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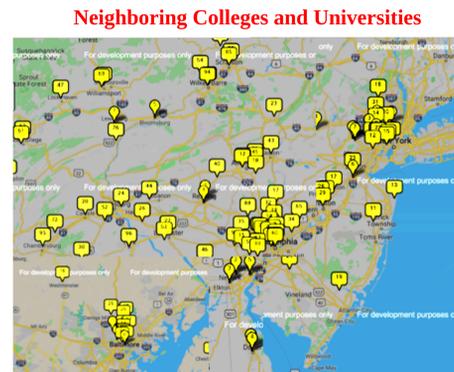


Who We Are

- Philosophy: We are a **'maker space'** for nanotechnologists that enables the exploitation of fundamental advances in nanoscience to realize nanotech materials, devices and systems
- We are a node of the NNCI network, offering lab access and assistance to external academic, industry researchers, and innovators
- MANTH is located in the Singh Center for Nanotechnology at the University of Pennsylvania.
- We are in the heart of the Mid-Atlantic region, home to **dozens of research universities** and government labs, large pharma, materials manufacturers, and biotech startups
- We consist of 3 core facilities and a partner:
 - Quattrone Nanofabrication Facility** (all aspects of nanofabrication) 10,000 sq. ft., ISO 5/6 nanofabrication cleanroom
 - Nanoscale Characterization Facility** (characterization through electron and ion beams) TEM, SEM, FIB
 - Scanning and Local Probe Facility** SPM, AFM, Raman/NSOM, TIRF/AFM probe techniques
 - Our partner, the **Community College of Philadelphia**, who we work with to develop educational programs for future "nano-aware" technicians
- New Equipment:
 - Rapid Thermal Annealer for high temperature processing
 - Vapor priming oven for lithography
 - Upgrades of the control hardware for critical tools in etch, lithography, and packaging.
 - New MRI:** "Acquisition of an Electron-Beam Lithography Tool for Research, Education and Training" (2117775) – will be used to purchase a state-of-the-art electron beam lithography tool for nanofabrication research
- New Staff:
 - Dr. Stephan Steimle, Krios Director
 - Dr. David Barth, Sr. Manager - Lithography & Advanced



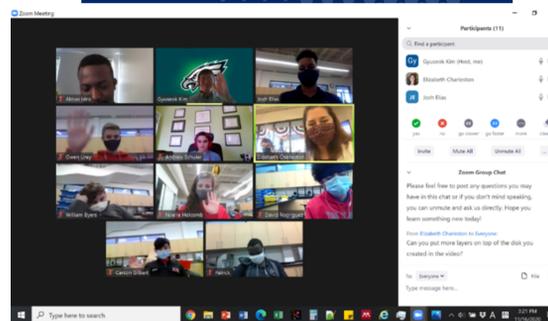
Singh Center for Nanotechnology



Neighboring Colleges and Universities

Education and Outreach

NSF INCLUDES



2021 NanoDay@ Penn via Zoom



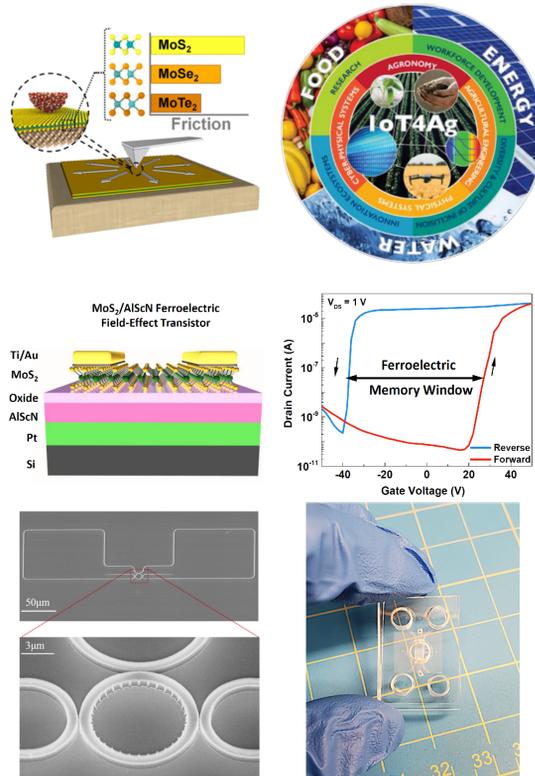
CCP Students working in the MANTH Cleanroom in summer 2021

- Each year, Penn research labs present aspects of their research to visiting high school students at MANTH on **Nanoday@Penn**. This year, because of the pandemic, six groups developed and led several online presentations instead for over 100 students from local schools.
 - MANTH pivoted to remote live-streamed presentations that were created and delivered by volunteers in five Penn labs, plus by a group from MANTH's QNF Graduate Student Fellow Program, for local classrooms grade 8 – 12.
 - 17 presentations were delivered. Some students joined from in-person classrooms with their teachers while other classes' students joined from their own homes.
 - For the participants, of the 10 teachers who responded to a follow-up survey, 9 would recommend this activity to other teachers. 99 (85%) students of the 116 responders to a post-activity survey question about whether they would recommend their session to another student responded "yes".
- Penn and the Community College of Philadelphia have teamed up in order to increase **nanotechnology related career opportunities** for community college students
 - Three nano-related courses have been developed at CCP, including "Introduction to Nanotechnology" that was held live (again) in summer 2021 and included visits to the MANTH fabrication cleanroom for hands-on processing experiences for the students.
 - CCP Nano Student Internship Program will commence in Summer of 2022.

Research and Impact

Understanding the Rules of Life
Quantum Leap
Harnessing the Data Revolution
Human Technology Frontier

- In a study published in the journal ACS Nano, Penn and UC Merced researchers, using the MANTH **scanning probe facility**, found that the presence of larger atoms within the lattice of a 2D material unexpectedly decreased the friction encountered by the tip of an atomic force microscope probe. Understanding the interplay between the sizes of individual atoms will be critical in tailoring new 2D materials for low friction applications.
- Researchers at Penn, Purdue, the University of California Merced, and the University of Florida have been recently awarded an **NSF ERC** grant to pursue the convergence of the Internet-of-Things and agriculture, or **IoT4Ag**. Nano-scale IoT will play critical roles in the main thrusts of the center.
- Penn researchers, funded by DARPA and the SRC, are exploring a recently discovered ferroelectric material, Aluminum Scandium Nitride (AlScN) for **non-volatile computer memory**, which can be deposited at low temperatures with constituent elements that pose little risk to transistor performance.
- Collaborators at Penn and around the globe have for the first time, fabricated a tunable orbital angular momentum (OAM) microlaser capable of emitting vortex beams of 5 different topological charges at room temperature on an III-V semiconductor platform. These devices hold the promise of enabling high-density data transmission in classical and quantum regimes.
- A major **interdisciplinary** research and development effort is under way, motivated by the significant and evolving threat posed by chlorine. A **Lung-on-a-Chip**, fabricated at MANTH, provides an in-vitro platform that reproduces the living tissues of the human respiratory tract and their native microenvironment in order to study the inhalation toxicology of Cl₂.

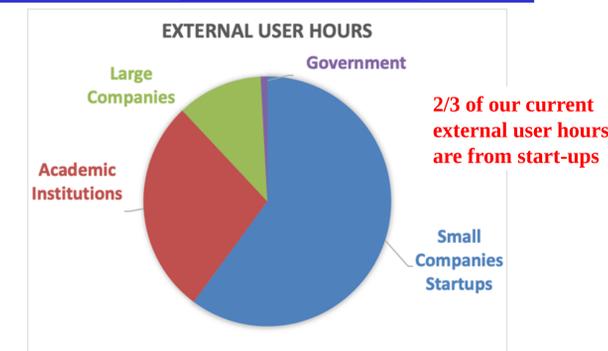


Vortex Laser and Lung on a Chip

Our Users

Understanding the Rules of Life
Quantum Leap
Convergence Research

- Researchers at MANTH **published over 300** nano-related journal papers and conference proceedings in calendar year 2020.
- In the first 5 years of the NNCI program, MANTH researchers have **published over 1600** papers, books and conference proceedings in areas that span many of the themes of the **NSF 10 Big Ideas**, including *Quantum Leap*, *Understanding the Rules of Life*, *Windows on the Universe*, *Growing Convergence Research*, and *The Future of Work*.
- The NNCI program provides MANTH with the resources to open its laboratories all researchers from academia, industry, and government. **1/3** of our users are from **external** institutions.
- When MANTH labs re-opened in June 2020, all users, including external users were invited back. Small companies and start-ups led the way, accounting for almost 2/3 of the external tool use hours as of September 2021.
- The MANTH **Innovation Seed Grant Program** provides startup lab access funds to small companies in order to jump-start innovation in the Philadelphia area. A survey of seed grant companies revealed that since 2018 they were awarded over **\$13M** in SBIRs and venture capital.
- Seed Grant recipients apply nanotechnology to fields as diverse as medicine, the environment, and energy.



Company	2018	2019	2020	2021	Grand Total
AAPlasma			149,949		149,949
Avisi		225,000	1,988,000		2,213,000
Elektrofi	750,000				750,000
Folia Water		225,000	750,000		975,000
Goepfert	459,995	755,000	350,000		1,564,995
InnaMed		1,199,435	1,400,000	1,200,000	3,799,435
Nanogress Solar		400,000	256,000		656,000
Therapeutic Articulations	222,255	750,000	260,000		1,232,255
Xallent		1,714,495			1,714,495
Grand Total	1,432,250	5,268,930	5,153,949	1,200,000	13,055,129

Innovation Seed Grant Companies were awarded \$13M since 2018