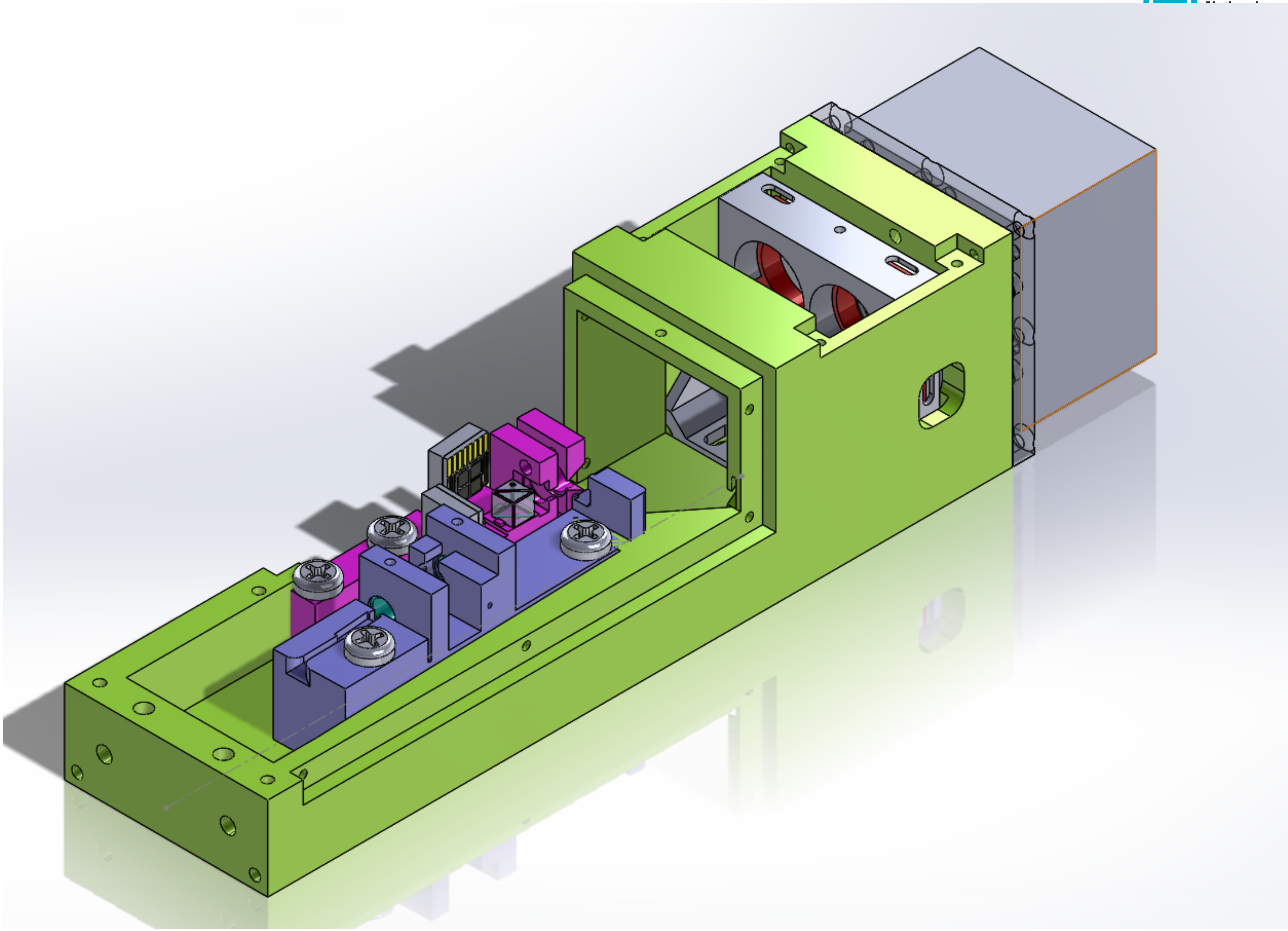
Corresponding points in real scenes are rarely planar or continuous.

Camera Perspective **Projector Perspective**



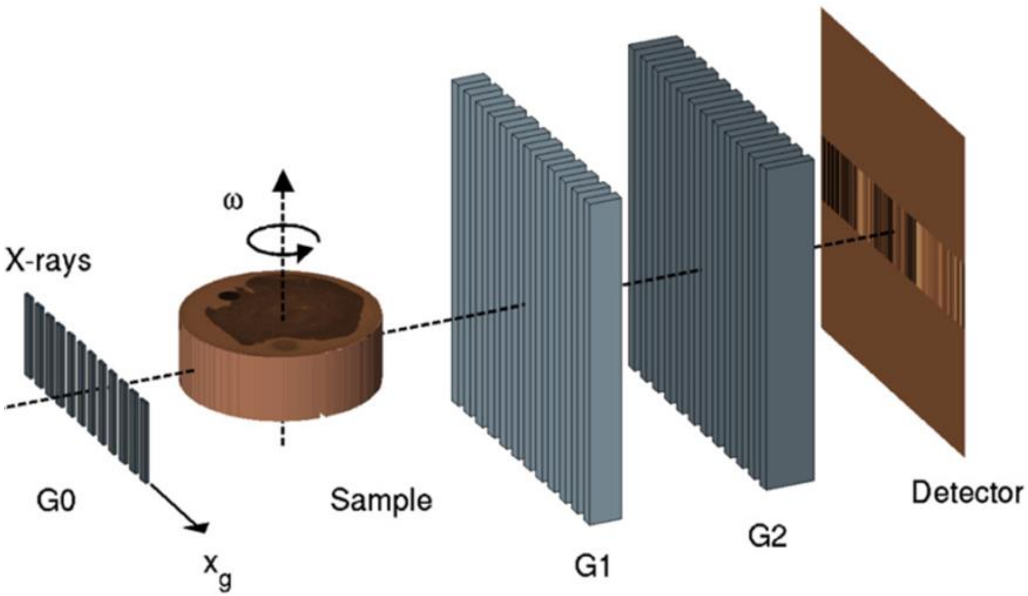
Magnetoencephalography





Grating-based XPCI

Talbot-Lau Interferometer

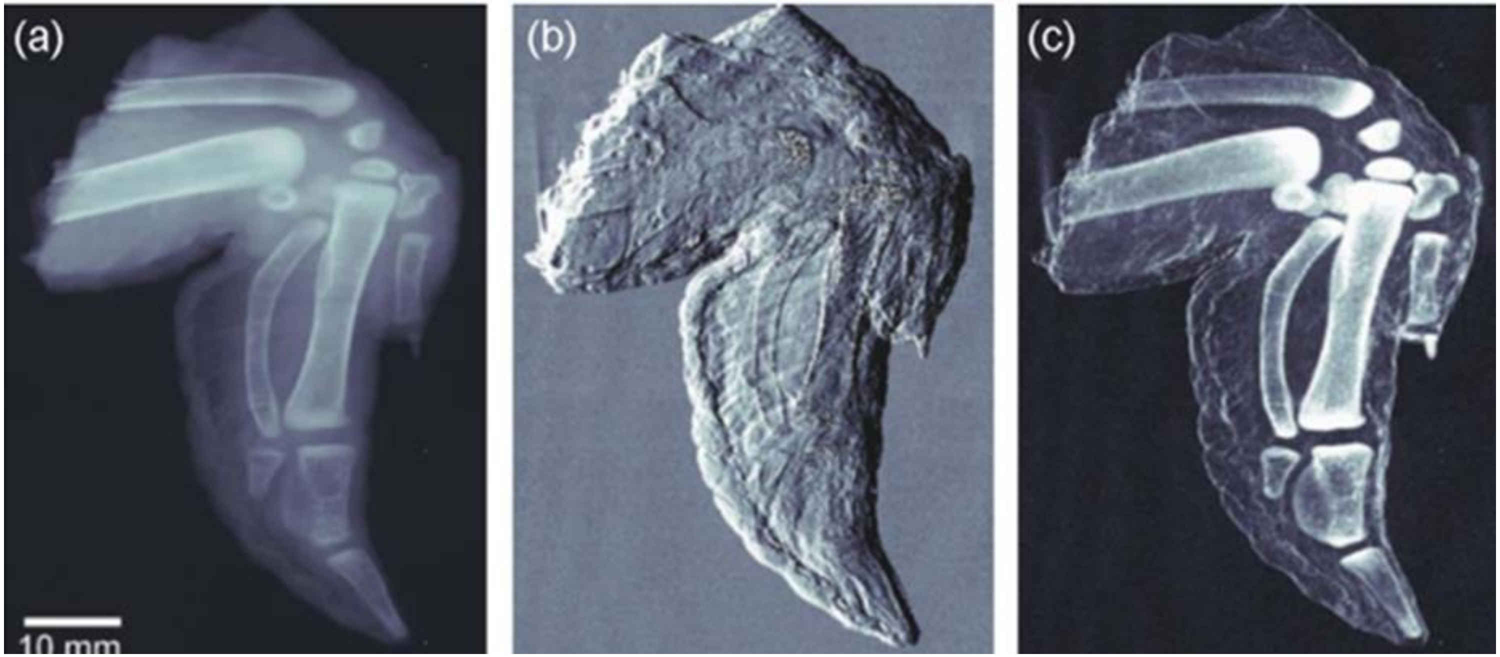


Source grating enables lab-based XPCI

- Source grating: G0
  - Relaxes requirements on source
  - Enables use of conventional x-ray tube
- Phase grating: G1
  - Beam splitter
  - Imposes a modulated phase shift on wavefront
- Analyzer grating: G2
  - Located a fractional-Talbot distance downstream from G1
    - G1 re-imaged as an intensity pattern
  - Enables sampling of narrow fringe pattern on detector

M. Nielsen, et. al., Phys Med Biol, **57**, 5971, 2012.

Complementary Data



Absorption
Contrast between dense high-Z regions and less-dense (low-Z) regions. No material detail or fine resolution.

Phase Contrast
Fine structure within the low-Z regions apparent.

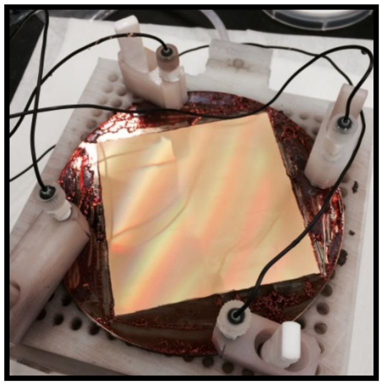
Dark-Field
Sharp contrast at boundaries. Microstructures cause scattering in bones.

To acquire only attenuation data leaves out significant information about the material properties

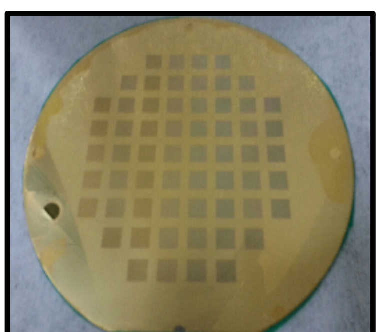
M. Bech, et. Al., Z. Med. Phys., **20,** 7, 2010.

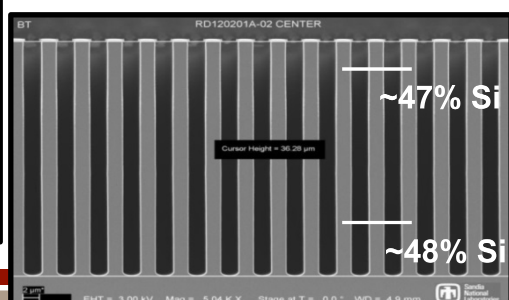
XPCI

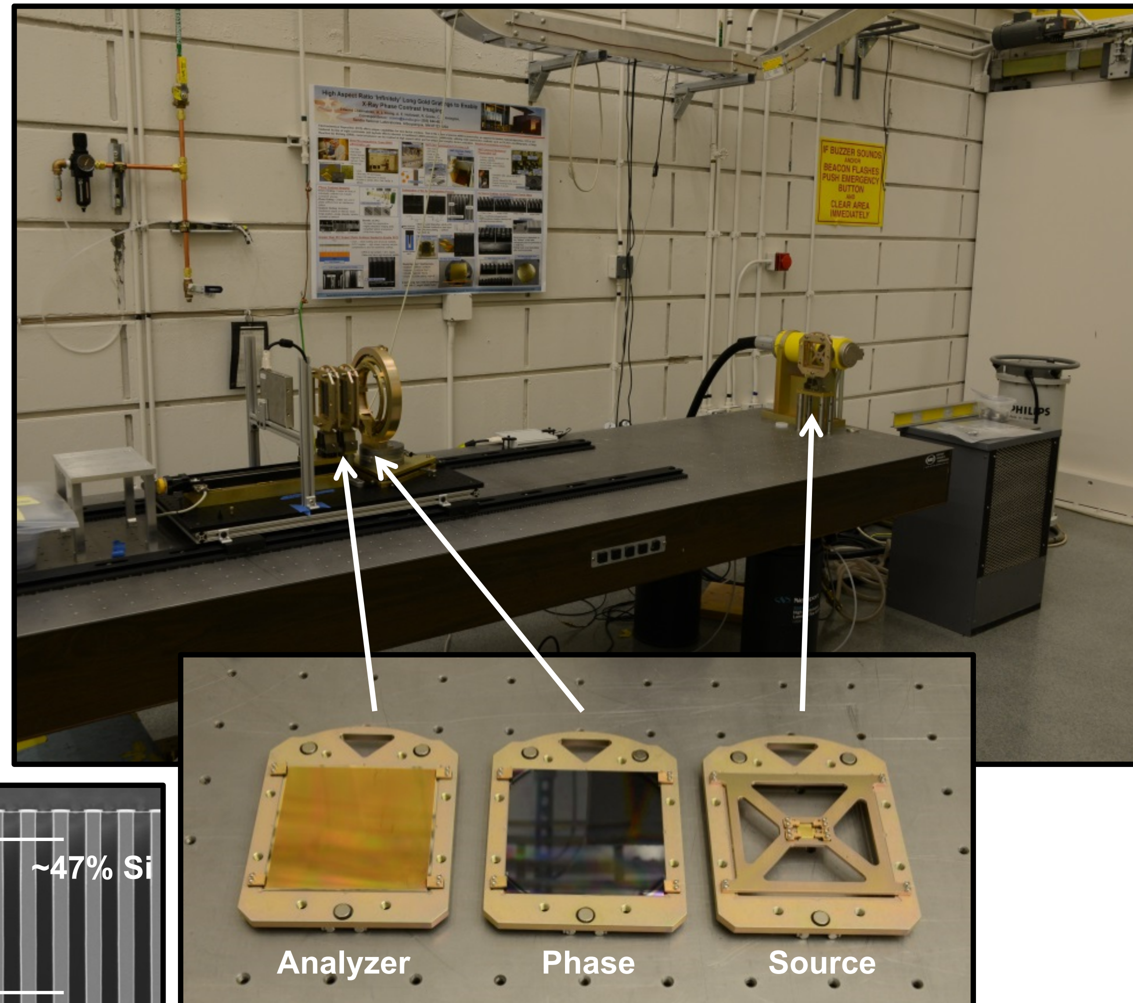
- Gratings mounted into XPCI system
  - G0 = 79.24um period
  - G1 = 3.873um period
  - G2 = 1.98um period



G2 grating after gold plating

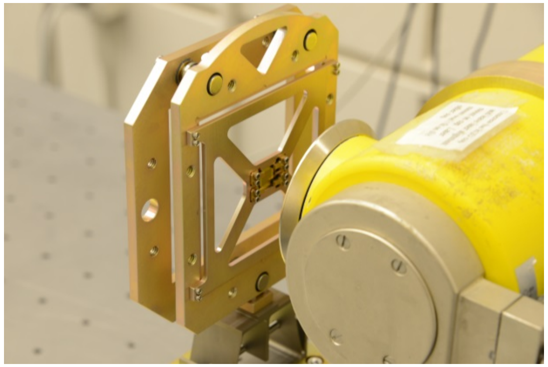


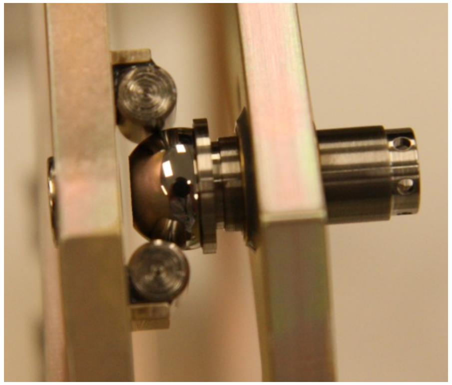


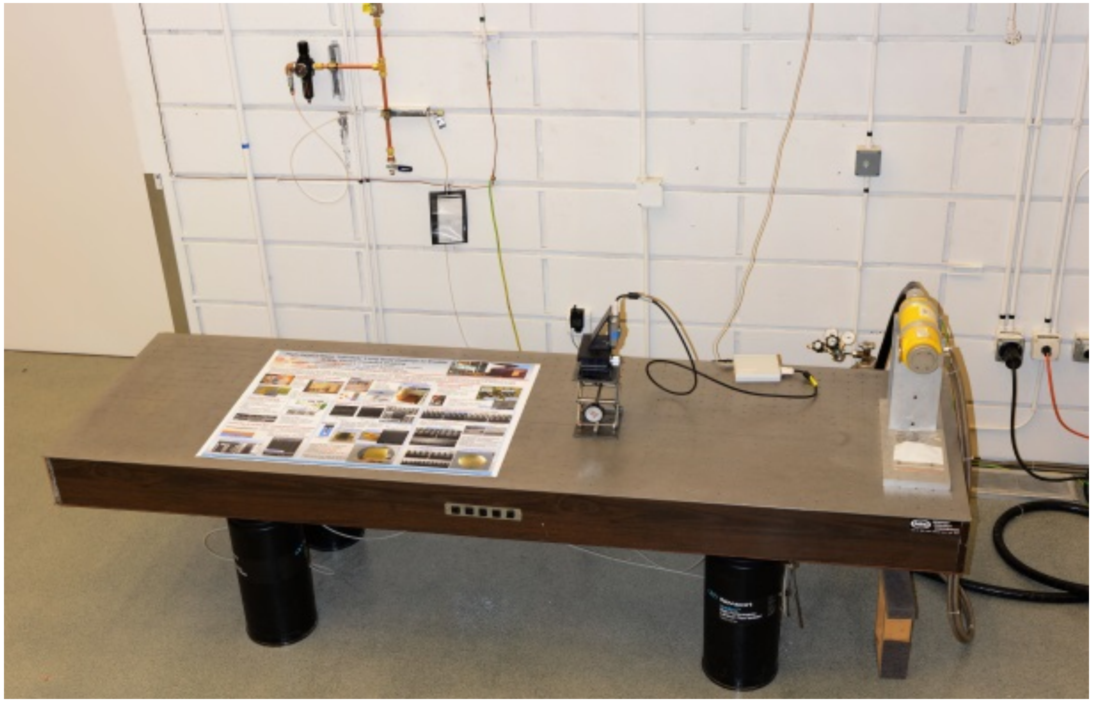


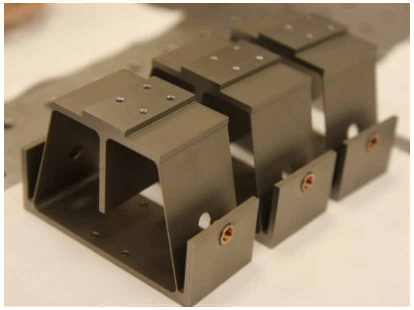
Mechanical Design

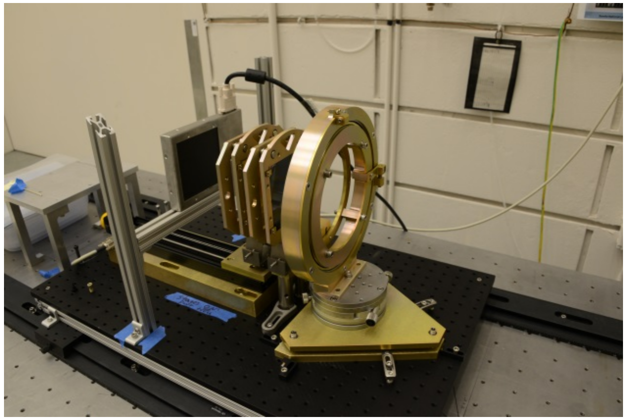
- Kinematic mount assembly
- Aerotech piezo
- Rotational flexures











XPCI Data Acquisition Labview Program

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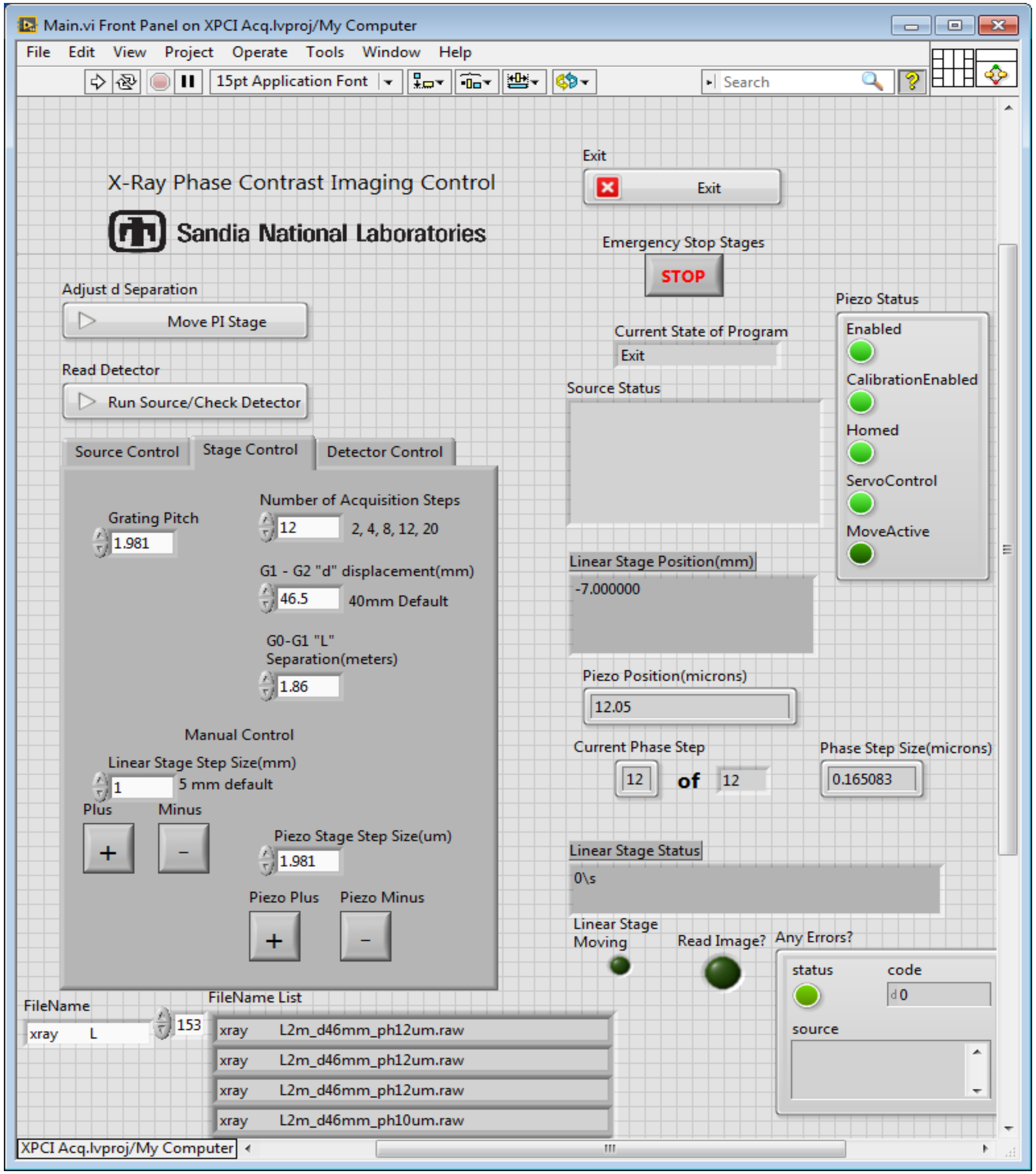
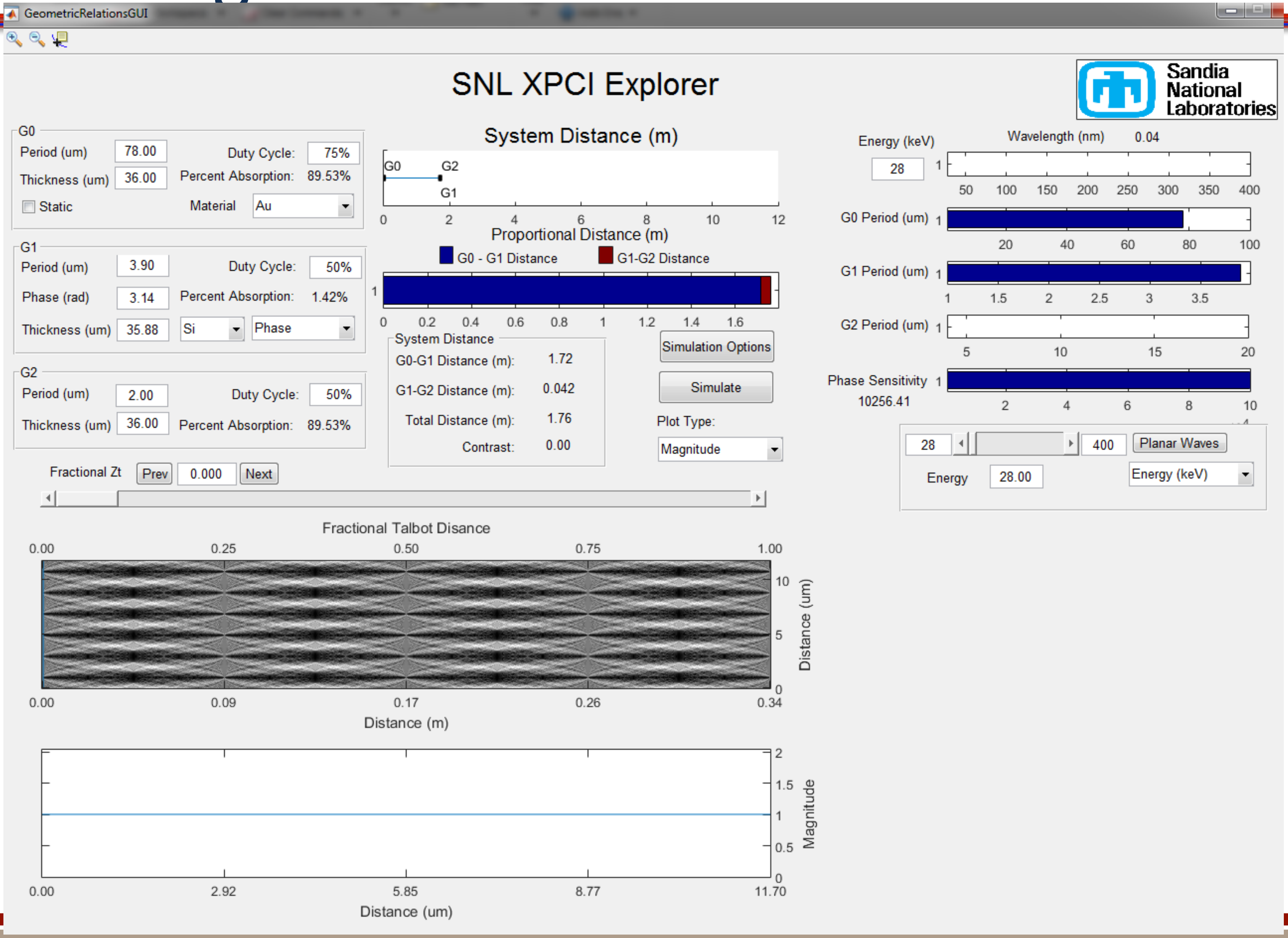
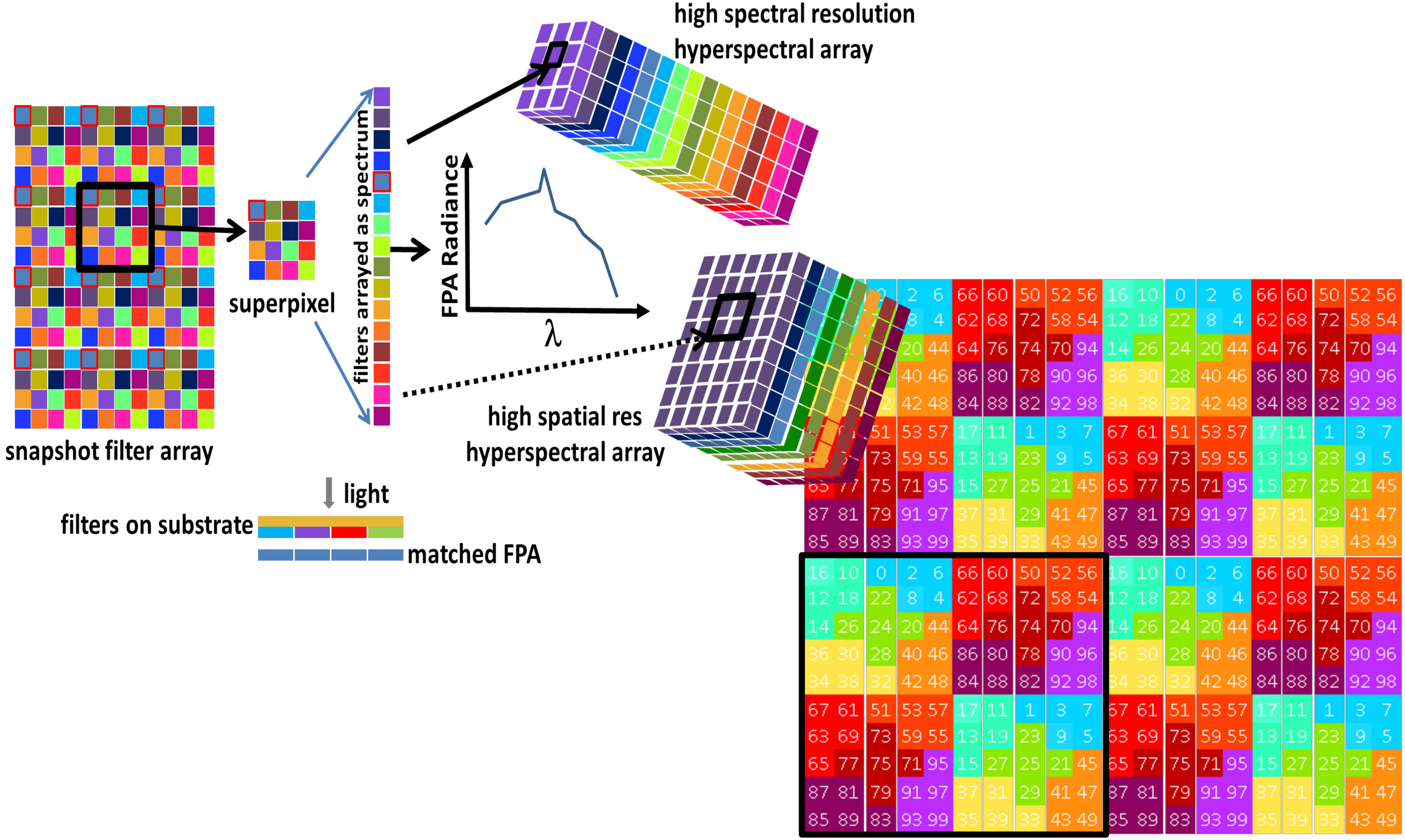


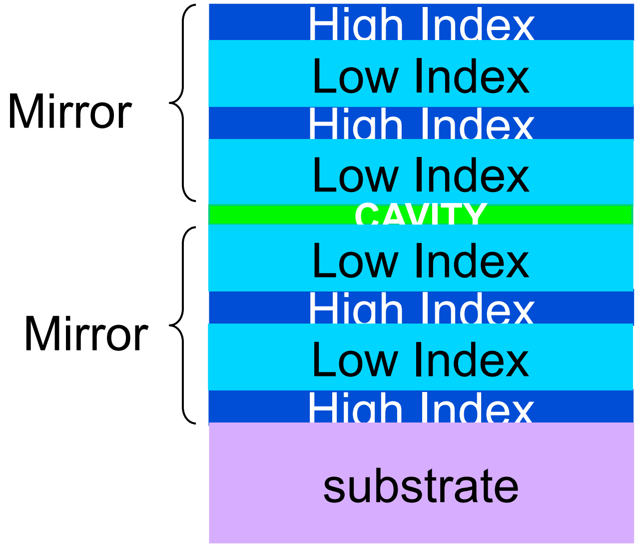
Modeling and Simulation

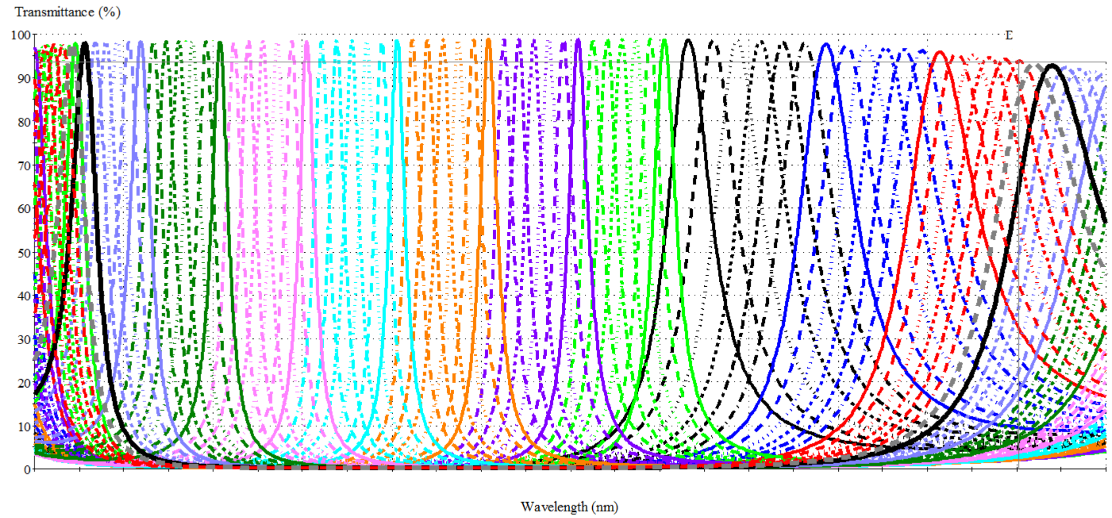


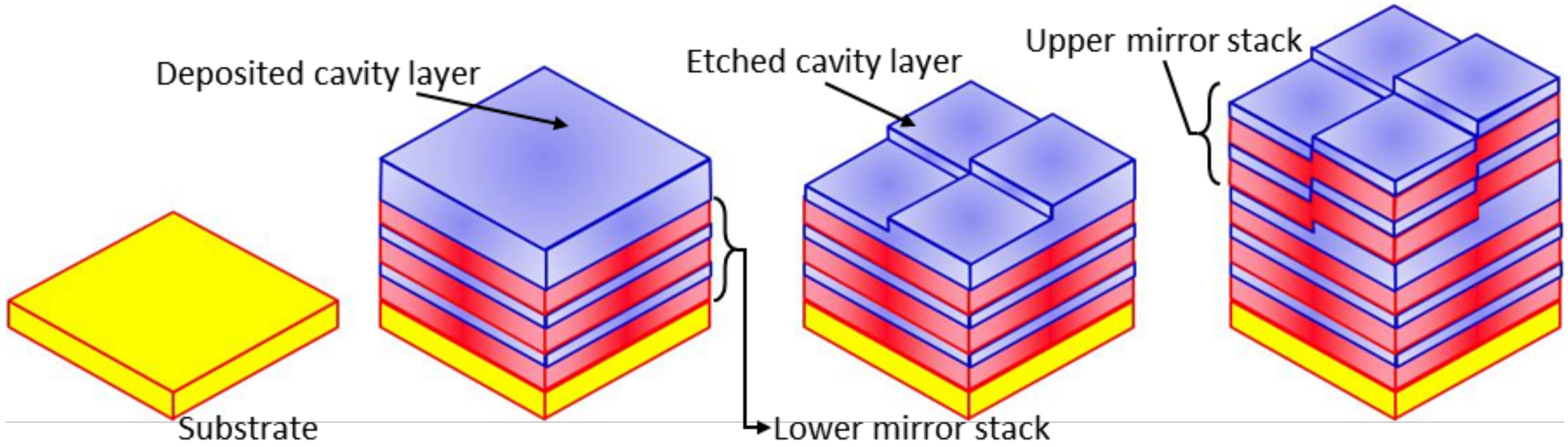
Hyperspectral Imaging: Spectral and spatial resolution



Fabry-Perot Structure







So what do I actually "do"

- Diffractive lens design (Zemax, GDCalc, GSolver)
- Coordinate micro-optic fabrication (layouts, masks, materials, people, process development)
- Material characterization (infrared absorption/transmission characteristics with different dopings, epoxies)
- Opto-Mechanical engineering (materials, epoxies, vibration, thermal)
- Image Processing (basic to analysis to reconstruction)
- Research vendors, ordering parts, capability development

A Year in the Life…

- Technical Project Work
  - Quantum information science
  - 3D imaging
  - Non-Conventional imaging
  - X-ray phase contrast imaging
- Project Management
  - Proposals, teams, budgets, schedules, deadlines, reports
- Developing New ideas
  - Internal R&D
  - External proposals
- Communicating Results
  - Internal
  - Conferences
    - ICCP, DIR, XNPIG, Photonics West, COSI, DCS, AQC
    - Technical Meetings
  - Publishing
- Building Collaborations
  - Internal
  - Academic (UIUC, UNM, NM Tech, LSU-CAMD)
  - Industry Partners

A Year in the Life…

- Technical Project Work
- Project Management
- Communicating Results
- Building Collaborations
- Developing New ideas