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James Badham

Galan Moody leads successful effort to secure $1.3 million for advanced 3D printing

A new age of 3D printing is here, even though the initial technology for what is also known as additive manufacturing arrived less than 20 years ago. UC Santa Barbara is stepping into the era with a $1.15 million grant from the National Science Foundation (NSF) to purchase the most cutting-edge 3D printing technology available: a 3D rapid nanoprinting system based on two-photon photolithography. The equipment will enhance the capabilities of the already widely recognized UCSB Nanofabrication Facility (aka the “Nanofab” or “Nanotech”).

“The unique capabilities of this system open the door to new approaches to nano- and micro-manufacturing of complex structures and devices that are no longer constrained by geometry nor confined to two-dimensional planes,” the authors wrote in their proposal.

By securing the grant, lead PI Galan Moody, UCSB professor of electrical and computer engineering, and four co-PIs — Marley Dewey (bioengineering), Andrew Jayich (physics), Sumita Pennathur (chemical engineering) and Andrea Young (physics) — are ensuring that UCSB can take a leadership role in pushing the boundaries of what the new technology can do.

“There are just a few universities in the U.S. that have tools with these capabilities,” said Moody.

Recent advances have brought 3D printing to the realm of the very small, supporting an array of applications by enabling on-chip 3D printing of microstructures, a capacity that will benefit researchers in many disciplines.

“Ten-nm-resolution lithography is available at off-campus commercial foundries,” Moody said, “but none is capable of creating complex 3D structures with nanoscale resolution and high speed for high-throughput prototyping, which are required for next-generation devices. Being able to make structures in true three dimensions opens new capabilities.”

Five researchers, five uses

The principal investigators’ research reflects the diverse focuses of potential users — and uses — of the new equipment.

Moody, an expert in integrated quantum photonics, will create new photonic chip designs for ultra-efficient entanglement distribution and networking.

Jayich will apply his expertise in trapped-ion systems to microprint 3D ion traps for optical clocks. Some of what he needs for experiments is not available on campus, and off-campus commercial vendors — except those who sell the new 3D-printing tools — are unable to provide what he needs for rapid fabrication of prototypes. The new tool will enable rapid prototyping of 3D-printed ion-trap structures on campus.

Dewey has a newly established research program at UCSB combining biomaterials with extracellular vesicles for skeletal repair and disease treatment, including broader impacts in coral regeneration and repopulation. She plans to use the system to create patterned biomaterials, or scaffolds, for a variety of purposes.

Pennathur intends to 3D print microsystems to analyze fluids, and to make micro-fluidic channels on chips to use as electrical control for such functions as turning valves on and off in therapeutic devices implanted in the body. She uses micro- and nanoscale devices to study chemical and biological systems, with a special emphasis on nanofluidic bioanalytical devices.

Young’s research combines nanofabrication and electronics to investigate the properties of electronic states in quantum materials. He can use the 3D tool to create what he calls a nano-SQUID, or superconducting quantum interference device, and attach it to the tip of an atomic-force microscope to enhance its ability to characterize materials.

All of the PIs will work closely with Nanofab technical and operational director, Brian Thibeault, to coordinate system installation and qualification, as well as training and educational outreach activities.

Like Jayich, Moody would like to do in-house work that is currently either not being done or has to be sent to vendors for required engineering. “Using the new tool to do it ourselves has multiple benefits,” he said. “We do the work faster and for less cost, my students will get trained on the very best equipment, and we can share the in-house knowledge with the rest of the UCSB photonics community.”

Fueling the future workforce

Moody sees educating students as a high priority. The proposal detailed plans to train not only UCSB students on the equipment, but also local community-college students. For the latter, that could mean access to good jobs without having to earn a Ph.D. or perhaps, depending on their circumstances, to attend university at all. “They will learn to use the equipment if they go through one of our boot camps or participate in one of the many UCSB internship programs operated with the support and leadership of the Center for Science and Engineering Partnerships,” Moody said.

Those programs include the Central Coast Partnership for Regional Industry-focused Micro/Nanotechnology Education (CC-PRIME). Led by Santa Barbara City College and run through the California NanoSystems Institute (CNSI) at UCSB, CC-PRIME partners with local technology companies of all sizes and regional community colleges to train students in nanofabrication skills. It is part of a broad effort to build a regional educational pipeline to cultivate the micro/nanotechnology workforce.

Some students who participate in such programs might opt to pursue a four-year degree or attend graduate school, but not all companies need someone with an advanced degree to run their fabrication processes. “If students have a certification saying, ‘I've gone through these boot camps,’ then they become valuable assets to companies,” Moody said. “That might lead some students to think, ‘Hey, I can do this. I've got the skills. Let me go get a job now’”.

What makes the new tech new

While both the original and the new processes of 3D printing share a name, the earliest technology was actually more of a two-dimensional framework, Moody explained. “Three-dimensional objects could be created, but only by aggregating (the ‘additive’ part of ‘additive manufacturing,’’ as the first generation of 3D printing was also called) very thin layers of materials, which had length and width but no real depth.”

Quantum networks, secure quantum communications, quantum sensors and optical quantum computers and simulators require high-quality sources of entangled photon pairs. Much research is devoted to improving source quality, especially the pair-generation rate, the number of photon pairs extracted from the chip per second. According to the grant proposal, optical extraction efficiency from integrated chips to fiber is limited by the diameters of the various modes, which typically differ by 10-50% for quantum networking. To get around that discrepancy and “get the light into the fiber,” Moody said, “we bring the fiber right to the edge of the chip to capture it before it can diverge.”

The new system makes it possible to print a tiny polymer lens fewer than 50 micrometers wide onto the edge of a chip, enabling it to guide the optical mode.

“We try to arrange the components such that the light doesn’t ‘see’ the fiber as a discontinuity. That allows the light beam coming out of the photonic chip to couple nicely into the fiber and keep going, resulting in very low loss,” Moody added. “That's really hard to do, because there is often a mismatch between the shape of the optical beam in our small wave guide and how it looks in the much-larger fiber. To make the transition requires a smooth 3D structure without any jagged edges, which can trap or scatter the light, resulting in loss.”

Smooth nanoscale 3D printing is essential for many structures and devices being made at UCSB. The new 3D printing technology can deliver it.

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Quantum Science

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