Capabilities, Equipment, and Facilities

The Center for Detectors (CfD) is located in Engineering Hall (Building 17) at the Rochester Institute of Technology. The CfD headquarters consists of approximately 7,000 square feet of office and research laboratory space. CfD lab space includes the Rochester Imaging Detector Laboratory (RIDL, see Figure 46), the Lobozzo Photonics and Optical Characterization Laboratory, the Integrated Photonics Laboratory, the Experimental Cosmology Laboratory, the Laboratory for Advanced Instrumentation Research (LAIR), the Quantum Imaging and Information Laboratory, the Suborbital Astrophysics Laboratory, and a semiconductor device optical property measurement laboratory.

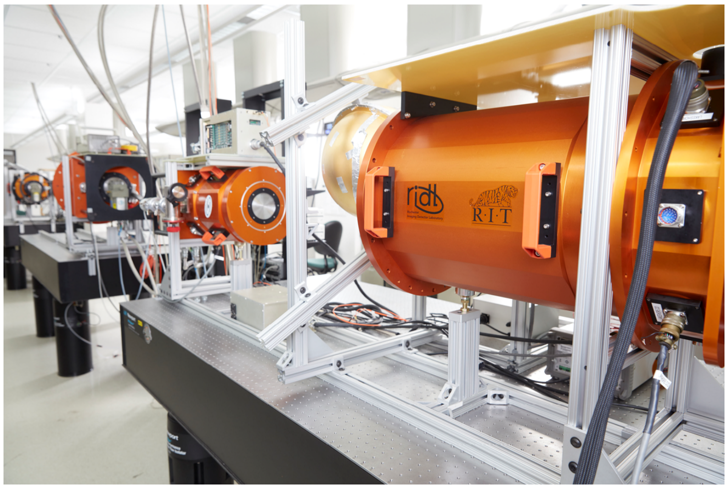


Figure 46. The photo above shows the cryogenic dewars in the Rochester Imaging Detector Laboratory.

Facilities within CfD include a permanent clean room, ESD stations, vacuum pumping systems, optical benches, flow tables, light sources, UV-IR monochromators, thermal control systems, cryogenic motion control systems, power supplies, general lab electronics, and data reduction computers. The equipment is capable of analyzing both analog and digital signals. In addition to these dedicated facilities, the CfD has access to facilities within the Semiconductor and Microsystems Fabrication Laboratory (SMFL) and other areas across the RIT campus.

Rochester Imaging Detector Lab

The RIDL detector testing systems use four cylindrical vacuum cryogenic dewars. Each individual system uses a cryocooler that has two cooling stages: one at ~60 K (10 W) and another at ~10 K (7 W). The cold temperatures yield lower detector dark current and read noise. The systems use Lakeshore temperature controllers to sense temperatures at 10 locations within the dewars and to control heaters in the detector thermal path. This thermal control system stabilizes the detector thermal block to 400 μK RMS over timescales greater than 24 hours. The detector readout systems include two Astronomical Research Camera controllers with 32 digitizing channels, a 1 MHz readout speed, and 16-bit readout capability. The readout systems also contain one Teledyne SIDECAR ASICs with 36 channels and readout speeds up to 5 MHz at 12-bits and 500 kHz at 16-bits, custom FPGA systems based on Altera and Xilinx parts, and a JMClarke Engineering controller with 16 readout channels and 16-bit readout designed specifically for Raytheon Vision System detectors. Figure 47 shows the electronics packages.

Figure 47 The three electronics packages used to test detectors are the Astronomical Research Camera Controller (left), JMClarke Engineering (middle), and the Teledyne SIDECAR ASIC (right).

The controllers drive signals through cable harnesses that interface with Detector Customization Circuits (DCCs) consisting of multi-layer cryogenic flex boards. The DCCs terminate in a single connecter, which then mates to the detector connector. Three-axis motorized stages provide automated lateral and piston target adjustment. Two of the dewars have a side-looking port that is useful for exposing detectors to high energy radiation beams. The RIDL also has two large integrating spheres that provide uniform and calibrated illumination from the ultraviolet through the infrared. The dewars are stationed on large optical tables that have vibration-isolation legs (Figure 48).

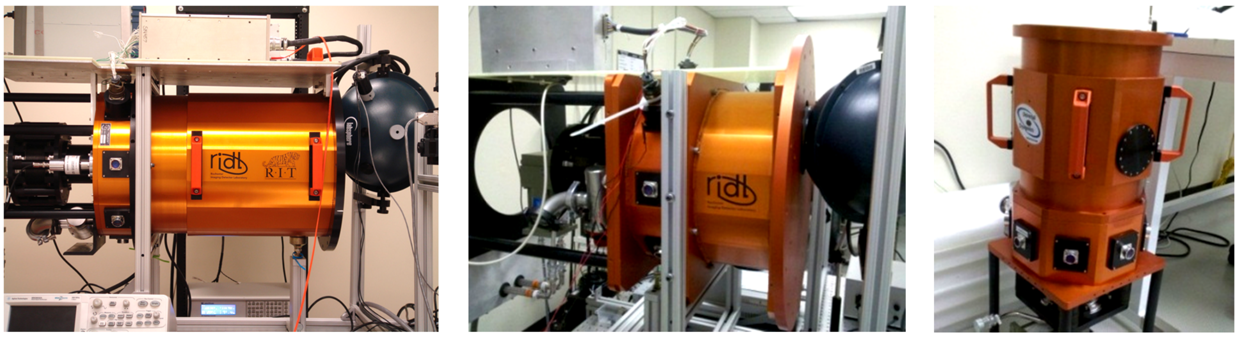


Figure 48. Detectors are evaluated in four custom dewar test systems. The fourth dewar (not pictured) is a duplicate of the one on the left.

The lab equipment also includes a PicoQuant laser for LIDAR system characterization and other testing that requires pulsed illumination. In addition, the lab has monochromators with light sources that are able to produce light ranging from the UV into the IR, with a wavelength range of 250 nm – 2500 nm. NIST-traceable calibrated photodiodes (with a wavelength range of 300 nm – 5000 nm) provide for absolute flux measurements. RIDL also has a spot projector to characterize the interpixel response of the detectors, including optical and electrical crosstalk. Figure 49 shows a laser spot projection system on a 3D motorized stage that produces a small (~few µm) point source for measurements of intrapixel sensitivity.

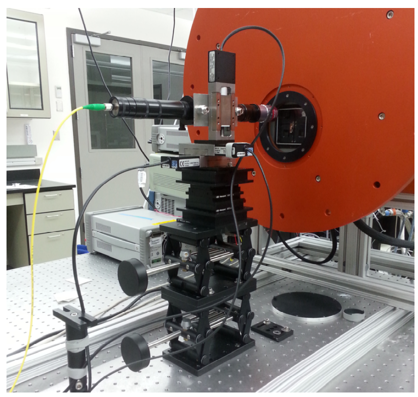


Figure 49. In the photo above, a laser spot projector with a three-axis motion control system projects a small spot of light within individual pixels of detectors in order to measure the response in all regions of a pixel.

RIDL has many data acquisition and reduction computers, each with eight to twenty-four threads and up to 32 GB of memory for data acquisition, reduction, analysis and simulations. A storage server with 10 Gbps optical network connection is the primary data reduction computer; it has 50 TB of mirrored storage space. Custom software runs an automated detector test suite of experiments. The test suite accommodates a wide variety of testing parameters using parameter files. A complete test suite takes a few weeks to execute and produces ~0.5 TB of data. The data reduction computers reduce and analyze the data using custom automated code, producing publication-quality plots in near-real time.

Lobozzo Photonics and Optical Characterization Lab

The RIT Integrated Photonics Group conducts research in the Lobozzo Photonics and Optical Characterization lab (Figure 50). Dr. Preble and his team develop high performance nanophotonic devices and systems using complementary metal–oxide–semiconductor compatible materials and processes. Their work enables unique performance and efficiency by leveraging the inherently high bandwidths and low power of photons with the intelligence of electronics. The Lobozzo lab includes a Ti:sapphire laser, optical parametric oscillator, atomic force microscope, ion mill, cryogenic optoelectronic probe station, and telecom test equipment. Other CfD faculty and students use the lab for terahertz measurements and time-resolved photoluminescence.

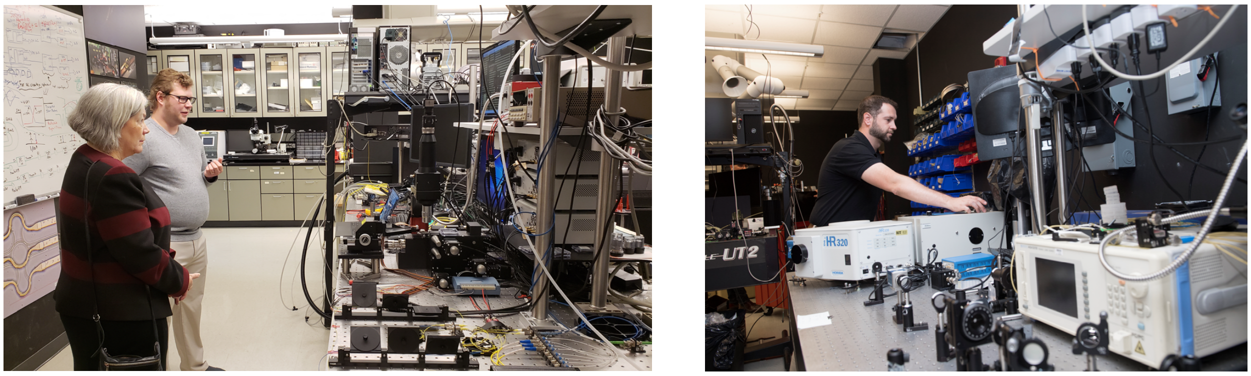


Figure 50. (left) Dr. Howland shows RIT Provost, Ellen Granberg the Photonics and Optical Characterization Lab. (left) Michael Fanto, one of Dr. Preble's PhD students works in the lab.

The Integrated Photonics Group added space for quantum integrated photonic experiments last year. Researchers use this lab to design and develop scalable quantum computing, communication and sensing circuits integrated on Silicon Photonic chips. These chips densely integrate photon sources, entanglement circuits and single photon detectors onto a phase stable platform. The Air Force Office of Scientific Research (AFOSR) provided funding through the Defense University Research Instrumentation Program for a Photon Spot single photon detector system (Figure 51, *right*) which has high detection efficiencies (>85%) and very low dark counts (<200Hz). The system has detectors for both short-wave infrared and UV wavelengths. The National Science Foundation, Air Force Research Laboratory, and the Gordon and Betty Moore Foundation fund the laboratories' research projects.

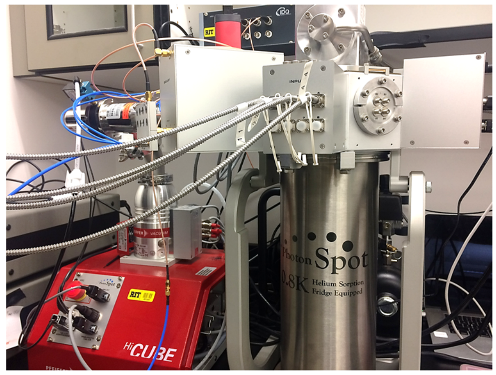
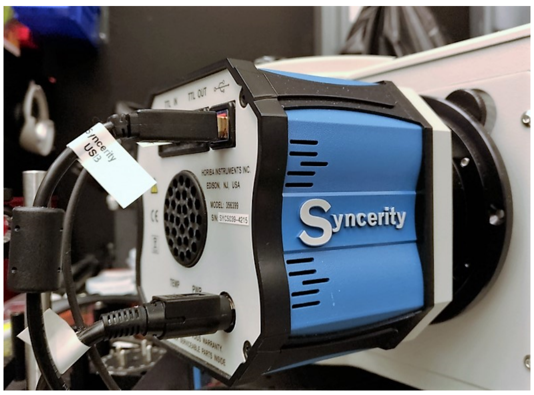


Figure 51. (left) The photo above shows the optical table used to run quantum integrated photonic experiments in the newly opened Integrated Photonics Lab. (right) This photo shows the Photon Spot single photon detector system funded by AFOSR.

CfD professor Dr. Jing Zhang leads a semiconductor device optical property measurement lab located within the Lobozzo laboratory. This lab contains a photoluminescence (PL) system, seen in Figure 52, including an iHR320 spectrometer, a Syncerity CCD Array detector, a liquid helium cyrostat and a 325 nm HeCd laser. There is LabSpec software capable of measuring semiconductor luminescence spectrum with wavelengths ranging from 325 nm – 800 nm. The liquid helium cyrostat enables the system to conduct measurements at temperatures as low as 4 K.



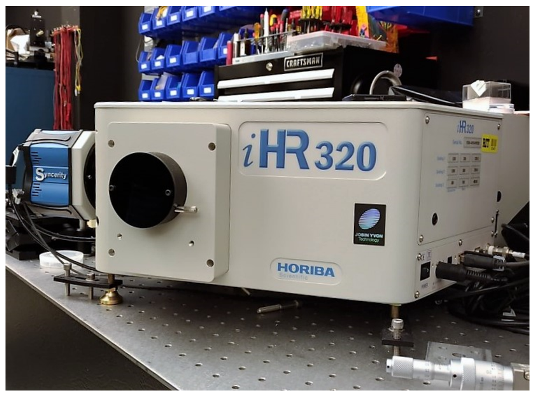


Figure 52. The Syncerity CCD Array detector (left) and the HR320 spectrometer (right) are part of the photoluminescence system.

The lab also includes an electroluminescence (EL) measurement setup (Figure 53) including a FLAME-S-UV-VIS-ES spectrometer (200 nm – 850 nm) and a rotatable stage that enables polarization-dependent and angle-dependent measurements.

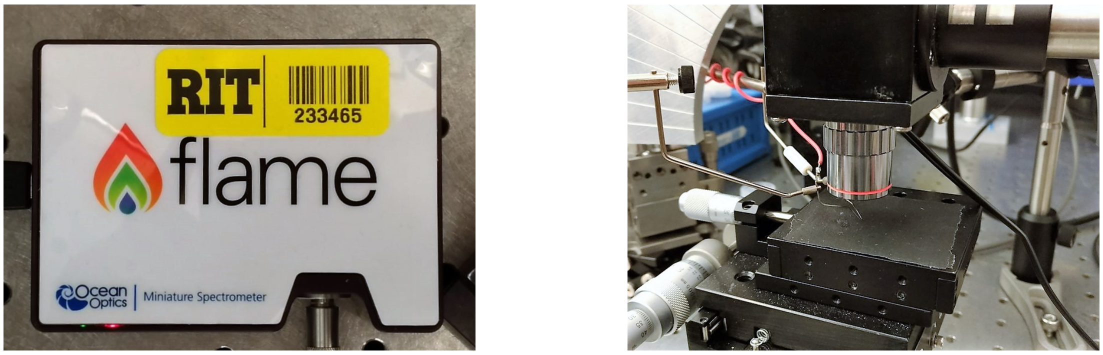


Figure 53. The electroluminescence measurement setup includes a rotating testing stage (right) and a FLAME 200 nm – 850 nm spectrometer (left).

Experimental Cosmology Lab

CfD professor Dr. Michael Zemcov directs the Experimental Cosmology Laboratory. This 375 square foot lab is capable of creating technologies for ground- and space-based applications in experimental astrophysics. The lab has equipment for fabricating and testing physical components and complementary software (Figure 54). Inside the lab are two Oerlikon Leybold Turbolab turbo-molecular pump systems, optical benches, lifting equipment, and tooling and component fabrication equipment. Multiple computers within the lab run sophisticated algorithms for astrophysics simulations. The lab also includes a millimeter wave spectrometric readout system for transition edge superconducting bolometers, as well as two liquid helium cryostats and an electronic fabrication station. A new vibration test system and rapid-prototyping PCB mill add to the capabilities for cosmology instrumentation and testing in this lab.

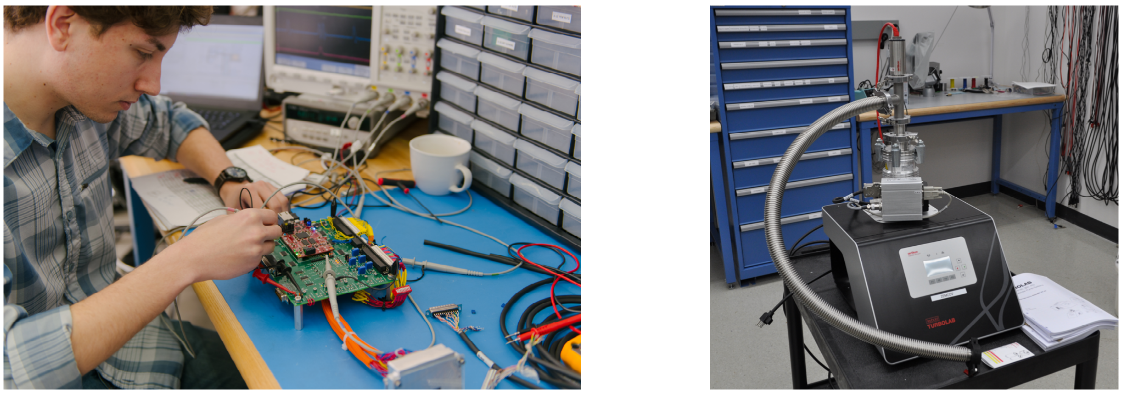


Figure 54. (left) Former CfD student, Ben Stewart is working with the FPGA-based control board, function generators, and oscilloscopes, used to develop CSTARS. (right) The picture shows one of the Oerlikon Leybold Turbolab turbo-molecular pumping stations in the lab.

Laboratory for Advanced Instrumentation Research

The Laboratory for Advanced Instrumentation Research (LAIR), led by CfD professor Dr. Zoran Ninkov, is in the Chester F. Carlson Center for Imaging Science, a short distance from the CfD Headquarters. The LAIR develops novel and innovative instruments for gathering data from a wide variety of physical phenomena and trains the next generation of instrument scientists who will occupy positions in government, industry, and academia. It includes hardware and software for developing terahertz (THz) imaging detectors using Si-MOSFET CMOS technology (Figure 55). Over the years, Dr. Ninkov and his team developed a wide variety of instruments at LAIR, including digital radiography systems, liquid crystal filter based imaging systems for airborne (UAV) mine detection, a speckle imaging camera for the

WIYN 3.6 meter telescope, a MEMS digital micromirror based multi-object spectrometer, and an X-ray imaging systems for laser fusion research. NASA, the NSF, NYSTAR and a variety of corporations such as Exelis, ITT, Kodak, Harris, Moxtek and ThermoFisher Scientific, have funded this research.

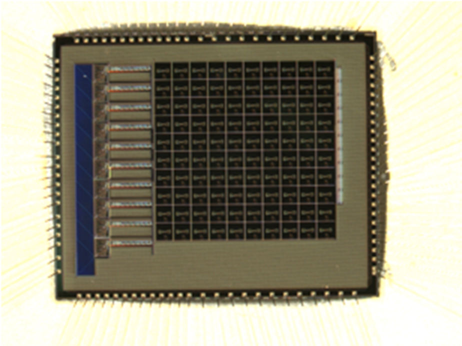
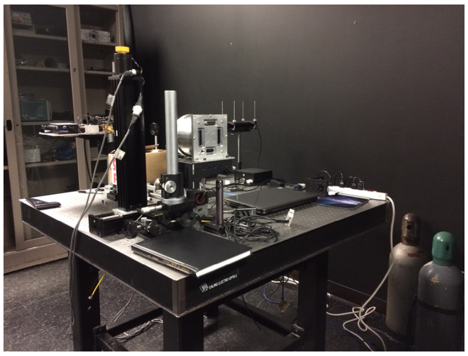



Figure 55. Student researchers in the LAIR developed a terahertz detector (left) and characterized it in the laboratory (right).

Epitaxially-Integrated Nanoscale Systems Lab

CfD professor Dr. Parsian Mohseni leads the Epitaxially-Integrated Nanoscale Systems Laboratory (EINSL). This lab, part of RIT's Nanopower Research Laboratory (NPRL), focuses on atomic-level semiconductor assembly and metalorganic chemical vapor deposition (MOCVD). The lab develops devices used for photovoltaics, optoelectronics, and nanoelectronics. Their research finds real-world applications in solar energy, solid-state lighting, and lasing. Current research areas in the EINSL include metal-assisted chemical etching of semiconductors using non-conventional catalysts, multi-junction III-V nanowire on silicon solar cells, and GaAsP/GaP nanowire white light LEDs.

Researchers in the EINSL have access to the wide range of capabilities provided by the NPRL, seen in Figure 56, which include a Perkin Elmer Lamda 900 UV-Vis-NIR optical spectrometer and a metal organic vapor phase epitaxy (MOVPE). NPRL also has multiple advanced microscopic imaging systems, including a Nikon Eclipse Digital Nomarski microscope, Hitachi S-900 High Resolution Near Field FE-SEM, and Zeiss Digital Microscopic Imaging System.

Figure 56. (left) PhD student Mohad Baboli loads a sample in the AIXTRON 3×2 Close Coupled Showerhead metal-organic chemical vapor deposition reactor, part of the MOVPE. (right) PhD student Alireza Abrand is processing samples in the fume hood.

Quantum Imaging and Information Lab

In the new Quantum Imaging and Information laboratory, Assistant Professor Gregory Howland studies how to create, manipulate, and detect quantum mechanical phenomena in the spatial degrees-of-freedom of quantum light. These “Quantum Images” encode large amounts of quantum information of single or entangled photons and serve as a platform for quantum sensing, quantum communication, and quantum computing. Specific research topics range from the applied – such as extreme low-light imaging – to the fundamental – such as quantifying large dimensional quantum entanglement. The 700 square foot laboratory will provide optical benches, laser sources, and single-photon detectors quantum-optical experiments using bulk, fiber, and integrated optics.

Suborbital Astrophysics Lab

The Suborbital Astrophysics Laboratory provides RIT with capabilities to design, integrate, and calibrate sounding rocket payloads for astrophysical science. It includes clean facilities to allow disassembly and assembly of rocket instruments, optical and electronic development and validation instruments, and cryogenic and vacuum capabilities. In this lab, Dr. Zemcov and his team are readying the CSTARS and CIBER-2 payloads for flight from White Sands Missile Range, NM (Figure 57).

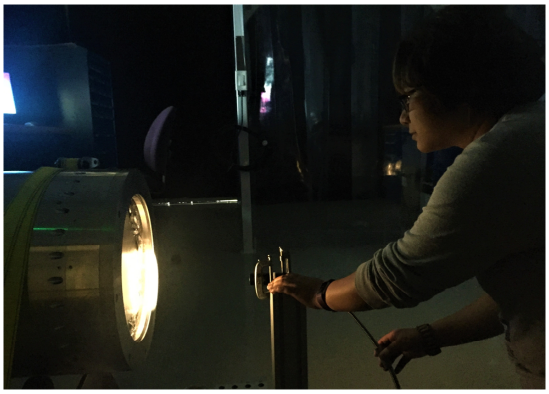
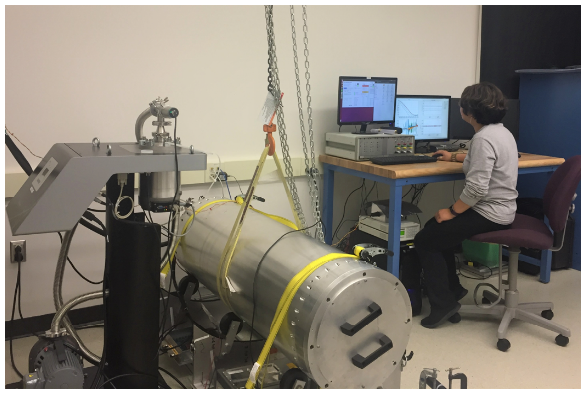



Figure 57. (left) In the picture above, Chi Nguyen measures light levels while characterizing the CIBER-2 payload. (right) Nguyen monitors the temperature for CIBER-2 during an experiment in the Suborbital Astrophysics Lab.

Semiconductor & Microsystems Fabrication Lab (SMFL)

CfD uses the SMFL, a 10,000 square foot cleanroom space in class 1000, 100, and 10. Using the SMFL’s resources, the Center can fabricate detectors with custom process flows and multiple process variations.

The Center’s flow bench and probe stations offer wafer-level testing, even during the fabrication process, allowing mid-process design changes (Figure 58). The probe station accommodates electrical and circuit analysis of both wafers and packaged parts, including low current and radio frequency (RF) probing.

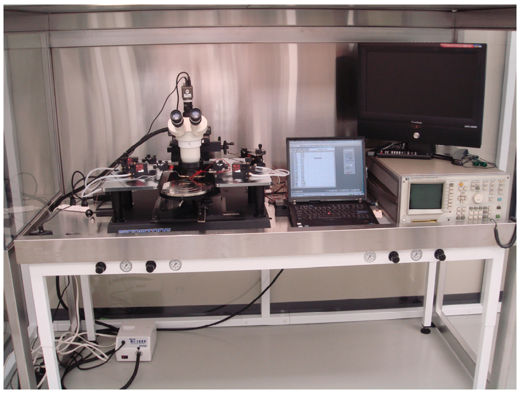


Figure 58. Shown above is the flow-bench lab probe station CfD researchers use to test device wafers.

The Amray 1830 Scanning Electron Microscope (SEM; see Figure 59), in the SMFL is used for high-magnification imaging of devices, and the WYKO white light interferometer is used for surface topography measurements. The SMFL also has other in-line fabrication metrology capabilities, including material layer thickness, refractive index, and wafer stress characterization tools.

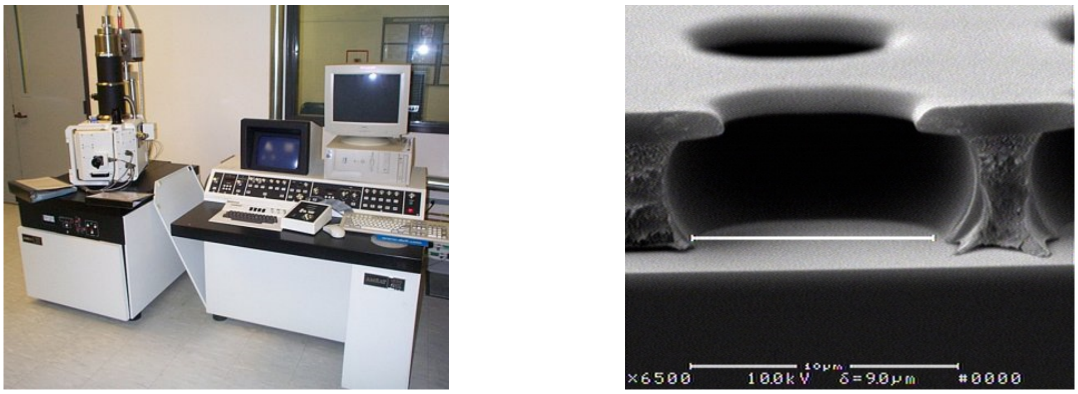


Figure 59. (left) CfD researchers use the Amray 1830 Scanning Electron Microscope to image devices. (right) The SEM image shows a sample prepared for indium bump deposition.

Figure 60 shows a customized setup consisting of two voltage power supplies, an oscilloscope, an LCD screen for viewing devices through the microscope probe station, and a custom circuit board for specific device diagnostics. The dedicated lab computer also runs a specially designed data acquisition program to collect and analyze data from prototype devices.

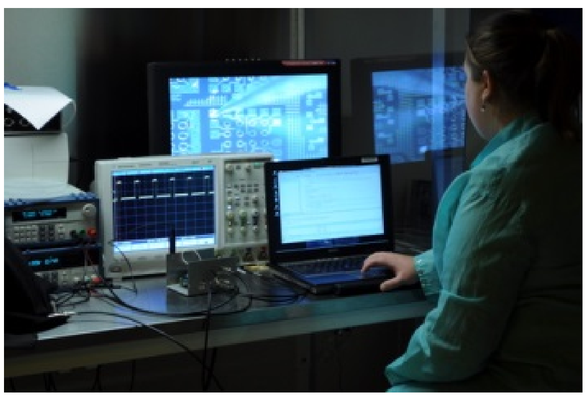


Figure 60. Former PhD student Kimberly Kolb conducts electrical experiments on one of the devices being characterized in the CfD.

The covered probe station ensures that no stray light enters the testing environment. These conditions provide the basis for valuable testing and data analysis. In the figure, the probe tip is in contact with a single test device via a metal pad with dimensions of only 70 µm by 70 µm (an area of 0.005 mm^2), seen in Figure 61.

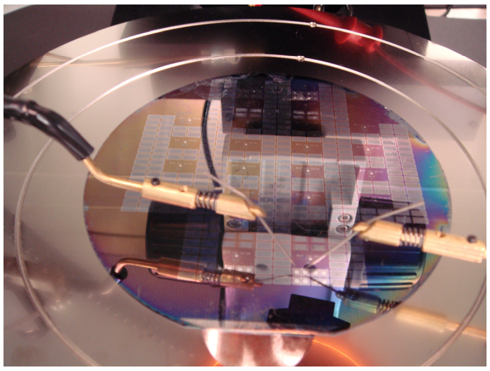


Figure 61. The image shows wafer testing using the probe station.

In addition to fabrication and testing capabilities, the CfD has access to sophisticated simulation software to predict the performance of devices, from fabrication processes to performance of a completed device. Silvaco, Athena, and Atlas are powerful software engines that simulate the effects of processing on device substrates and the electrical characteristics of a fabricated device. Athena simulations can describe all of the processes available in the SMFL, building a physics-based model in 3D space of a device from initial substrate to completed device.

Additional Labs

The CfD uses many other RIT facilities, including the Brinkman Lab, a state-of-the-art facility for precision machining, and the Center for Electronics Manufacturing and Assembly (CEMA), a facility for electronics packaging (Figure 62).

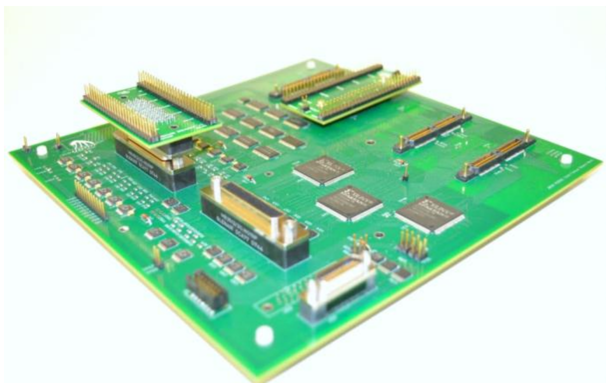


Figure 62. This image shows a cryogenic multi-layer circuit board designed in the CfD and populated in CEMA. All of the components on this board work at temperatures as low as 40 K, nanoTorr pressure levels, and in the presence of high energy particle radiation.