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)
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
**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
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
4th 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-HNO₃ 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
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

- **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

B₁ field with load:
  top – 34 MHz (²³Na)
  bottom – 128 MHz (¹H)
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
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