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Quantum physicist Ido Kaminer is investigating new ways to generate higher-quality X-rays.

FRESH INSIGHTS

Down to the last detail

Using an innovative technique, quantum physicist Ido Kaminer is magnifying new possibilities in X-ray science

BY DIANA KWON

The discovery of X-rays in 1895 took the world by storm. When German physicist Wilhelm Conrad Röntgen first used the technology to generate images of the bones in his wife's hand, the public was blown away by the eerie photographs, and the medical community immediately recognized their clinical value. Today, X-rays are routinely used in diagnostic imaging and certain therapies, as security scanners and for various industrial functions. However, most modern-day machines still rely on the X-ray-generation technique invented by Röntgen more than a century ago.

That may soon change: a group of scientists in Israel has developed a method of creating more powerful X-rays using quantum materials. Ido Kaminer, a physics and nanotechnology researcher who leads the AdQuanta Group at the Technion – Israel Institute of Technology, is investigating new ways to generate radiation in different parts of the electromagnetic spectrum, and specifically X-rays. Just as we have made tremendous strides with visible light, for which the applications are almost endless, in Kaminer's view, improvements in X-ray science could lead to wide-ranging technological breakthroughs. This is an area of physics "where we just don't know enough compared to the potential it has," says Kaminer, an Azrieli Early Career Faculty Fellow.

There are already sources of X-rays that can achieve much higher-quality results. Synchrotrons and free-electron lasers reveal the molecular and atomic details of structures, making them useful across a wide range of scientific disciplines. But they are enormous—the particle accelerator at the SLAC National

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Accelerator Laboratory in California is more than three kilometres long—and expensive, which prevents wider use. "Those are considered the best X-ray sources, but they're not compact enough to put in a dentist's office," Kaminer says.

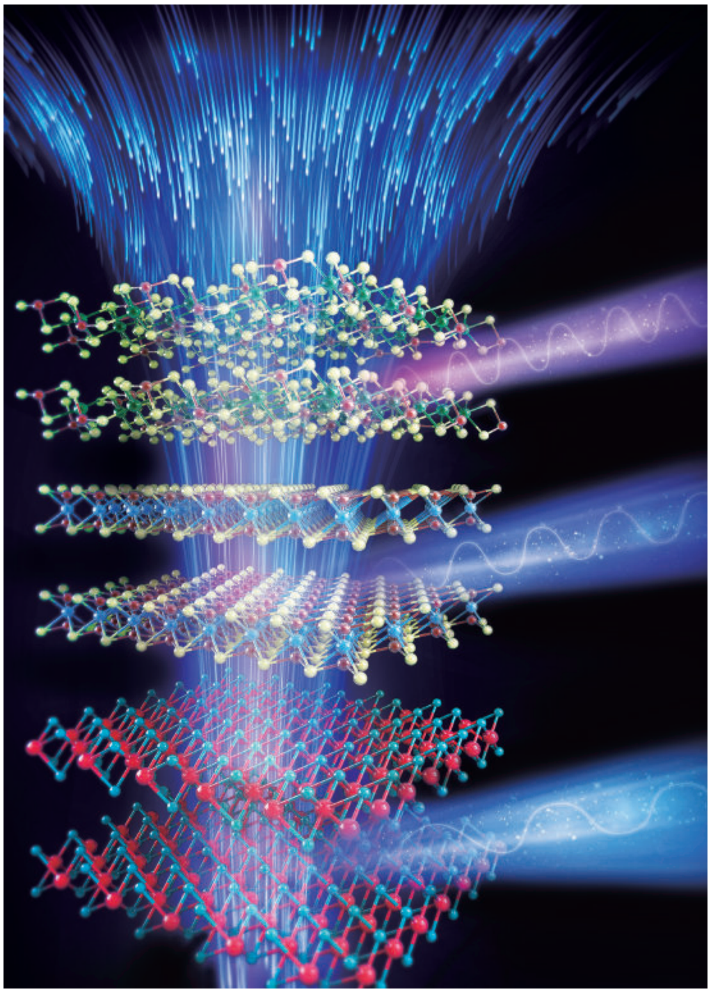
Kaminer's team is developing concepts for compact X-ray sources with synchrotron-like abilities. Recently, they achieved a significant breakthrough by building an X-ray source with van der Waals materials (named after Nobel Prize–winning physicist and idea originator Johannes Diderik van der Waals), which are made from atomically thin two-dimensional layers that, uniquely, can be manufactured one atomic layer at a time. By passing electrons through sheets of these materials held together by weak connections called van der Waals forces, the researchers produced directional beams of X-rays capable of generating high-resolution images. According to Kaminer, the key to this technique is optimizing the geometry between layers, since the distances between them determine the wavelength and direction of the X-rays.

This research builds on work Kaminer began in 2015 as a postdoctoral student in the Department of Physics at the Massachusetts Institute of Technology, where he and his collaborators outlined the theoretical foundations for new methods of producing X-rays. Kaminer's current team recently provided experimental evidence for a high-quality X-ray source that is not only compact, but tunable—meaning it is possible to change the colours of X-rays generated. In September 2020, *Nature Photonics* published their study, "Tunable free-electron X-ray radiation from van der Waals materials," which involved 18 other researchers from academic institutions in Israel, Denmark, Singapore, Spain and the United States.

"We used van der Waals materials for the first time to produce X-rays and showed their advantages in making X-ray sources…This created an effect in X-ray science that has not been achieved before. That's part of what's making me so excited," Kaminer says. "It was quite a journey—and it's still ongoing."

The next step for Kaminer's group is to refine this X-ray technology to meet the needs of specific applications. The potential uses are far-reaching. In medicine, the technology could be used to view infinitesimally smaller features of the body, such as cells, and one day possibly even individual molecules. Designers of products such as computer chips could determine the precise composition of elements within materials. The police and military could better identify security threats in airports and other public areas. More broadly, this advance in X-ray science could enhance the research capacity of scientists in many disciplines.

There is still a ways to go before accomplishing those goals, Kaminer says, "but we've made an important step." ▲



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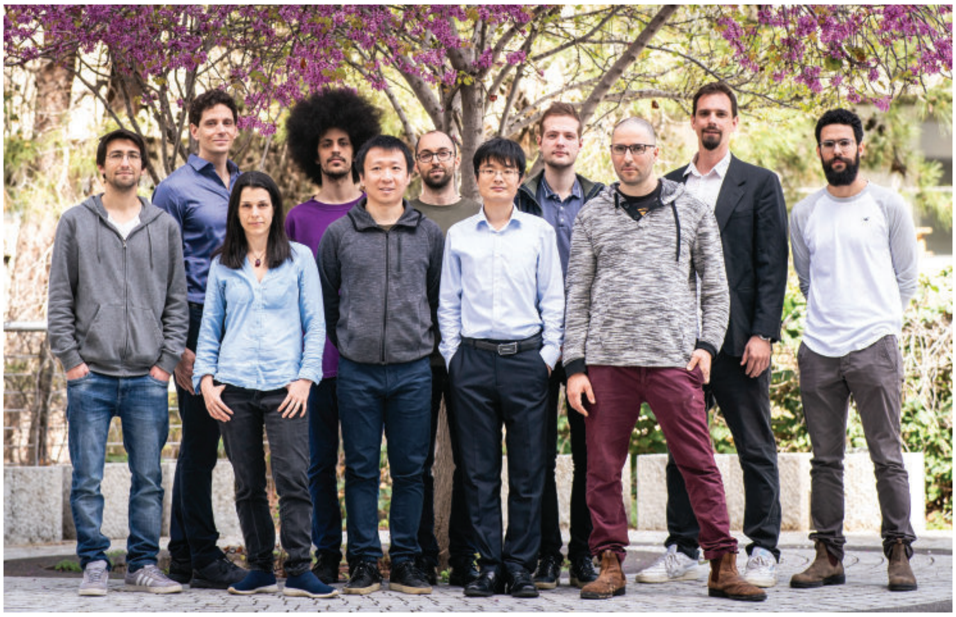

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Ido Kaminer and his research team at the Technion – Israel Institute of Technology.