

## Description of Skills

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*Summary:* Experiments are designed and built to explore new physical phenomena in condensed matter systems. A broad range of engineering and trade skills has allowed implementation of many novel instruments and components, recycling systems, customized automation, and repair of manufactured components and equipment. Such foundational abilities are necessary when designing complex systems, and greatly extend limited resources crucial in small R&D and academic research environments.

### Optical measurement systems: designed and built

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- Novel heterodyne Kerr and Faraday measurement systems at THz and MIR frequencies
- Double-modulation gating techniques with continuous scan FTIR spectroscopy and polarization-modulated laser sources in Kerr/Faraday/cyclotron resonance systems
- Voigt and Faraday geometry magneto-optical broadband reflection and transmission spectroscopy measurement system (step-scan and continuous scan variants)
- THz measurement platforms to characterize and facilitate research of carbon nanotube and graphene hot-bolometer THz detectors
- Full automation of optical and magneto-optical measurement systems for unattended data acquisition that incorporate spectrometers, lasers, magnet system, multiple actuators and rotation stages, and wide-ranging temperature control
- Simultaneous reflection and transmission spectroscopy with *in situ* laser photodoping
- Broadband FIR measurement system to 2 mm wavelength with step-scan FTIR spectrometer (custom hardware /software), high power Hg vapor lamp, and He-3 bolometer detector system
- Magneto-microwave reflection and transmission waveguide system operating at 100 GHz utilizing a 14T magnet and Gunn diode
- Differential photocurrent measurement system utilizing novel THz-laser circular-polarization modulation
- Concurrent dc magneto-transport/dynamic capacitance/high-voltage gating and magneto-optics

### Optical components: designed and built

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- **Lasers:**
  - THz: FIR CW molecular laser cavity with dielectric waveguide, 1000-50 um at 50mW; gas recapture/reuse system; output coupler; novel Fabry-Perot resonator from Si slab to characterize lasing frequency
  - NIR: modify IR CO<sub>2</sub> CW 50W tunable (grating) laser system: cooling block for grating; mu-metal shielding of laser cavity; new Brewster windows, output couplers, gratings, cathode
  - Phase-lock laser feedback stabilization of dual laser system with computer control
- **Detectors:** graphene and carbon nanotube based detector research for use in THz regime; repair/tune/rewire Ge and Si bolometer elements, cold & warm amplifiers; absolute calibration of detector sensitivities; simulation platform to qualify photomultiplier tube performance in NO<sub>x</sub> air analyzers; calibration of FIR laser intensity with pyroelectric THz detectors utilizing nanotube forests
- **Optics:** optically polish windows, filters, substrates, semiconductors, semimetals, and metals; antireflection coatings; membrane vacuum windows (Kapton, polypropylene) and beam splitters (mylar); grind-cut silicon & quartz vacuum windows and cold filters; fabricate gold and aluminum mirrors; recondition optical surfaces
- **Electro/mechanical optics:** traveling wave electro-optical modulator; photo-elastic modulator based measurement systems; waveplate/polarizer rotation system; piezo stacks;
- **Optical hardware:** many (especially non-magnetic) optical mounts and fixtures; dozens of optical translation/rotation stages for AMO laboratory

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## **Cryogenic systems: Designed/Built/Modified**

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### **Designed and built:**

- Cold shield and sample mounts in Oxford magnet system (thermal, mechanical, and optical analyses); cold filters/windows; thermal blankets
- Laboratory helium recovery system encompassing five laboratory spaces; consultant for multi-lab helium recovery system at IREAP
- Low-budget helium exhaust flow meters from automotive mass-air-flow sensors
- He-3 gas handling systems (sealed pump and storage tanks) for 150mK bolometer; He-3 bolometer cryostat heater electronics, external tank, and thermometry
- He-4 dip probe: dc-resistivity/ac magnetic susceptibility/thermometer calibration
- Swappable Faraday and Voigt geometry cold heads

### **Modified/Repaired:**

- Modify multiple cryostat systems: wind heaters; thermometry; rewire multiple cryostat systems; fabricate and install windows/filters; enhance optical stability; actuators; fabricate hardware to mitigate back reflection from mirrors
- Repair leaks: cryogen reservoirs, vacuum jackets

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## **Device Fabrication**

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- class 1000 clean rooms (UMD, Penn state, UT Austin)
- *Lithography*: e-beam and UV
- *Deposition*: metal film and organics; Parylene; PLD
- *Gating*: conformal dielectrics; liquid/solid electrolytes; surface chemical dopants; ion implantation
- *Diagnostics*: profilometers; probe stations; e-beam and optical microscopes; Hitachi and Joel SEMs; ellipsometry; FTIR/grating spectroscopy; transport measurements; magnetic susceptibility; XRD
- *Other*: glove boxes; etching; annealing; dicing; polishing; wire bonding; spin coating

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## **Computing/Software**

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- *Platforms*: Windows, Linux
- *Maintain computer resources*: ~10 lab PC's for 15 years without data loss; group databases & experimental data; software installation & updates; site licensing
- *Programming*: Labview, C++, Fortran, Visual Basic and C++, asm, html, G code, Arduino scripts
- *General modeling/Analysis*: Mathematica, MatLab, MathCad, Origin/SigmaPlot
- *Physical modeling*: optical spectra (RefFit); Ion implantation/particle-matter interaction (SRIM/TRIM); band structure modeling & optical response (VASP); electrostatics (HFSS)
- *Mechanical Drafting*: Vellum Graphite and Cobalt, SolidWorks
- *Documents*: LaTeX/MikTeX/WinEdt, Adobe Illustrator/Dreamweaver/Photoshop, Zotero, MSOffice

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## **General Machining/Facilities Construction**

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- *Supervise*: machine shop; chemistry room; helium recovery system; four lab areas
- *Mechanical drafting*: well over 100 drawings
- *Hot works*: MIG, TIG, oxyacetylene welding; brazing; soldering; tempering; cutting
- *Machining*: CNC mills & lathes, many other standard machine shop tools
- *Electrical work*: conduit, panel wiring/breaker installation; wire plugs/sockets/outlets (2-wire to 5-wire configurations), motors, compressors, disconnects, ballasts, high current and high voltage
- *Gas/Water handling*: Multitude of vacuum, gas, and water/coolant manifolds: ½" - 3" PVC, copper capillary tubes to 3" diameter pipe, stainless steel tubing; water/coolant pumps and chillers
- *HVAC*: Design 4-ton chiller system; refrigerant certification; refrigerant charging and refrigeration repair; fan coil & ventilation ducts installation

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### **Electronics**

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- *Circuits*: op-amp based amplifiers; active and passive filters; triggers; thermocouple amplifiers; heaters with PID feedback; laser stabilization; high power Zener diode circuit protection; snubbers; various interlocks; Arduino (O<sub>2</sub> concentration display)
- *Integrated components*: multiple implementations of national instruments data acquisition and control hardware; servo and stepper motors (homing and limit switches); motorized/solenoid valves actuated by computer controlled relays;
- *Repair*: wide range of gauges, controllers, computer boards, rectifiers/power circuits, power supplies, amplifiers, lock-in amplifiers, sputtering and evaporation systems, temperature controllers

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### **Vacuum systems**

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- *Design and build*: portable UHV pump station; vacuum windows and mounts; flexible vacuum coupling connecting spectrometer to magnet system to accommodate optical alignment
- *Repair*: multiple turbo/diffusion and mechanical pump systems; rebuild direct drive rotary vane vacuum pumps; repair and maintain; helium leak detection

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### **Other**

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- *Automechanic*: rebuild engines, transmissions, body work, suspension, electrical, etc. for passenger trucks and cars
- *Music related*: Develop software for MIDI performance controller; Fabricate and build MIDI controlled kick-board salvaged from Hammond organ; Piano refurbishing, tuning, and repair