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MEDIA RELEASE

UP chemists make light work

A University of Pretoria (UP) master's student has built an all-optical system to trap and control particles that can detect water pollutants at extremely low concentrations, even in tiny volumes. This work signals a move from "test tubes" towards light-driven "chemistry-on-a-chip" approaches.

Chemistry student Ané Kritzinger is part of UP's Environmental Monitoring and Sensing Research Group, which is led by Professor Patricia Forbes. This interdisciplinary research project aims to advance the emerging field of chemistry applications in optics, and was made possible through collaboration with partners at the Structured Light Laboratory at the University of the Witwatersrand.

By combining optical tweezing with fluorescence spectroscopy of quantum dots (fluorescent nanoparticles with optical properties that make them ideal analytical sensors), the researchers are paving the way towards an ultra-sensitive analytical instrument. Prof Forbes explained that the system could be used to test river water collected from an agricultural area where rainwater run-off has potentially transported pesticides into the water, which could be harmful to the environment and humans.

Kritzinger explained the process of optical trapping and tweezing: "When you shine light on your hand with a torch, for example, it doesn't make your hand move. The reason for this is that while light can exert a force, it is very small. In the microscopic world, however, we can use light to trap (hold) particles and even move them around in a controlled way – the very small forces are appreciable in this world. We can use a laser to 'hold' a specific particle of interest in order for us to analyse it, in this case, by observing the light given off by the particle. Essentially, light acts like a pair of tweezers: we can pick things up and move them around."

The UP researchers are co-authors of a recent research paper, published in *Nature Photonics*, along with their collaborators from Wits and other photonics research groups from international universities. Experiments conducted on the optical trapping and tweezing system built by Kritzinger were used as one of the applications to prove a breakthrough in optics.

What does the research show?

When light travels through media like water, turbulent air or imperfect and misaligned optical elements (like lenses), the laser beam is distorted.

However, in this paper, the researchers showed that the polarisation inhomogeneity of vectorial light is not affected by the perturbing media. Light has intensity and colour as well as other properties or dimensions, which includes polarisation relating to the direction of vibration of the light. In vectorial light beams, this polarisation varies across the beam, giving it interesting properties as explored in this paper. The findings will benefit the optical communication and imaging communities alike. According to Kritzinger, optical communication involves sending information faster and more securely using photons of light (through fibres or air), instead of electrons, through copper cables. In terms of imaging, an example would be clearer imaging of biological samples, such as cancer cells, by using light.

In the case of the optical trap, by using vectorial light, the team had better control of the trapped particles. The optical trap has many parts and is a complicated set-up where things could go wrong, like a lens not being in the correct position, causing the trap to malfunction. By using vectorial light, the team could correct for this without having to determine the exact cause of the problem.

The significance of this research is highlighted by several real-world examples where light travels through liquids, turbulent air and optical fibre. “This research project affirms the importance of collaborations across disciplines to advance science,” Prof Forbes said. “By pushing the boundaries of analytical science, we aim to improve environmental and human health and thereby quality of life.”

“Light being distorted when passing through distorting media seems self-evident,” said Prof Andrew Forbes, Head of the Structured Light Laboratory at the School of Physics at Wits, who co-supervised Kritzinger. “Now we have discovered a hidden property in light that remains unchanged, a figurative ‘beacon in the dark’ that can be exploited for applications such as imaging, sensing and communication. It is exciting that both the team and the applications require skills from across disciplines, from chemistry to physics; the best science is always found at the interface of fields.”

“This research has it all: from fundamental theory to practical real-world experiments,” Kritzinger said. “It resolved a standing debate in the optics community about the robustness of vectorial light in complex media and opened a new avenue for applications of vectorial light. The most exciting part of my master’s research and this project was to get to work with and learn from brilliant postgraduate students and world-class researchers.”

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Photo captions:

Lab
Ané Kritzinger, an MSc Chemistry student who is part of UP’s Environmental Monitoring and Sensing Research Group, at her optical trapping set-up in the Structured Light Laboratory at the University of the Witwatersrand. Photo: Supplied by Ané Kritzinger

Wall
MSc Chemistry student Ané Kritzinger showing the pattern of a structured laser light beam used in her experiments. Photo: Supplied by Ané Kritzinger

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About the University of Pretoria

The University of Pretoria (UP) is one of the largest contact and residential universities in South Africa, with its administration offices located on the Hatfield Campus, Pretoria. This 114-year-old institution is also the largest producer of research in South Africa.

Spread over seven campuses, it has nine faculties and a business school, the Gordon Institute of Business Science (GIBS). It is the only University in the country with a Faculty of Veterinary Science, which is ranked top in Africa. UP has 120 academic departments and 92 centres and institutes, accommodating more than 56 000 students and offering about 1 100 study programmes.

UP is one of the top five universities in South Africa, according to the 2019-2020 rankings by the Center for World University Rankings. The QS World University Rankings also placed UP among the top 100 universities worldwide in three fields of study (veterinary science, theology and law), and UP is in the top 1% in eight fields of study (agricultural sciences, clinical medicine, engineering, environment/ecology, immunology, microbiology, plant and animal sciences and social sciences), according to the Web of Science Essential Indicators.

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