Center for Imaging and Sensing (CIS)

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Center Organization

- Objective
  - To assist our industrial partners in their quality assurance and imaging requirements
- What we deliver
  - Inspection and imaging methodologies
  - Fundamental sensor and instrumentation research
  - Turn-key prototype system development
  - Circuit design, simulations, layouts
- Organization
  - Two full-time ECE faculty
  - Funded graduate research assistants
  - ECE software/hardware tools, shop resources

Approach

- Regular meetings with our partners
  - Company-specific research updates
  - Demonstration of prototypes
  - Presentations by undergraduate/graduate project students
- Use of industry standard tools
  - HFSS, ADS, Matlab, SolidWorks, etc.
- Dissemination of research
  - Research reports
  - Conference/journal publications
  - Student theses

1st Example: Electrical Impedance Tomography (EIT) of Polycrystalline Diamond Cutters

- Problem description
  - Have to characterize cutter performance nondestructively
  - Need to detect hidden defects in a cost-effective way
- Approach
  - Measure electrical conductivity
    - Diamond table conductivity depends on residual metal content
    - Metal content is correlated with cutter performance characteristics
  - Localized conductivity measurement can detect defects (metal-rich zones, cracks)

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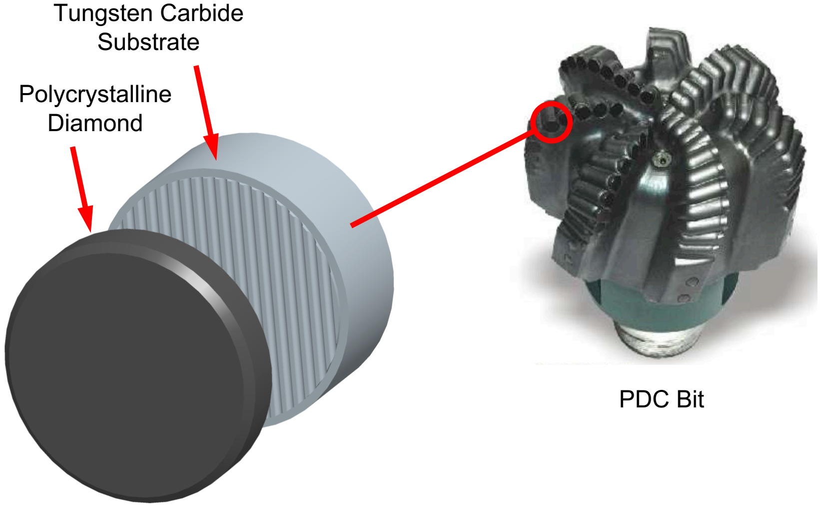
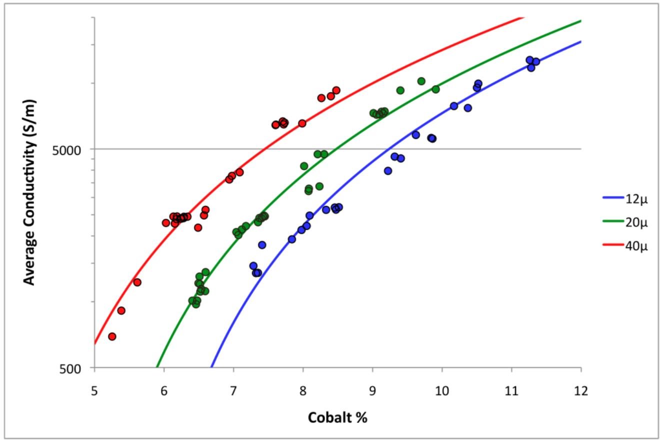
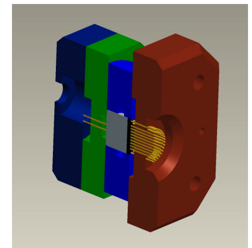
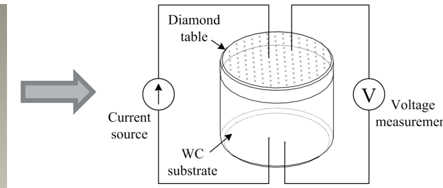




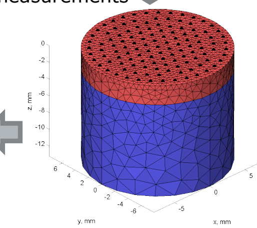
EIT System Development

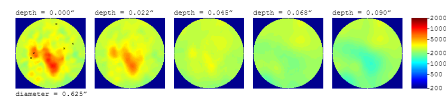
- What we built
  - EIT data acquisition system
    - Sensor with 120+2 pogo pins
    - Analog front end (custom PCB)
    - Pneumatic system for placing cutter in contact with the sensor
    - Machine vision system for diamond table thickness measurement
  - Custom-developed 3D EIT software
    - FEM forward solver
    - GPU-accelerated iterative inverse solver
- Outcomes
  - Two machines in industrial use for more than 5 years
  - Conductivity dataset acquired and reconstructed in 5 sec
  - 1 journal paper, 3 conference papers
  - 1 patent granted



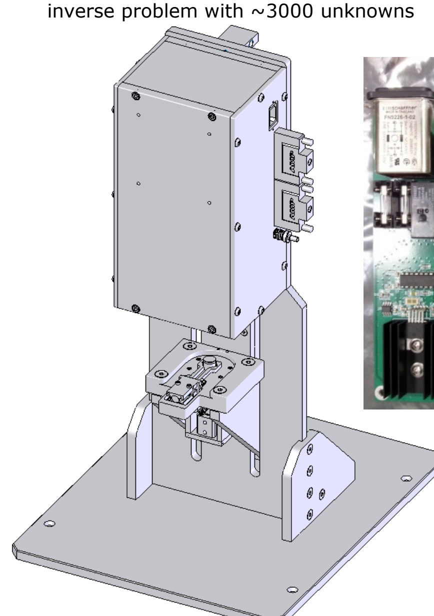


~3000 measurements



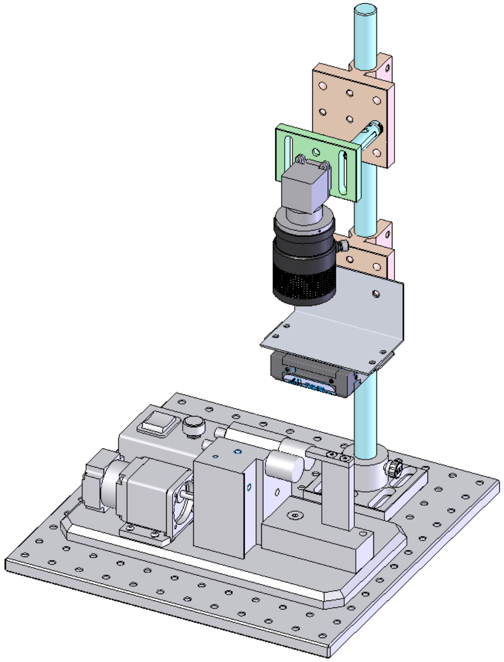


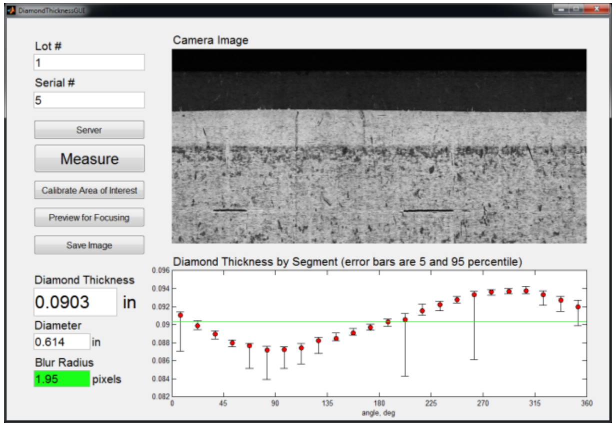
Conductivity reconstruction is a nonlinear inverse problem with ~3000 unknowns



2nd Example: Machine Vision System for Diamond Thickness Measurement

- Problem description
  - Diamond cutter EIT requires diamond thickness for quantitative conductivity measurements
- What we built
  - Machine vision system using specular reflection contrast
  - Cutter is rotated by an existing roller system
  - Full rotation is detected by image correlation
  - Blur radius measurement for focusing
- Outcome
  - One prototype in use and coupled to one of the EIT machines



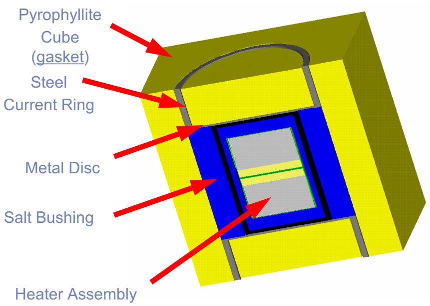


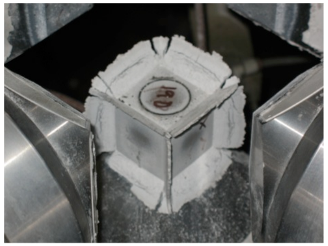
3rd Example: High-Pressure Gasket Moisture Content Measurement

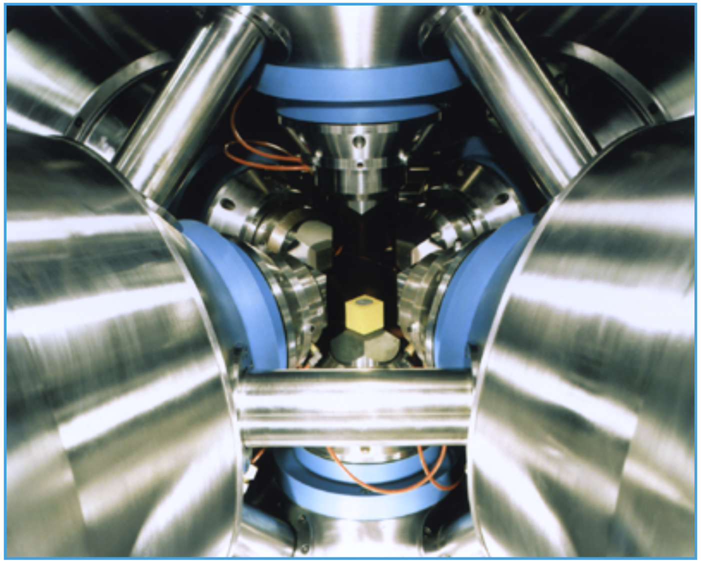
- Problem description
  - Soft material is used as a gasket and pressure transmission medium
  - Excess moisture gasket can cause failure during decompression
    - Potential catastrophic damage to press anvils
  - Need a nondestructive method of monitoring gasket moisture content
- Approach
  - Electric RF field/moisture interaction

US Synthetic

Pressure cell assembly

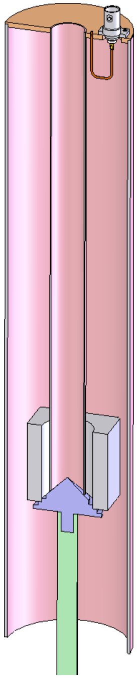


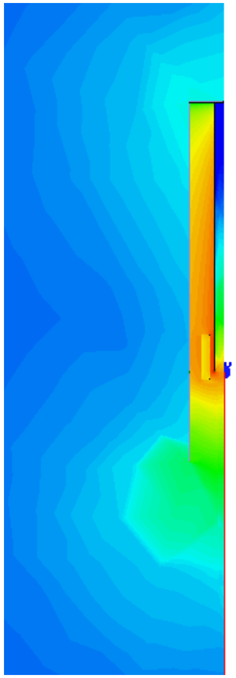


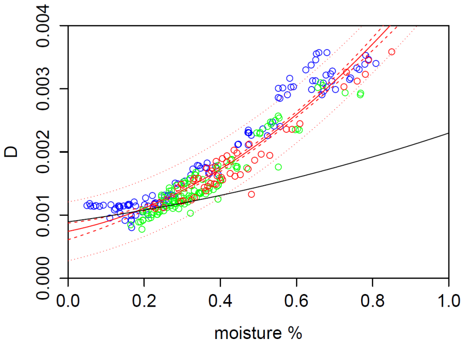


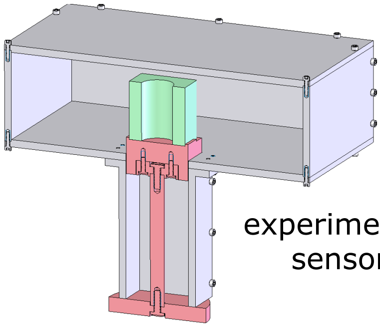
High-Pressure Gasket Moisture System

- What we built
  - Coaxial resonator sensor
  - Sample loader
  - Rapid moisture content estimation software
  - Experimental multimode cavity sensor
- Outcomes
  - 5 moisture meters installed at our industrial partner
  - 3 QNDE papers
  - 1 patent application filed





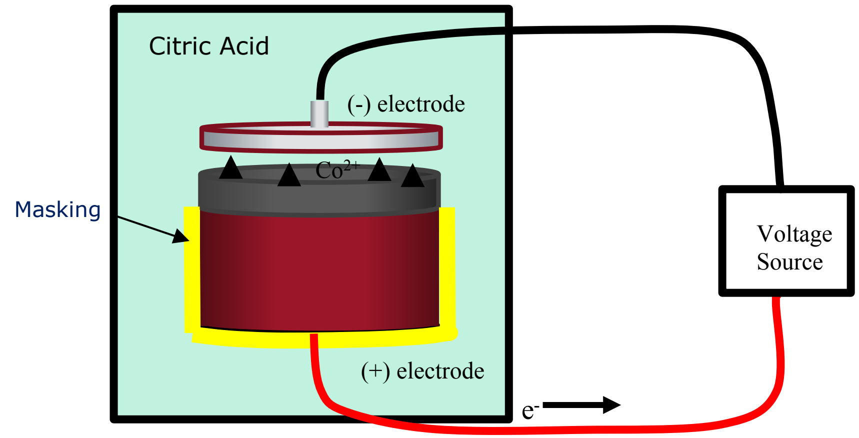


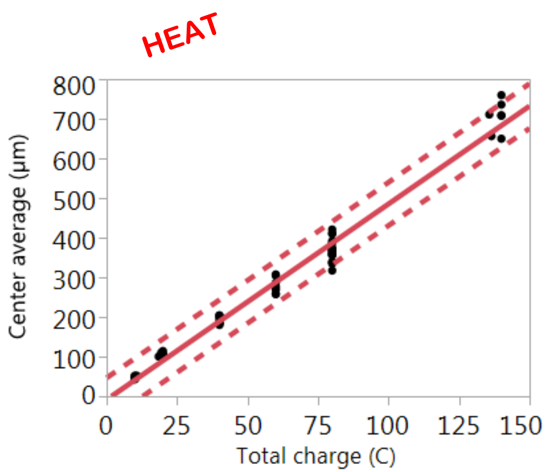


experimental sensor

4^{th} Example: Electrochemical Leaching of Polycrystalline Diamond

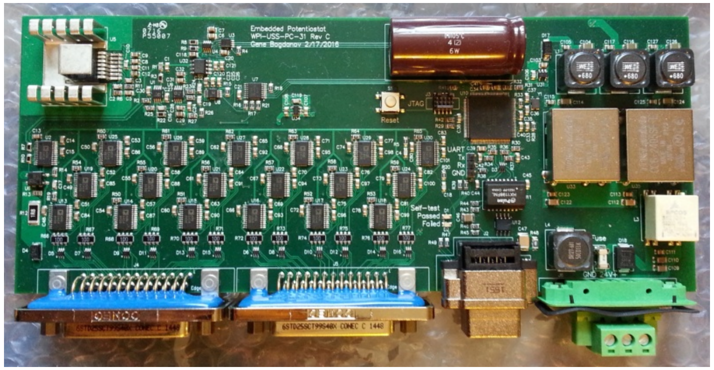
- Problem description
  - Metal must be removed from polycrystalline diamond to a certain depth to meet performance specifications
  - Existing process using HF-HNO_3 mix is slow, inconsistent, prone to yield issues, and dangerous
  - Our partner needs a replacement process
- Approach
  - Electrochemical metal removal
  - Amount of metal is related to accumulated charge
  - Nontoxic chemicals

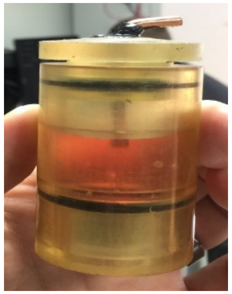


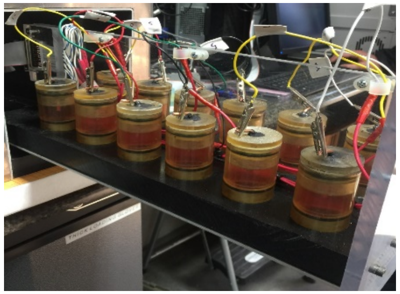


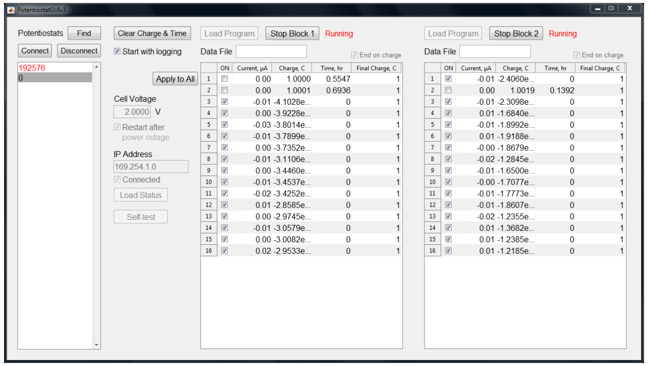
Electrochemical Leaching System

- What we built
  - Multichannel (48-channel) potentiostat
    - Applies voltage to cells
    - Measures current in each leaching cell
    - Accumulates charge
    - Stops current when reaching calculated charge level
    - Ethernet connectivity
  - Central control software for large number of potentiostats
  - Individual cutter cells (jointly developed)
  - Oven for heating cells (jointly developed)
- Outcomes
  - 6 potentiostat prototypes deployed (24, 32 and 48-channel versions)
  - Large amount of data collected
  - 1 patent application filed









5th Example: Lock-in Thermography for Bearing Braze Joint Inspection

- Problem description
  - Bearings for well drilling use polycrystalline diamond
  - Diamond-tipped inserts are brazed into the bearing body
  - Poor braze joints cause premature failure
  - Need a nondestructive braze joint inspection
- Approach
  - Low braze joint area results in weak thermal contact with the body
  - Measure thermal conduction from inserts to the body via lock-in thermography

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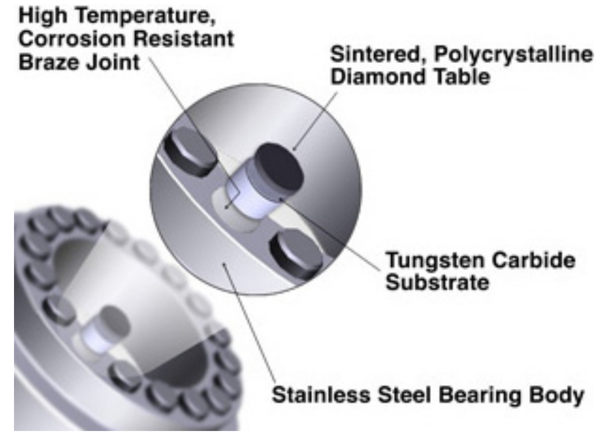
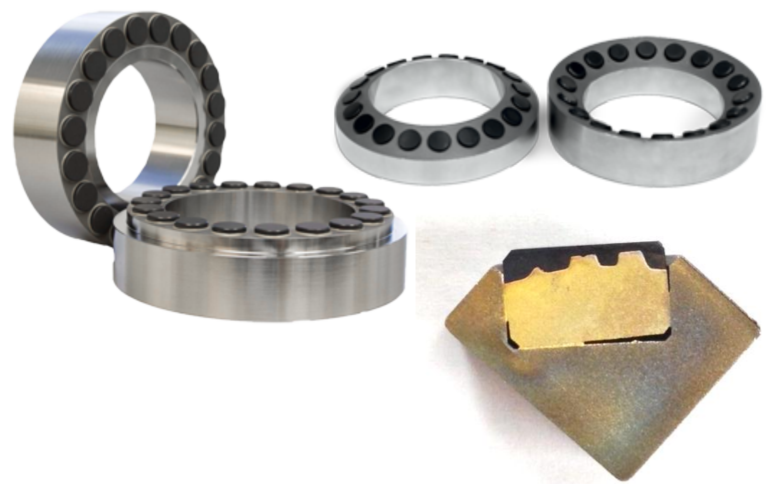
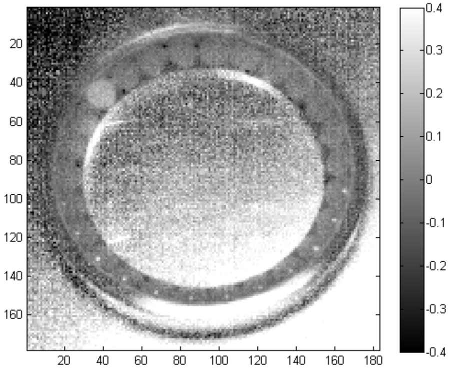




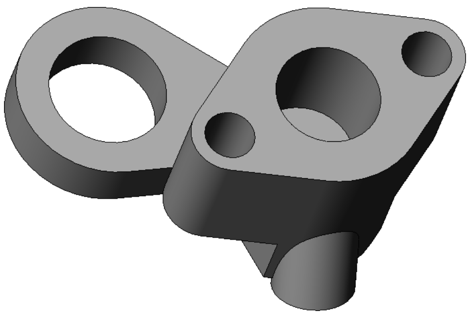
Bearing Braze Joint Inspection System

- What we built
  - Lock-in thermography system
    - Heating by 1000 W halogen lamp
    - Sinusoidal modulation of lamp output
    - IR camera images surface temperature evolution over time
  - Software to compute phase shift between heat source and temperature
    - Robust measure of thermal diffusivity
- Outcomes
  - 1 prototype constructed
  - Successfully detected 1 bad braze joint in a limited number of samples

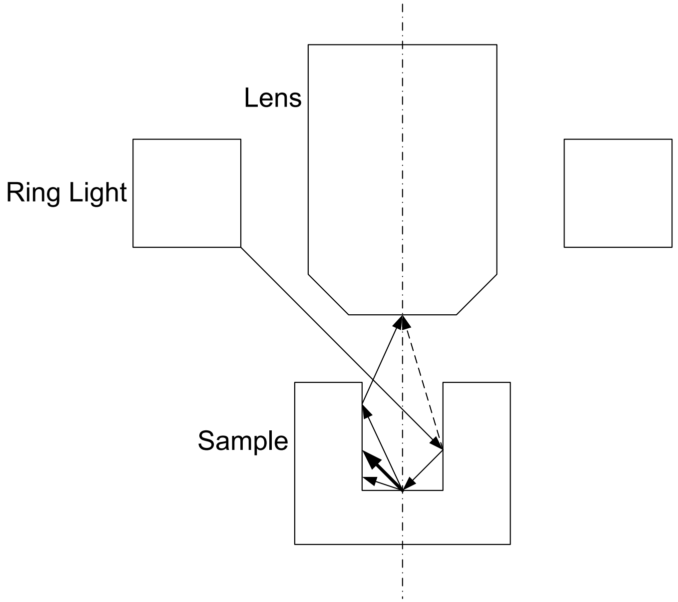


6th Example: Bore Inspection

HITCHINER
Since 1946

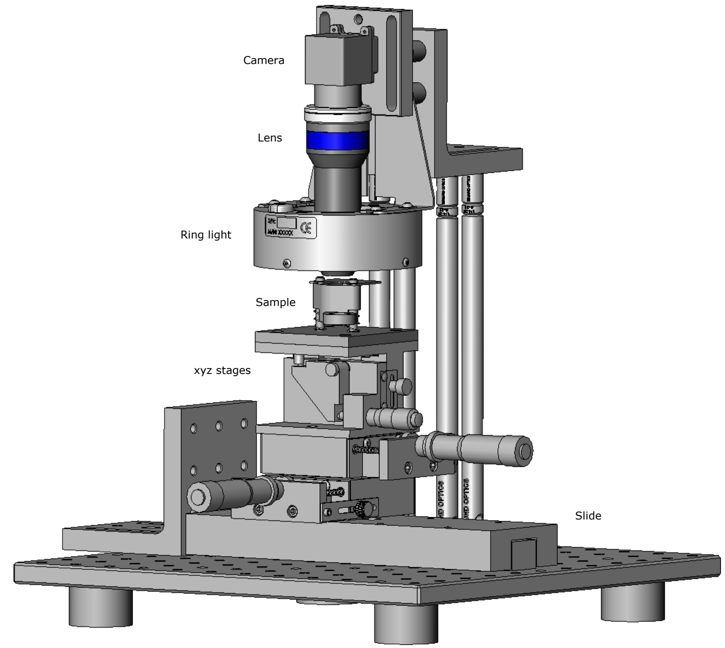


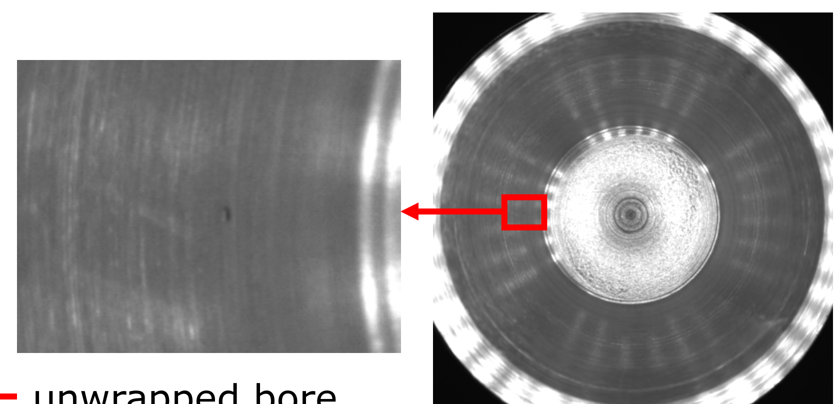
- Problem description
  - Need to detect surface-breaking pores with resolution of 100µm in diameter on bore wall
- Approach
  - Machine vision
  - Specular reflection contrast
    - Bore wall strongly reflective
    - Pores less reflective
  - Fast, low cost
    - No sophisticated part manipulation (e.g. rotation-translation)

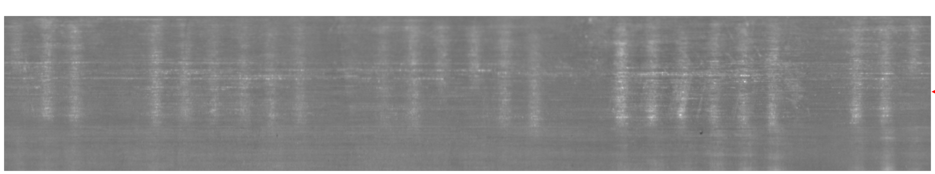


Bore Inspection System

- What we built
  - Imaging system
    - High-resolution 5 MP camera
    - Wide angle, short standoff lens
    - Ring light illumination
  - Sample loader
  - Image processing software
    - Bore wall unwrapping
    - Defect detection
- Outcomes
  - Simulated pores detected on wide-bore (0.452”) parts
    - Parts modified: rough bore bottom
  - Revision is under development to improve contrast
    - Axial illumination



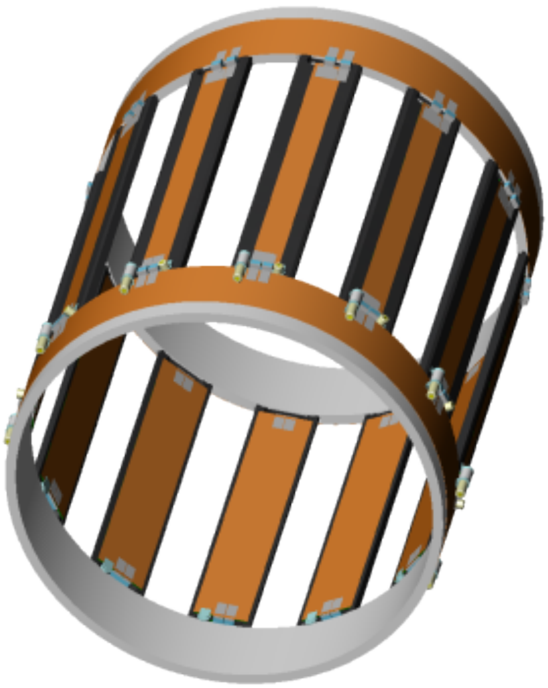




unwrapped bore

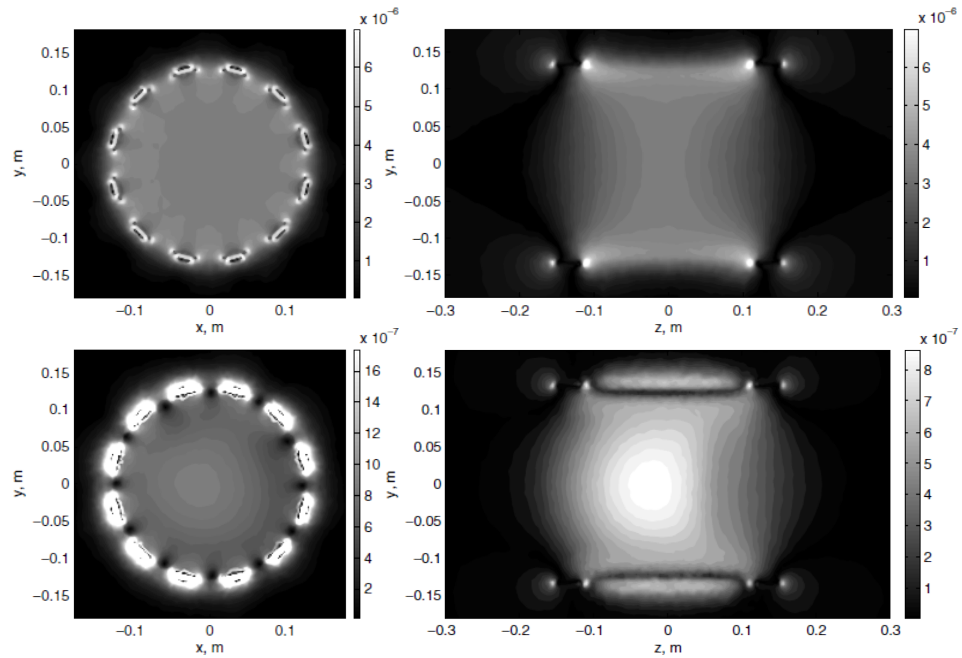
7th Example: Magnetic Resonance Imaging Dual-Tuned Head Coil

- Problem description
  - Demand for dual-tuned clinical MRI transmit/receive head coils for sodium (^{23}Na) and hydrogen (^{1}H) at 3T for stroke imaging
  - Wide frequency separation between ^{23}Na at 34 MHz and ^{1}H at 128 MHz
    - Higher frequency circuits inhibit the performance at the lower frequency, which is most critical
- Approach
  - Experimental coil design
    - Birdcage at low frequency (34 MHz)
    - TEM-like coil at high frequency (128 MHz)

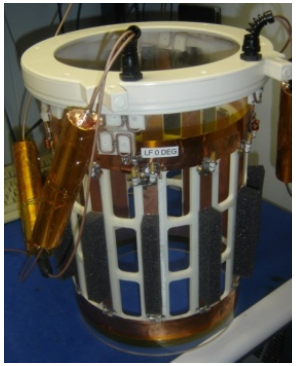


MRI Dual-Tuned Head Coil

- What we built
  - Simulated competing coil designs
    - Experimental birdcage-TEM coil
    - Typical dual-tuned birdcage coil
    - Dual-tuned TEM coil
  - Built and tested a prototype birdcage-TEM coil
- Outcomes
  - NIH SBIR grant awarded
  - Prototype performed similarly to simulation

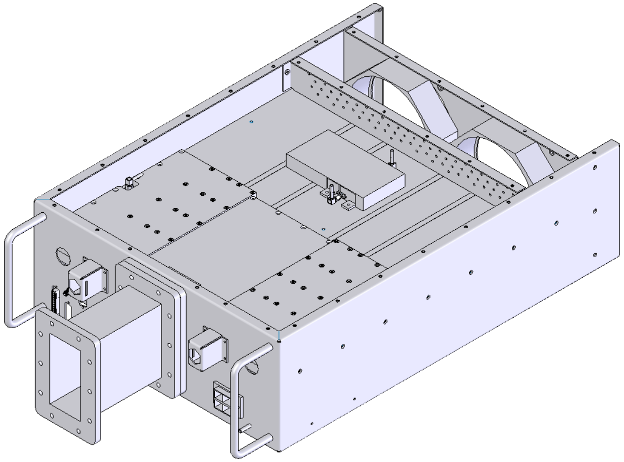


B_1 field with load:
top – 34 MHz (^{23}Na)
bottom – 128 MHz (^{1}H)

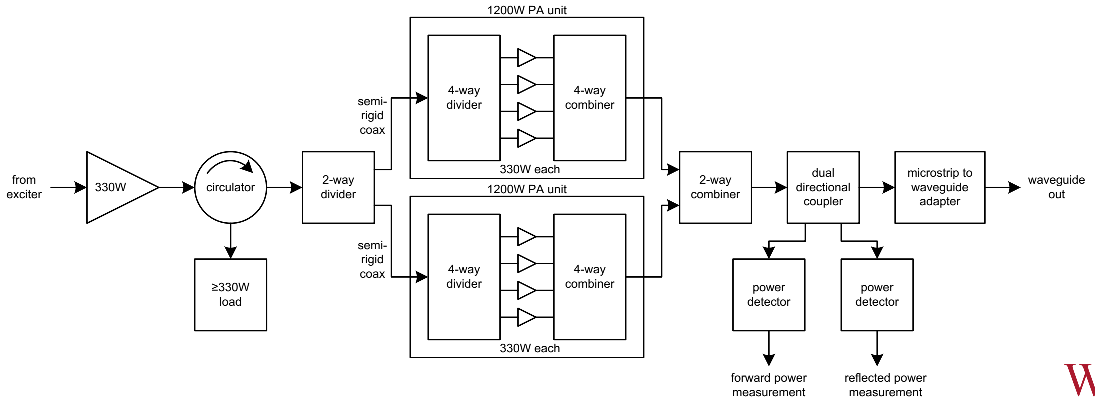


8th Example: Solid-state 2 kW 2.45 GHz Microwave Generator

- Problem description
  - Semiconductor industry looking to replace magnetron MW generators with solid-state versions
    - More controllable and reliable
  - Challenges
    - small package (4U rackmount)
    - waveguide output
    - efficient, pulsing capable
    - low cost, short development time



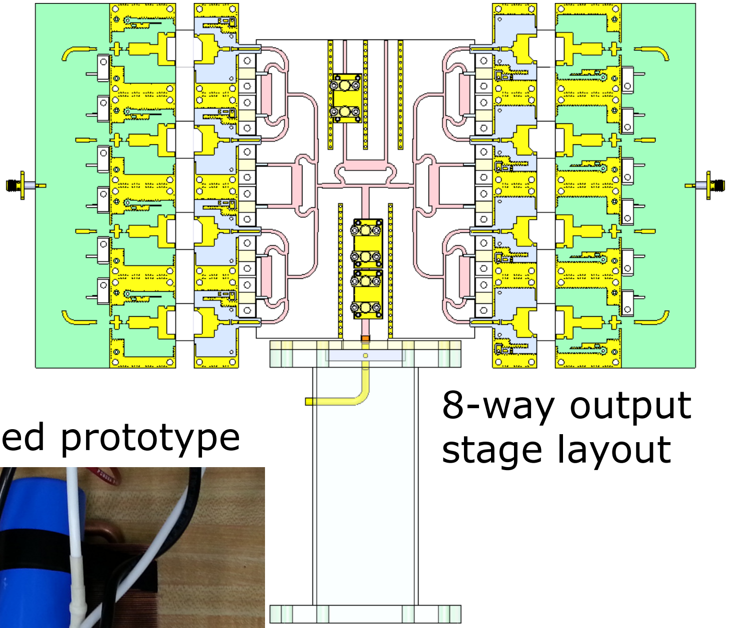
- Approach
  - Combine outputs of eight 330 W solid-state power amplifier modules



ERENO

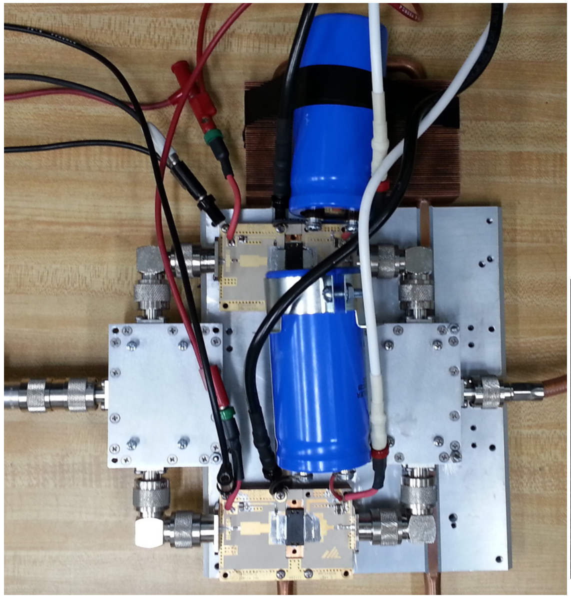
Solid-state Microwave Generator

- What we did
  - Designed output stage with custom MW components:
    - power combiners
    - power dividers
    - directional couplers
    - waveguide transition
  - Tested 2-way combined 330 W modules
- Outcomes
  - 2-way prototype performed well
    - up to 550 W output
    - no oscillation
    - pulsing capable



8-way output stage layout

2-way combined prototype



custom 2-way combiner