

Commentary

Pursuing science across nationalities and disciplines

At our home base at the Okinawa Institute of Science and Technology (OIST) Graduate University, my wife, Anya Dani, works as an art conservator in collaboration with local museum personnel to preserve Okinawan artifacts, and I run a physics research unit specializing in femtosecond spectroscopy. In December 2014 we took the long journey to Buffalo State College (BSC) in New York, where Anya's mother, Katherine Conway-Turner, had recently become president.

Barely off the plane, we headed to BSC for a tour of the art conservation and physics departments to find out about their latest projects.

Sipping tea in the art conservation department, I spoke with scientist Aaron Shugar and conservator James Hamm, who explained to me the importance of taking cross sections of paintings to analyze the layers of paint and other decorative coatings. Such analysis enables art conservators to uncover critical information about the history and authenticity of a piece of art and to aid in its restoration.

According to Aaron, the conventional approach of using a scalpel to remove a small cross section of the artwork is not ideal and could damage the painting further. Curious about my research, Aaron asked if a femtosecond laser could be used to create a clean cross section of a painting. In theory it could, but I had certainly never tried it. I had used femtosecond lasers to engineer optoelectric devices, image electrons in motion in a solar cell device, and study photocarrier dynamics in novel materials.¹ But never had I fired laser beams at a painting.

Anya immediately appreciated the value of the idea and saw it as a good opportunity for my research unit to partner with the art conservation programs at both OIST and BSC.

Many physicists might have left it there. But having just begun my career at OIST, a new international research institute that prides itself on interdisciplinary research, I saw the collaboration as a great opportunity to dip my toes in unfamiliar



KESHAV DANI, leader of the femtosecond spectroscopy unit at the Okinawa Institute of Science and Technology and author of this Commentary, standing outside one of the university's skywalks.

waters. By using femtosecond lasers to solve an art conservation problem, I could break down barriers between the two seemingly distinct disciplines and potentially make an important contribution to the study of cultural heritage. And it certainly helped my wife working alongside me professionally; after all, we make a good team in our personal lives.

I made no promises to Anya, Aaron, or James. If I could find time to work on the project, I would do so with enthusiasm. Before our tour was over, Aaron handed me a package of paintings to work on, if time ever permitted. Anya and I returned to Okinawa with the precious cargo safely stowed in our luggage.

Paintings and lasers

The paintings sat in my office collecting dust for several months. In the summer

of 2015, Anya gave the project a nudge by hiring an intern from the art conservation department at BSC to pursue, among other things, our interdisciplinary idea. After many months of collaboration between OIST's femtosecond spectroscopy unit and the OIST and BSC art conservation programs, we successfully demonstrated that femtosecond lasers could cut a tiny cross section from the corner of a painting with minimal damage to the surrounding area.

Unlike normal lasers that produce a continuous light beam, femtosecond lasers produce extremely short pulses that last just a few millionths of a billionth of a second. During that seemingly insignificant amount of time, the pulses can deliver more power than that needed to launch a shuttle into space. Moreover, femtosecond lasers deliver

their energy so quickly that damage from heat transfer is avoided.

Culminating in a recent publication,² our interdisciplinary and international collaboration provided a safe and non-damaging new technique for analyzing and sampling artwork.

Although such collaborations between scientists and art conservators aren't widespread, that sort of research is commonplace at OIST. Since I joined the institute in late 2011, I have witnessed mathematicians working with ecologists, chemists with engineers, and physicists with biologists to solve big scientific problems that no one discipline could solve alone and to innovate at the boundaries of academic disciplines.

Femtosecond light

Thanks to the close-knit community at OIST, I get exposed to worlds outside my own, including that of neurobiologists. In a collaboration that grew out of a conversation at a weekly OIST tea in 2012, we learned with Takashi Nakano and Jeff Wickens of the neurobiology unit that it might be possible to manipulate brain activity using femtosecond lasers. Together with chemists at the University of Otago in New Zealand, we attached gold nanoparticles to liposomes (spherical vesicles made of a lipid bilayer), pre-loaded them with dopamine—a key neurotransmitter in the central nervous system—and used femtosecond lasers to repeatedly release precise pulses of dopamine and other chemicals.³

In that truly interdisciplinary research, chemists, neurobiologists, and physicists worked together to design an experiment that capitalized on our various areas of expertise. Our latest results³ demonstrate the applicability of the technique to interface with neural functioning, with implications for future brain and behavior research.

Using powerful femtosecond lasers to nondestructively release chemicals in a brain slice may be an unexpected application. But in general, neuroscientists are no strangers to femtosecond lasers: The devices are used ubiquitously in two-photon microscopes to image neurons.

At a swing dance class at OIST in the fall of 2014, graduate student Viktoras Lisicovas, who worked in the information processing biology unit, approached me about building a novel type of two-photon microscope that would allow

him to image multiple neurons simultaneously in a live *Caenorhabditis elegans* roundworm. A traditional two-photon microscope, in which a tightly focused optical beam is scanned across the field of view, was too slow to record such an event.

So we embarked on a project to build a novel two-photon microscope demonstrated by Yaron Silberberg and colleagues at the Weizmann Institute of Science⁴ and independently by Chris Xu and colleagues at Cornell University.⁵ Instead of focusing the light beams tightly in space, as conventional techniques do, we focused them in time, which allowed us to image simultaneously a larger field of view and thus multiple neurons in *C. elegans*. With the first images just now coming out of our microscope, we hope that this work between physicists and neuroscientists will lead to a deeper understanding of the collective behavior of neurons in live *C. elegans*, and fruitful future collaborations between physicists and neuroscientists in general in the years to come.

A new model

Interdisciplinary and international research embodies OIST's core values. By actively discouraging the separation of scientific disciplines—both metaphorically and physically—and by having more than 50 countries and regions represented in the university community,

the institute is at the forefront of a new model of research and education. In my unit alone, our 13 people represent 8 nationalities and speak more than 15 languages, including French, Lithuanian, Cantonese, Mandarin, Filipino, Hindi, and, of course, Japanese and English.

Without the support and administrative structure of OIST, the breadth and depth of collaborations I've described between physicists and people from other disciplines would probably never have happened. The sense of trust and teamwork that has developed among the faculty across disciplines, the willingness of researchers to try innovative ideas, and the flexibility in funding, personnel, and experimental setup all help in developing successful interdisciplinary projects that further our shared pursuit of knowledge.

References

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LETTERS

More details on Israel's water story

In a letter in the January 2017 issue of *PHYSICS TODAY* (page 12), Gabriel Antonius takes offense at a report in the June 2016 issue (page 24) that covers Israel's innovative water technology. He claims that "a key policy explaining the effectiveness of Israel's water management" is "monopolizing water in occupied Palestinian territories" by denying Palestinians the right to drill wells or repair existing ones and by destroying wells, irrigation systems, and water lines. The source for that claim is one report from 2009 by Amnesty International, an organization known for

anti-Israel incitement¹ but certainly not known for its expertise on water use and maintenance. That eight-year-old, biased report has been widely debunked in several detailed documents.²

Since the signing of the Oslo agreements between Israel and the Palestinian Liberation Organization, the amount of fresh water available to the Palestinian Authority (PA) has increased considerably. In fact, if one takes as starting point the year 1967 when Israel gained control over the West Bank, per capita freshwater consumption in the Palestinian-controlled regions of the West Bank