Engineering Research Center on Mid-InfraRed Technologies for Health and the Environment (MIRTHE)

Princeton University (lead institution)

Sensing the world around us with ubiquitous and affordable technologies

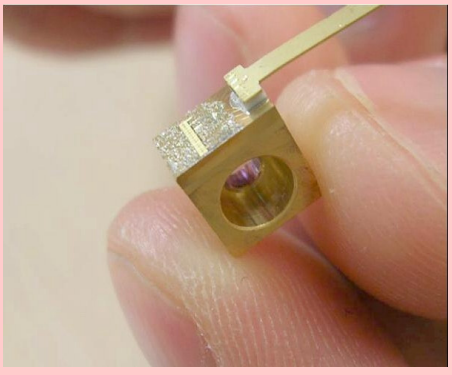
A National Science Foundation Engineering Research Center since 2006

Partner Institutions:

- ***City College of New York***
- ***The Johns Hopkins University***
- ***Texas A&M University***
- ***University of Maryland Baltimore County***
- ***Rice University***

The Engineering Research Center on Mid-InfraRed Technologies for Health and the Environment (MIRTHE) develops knowledge, technologies, and engineered systems based on mid-infrared (mid-IR) trace-gas spectroscopy that will provide unprecedented optical and chemical sensing capabilities for environmental monitoring, homeland security and medical diagnostics. MIRTHE advances mid-IR Quantum Cascade lasers, detectors, and ultrasensitive sensor systems for point and remote sensing to a maturity level that will support ubiquitous and affordable technologies while demonstrating specific applications through testbeds in environmental sensing, security, and medical screening. These technologies will promote better standards of living, improve understanding of human physiology and the environment, and enhance medical capabilities in the treatment of serious diseases. In the process, MIRTHE will transform society by opening up new avenues to a cleaner, safer environment and improved health care, while creating new product lines for the semiconductor, test & measurement, and chemical, petrochemical, and medical equipment industries.

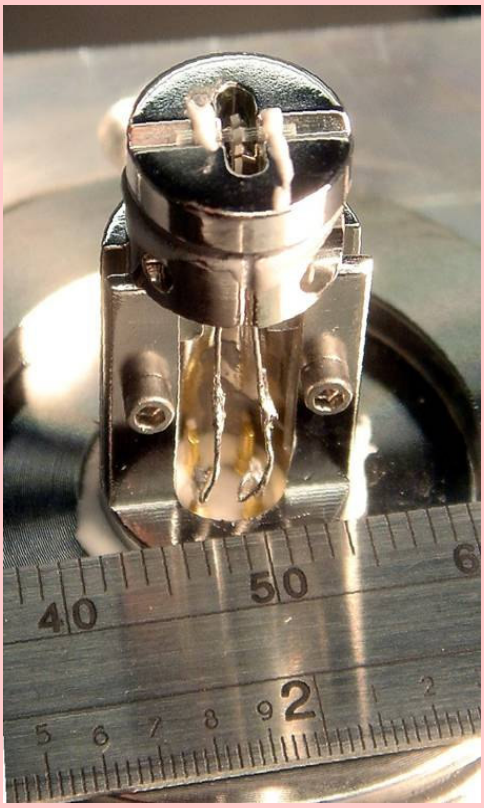
MIRTHE provides its students with a broadly interdisciplinary education in fields essential for the future economic health of our nation, such as materials and device science, nanotechnology, fundamentals of sensing, optoelectronic systems design and manufacturing, environmental chemistry, climate research, medical diagnostics, homeland security and technology policy. An outreach strategy designed for maximal impact develops education modules, exhibits, and web-based learning tools to disseminate the newfound knowledge to the engineering community and the public at large. MIRTHE's diversity strategy involves center faculty and dedicated staff engaged in mentoring and early career training of women and underrepresented and disabled faculty, staff, and students. MIRTHE's outreach and diversity programs are closely coupled with the Center's research thrusts, enabling vertically integrated teams that are diverse in gender, race, and ethnicity. By these means, MIRTHE educates and delivers a new and diverse generation of engineering professionals for an internationally competitive workforce.



Quantum Cascade laser

Research

The technological foundation of MIRTHE's engineered systems is mid-IR laser absorption spectroscopy. Chemicals that are vapors under normal conditions typically have their strongest and uniquely identifying "fingerprint" absorption lines in this wavelength range. Matching mid-IR laser sources and refined detection techniques enable trace gas sensing systems with excellent specificity, with sensitivities at and below the parts-per-billion level, and with fast and real-time response. Building upon semiconductor laser technology and microelectronics systems integration, MIRTHE develops systems with inherent potential for compactness, mass market manufacturing, and low cost.

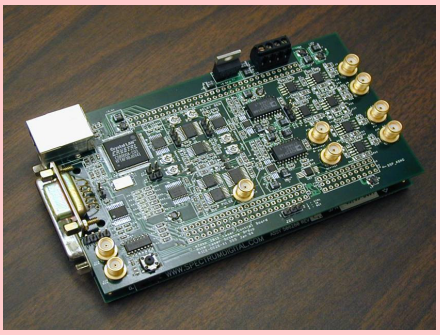


Quartz resonator photoacoustic sensing cell

MIRTHE's research projects are organized into three levels: foundational level (components and hardware), systems integration (systems and software), and applications and testbeds.

The "Foundations" level encompasses in three thrusts (1) the research and development of mid-IR semiconductor light sources, especially Quantum Cascade lasers, detectors, and the materials research necessary to facilitate both.

The central level, “Sensor Systems,” assembles the devices developed by this foundational work into systems, together with systems-level modeling, optical and acoustic cavities, and refined signal processing techniques. Three different sensing techniques are employed: photoacoustic sensing—in particular Quartz-Enhanced Photoacoustic Spectroscopy, which, with its miniature sensing cells, holds great promise for ultra-compact systems; cavity enhanced sensing; and LIDAR (light detection and ranging). This systems-level research also refines and specifies the components requirements and enables new sensing applications.



Mid-IR spectrometer electronics

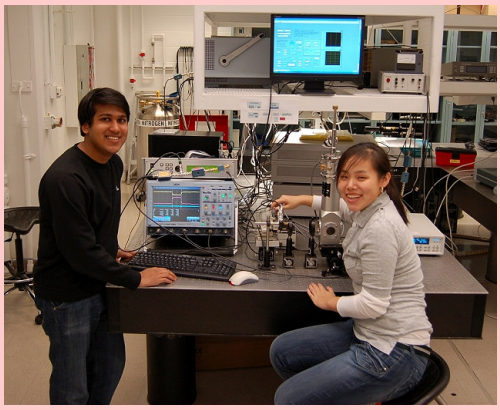
The applications level, “Sensor Applications and Testbeds,” employs specific sensors to show proof-of-principle of the sensors in real-world settings, all the while feeding performance data and requirements back into the development levels. Key applications in the environment are the detection and quantification of trace gases involved in the carbon cycle, and urban air quality monitoring—especially detection of precursors for ground-level ozone formation or of aerosols. Applications in homeland security include sensors for toxic chemicals. The targeted applications in health-care are centered around breath analysis of indicators for kidney and liver disease and oxidative stress, such as inflammation or asthma.

Education

With faculty and industry participation spread across a wide spectrum of disciplines, MIRTHE provides unprecedented opportunities to build an intellectually fascinating learning environment that is rich in real-world challenges and complex systems solutions, while fostering a student body that is diverse in gender, race, and ethnicity. MIRTHE’s education and outreach programs are designed to reach students, teachers, and practitioners across a broad range of interests as well as the public at large. MIRTHE is an engine of teaching and learning, nurturing and graduating a large number of highly trained, diverse young professionals in the fields of environmental monitoring, homeland security, and health diagnostics—all areas of significant national interest—putting in place a pipeline for workforce development in mid-IR technologies that will remain beyond the life cycle of the Center.

MIRTHE employs dedicated staff who, in close collaboration with center faculty and students, develop, implement, and monitor the education and diversity outreach programs at all educational and professional levels: K-12, undergraduate, graduate, and the public. MIRTHE embodies a process that captures student interest at all levels, integrates them into the MIRTHE research community, develops their talents and careers, and promotes their transition into the workforce. The Center’s educational and outreach programs can be divided into two broad categories:

- “MIRTHE Academy”—Year-round, multi-year core programs that primarily serve the students involved in conducting research and taking courses with MIRTHE faculty and industrial outreach partners, and that are aimed at long-term career and workforce development. Programs include strategic partnerships with Louis B. Stokes Alliances for Minority Participation (LSAMP) and Alliances for Graduate Education and the Professoriate (AGEP) institutions, new course and curriculum development, workshops, active student exchange among partner organizations and internationally, involvement with industry, and strategic junior faculty appointments.
- Educational Outreach and Informal Education—Outreach projects are geared to reach a much broader audience with maximum impact, including learning and information modules for K-12, support of science fairs, research experience for high school students, summer Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET) programs, and informal education programs. These programs also act as “feeders” for MIRTHE’s diverse core student body.



Undergraduate students perform cutting-edge research in summer programs and year-round.

Industrial Collaboration and Technology Transfer

MIRTHE conducts an active industrial outreach program based on several basic principles and major goals. MIRTHE aims to develop an affordable, market-ready sensing technology that results in profitable product lines and new revenue streams for important industry sectors. For this goal to be reached, industry expectations, manufacturing constraints, and market realities are continually communicated to center faculty, staff, and students by industrial partners. Likewise, practitioners in industry and government are kept up-to-date on the latest technology breakthroughs generated by the partner universities and beyond. MIRTHE facilitates this essential exchange of ideas and information through structured means such as websites, email alerts, quarterly meetings, workshops, and the generation of a technology roadmap.

In addition to formal means of information exchange, MIRTHE provides opportunities for frequent contact among individual researchers, teams, and managers from industry and the researchers, students, staff, and faculty in academia, both individually and in teams. MIRTHE facilitates this interpersonal exchange in part through industry researchers working at MIRTHE’s facilities and through students on internships with industrial and/or other practitioners. In addition, topical workshops and “piggyback” meetings during annual meetings of professional societies or other large conventions provide recurring opportunities for center personnel to meet and engage with those outside of the immediate consortium.

MIRTHE’s industrial outreach program is placed within a formal, multi-tiered partnership framework that is highly flexible in design to reflect the broad spectrum of industry sectors in MIRTHE, which encompass the semiconductor, test & measurement, and chemical, petrochemical, and medical equipment manufacturing industries, as well as government labs. The flexible framework also reflects the varied nature of participating companies, which range from small start-up companies to large multinational firms.

Finally, MIRTHE assists in forging early connections between potential employers and the large, superbly educated and diverse workforce graduating from MIRTHE’s institutions. Student connections with industry take the form of student summer internships at industrial partners, daily interactions between students and industrial researchers working at MIRTHE facilities, and informal interactions at workshops, lectures, and technical conferences. Industry in turn benefits from the creation of a motivated and highly educated work force to whom technology transfer will come naturally, as the students will have worked in this exciting and important field throughout their undergraduate and/or graduate careers.

Facilities

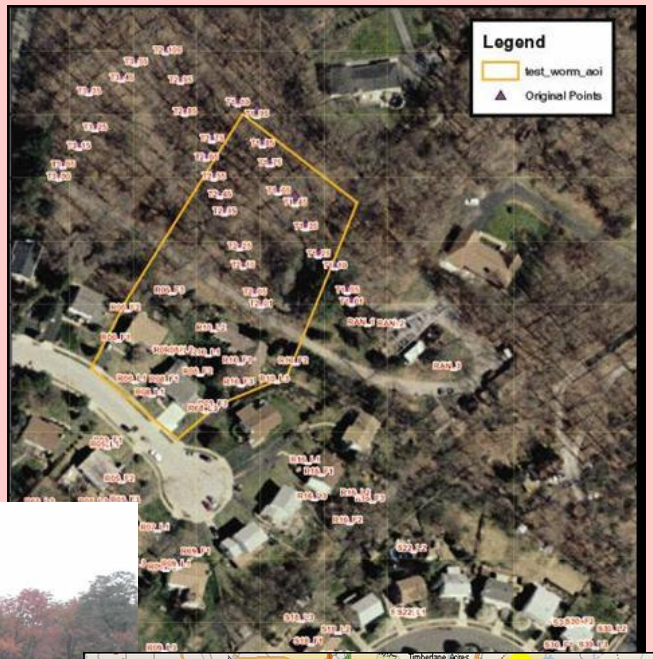
MIRTHE occupies about 5,000 sq ft of laboratory space for growth, characterization, packaging, optical testing, and systems integration. Additional space is provided for a central administrative office for the MIRTHE director and the center education and industrial outreach staff. Office and laboratory space is also available for frequent external visitors.

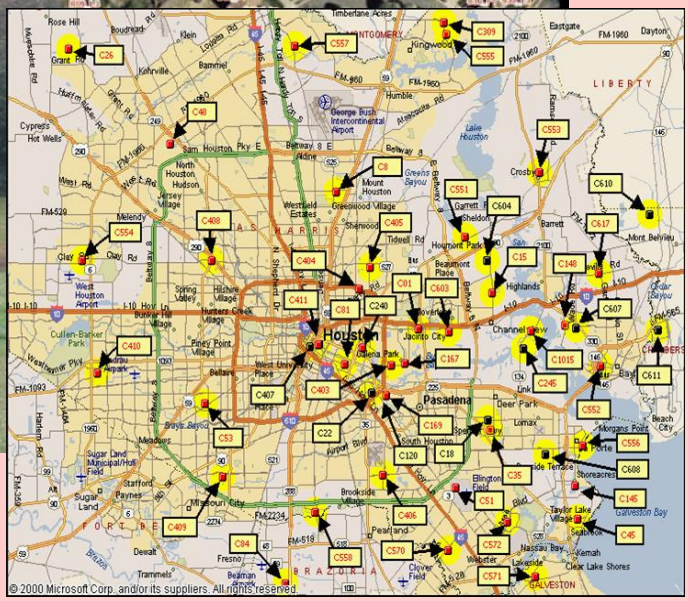
MIRTHE also benefits from major shared facilities ranging from materials characterization to device fabrication and environmental field-testing stations at Princeton and its core and outreach partners. Individual faculty labs and access to clinical research through partnering medical faculty complement the facilities.

Center Configuration, Leadership, Team Structure

MIRTHE is a multi-institutional center with partners Princeton University (lead organization), City College of New York, Johns Hopkins University, Rice University, Texas A&M University, and the University of Maryland Baltimore County. Interdisciplinary teams at each partner institution contribute to executing MIRTHE’s

vision and goals; and MIRTHE projects typically involve collaboration among at least three partner institutions. MIRTHE's leadership team consists of a Center Director and two Deputy Directors, who also serve as thrust leaders, as well as two additional thrust leaders. Dedicated staff for center management, education, and industrial and educational outreach complete the leadership team. MIRTHE has an active student leadership council, as well as three (academic, industrial, and scientific) advisory boards.





Urban and suburban environments employ networks of air quality sensing stations.

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