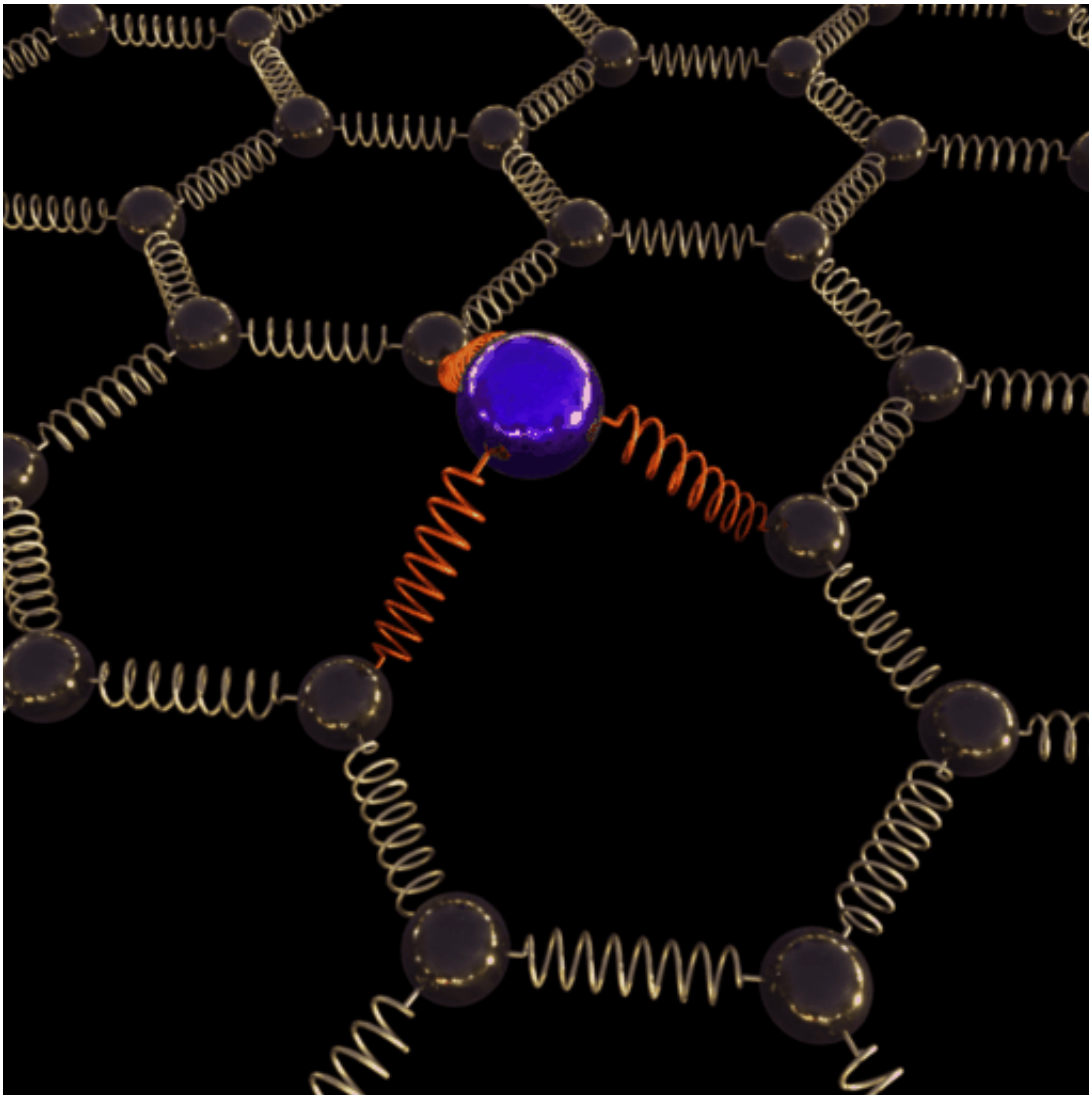


'Tickling' an atom to investigate the behavior of materials

March 6 2020



The animation shows the vibration energy of the silicon atom in the graphene crystal. Credit: D. Kepaptsoglou, SuperSTEM

Scientists and engineers working at the frontier of nanotechnology face huge challenges. When the position of a single atom in a material may change the fundamental properties of that material, scientists need something in their toolbox to measure how that atom will behave.

A research team led by the University of Leeds, in collaboration with colleagues at the Sorbonne University in Paris, France, have shown for the first time that it is possible to develop a diagnostic technique loosely related to the idea of a tuning fork.

A tuning fork produces a fixed tone when [energy](#) is applied to it—in that case, when it is struck. But if the fork is somehow altered, it goes out of tune: the tone changes.

The technique being used by the research team involves firing a beam of electrons at a single atom in a solid. That energy stream causes it and the [atoms](#) that surround it to vibrate.

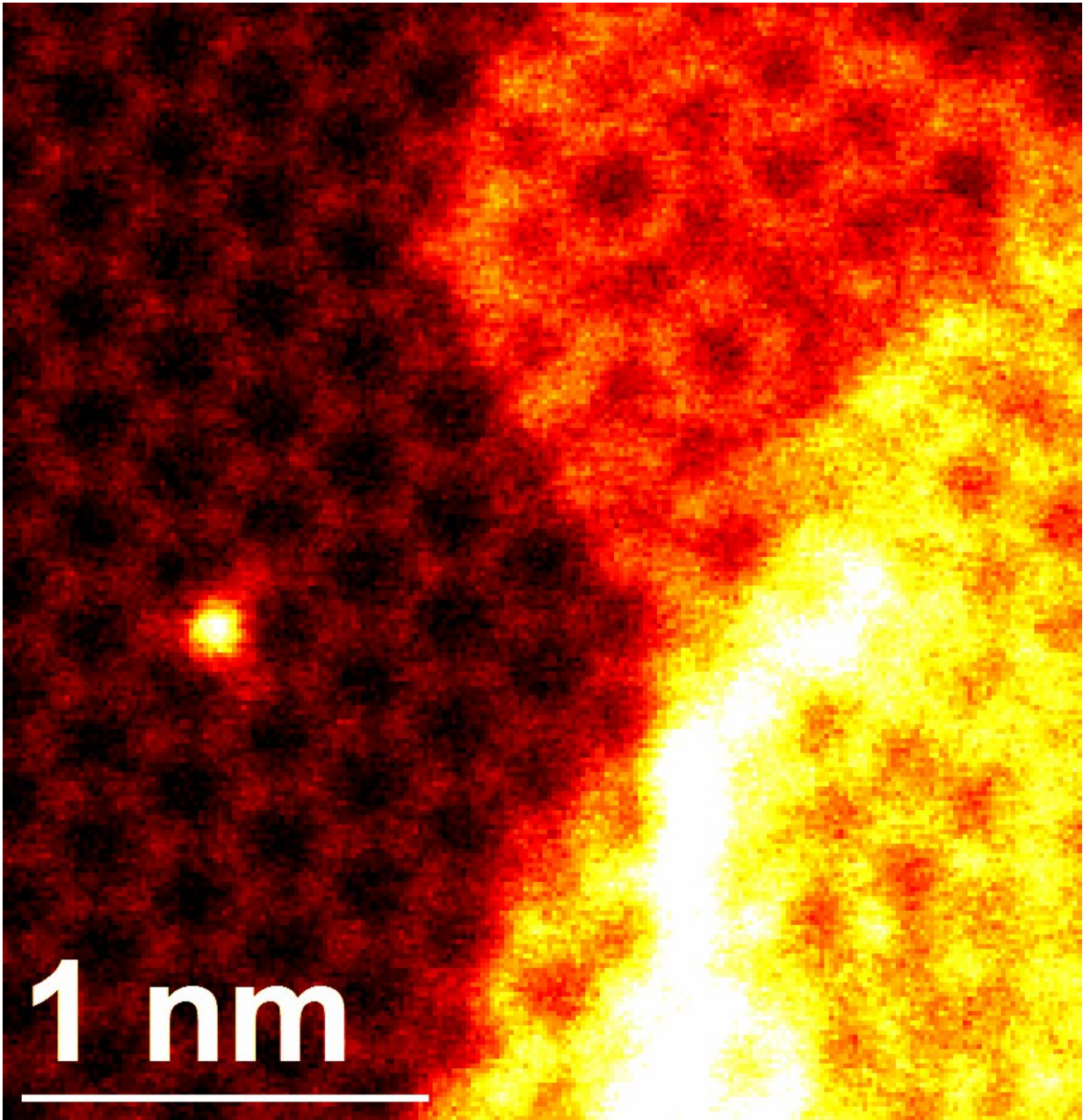
This creates a unique vibrational energy fingerprint, akin to the fixed tone from a tuning fork, which can be recorded by an electron microscope. But if a [single atom](#) impurity is present, another chemical element, for instance, the vibrational energy fingerprint of that impurity will change: the material will 'sound' different at this precise location.

The research opens up the possibility that scientists will be able to monitor materials for atomic impurities.

The findings, Single Atom Vibrational Spectroscopy in the Scanning Electron Microscope, are published today in the journal *Science*.

Quentin Ramasse, Professor of Advanced Electron Microscopy at Leeds who led the project, said: "We now have direct evidence that a single "foreign" atom in a solid can change its vibrational property at the

atomic scale.



An image taken from an electron microscope showing the single atom of silicon in the graphene crystal. It is brightly coloured and to the left hand side of the image. Credit: Q. Ramasse, SuperSTEM

"This has been predicted for decades, but there has not been any experimental technique to observe these vibrational changes directly. We have been able to show for the first time that you can record that defect signature with atomic precision."

The researchers used the SuperSTEM Laboratory, the UK National Research Facility for Advanced Electron Microscopy, supported by the Engineering and Physical Research Council (EPSRC).

The facility houses some of the most advanced facilities in the world for investigating the atomic structure of matter, and is operated under the auspices of an academic consortium led by the University of Leeds (also including the Universities of Oxford, York who were involved in this project, as well as Manchester, Glasgow and Liverpool).

The scientists located a single impurity atom of silicon in a large graphene crystal (a form of carbon only one atom thick) - and then focused the beam of their [electron microscope](#) directly on that atom.

Professor Ramasse said: "We are hitting it with an electron beam, which makes the silicon atom move around or vibrate, absorbing some of the energy of the incoming beam of electrons in the process—and we are measuring the amount of energy that is being absorbed."

The animation illustrates schematically how the silicon vibrates, and how that vibration begins to affect neighbouring atoms, and is inspired by extensive theoretical calculations by the team of Dr. Guillaume Radtke at the Sorbonne University, who collaborated on this project.

"The vibrational response we observe is unique to how this particular silicon atom is located within the graphene lattice," added Dr. Radtke. "We could predict how its presence would perturb the surrounding network of carbon atoms, but these experiments represent a real

technical achievement because we are now able to measure with atomic precision such a subtle change."

More information: F. S. Hage et al. Single-atom vibrational spectroscopy in the scanning transmission electron microscope, *Science* (2020). [DOI: 10.1126/science.aba1136](https://doi.org/10.1126/science.aba1136)

Provided by University of Leeds

Citation: 'Tickling' an atom to investigate the behavior of materials (2020, March 6) retrieved 24 April 2024 from <https://phys.org/news/2020-03-atom-behavior-materials.html>

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