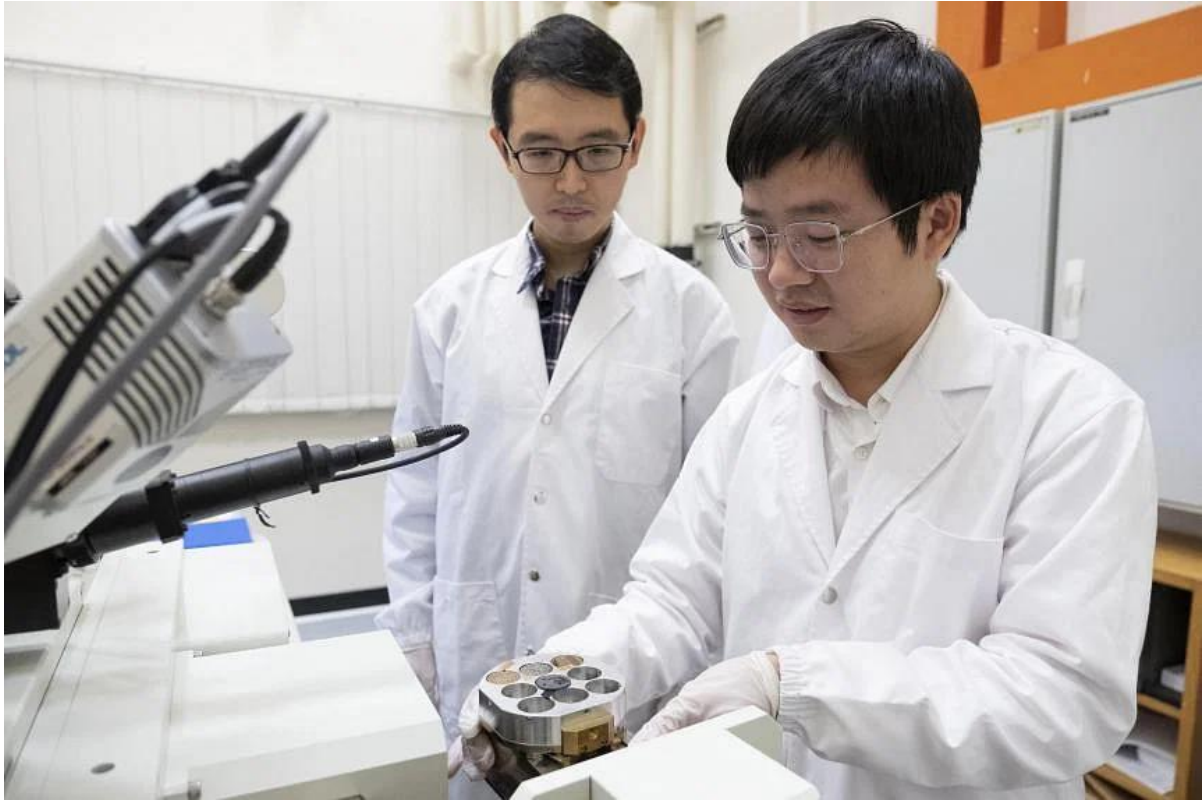


NTU scientists first to prove quantum theory in giant leap for precise X-ray imaging



Nanyang Technological University's Nanyang Assistant Professor Wong Liang Jie (left) and research fellow Huang Sunchao loading a sample into a scanning electron microscope used in their quantum recoil experiments. PHOTO: NTU

Josiah Teo and Lucas Tan

SINGAPORE – A team of seven scientists from Nanyang Technological University (NTU) is the first in the world to demonstrate an 83-year-old quantum physics theory, in a breakthrough that will pave the way for more precise X-ray imaging.

The team, led by NTU's Nanyang Assistant Professor Wong Liang Jie from the School of Electrical and Electronic Engineering, successfully showed in experiments that X-rays are emitted at lower energy levels, as predicted by quantum recoil theory, when charged particles such as electrons pass through a material to produce radiation.

Harnessing quantum recoil, which has eluded scientists for decades, will enable more precise X-ray machines to be developed for imaging human tissue samples and detecting flaws in semiconductor chips.

Radiation such as X-rays can be produced when electrically charged particles such as electrons are accelerated to increase their energy, and passed through a material, disturbing its atoms. As the atoms settle back into their original states, radiation is emitted.

Russian physicist Vitaly Ginzburg hypothesised in 1940 that the energy of the radiation would be lower than what is predicted by classical physics.

This would happen as a result of electrons slowing down and getting deflected as they interact with the atoms of the material they pass through.

This phenomenon is known as “quantum recoil”.

Classical physics assumes that the changes to the electrons’ energy and path as they interact with the atoms are negligible, and thus have an insignificant impact on the energy of the radiation produced.

Proving quantum recoil had frustrated scientists for decades.

Special materials, such as those with repeated patterns in their atomic structures, were required – but the precision required to create them had been limited by the technology available.

The NTU team, which had already been researching the production of X-rays by exposing inorganic compounds about the size of computer chips to moving electrons, turned their experiments to quantum recoil.

With a scanning electron microscope, they bombarded separate samples of graphite and hexagonal boron nitride (h-BN) with electrons.

The energies of the X-rays emitted were measured and found to match the values predicted by quantum recoil theory.



A scanning electron microscope used in Nanyang Technological University's quantum recoil experiments. PHOTO: NTU

“It was a happy accident as we were already working with X-rays to develop a more compact way to tune and generate X-rays of different energies for medical, industrial and security applications,” Prof Wong told The Straits Times.

This meant that the team was aware of the unique properties of materials such as graphite and h-BN.

Graphite is a form of carbon used in pencil lead, while h-BN is frequently used to make lubricants in paints.

Both compounds have closely packed layers of atoms in repeating patterns, where each layer is a single atom thick.

“We put two and two together and realised that we could use these materials in experiments to demonstrate quantum recoil.”

The team found that quantum recoil and the resulting radiation energy can be modified by tweaking the electron energy, the atomic composition and the tilt angle of the material.

Building upon their previous work, the researchers developed a way to enable the same X-ray machine to generate X-rays of specific energy levels to identify human tissues more accurately.

The team is working with Singapore biomedical equipment manufacturing company CTmetrix to develop more compact and precise tunable biomedical X-ray machines. They aim to have a prototype ready by the end of 2023.

Dr Edward Morton, chief technology officer of CTmetrix, said: “We are investing in a practical demonstration system, based on the quantum recoil phenomenon, to solve problems in biomedical imaging. When our product is ready, this will support the global bioscience industry in understanding disease and the impact of medical treatments.”

Singapore company Component Technology is also looking to tap the NTU team’s technology to develop tunable X-ray inspection machines to check semiconductor chips for defects such as voids, or air pockets that can lead to chip failure.

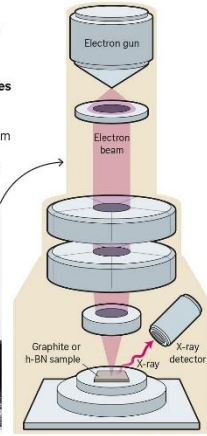
<https://www.straitstimes.com/singapore/ntu-scientists-first-to-prove-quantum-theory-in-giant-leap-for-precise-x-ray-imaging>

How everyday objects helped prove quantum theory

Quantum recoil, a physics theory which seeks to accurately predict the energy of radiation like X-rays being produced, was first proposed by Russian physicist Vitaly Ginzburg in 1940. Limitations in technology had restricted the demonstration of this quantum physics phenomenon until a team from Nanyang Technological University (NTU) successfully verified it. **Josiah Teo** and **Lucas Tan** find out how chemicals in pencil lead and paint lubricant helped solve the puzzle.

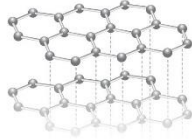
1 Shooting electrons

A scanning electron microscope is used to bombard electrons at **samples of graphite and hexagonal boron nitride (h-BN)**, which are between 50nm and 100nm thick. This is about one thousand times thinner than a sheet of paper.



2 X-rays are produced

Free-moving electrons interact with thin layers of atoms (right). As electrons from the electron gun are shot through these layers, X-rays are produced.

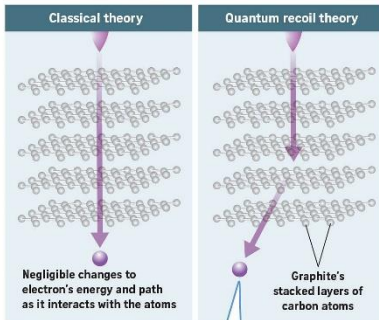


3 Quantum recoil effect from pencil lead and paint lubricant

- NTU scientists generated X-rays from graphite, found in pencil lead, and h-BN, used to make paint lubricants.
- Their naturally occurring patterns repeated across the layers are supposed to **amplify the quantum recoil effect to a level that is measurable.**



4 Results match forecast



- Electrons slow down and are deflected by the atoms as they pass through the layers.
- Quantum recoil theory predicts that this will significantly affect the energy of the X-ray produced, whereas classical physics predicts it will not.

The X-rays emitted in the experiment are measured and found to have matched the values forecast by the quantum recoil theory.

Real-world applications

- By verifying that quantum recoil is real, the energy of the X-ray produced in X-ray machines can be predicted and adjusted more precisely.
- This could improve the accuracy of biomedical imaging.



- The improved precision could enhance checks for faults in semiconductor chips.