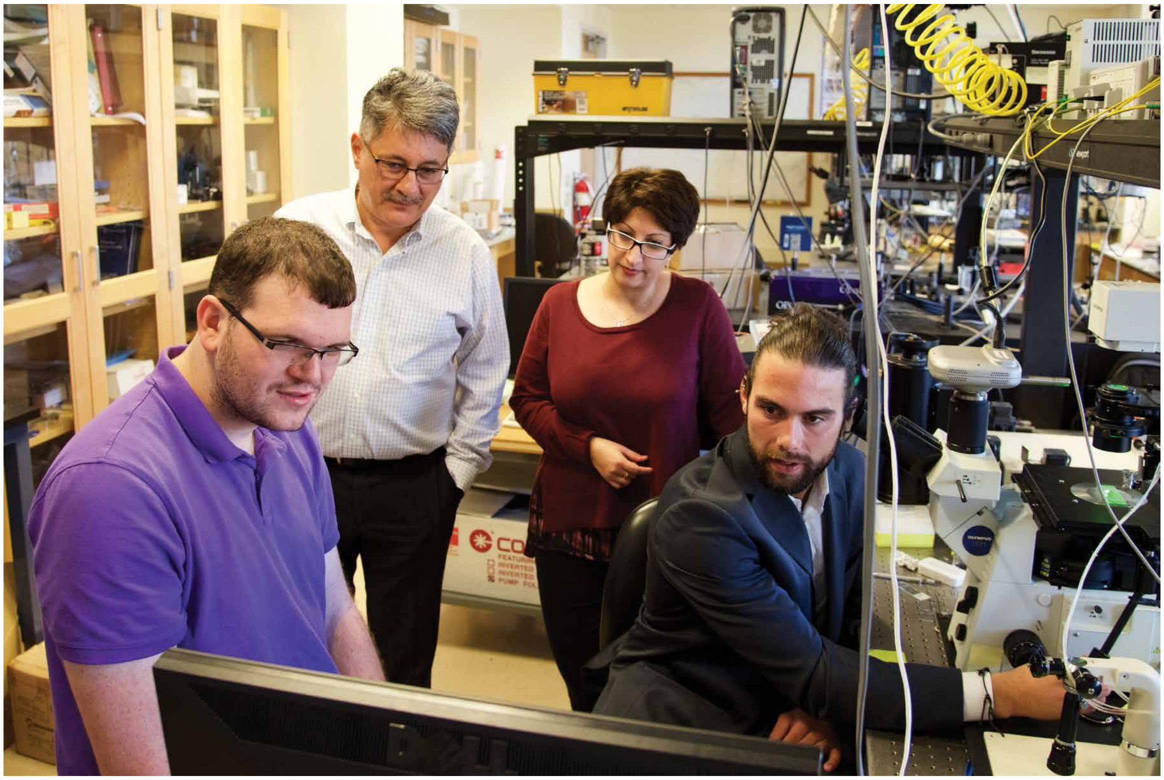
# From Planets to

## New Optical Devices Target Real-World Problems



*Aaron Brettin (from left) Professor Vasily Astratov, Farzaneh Abolmaali and Kylen Blanchette work in the lab.*

When Vasily Astratov explains complex principles of physics, specifically in the world of optics, he turns to St Paul's Cathedral in London and its Whispering Gallery. Whisper on one side of the iconic dome, and someone standing a hundred feet away on the other side can hear the whispered words.

"The dome or spherical shape helps trap the sound inside the cavity and transmits it around the inside surface," says Astratov, a professor in the Department of Physics and Optical Science. "The same principle is at work in optics."

Optics involves the study of light. Instead of a large cathedral dome, think of a microscopic sphere. "A different form of wave – electromagnetic – traps visible light in much the same way acoustic waves trap sound," he says. "Just as the cathedral can trap sound, a microsphere can trap visible light."

However, there is one important difference with the acoustic waves. The light trapped in microspheres has an evanescent component – a kind of "cloud" extending from the microsphere, very much like an atmosphere on a planet. When the light wave resonates inside the sphere, this cloud becomes thicker and it extends longer. This electromagnetic cloud is extraordinarily sensitive to variations in the microsphere environment. More than a decade ago, researchers Stephen Arnold and Frank Vollmer suggested using such evanescent clouds for sensing of individual protein and viruses.

It has become apparent that the applications of this phenomenon are unlimited, Astratov says. "One of the lines of thinking in the modern optics community is that this evanescent field can also help us see extraordinary small details of the objects in the atmosphere of the microspheres, which are not ordinarily seen in standard optical microscopes," he says.

Knowledge of this phenomenon and its implications for scientific research have propelled Astratov to submit patents on optical components that use microspheres to provide super resolution capabilities - one with his former student in 2012 and another with his Air Force Research Lab collaborators in 2015. Astratov, a native of St. Petersburg, Russia, received his doctoral degree at the Ioffe Institute, one of Russia's largest institutions for research in physics and technology, part of the Russian Academy of Sciences and a home institution for several Nobel laureates.

It was there in the mid-1990s that he pioneered studies of synthetic opals as novel three-dimensional photonic crystals for visible light.

A leader in his field of study, Astratov has named a new field of study, microspherical photonics, to describe the research directions of his group. In microspherical photonics, individual spheres are focusing and trapping light, and they "whisper to each other" due to an overlap of their evanescent electromagnetic clouds.

"There are many applications where you need extreme accuracy, such as precise laser surgery to attach a retina or remove a fibrotic membrane, for example," he says. "We want to explore the many applications."

Since joining UNC Charlotte in 2002, his work in the field has yielded several technologies – the new optical device and laser scalpels to focus laser beams, for example – with four patents and two more pending.

The new optical devices take the study of light to a new level, moving into the realm of photonics which, simply defined, is a combination

# Microspheres



of optical science and engineering. The optical devices based on microspherical photonics promise to deliver a cost-effective solution to physicians, scientists, lab technologists and others who want to improve the performance of their microscopes and their diagnostic capabilities.

"Optical microscopes are fundamentally limited in their resolution due to diffraction of light," Astratov says. "The outer edges of an object remain blurred when viewed through a microscope. Use of these evanescent electromagnetic fields and our new optical component helps overcome that limitation."

In Astratov's lab, doctoral student Aaron Brettin leans over a microscope, carefully placing a sample under its objective lens. The optical component, made from elastomeric transparent material with embedded barium-titanate glass spheres, looks like razor thin sheets or microscope coverslips. By placing them over the sample, the microspheres are as close as possible to the objects to be viewed, catching their evanescent electromagnetic fields and allowing greater resolution capabilities, an enhancement for imaging biological structures.

According to Astratov, these new coverslips with embedded spheres help scientists view not just the cellular level but also to resolve the subcellular structures, a critical component in biomedical research. While numerous industries such as pharmaceutical, semiconductor, optoelectronics, computer chip and, especially, microscope manufacturing companies, may benefit from the work in Astratov's lab, the biomedical area is what draws him the most.

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*—Vasily Astratov*

"The application I find most exciting and practical is the potential use by pathologists and histologists," he says. Physics, in this case microspherical photonics, gives insights into diseases by helping pathologists more readily see the subcellular level of human tissues, proteins, bacteria and viruses.

In initial research with pathologists at a nearby hospital, Astratov and his team received valuable feedback to take back to the lab to improve their process. "By gaining insights into the methodology entailed with their diagnostic processes, I was able to extrapolate new ways to improve our own product fabrication," says Kylen Blanchette, a senior physics and mathematics major.

While higher resolution is available with scanning and transmission electron microscopes, Astratov says that they have their drawbacks. "They are expensive, they require a high level of training, and they also destroy cells," he says.

Even though the standard optical microscopes have less than optimal resolution due to the diffraction limit, doctors prefer them. This is why the new optical components hold great promise for the industry. Astratov is working with the Charlotte Research Institute and the Office of Technology Transfer to form SupriView, a company that will manufacture and sell microsphere-embedded slabs.

He also plans to expand the technologies related to microspherical photonics, including further development of ultra-precise laser scalpel technologies for tissue surgery and new ways for sorting dielectric microspheres by using their resonant whispering gallery properties.

The latter technology is based on breakthrough research in his lab devoted to observation and study of the giant resonant light forces in microspherical photonics, highlighted in *Optics & Photonics News* as one of best achievements in 2013.

His innovative laser scalpel technology received a prize in 2013 in the Charlotte Venture Challenge, a competition for early-stage high growth companies. Through the National Science Foundation Industry/University Cooperative Research Center on Metamaterials, his team receives funding from the Air Force Research Lab, part of the U.S. Department of Defense.

Astratov's team relies on the fabrication facility at AFRL to develop the nanoplasmonic arrays or objects that are used in super-resolution studies. They also work together to publish results of their research, and AFRL has for many years provided summer student internships.

Astratov and doctoral student Farzaneh Abolmaali will present designs of their optical devices in early 2017. Astratov is a program committee member of a subconference on Nanoscale Imaging, Sensing and Actuation for Biomedical Applications and an invited speaker at Photonics West, the world's largest event focusing on photonics technologies, including medical technologies and smart manufacturing.

Abolmaali selected physics, specifically optics, "where the fundamental knowledge of light can be connected with engineering and technology and then becomes practical." The new optical devices, Abolmaali says, "are an example of how optics bridges science and engineering."

For Astratov and his collaborators, the devices serve as inspiration for his continuing research into how microspherical photonics can help solve real-world problems. &

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