# Cornell NanoScale Science & Technology Facility

NNCI ANNUAL CONFERENCE
October 19-21, 2022

# Cornell Nanoscale Facility (CNF)

## Who are we?

Prof. Christopher Ober
PI, Director

Prof. Claudia Fischbach-Teschl,
Co-PI, Assoc. Director

Ron Olson
Director of Operations

Lynn Rathbun, Ph.D.
Laboratory Manager

- World-class open user facility for micro- and nanofabrication to assist users from across the country and around the world
- Projects range from pure university research to product development for small and large companies
- Added new capabilities to CNF in 2022 through acquisitions, updates and partnerships
- Led formation of New York State Nanofabrication Network
- CNF's 45th Anniversary - **Strategic planning workshop (2 days ago)**

Addressing NSF's 10 Big Ideas on Data Revolution, Quantum Leap, Convergence, Rules of Life, Future of Work, …

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# CNF STAFF

*Innovators and Expertise*




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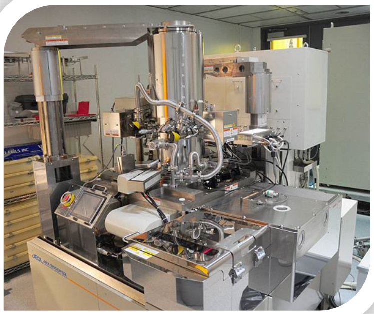
# CNF: Facilities

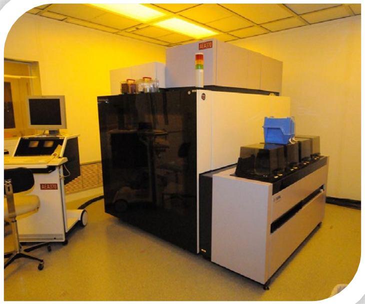
## Advanced Lithography Suite

- JEOL 9500 and JEOL 6300
- 2 UV Steppers (i-line and g-line)
- Contact Lithography (x3)
- Nanoscribe 3D printer
- ASML 300C Deep UV Stepper (248 nm)
- Mask Fabrication (x2)
- Nanoimprint
- Direct Laser Writing capability given to Heidelberg

## Broad Process Support / Test and Characterization

- 20 dry etch chambers
- Deep Silicon Etchers
- ALE, RIE and ICP RIE
- Vapor HF and XeF2
- Ion Milling
- Ashing and descum
- ALD x2, PECVD x2
- 11 CVD tubes
- 10 Atmospheric tubes
- 8 Advanced evaporation and sputtering
- AlN sputtering
- Electron Microscopy
- Optical Microscopy
- Electrical
- Optical
- Profilometry
- Microfluidic





- Packaging, Backend and Support tools
- Software and Computation
- 3D Fabrication and 3D Imaging
- Dedicated facilities for microfluidics and soft lithography
- Ability to process a very wide range of heterogeneous materials without cross contamination as well as different wafer sizes – ( pieces up to 200 mm)

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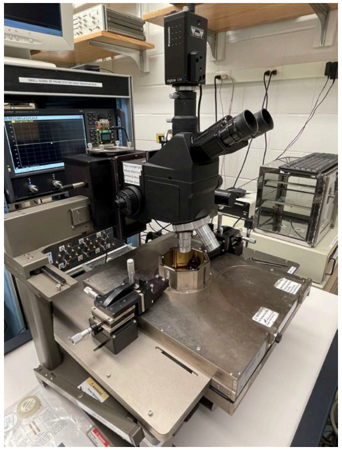
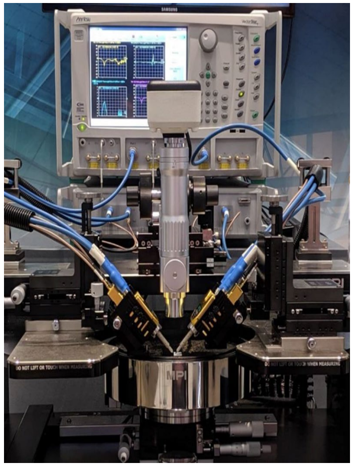
# CNF: New Equipment

- **Microwave small signal probe station and electronics**
  - A Cascade Summit 9600 probe station with 6-inch chuck
  - Agilent E8364B PNA network analyzer capable of RF measurement in 10 MHz to 50 GHz frequency range with 104 dB of dynamic range, 26 μsec/point measurement speed
- **Microwave Large Signal test system -Load-pull System**
  - A Cascade Summit 11K probe station with 8-inch chuck
  - Load-pull system is capable of large signal RF measurement up to 20 GHz and -20 dBm maximum output power
- **mm-Wave vector network analyzer and probe station**
  - MPI TS2000-IFE Series automated probe station with 1 μm precision
  - Anritsu ME7838G vector network analyzer (VNA) capable of single-sweep measurement from 10 MHz to 220 GHz with dynamic range of 120 dB at 10 MHz, 112 dB at 67 GHz, 108 dB at 110 GHz, and 100 dB at 145 GHz
- **DC probe station and electronics**
  - A Cascade Summit 12K probe station with 8-inch chuck
  - Four high-resolution source measurement units (HRSMU) with ±100 V max, one high-power source measurement units (HPSMU) with ±200 V max



Microwave Small Signal Probe station

Microwave Large Signal



Mm-wave vector network analyzer and probe station

DC probe station

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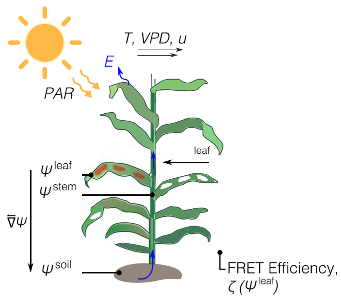
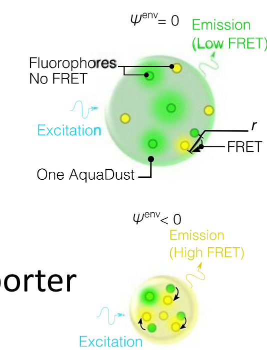
# A minimally disruptive method for measuring water potential in plants using hydrogel nanoreporters

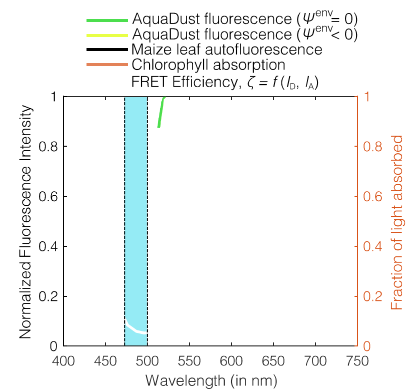
## User Research

FloraPulse




AquaDust as an *in situ* reporter of water potential (ψ)




In PNAS, Gore, Stroock and colleagues used the Cornell Nanoscale Facility to produce in part nanoscale water potential sensors. Leaf water potential is a critical indicator of plant water status, integrating soil moisture status, plant physiology, and environ- mental conditions. There are few tools for measuring plant water status (water potential) in situ, presenting a critical barrier for developing appropriate phenotyping (measurement) methods for crop development and modeling efforts aimed at understand- ing water transport in plants. Here, they present the development of an in situ, minimally disruptive hydrogel nanoreporter (AquaDust) for measuring leaf water potential. The gel matrix responds to changes in water potential in its local environment by swelling; the distance between covalently linked dyes changes with the reconfiguration of the polymer, leading to changes in the emission spectrum via Förster Resonance Energy Transfer (FRET). Upon infiltration into leaves, the nanoparticles localize within the apoplastic space in the mesophyll; they do not enter the cytoplasm or the xylem. They conclude that AquaDust offers potential opportunities for high-throughput field measurements and spatially resolved studies of water relations within plant tissues.

This work was performed, in part, at Cornell NanoScale Facility, an NNCI member supported by NSF grant NNCI-2025233.

P. Jaina, W. Liub, S. Zhu, C. Yao-Yun Chang, J. Melkonian, F. E. Rockwell, D. Pauli, Y. Sun, W. R. Zipfel, N. Michele Holbrook, S. Jean Rihag, M. A. Gore and A. D. Stroock, PNAS 2021 118(23) 1-9, e2 a008276118
This work was supported by USDA National Institute of Food and Agriculture 2017-67007-25950; and AFOSR FA9550-18-1-0345.

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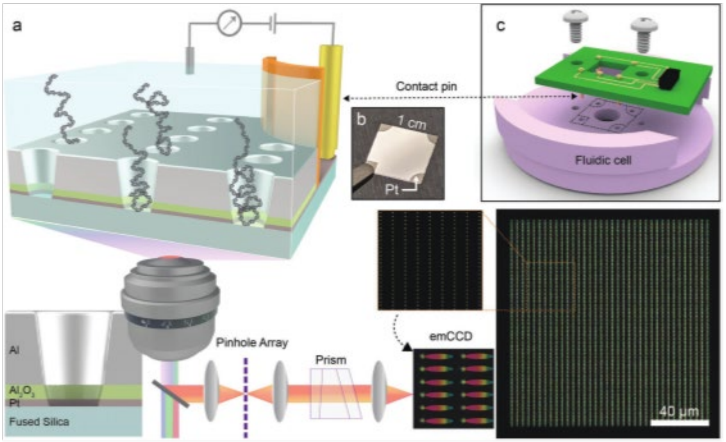
# Rapid Identification of DNA Fragments through Direct Sequencing with Electro-Optical Zero-Mode Waveguide

## User Research

In Advanced Materials , Wanunu and colleagues (Northeastern) reported on electro-optical zero-mode waveguides (eZMWs) fabricated at the Cornell NanoScale Facility. n contrast to sequence-specific techniques such as polymerase chain reaction, DNA sequencing does not require prior knowledge of the sample for surveying DNA. However, current sequencing technologies demand high inputs for suitable library preparation, which typically necessitates DNA amplification, even for single-molecule sequencing methods. Here, eZMWs are presented, which can load DNA into the confinement of zero-mode waveguides with high efficiency and negligible DNA fragment length bias. Using eZMWs, highly efficient voltage- induced loading of DNA fragments of various sizes from ultralow inputs (nanogram-to-picogram levels) is observed. Rapid DNA fragment identification is demonstrated by burst sequencing of short and long DNA molecules (260 and 20 000 bp) loaded from an equimolar picomolar-level concentration mixture in just a few minutes. The device allows further studies in which low-input DNA capture is essential, for example, in epigenetics, where native DNA is required for obtaining modified base information.




Wanunu et al., Adv. Mater. 2022, 34, 2108479

NIH/National Human Genome Research Institute HG009186 and HG011087
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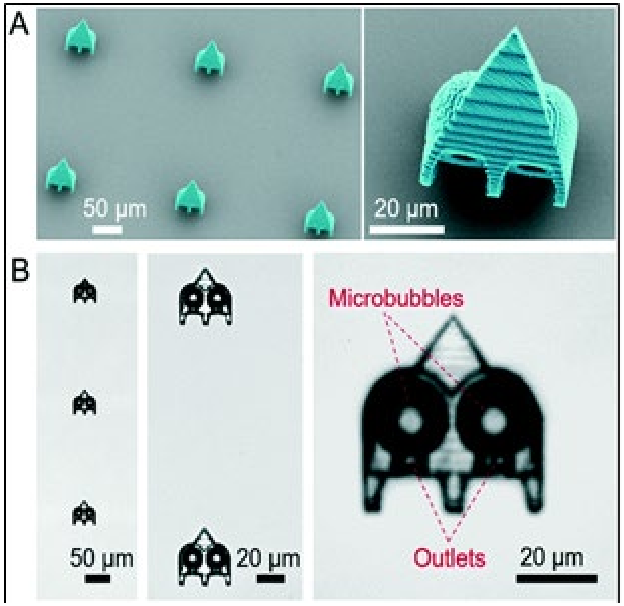
This work was performed, in part, at Cornell NanoScale Facility, an NNCI member supported by NSF grant NNCI-2025233.

# Biologically Inspired Micro-Robotic Swimmers Remotely Controlled by Ultrasound Waves

## User Research

In Lap on a Chip , Luo and Wu (Cornell) report on the fabrication of 3D micro-robotic swimmers the size of animal cells using CNF's Nanoscribe 2-photon 3D printer ( Figure 42 ). The micro- swimmers are powered by the microstreaming flows induced by the oscillating air bubbles entrapped within the micro-robotic swimmers. Previously, micro-swimmers propelled by acoustic streaming require the use of a magnetic field or an additional ultrasound transducer to steer their direction. Here, we show a two-bubble based micro-swimmer that can be propelled and steered entirely using one ultrasound transducer. The swimmer displays boundary following traits like biological swimmers known to be important for performing robust biological functions. The micro-robotic swimmer has the potential to advance the current technology in targeted drug delivery and remote microsurgery




T. Luo and M. Wu, Lab Chip, 2021, 21, 4095.

This work was performed, in part, at Cornell NanoScale Facility, an NNCI member supported by NSF grant NNCI-2025233.

This work was supported by National Cancer Institute (R01CA221346). The Nanoscribe Photonics GT printer was made possible via NSF-MRI-1919653

# CNF: Impact

NNN New York State Nanotechnology Network

## NYS Nanotechnology Network (NNN)

- 14 NYS schools & 20 companies
- NYS Nanotechnology Network Symposium (May 19, 2022)
  - "Bridging the Workforce Gap"
  - Showcase the NYS student talent pipeline
  - Focus on connecting NYS students with industry partners
  - Exchange information and sharing technology research activities

**Impact to be measured**

- How many students got interviews?
- How many students got internships/co-ops ?
- How many students got jobs?
- How many students made networking connections?

**-Through follow-up survey**

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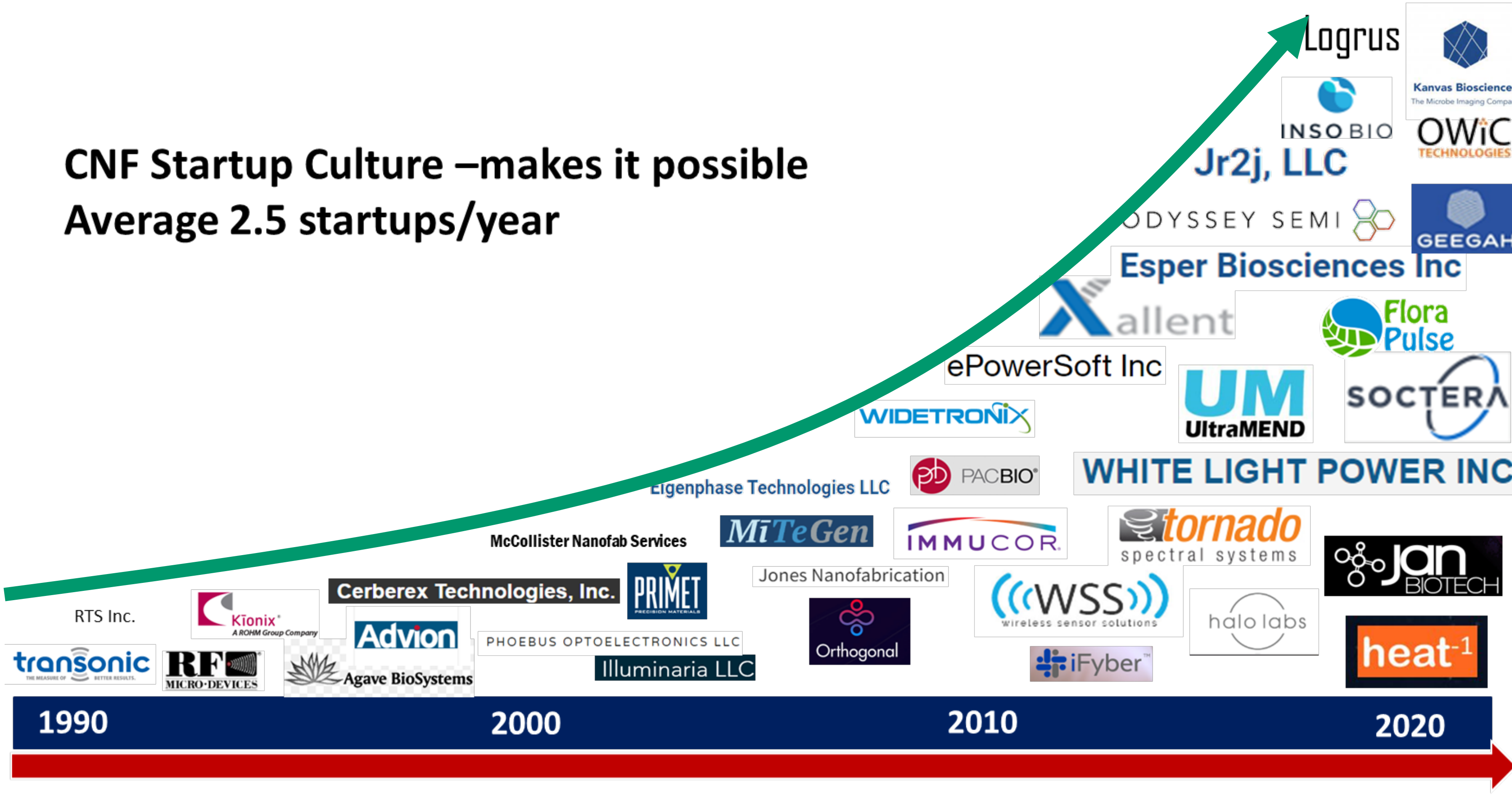
# CNF Startup Activities

**CNF Startup Culture –makes it possible**
**Average 2.5 startups/year**

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# CNF: Economic Impact

## CNF is a powerful engine of Economic Development

- **129 different companies** (34 Large and 95 Small) have used CNF for research/prototyping under NNCI
- **17 new start ups** (see logos)
- **Pacific Biosciences a** CNF startup from 2010. Has a market cap of **$1.09 Billion** as of May 2022
- Partnership with two Cornell business incubators:
  - **Praxis**: Engineering and Physical Sciences Business Incubator, co-located in Duffield Hall
  - **The McGovern Center**: Life Sciences business incubator at Cornell
  - Membership in incubator enables reduced rates
- **NILT** from Denmark set up its North American operation in Ithaca to take advantage of CNF's JEOL 9500 and ASML stepper
  - Now a major industrial user

WHITE LIGHT POWER INC

JR2J, LLC

# Measuring Economic Impact

- Revenue/funding being generated from companies
- Company capitalization value
- Leverage of academic grant support dollars.
- Cost benefit in industrial user fees
- Number of employees
- # Companies utilizing the CNF
- # Startups companies that have started at CNF
- # Companies that have utilized CNF for research and prototyping
- Hands-on training performed

# Educational Impact

- Since 1986, CNF has trained 9155 users – most are students
  - The number of undergrad, grad student, and post-doctoral users working in NNCI sites.
  - The STEM majors of students who use NNCI.
  - The number of students who are hired by the semiconductor industry.
  - The diversity of the student body and their relevant majors.
  - The diversity of the semiconductor workforce before and after creation of the CHIPS Act.
  - The effectiveness of programs built today will be determined by what the participants do in 10 years.
    - Where are participants employed?
    - Are they employed in the microelectronics industry?
    - Have they founded startups?