2017 - 2018 Annual Report

WASHINGTON
NANOFABRICATION FACILITY

Part of the National Nanotechnology Coordinated Infrastructure
at the University of Washington

LETTER FROM THE DIRECTOR

A New Era at WNF

With the completion of the second and final phases of the Washington Nanofabrication Facility renovation project in October 2017, we ushered in an exciting new era in which our growing fabrication community now has access to a cleanroom that is three times larger, 1,000 times cleaner, and operates more reliably than ever before. Admittedly, there were several setbacks along the way including construction delays and defects as well as substantial downtimes from tools that were heavily stressed during the renovation. Despite these short-term setbacks, this long-term investment in our fabrication infrastructure will ultimately benefit the University of Washington by maintaining its leadership in nanotechnology research and innovation in the region, nation and around the world. In fact, we are already seeing returns on this investment in the form of increased lab activity compared to pre-construction levels.

This past year, WNF proudly helped to recruit Professor Mo Li to UW by adding new processing capabilities, including two vapor phase etchers, which are critical to Dr. Li's research. WNF also added several new pieces of equipment including a RiteTrack resist coater/developer track system as well as two new Atomic Layer Deposition (ALD) systems. Through a Major Research Instrumentation (MRI) grant from the National Science Foundation, WNF was able to purchase a Nanoscribe nanoscale 3D printer. We enabled new device research by coupling conventional fabrication techniques with 3D printing. In the coming year, WNF hopes to continue to help attract new faculty who will be active members of the fabrication community.

Training future engineers and technicians is key to fostering regional innovation because high-tech companies need a skilled workforce in order to grow. In FY18, WNF doubled its workforce development efforts, welcoming 32 undergraduates including 22 students from the University of Washington as well as interns from local colleges, Women In Science and Engineering (WISE), and summer students from Saudi Arabia. Furthermore, WNF trained over 30 regional attendees in nanofabrication techniques with a 40-hour intensive short course that was offered in the Spring and Fall. With nearly half of the students coming from industry, it is clear that WNF is recognized as a regional resource for not only fabrication capabilities, but also for providing engineers and technicians a wide range of fabrication skills.

Looking ahead, WNF will continue to evolve and offer new capabilities, increasing its already noteworthy role in the region as a center of excellence. WNF will continue to provide important workhorse processing capabilities, while also forging new expertise in emerging capabilities and areas of specialization. Over the course of the next year, WNF will work with both industry and UW faculty and staff to establish a new piezoelectric MEMS fabrication capability. Though this effort faces a number of challenges including materials compatibility and regulations, the WNF is well-positioned and has a demonstrated track record of tackling such challenges. Establishing this capability will ensure that WNF stays relevant on the global scale as the MEMS industry starts to develop piezo-MEMS devices. Moreover, this initiative will anchor WNF's prominent role within the National Nanotechnology Coordinated Infrastructure (NNCI) as well as continue to expand WNF's global impact well beyond North America.

I would like to thank the dedicated staff, researchers, and industrial partners for making the WNF community so vibrant. We look forward to the many opportunities that lie ahead as WNF continues to evolve and grow.

Sincerely,

Michael Khbeis

Director, Washington Nanofabrication Facility
University of Washington

Facility Update

WNF is the largest, open-access, full-service, micro and nanotechnology user facility in the Pacific Northwest. With the completion of a $37.5 million renovation, WNF can now better serve the regional and global nanotechnology community.

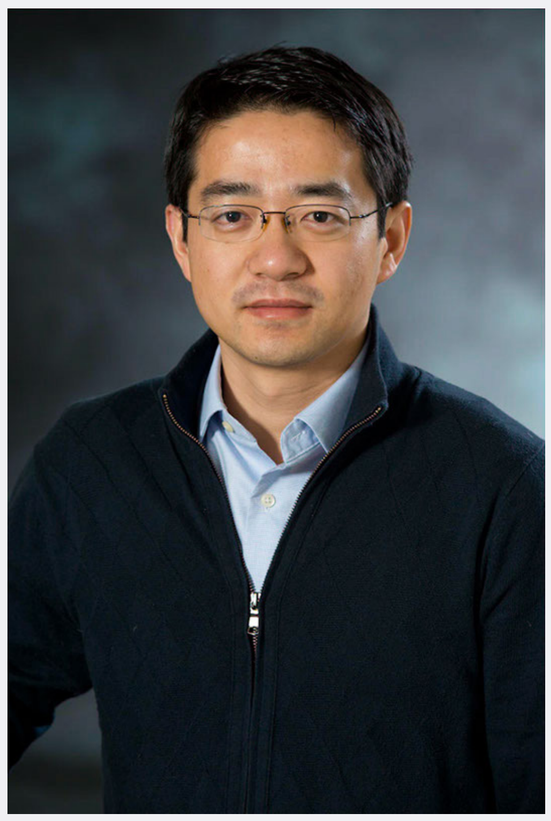
Upgrades to the core building infrastructure drastically improved the cleanliness of the cleanroom, which is reflected in its re-classification as an ISO Class 5 cleanroom. With a larger overall cleanroom space, spanning 15,000 square feet, WNF can now support more equipment and more users. In addition to being a draw for new users, the renovated cleanroom has also been useful in recruiting new faculty to UW.

Demand for space will continue as WNF acquires the capabilities and state-of-the-art equipment necessary to meet the ever-changing and expanding needs of research clients.

Renovated Cleanroom Helps Attract Distinguished Faculty

Faculty Feature

"My work cannot be done without a good fabrication facility," says Mo Li, a recently recruited University of Washington Professor and Institute of Nano Engineered-Systems affiliated faculty member. Jointly appointed to the departments of Electrical and Computer Engineering and Physics, Li's research interests span from precisely measuring fundamental physics parameters to developing new device functionalities and materials for optical and wireless communications and sensing applications. Li comes to UW from the University of Minnesota, another preeminent nanofabrication institution and NNCI site. Li is a leading researcher in the fields of integrated photonics and Micro-Electro-Mechanical Systems (MEMS), who has received numerous distinctions including a NSF CAREER Award, McKnight Land-Grant Professorship, and Air Force Office of Scientific Research Young Investigator Award. Recruiting him to UW was no small feat.



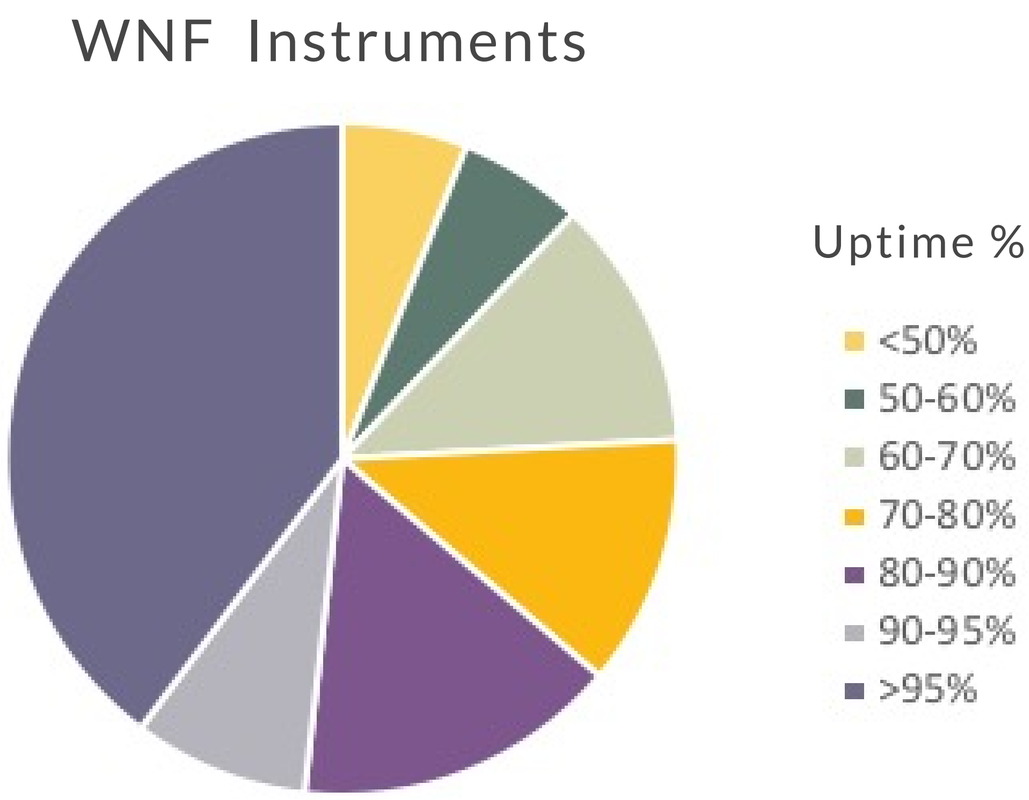
Dr. Mo Li

Li was drawn to UW because of the people, but feels he is, "coming to UW at a really good time as WNF has just completed a major renovation – upgrading both the building and the tools. It is really the tools inside the building that are doing the work. I was really excited to see that as part of the renovation they added a number of state-of-the-art tools in addition to the many tools they already had." With applications ranging from medicine to energy, specialized tools are often needed to advance nanotechnology research and development. Understandably, most facilities cannot accommodate the needs of all researchers. As part of his startup package, WNF acquired two new etchers – a dry vapor HF and xenon difluoride – to release MEMS structures from both silicon and non-standard materials. Li notes these tools are not only key to his work, but will "give his research momentum."

Instrument Uptime

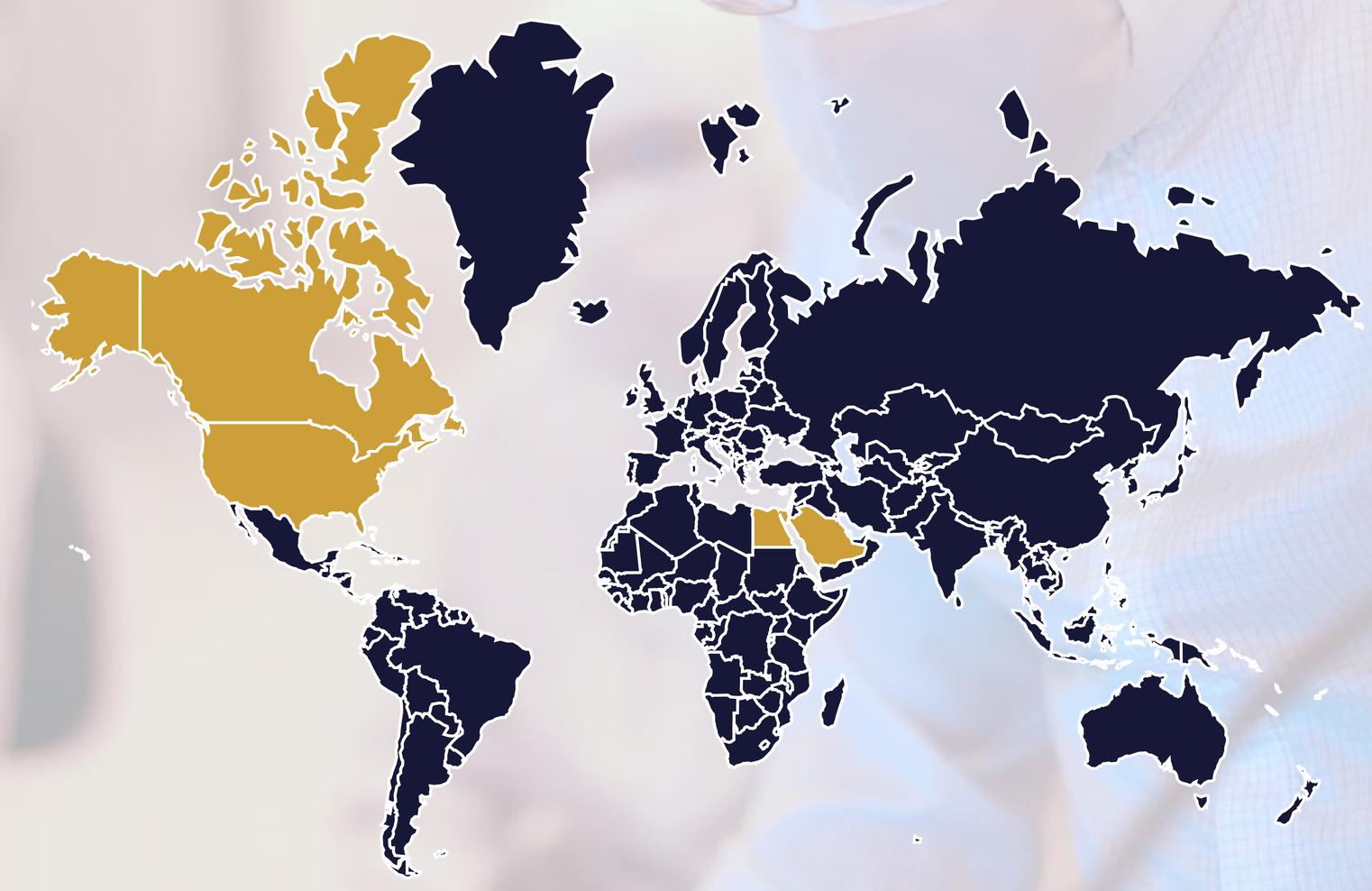
Many WNF instruments have an uptime of >95% based on a 24/7, 365 model. Unfortunately, disruptions due to construction did significantly impact the uptime metrics for a number of instruments this past year. With the conclusion of major renovation activities, instrument uptimes are expected to be considerably higher next year.

Continued investment in modernizing WNF's tools and spare parts is important and necessary to ensure users have access to well functioning instruments. For example, the Oxford DRIE (Deep Reactive Ion Etcher) had a 66% uptime in FY18 and has since been down for the past 3 months. Replacing this piece of equipment will cost roughly $850k.

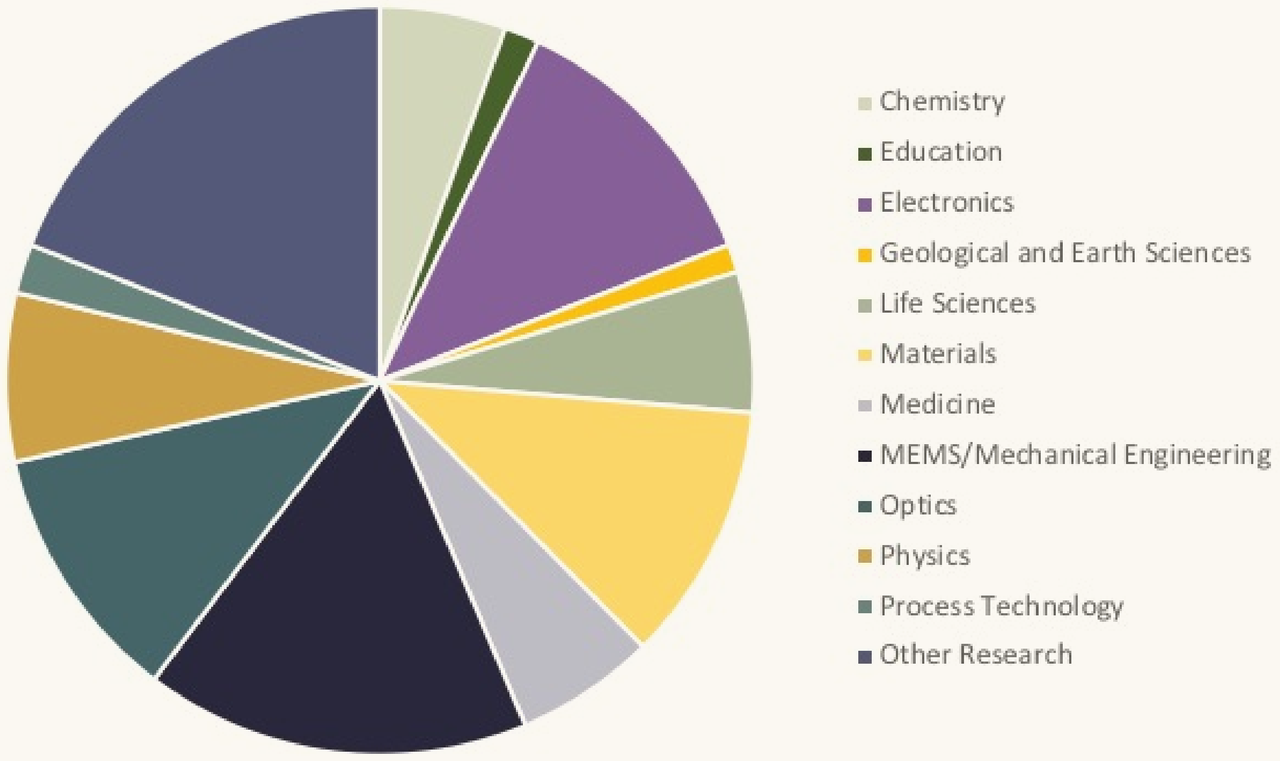


User Base

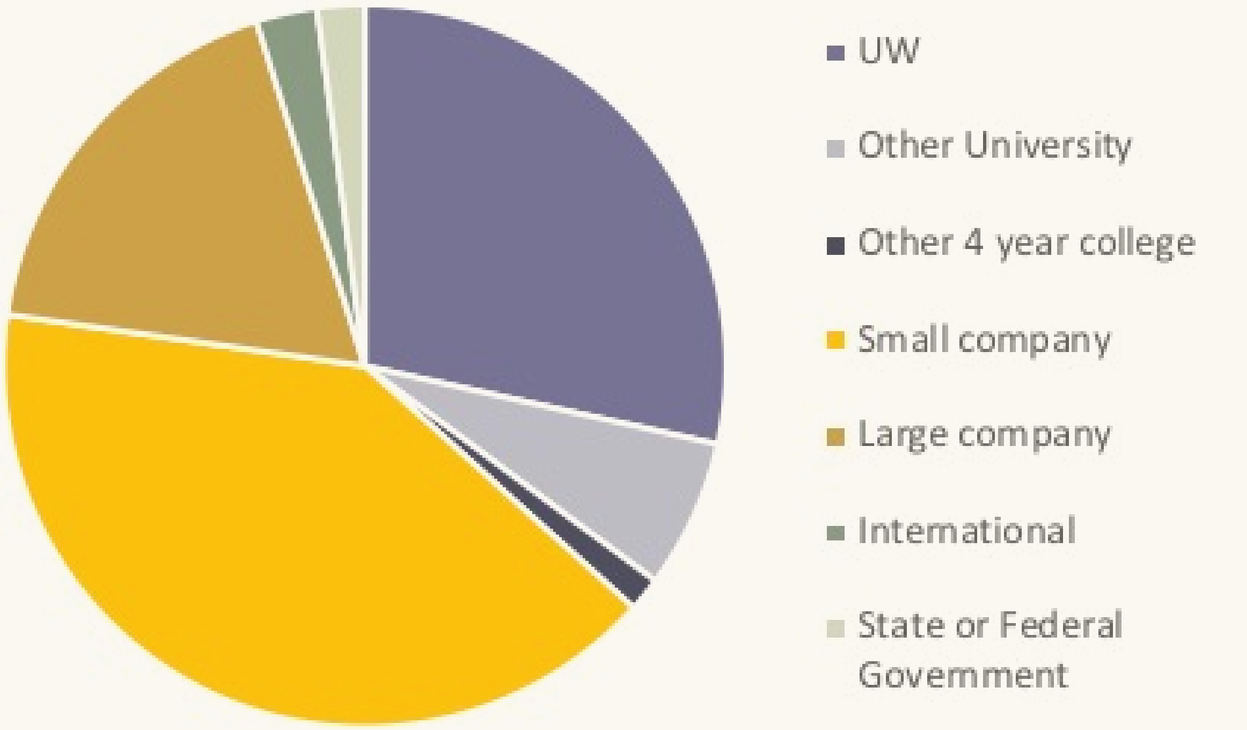
WNF supports a large and distributed user base of researchers and engineers from a variety of disciplines and sectors.



In addition to offering expertise and assistance to local cleanroom users, WNF engineers are also available to work with remote users on finite fabrication projects.



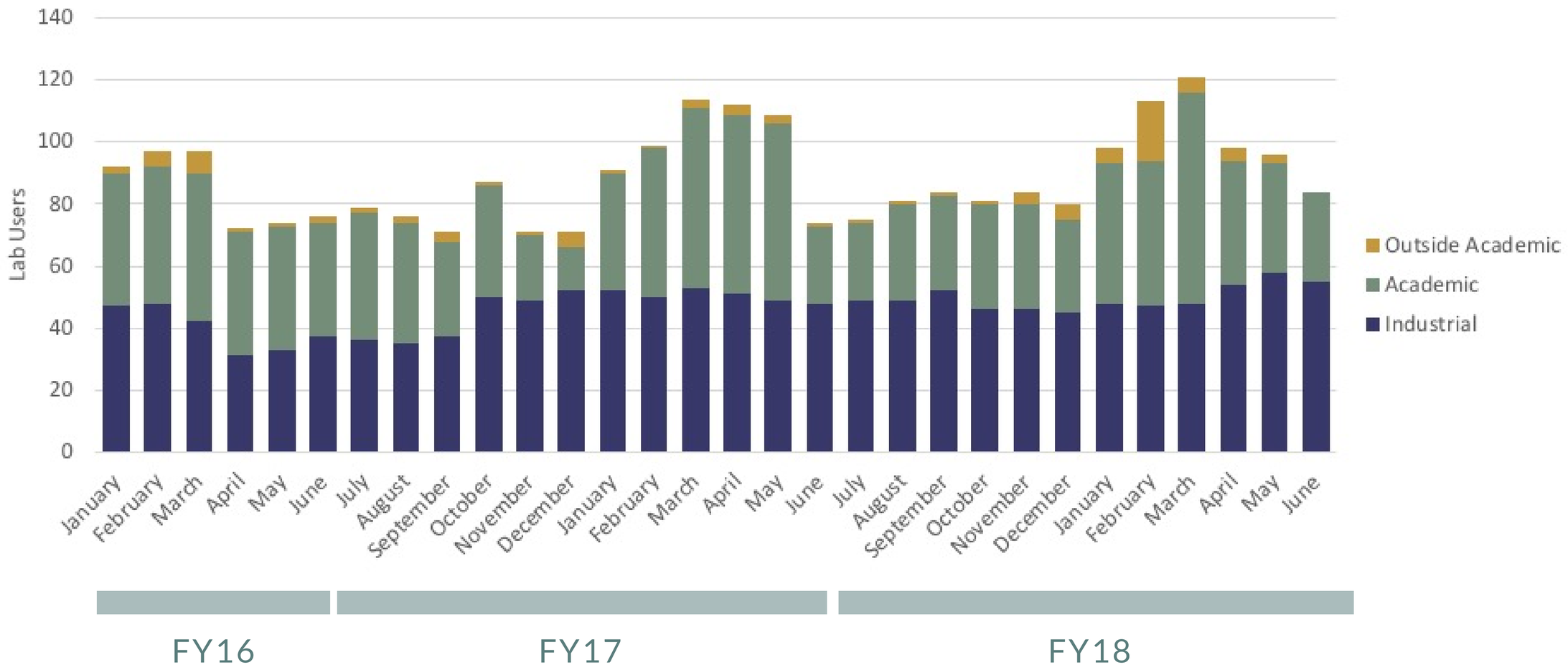
The breadth of equipment and expertise available at WNF provides extensive capabilities to researchers across many different fields including Micro-Electro-Mechanical Systems (MEMS), medicine, and electronics.



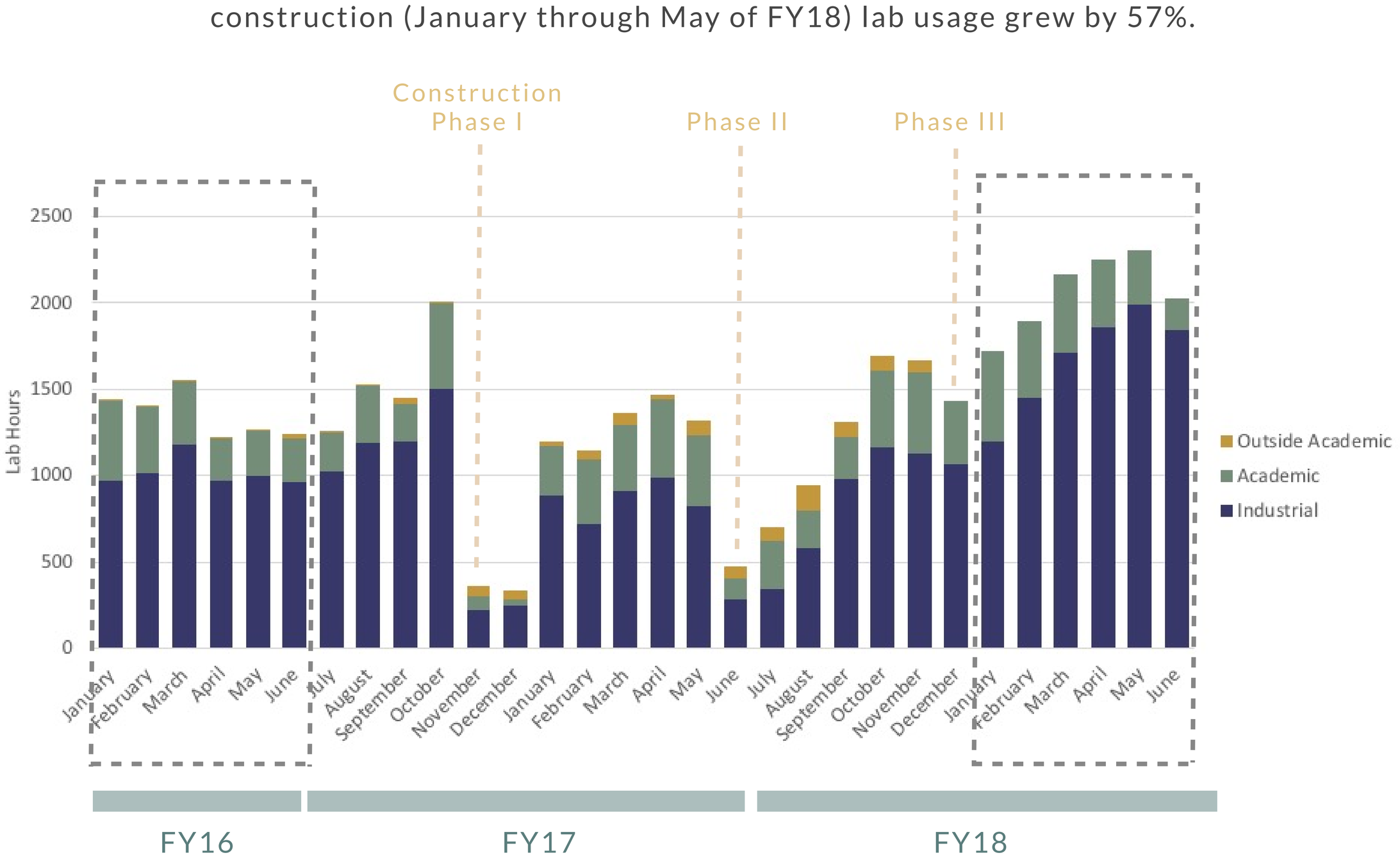
WNF's services cater to clients from academia, industry, and government.

Lab Usage

While WNF has not seen a huge uptick in lab users since construction ended in December 2017, there has been a notable increase in lab usage by current users.



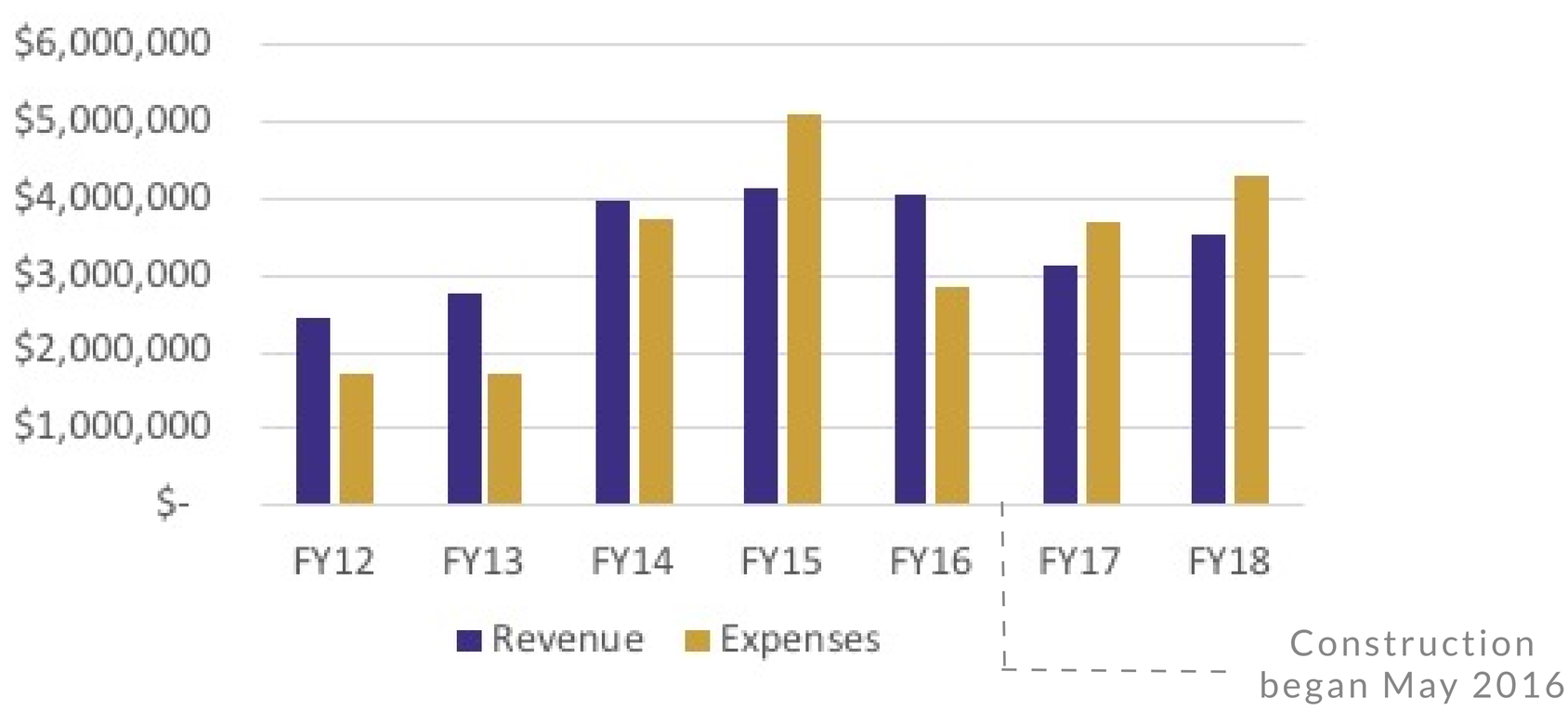
In comparison to pre-construction lab usage (January through May of FY16), post-construction (January through May of FY18) lab usage grew by 57%.



This suggests that WNF has not only recovered from the effects of construction, but is also starting to reap the benefits of a renovated cleanroom.

Operational Status

Since the College of Engineering began managing WNF operations in 2011, both revenue and expenses have increased, with revenue generally exceeding expenses. However, construction disruptions as part of the $37.5 million upgrade resulted in a budget deficit for both FY17 and FY18.



FY 2018

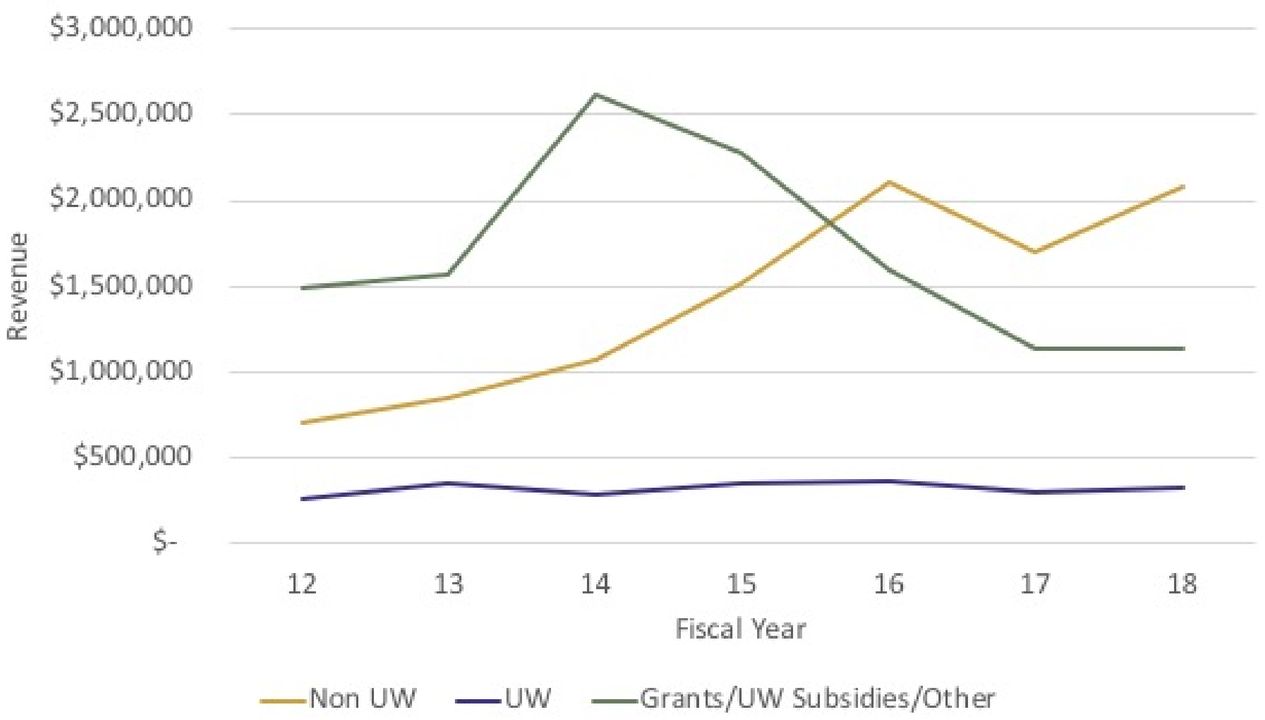
Revenue	
Designated Operation Funds	$ 395,000
Research Cost Recovery	$ 164,500
User Fees - External	$ 2,081,968
User Fees - Internal	$ 331,022
Grants	$ 578,481
Operating Subsidy	$ -
Total Revenue	$ 3,550,971
Expenses	
Total Salaries and Benefit	$ 1,542,107
Other Contractual Serv	$ 317,445
User Support	$ 32,941
Travel	$ 28,353
Supplies, service contract & repair	$ 1,348,454
Equipment	$ 708,504
Indirect Cost	$ 312,338
Institutional Overhead	$ -
Total Expenses	$ 4,290,141

Though WNF is in a deficit for FY18, it should be noted that since wrapping up major renovations in December 2017 monthly revenue has not only recovered, but has grown by 20%. These increases in revenue reflect a boost in utilization of the upgraded facility by current users.

Moreover, WNF's deficit largely comes from investments in new equipment, which amounted to over $700k in capital expenditures for FY18. These investments are critical to ensuring users have access to the technology and tools necessary to conduct cutting-edge nanofabrication research and development. Unfortunately, this specialized equipment is very expensive.

The future operating health of WNF looks promising despite necessary construction to replace improperly installed flooring. WNF will do its best to mitigate any construction disruptions so that user access to the cleanroom will be minimally affected and impacts to FY19 revenue will be limited.

Notably, while revenue from UW subsidies and grants have decreased since FY14, WNF has successfully increased revenue streams from outside the university (Non UW), largely by attracting professionals from industry to use the facility. WNF is dedicated to serving UW researchers, but revenue generated from UW users has remained relatively constant over the years. In FY19, WNF is working to raise the visibility of its services and capabilities on the UW campus in hopes of increasing the number of UW users and further fulfilling its mission to serve the UW research community.



Instrument Highlights

WNF supports clients with diverse research interests by providing access to, and maintaining, specialized fabrication tools and important "workhorse" tools that run 24/7. WNF's substantial equipment inventory and knowledgeable staff enable basic and applied research, advanced research and development, and prototype production.

2 new Picosun Atomic Layer Deposition (ALD) Reactor systems were installed in Fall 2018

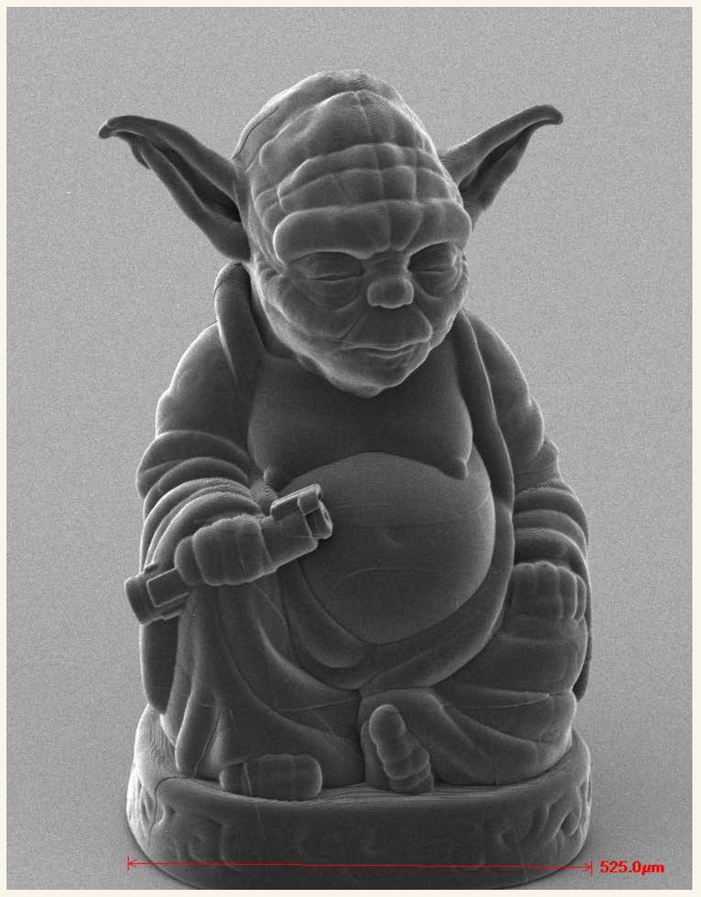
New etchers - Dry Vapor HF and Xenon Diflouride

Dry vapor HF etcher releases *silicon* MEMS structures and enables free movement. XeF2 etcher is also a dry vapor etcher used to release MEMS structures; however, unlike HF, XeF2 can accommodate a much wider variety of non-standard materials.

Nanoscribe: A Sub-Micron Resolution 3D printer

Instrument Feature

Researchers and engineers across many fields, including optics, medicine, fluidics and mechanics, are increasingly interested in creating nanoscale parts for a variety of different applications. However, conventional equipment cannot fabricate three-dimensional nanostructures with sufficiently high resolution. WNF is excited to offer users access to the Nanoscribe 3D Printer, a cutting-edge lithography system that produces unique 3D structures with 500nm resolution. This two-photon laser writer allows for additive manufacturing and maskless lithography within the same device. Its high printing resolution gives users greater design freedom when creating very small, complex parts with intricate features. Moreover, the Nanoscribe uses a simple workflow to rapidly fabricate micro-sized parts from virtual 3D models.



A nanoscale Yoda Buddha printed by students learning to use the nanoscribe

The Nanoscribe has many advantages over conventional manufacturing techniques. Current users appreciate that they can quickly change or adjust a process or structure thus avoiding long turnaround times. In addition, because users are not restricted to Nanoscribe resins, it is possible to test different materials with different properties – this is especially important for users designing parts for specialized applications. It should also be noted that though the Nanoscribe is of course known for its ability to print 3D microstructures, it can also fabricate 2D structures with high resolution.

For those interested in using the Nanoscribe, WNF engineer and staff member, Duane Irish, is available to train new Nanoscribe users and work with them to design functional processes. After just two training sessions, users can independently operate this unique tool. This new instrument is already heavily used. Its popularity stems from its next generation capabilities, as well as its ability to accommodate a wide range of projects, from biology and bioengineering to chemistry and electrochemical projects to mechanics and light interaction projects.

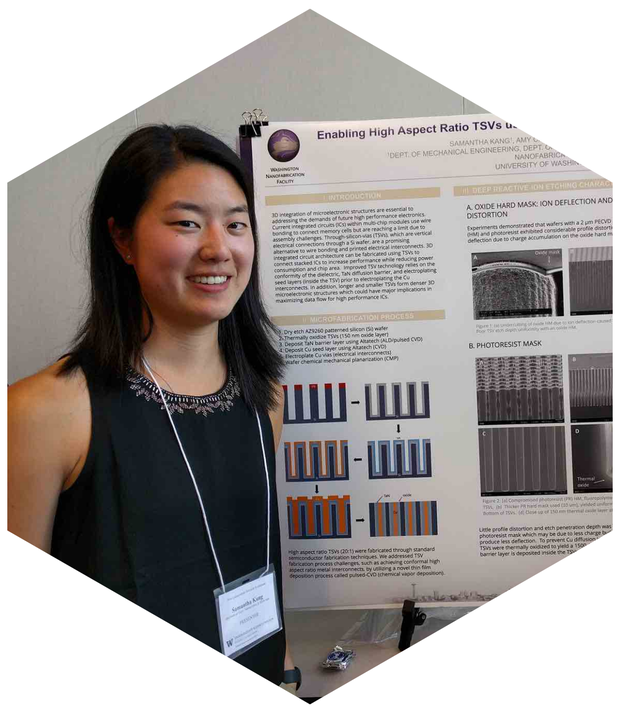
The Nanoscribe was brought to the University of Washington campus through a National Science Foundation Major Research Instrumentation grant (#1624513).

Workforce Development

WNF promotes economic and job growth in the region by fostering innovation and by cultivating an exceptional talent pool with hardware engineering and nanofabrication expertise. Seattle tech companies, from start-ups to large companies, need experienced employees with specialized training. To stay competitive in research and development, the Pacific Northwest must grow this workforce.

WNF supports a pipeline of highly skilled researchers, engineers and technicians to supply increasing demand from industry. With both academic and industrial users in its facility, WNF is uniquely positioned to act as a bridge between academia and industry in the region.

Training Activities



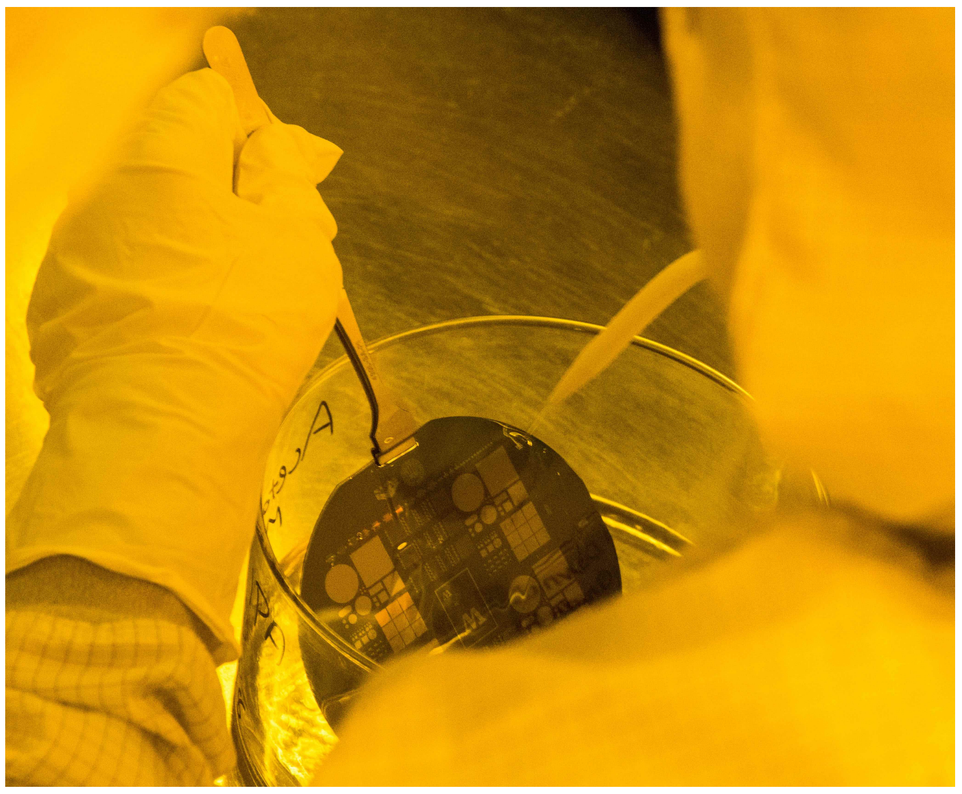
Internship Program

Providing undergraduates engaging research opportunities is one of several ways WNF supports workforce development in the Seattle area. As it has for several years now, WNF hosts undergraduate researchers through UW's Undergraduate Research Program. Students are afforded the opportunity to work with WNF staff on research projects and gain hands-on experience that could help to advance their academic and professional careers. This past year WNF employed a record-breaking 32 students. Many WNF alumni have gone on to pursue nanofabrication careers in both academia and industry, including at Google, Microvision Inc, Modern Electron, Micron Technologies, among other companies.

Nanofab Short Course

Twice this past year, WNF offered a five-day survey course to students, faculty and industry professionals, as an introduction to key nanofabrication techniques, tools and methods. This intensive Short Course included lectures coupled with hands-on laboratory sessions to give attendees a more thorough understanding of fabrication technologies as well as firsthand experience using fabrication equipment. Each of the 2018 short courses was well attended by a mix of academic and industry users and the feedback from participants was very positive.

The current course fee is $600 for academics and government employees and $1200 for industry professionals. WNF will continue offering this short course biannually with one session in March during UW's Spring Break (March 25-29, 2019) and the other session in September before the start of the Fall Quarter (September 16-20, 2019).



What participants said about the course:

"The time in the fab seeing and using the tools was extremely helpful and valuable. The sequence of lab steps was very well-designed, efficient, but also gave good coverage of many tools and processes!"

"This course has given me a more in depth understanding of the processes we use." (industrial user)

"As a student, it helped me understand options available and I feel like my mind is bursting with ideas to apply our nano-lab!"

"I now have a better understanding of what the instruments in the WNF are and what they do."

Nanofabrication Engineer Andy Lingley Reflects on WNF's Role in his Career Development

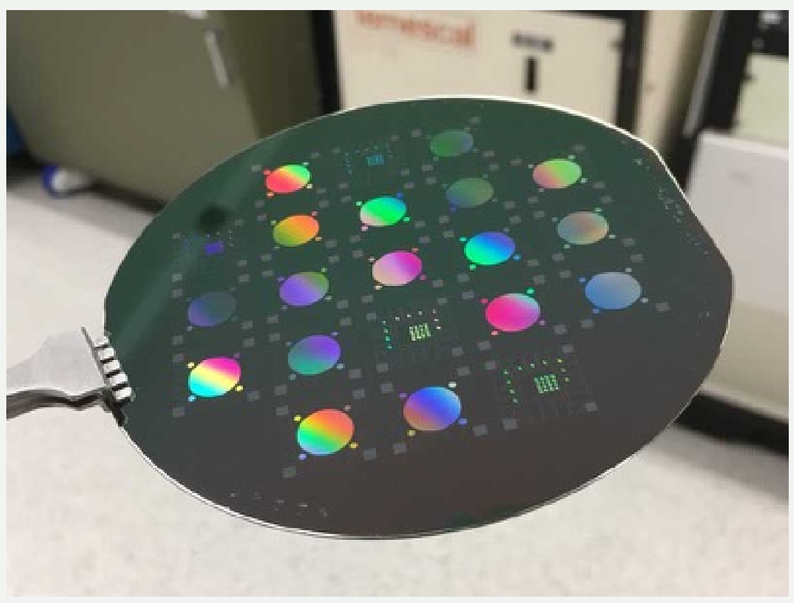
Industrial User Feature

"One of the really wonderful things about WNF is how it feels like a community," says Andy Lingley, a nanofabrication engineer at Modern Electron, a cleantech startup located in Bellevue, Washington. Lingley joined the WNF community in 2007 when he was a new graduate student at UW, and he continued to work with WNF as his career progressed. Lingley offers a unique perspective of WNF as someone who has utilized its nanofabrication capabilities as an academic user, staff scientist, and industrial user.

Dr. Andy Lingley

Lingley's first interactions with WNF were as a graduate student in the lab of electrical and computer engineering affiliate professor, now Amazon vice president, Babak Parviz. Lingley used WNF tools to fabricate contact lenses embedded with sensors or LEDs, which is being adapted for diabetic patients as a non-invasive glucose monitor. "WNF exposed me to a wide variety of microfabrication projects, including solar cells, flexible substrates for electronics, and neural electrodes — all of which require working with different materials and at different size scales," Lingley recounted. "At WNF, there was a lot of in-house expertise for each of these applications."

After finishing his Ph.D. in 2012, Lingley jumped at the opportunity to join WNF full-time. "Working as a staff scientist at WNF allowed me to see even further under the hood, and to understand the equipment and processes well enough to teach graduate students and industrial users." In 2015, Lingley started working for Modern Electron. This local startup has received over $10M in venture capital funding to develop advanced thermionic energy converters as cheaper, more reliable, and lightweight alternatives to conventional steam turbines. Lingley credits the breadth of his experience at WNF for his ability to adapt to and succeed in a startup. "I was given the opportunity to get in on the ground floor with Modern Electron, which is an entirely different environment from performing research or operating the WNF clean room," Lingley explained. "But, thanks to my time at WNF and my various roles, I came in with a thorough understanding of the semiconductor industry and the technical capabilities of the facility. This has really helped me drive progress at Modern Electron."



A microstructured semiconductor used in Modern Electron's thermionic converters

WNF supports technology innovation and commercialization by giving startups access to specialized facilities and equipment that growing companies could not afford to purchase, nor would they want to. As an industrial user, Lingley has utilized a number of different WNF tools including the Canon Stepper for photolithography and SPTS Rapier for etching small, deep holes in silicon wafers. Modern Electron has also hired two undergrads trained through WNF's undergraduate research program, which Lingley says is a testament to the quality of students that come out of the program.

The next move for Modern Electron is toward a scaled-up, market-ready product. Even as the company transitions some of its manufacturing to external foundries, Lingley will continue to benefit from his relationship with WNF. "By interacting with other users, I've been exposed to the differences between academic and industrial cleanrooms. Scale-up is a fundamental step for a successful startup, and I'm excited to continue with this new challenge."

Education and Outreach

STEM Night at Federal Way

Engineering Discovery Day 2017

2017 Nanoday at the Pacific Science Center

Native American Student Day

WNF has partnered with the local K-12 STEM community at a number of outreach events to present nanotechnology activities to over 13,000 students and educators. At the Pacific Science Center's National Nanotechnology Day, WNF staff engaged thousands of guests through hands-on nanotech demos. WNF also encouraged Native American students to pursue nanotechnology training at UW by providing on-campus workshops at Native American Student Day.

Activity	Participants
National Nanotechnology Day	2057 guests in partnership with The Pacific Science Center
Engineering Discovery Days	8,764 students and 1,781 chaperones
K-12 Outreach events	2,600 participants
Cleanroom Internships	22 (7 women, 4 URM)
First Nation Campus visits	44 K-12 students

Coming up in 2019

In the coming year, WNF staff are developing opportunities to further engage faculty and students in departments and disciplines across UW and inform them of the wide range of tools and expertise available at WNF. In spring of 2019, WNF will be working closely with colleagues in the Northwest Nanotechnology Infrastructure to prepare for the 5-year NNCI grant renewal process.

Acknowledgements

We are grateful for the generous support we have received from the College of Engineering and the College of Arts and Sciences. We have been fortunate to work with faculty, staff, and students from numerous departments across the university, including Electrical and Computer Engineering, Mechanical Engineering, Chemical Engineering, Materials Science and Engineering, Physics, and Chemistry.

WNF is supported in part by funds from the National Science Foundation (awards NNCI-1542101 and MRI-1624513).

National Nanotechnology Coordinated Infrastructure