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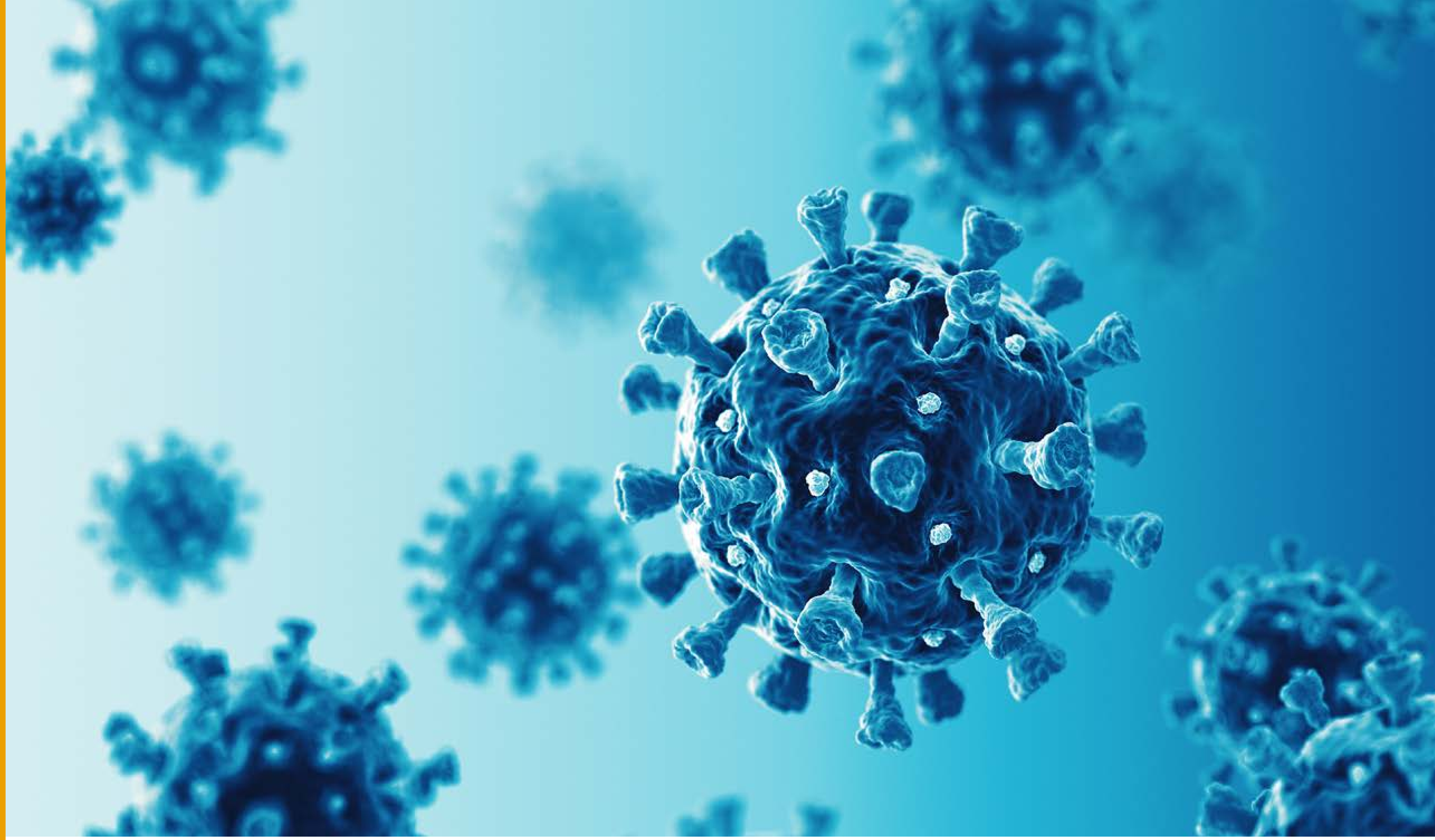

BETTER DIAGNOSTICS AND TREATMENTS

INFECTIOUS DISEASE

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As COVID-19 continues to spread around the world, we have become witness to the devastating, all-encompassing impact of infectious disease. First and foremost, the pandemic remains an ongoing public health emergency with over three million confirmed cases and hundreds of thousands of human lives lost. But COVID-19 has also emerged as an economic, social, and human rights crisis.

A pandemic also exacerbates inequalities in healthcare, public services, and education. Poor populations in countries without universal healthcare could be priced out of access to testing, treatment, and vaccines.

The repercussions of COVID-19 — and infectious diseases, in general — are staggering and catastrophic. Researchers worldwide are frantically working on solutions, and light-based technologies have joined the fight. Tried-and-true diagnostic techniques like optical microscopy employ light to test for the presence of microorganisms in a patient's sample. And our own labs at the Leibniz Institute of Photonic Technology in Jena, Germany are investigating next-generation imaging and spectroscopic methods that use laser light to identify pathogens and their resistance to medications, in order to optimize how patients are treated.

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SHINING A LIGHT ON DIAGNOSIS

Infectious diseases are illnesses caused by organisms such as bacteria, viruses, fungi, or parasites. While vaccination has greatly reduced the burden of infectious diseases, vaccine-preventable diseases like measles and pertussis remain a serious issue for populations without the financial means or access. In addition, diseases like malaria, HIV/AIDS, and COVID-19 currently lack an effective vaccine. This means that, in many cases, the accurate and rapid diagnosis of infectious diseases is the key to both patient survival and disease surveillance.

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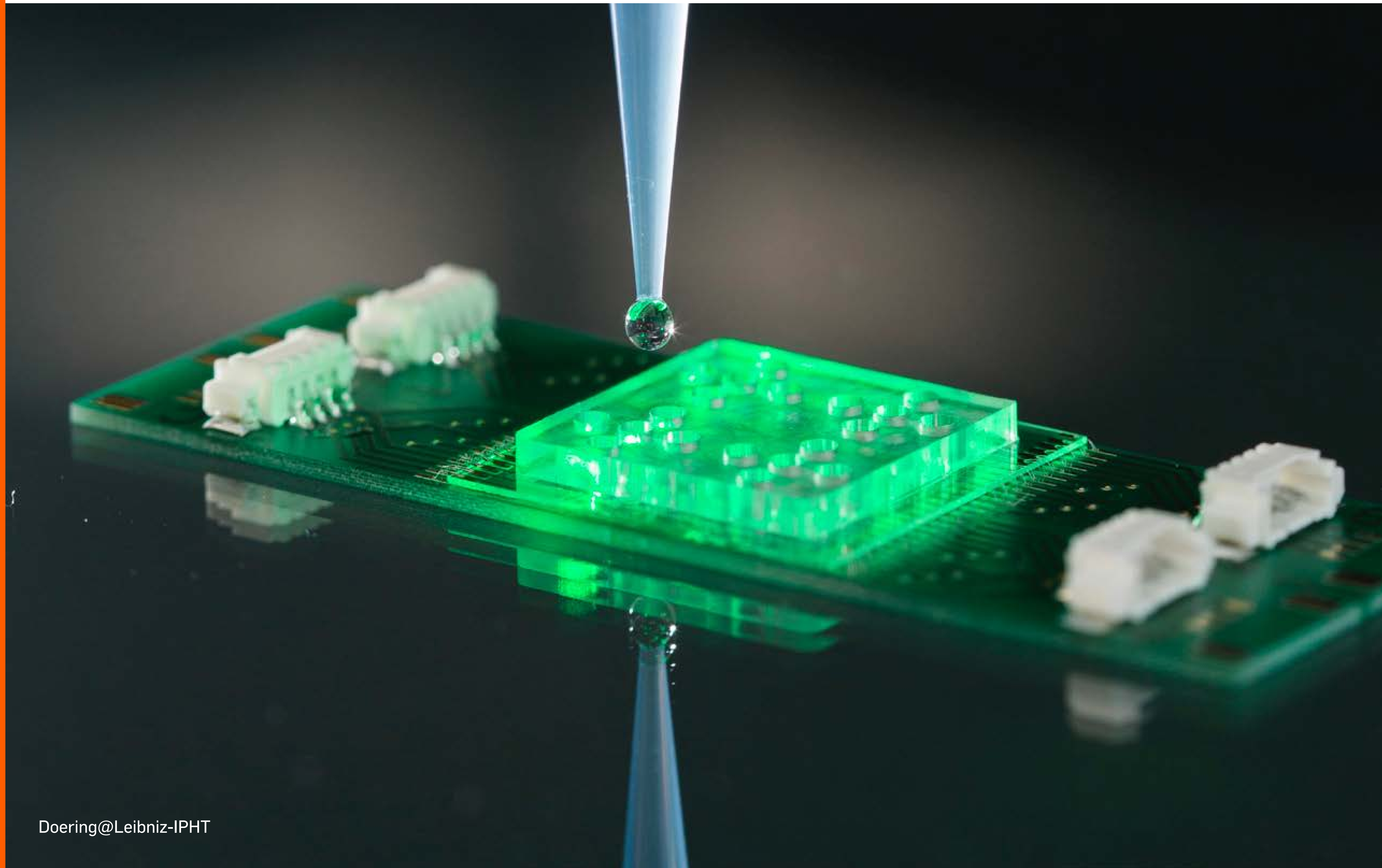
Advances in microscopy have been connected to our knowledge of pathogens since the 17th century. The invention of the microscope goes back to the 16th century, when two Dutch eyeglass makers placed multiple lenses in a tube and saw that objects on the other end became magnified. The first images were blurry and obscured, but improvements followed that increased the magnifying power and quality of the image.
In the 1670s, Dutch scientist Antonie van Leeuwenhoek used microscopes to observe single bacterial cells and other microorganisms for the first time.

Jena, our lab's home city in Germany, also has a rich history in microscope development and manufacturing. Carl Zeiss, a German scientific instrument maker, optician, and businessman, founded his microscope workshop in Jena back in 1846. It remains in business today, as one of the oldest existing optics manufacturers in the world. In addition, German scientists Ernst Abbe and Otto Schott worked closely Zeiss to improve the design of microscopes and refine the art of optical glass manufacturing.

Hundreds of years later, light microscopy remains the gold standard for laboratory confirmation of many infectious diseases. For instance, a blood specimen collected from a patient is smeared onto a slide, stained, and magnified with a light microscope to look for malaria parasites. According to the World Health Organization, more than 208 million people worldwide were tested for malaria by microscopic examination in 2017 alone.

Routine medical diagnostics often use light microscopy to detect bacteria by examining their shape and using staining techniques to differentiate one type from another. However, no information can be gained on the species of the bacteria or its resistance to antibiotics.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THE MOLECULAR FINGERPRINTS OF DISEASE

The next generation of diagnostic tests has to be better, cheaper, and faster than what is currently available in order to succeed, which is no easy feat. My lab is in the midst of trying to develop a contender for this title with a light-based molecular analysis technique called vibrational spectroscopy. The term “spectroscopy” refers to the study of how light and other kinds of radiation interact with matter.

If a laser is shined on a sample, the way some of the light scatters back depends on the molecules contained within it and how they vibrate in response to the light. Different molecules will scatter in different ways, effectively creating a molecular “fingerprint.” Together with deep learning algorithms, we can use this molecular fingerprint information to identify bacteria on a single-cell level.

The power of this light-based approach is that, first of all, it really speeds up the diagnostic process. We have used our device to analyze bacteria such as E. coli from samples of patients’ urine, with the entire procedure taking only an hour. Standard microbiological methods for urine testing typically take at least 24 hours. Instead of waiting a whole day or more, the results can be received — and more importantly, acted on — much faster with our technique.

In addition, we have the ability to give more information about a person’s disease for the purpose of individualized treatment. For example, vibrational spectroscopy in combination with microscopy can determine whether bacteria are resistant to a particular drug by observing their interaction. If bacteria are still multiplying in the presence of an antibiotic, we know they have developed resistance to it. The test only takes 90 to 120 minutes, and with that data, a physician can then optimize treatment for a patient without wasting precious time on ineffective or broad-spectrum drugs.

Vibrational spectroscopy can also be used to determine the source of an infection, not only by hunting for the pathogen itself, but also from observing changes in the patient’s white blood cells. The body’s immune response involves changes in certain white blood cells known as T and B cells in order to remember the foreign invader to better respond to the next infection. There are also others that fight invading pathogens without needed a prior encounter. Invading pathogens trigger an immune response that changes the overall biochemical composition of the immune cells and can be detected with the help of vibrational spectroscopy. With only a few drops of blood, this method can recognize the molecular fingerprint of a white blood cell that has encountered a certain pathogen and provide an accurate diagnosis.

Lastly, many light-based approaches have the advantage of being simpler to use with less sample preparation involved. Vibrational spectroscopy, for instance, does not use any stains, dyes, or markers to highlight the microorganism. The lack of extra chemicals speeds up the process and allows live cells to be measured in their natural state. Researchers who develop new drugs or perform basic research on pathogens may benefit from measurement techniques that will not interfere with the normal function of cells.

While vibrational spectroscopy remains an experimental technique, we hope to make a commercially available device for the clinic within the next five years. The device would characterize bacteria and perform fast antibiotic resistance testing. Right now, my lab is busy working on new diagnostic approaches to the COVID-19 crisis.

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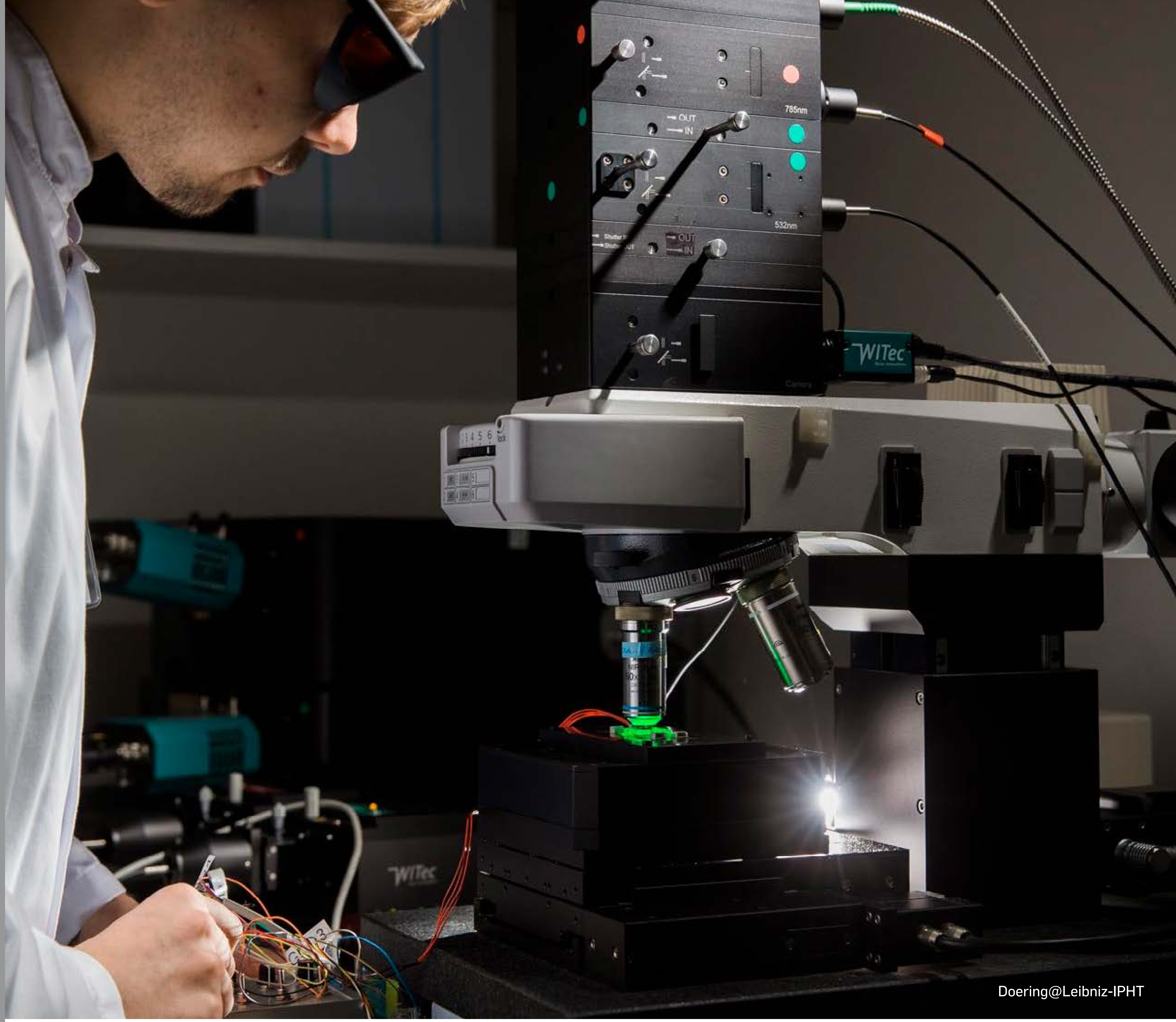
A BRIGHT FUTURE

In the field of infectious disease — a topic that is very much in focus in our current COVID-19 world — light-based technologies have already made an enormous impact with optical microscopy and PCR testing. The next five to ten years could see new techniques start to take hold that optimize the accuracy, cost, and speed of diagnostics. And with better diagnostics comes better treatment, including a greater push towards personalized medicine.



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As we fight this ongoing pandemic, we can find hope in the science and innovation that is working to bring forth tests, vaccines, and treatment. Throughout history, scientists have used light to find solutions to some of the most urgent problems facing society. The motto of the Leibniz Institute of Photonic Technology is "Photonics for Life," referring to the practice of developing light-based technologies that make our lives safer, healthier, and cleaner.

I take this idea to heart, and I believe in a future that will continue to use light to contribute to a better world for all.

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