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A golden key unlocks faster, sharper X-ray imaging

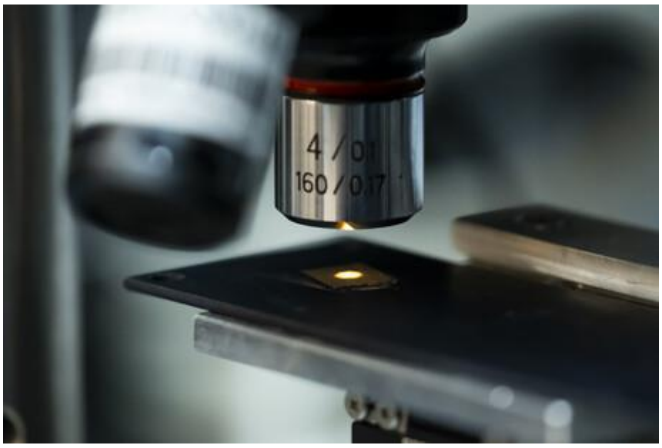

Image caption: Visible light is used to check if a sample made of perovskites and gold is correctly loaded for experiments to test the luminescence of the sample. Image credit: NTU Singapore.

An international team of scientists, led by Nanyang Technological University, Singapore (NTU Singapore) and the Łukasiewicz Research Network – PORT Polish Centre for Technology Development, has found a way to improve the sharpness of X-ray imaging and potentially boost the speeds at which X-ray scans can be processed. The key to their breakthrough, as detailed in the journal *Advanced Materials*, is a layer of gold added to devices that help visualise X-rays.

X-rays used in health and security scans are invisible, but they can be pictured using detectors that have 'scintillating' materials which absorb the radiation and 'light up' in a way that is similar to glow-in-the-dark paint. The visible light emitted by the scintillating materials is captured by sensors to create images based on the X-rays. The brighter the light, the sharper and more detailed the visuals.

Gold, meanwhile, is 'plasmonic' — meaning the electrons in the metal react to radiation by moving in synchronised wave-like patterns, akin to ripples forming after a pebble is dropped into water. These rippling electrons, also called plasmons, can interact with scintillating materials to accelerate the emission of visible light by the materials after they react with X-rays. This causes the light given off to become more intense.

The inspiration to use a plasmonic material together with scintillating materials arose from a marriage of two research areas that had not been explored before for X-ray detectors. Members of the research team previously found that after certain substances absorbed visible light, they also gave off visible light, which could get brighter if thin plasmonic gold at the nanometre scale was added. Other members of the team, who study how nano-sized structures enhance X-ray generation, were also working on X-ray detection.

Looking at the nanoplasmonic findings, an idea struck the team: since X-ray detection in X-ray scanners also depends on substances absorbing radiation to emit visible light, could nanoscale plasmonic materials augment detectors in these scanners? The scientists set out to prove this experimentally with gold.

The team's experiments used gold just 70 nm thick, or about 1000 times thinner than a strand of hair, which helps to keep material costs down. The researchers added the plasmonic gold layer to a scintillating material called butylammonium lead bromide, from the perovskite family of compounds.

The team discovered that adding a gold layer to the scintillating materials made the visible light they gave off 120% brighter. On average, the light emitted had an intensity of around 88 photons per kiloelectron volt. As a result, the X-ray images produced were 38% sharper and the ability to distinguish between different parts of the images was improved by 182%.

With the gold layer, the time the scintillating materials took to stop emitting light after absorbing the X-rays was also shortened by 1.3 ns on average, or nearly 38%, meaning they were ready for the next round of radiation more quickly. This suggests the potential for gold to speed up the processing of X-ray scans.

"Our results highlight the enormous potential of nanoplasmonics in optimising ultrafast imaging systems where high spatial resolution and high contrast are needed, such as X-ray bioimaging and microscopy," said study co-lead Assistant Professor Wong Liang Jie, from NTU Singapore. He said the improvements in X-ray detection demonstrated by the study stand to benefit airport security clearance too, as items in luggage might be more easily detected with crisper and higher-quality X-ray images, while bags could be screened more quickly.

"Combining this improvement with other technologies will result in state-of-the-art functionalities in radiation imaging, such as to enhance X-ray analysis done in colour or improve the accuracy of 'time of flight' X-ray medical imaging," added study co-lead Dr Muhammad Danang Birowosuto, from Łukasiewicz – PORT. The researchers are next planning to add nano-sized notch-like patterns to the surface of the gold layer to boost the visible light given off by X-ray absorbing scintillating materials, as earlier research has shown that tiny notches can enhance visible light production.

Dr Dennis Schaart from Delft University of Technology, who was not involved in the study, said the team's findings open a new avenue for the improvement of radiation imaging detectors based on scintillators, which convert X-ray or gamma-ray photons into measurable light signals.

"The findings presented in this latest research point the way towards a new class of scintillation detectors in which the intensity and speed of light emission are enhanced through the manipulation of quantum-mechanical phenomena," he said.

"In principle, this offers highly exciting prospects for scintillator developers to engineer optimal materials for a wide variety of applications. If the results presented in the research can be reproduced and scaled towards industrially produced scintillators, this will likely contribute to, for example, more accurate, more affordable and more accessible medical diagnosis, as well as faster security scans."

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