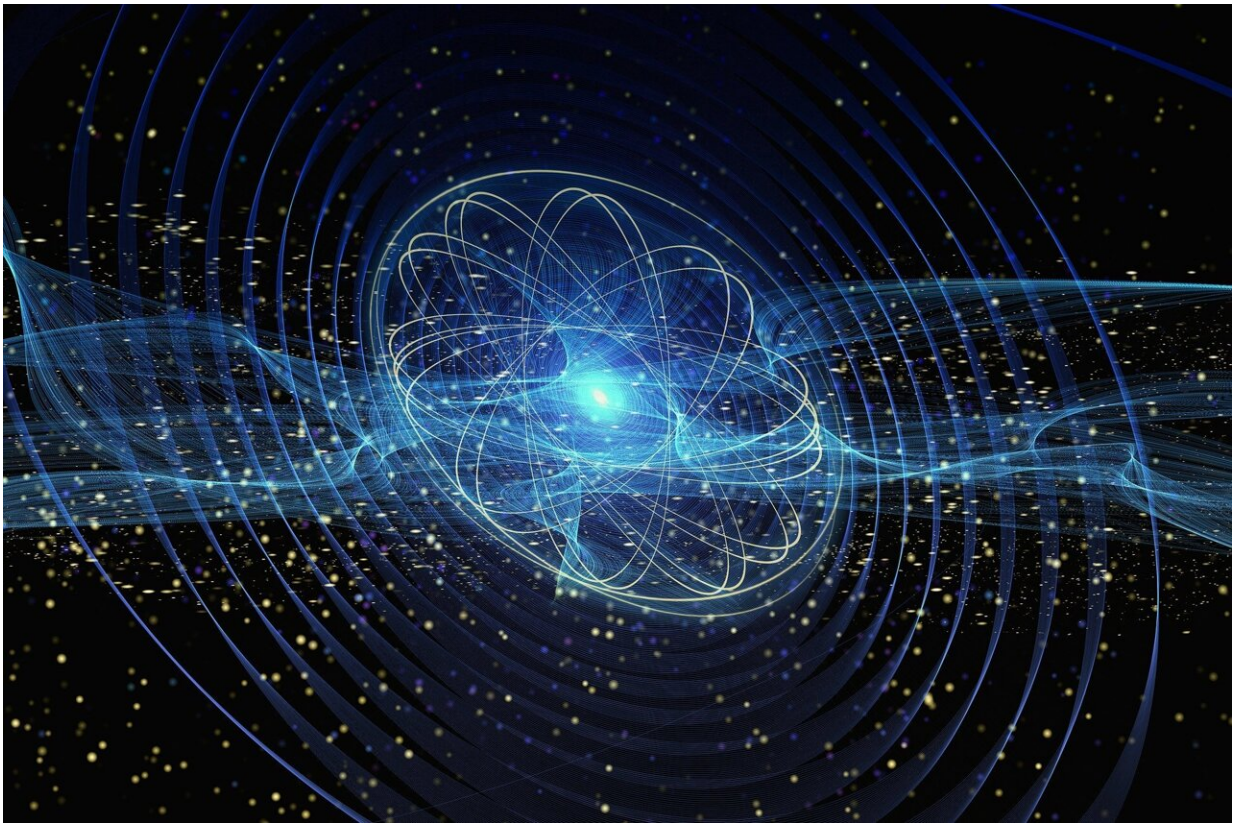


# The 'breath' between atoms—a new building block for quantum technology

June 1 2023

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University of Washington researchers have discovered they can detect atomic "breathing," or the mechanical vibration between two layers of atoms, by observing the type of light those atoms emitted when

stimulated by a laser. The sound of this atomic "breath" could help researchers encode and transmit quantum information.

The researchers also developed a device that could serve as a new type of building block for quantum technologies, which are widely anticipated to have many future applications in fields such as computing, communications and sensor development.

The researchers published these findings June 1 in *Nature Nanotechnology*.

"This is a new, atomic-scale platform, using what the scientific community calls 'optomechanics,' in which light and mechanical motions are intrinsically coupled together," said senior author Mo Li, a UW professor of both electrical and computer engineering and physics. "It provides a new type of involved quantum effect that can be utilized to control single photons running through integrated [optical circuits](#) for many applications."

Previously, the team had studied a quantum-level quasiparticle called an "[exciton](#)." Information can be encoded into an exciton and then released in the form of a photon—a tiny particle of energy considered to be the quantum unit of light. Quantum properties of each photon emitted—such as the photon's polarization, wavelength and/or emission timing—can function as a quantum bit of information, or "qubit," for [quantum computing](#) and communication. And because this qubit is carried by a photon, it travels at the speed of light.

"The bird's-eye view of this research is that to feasibly have a quantum network, we need to have ways of reliably creating, operating on, storing and transmitting qubits," said lead author Adina Ripin, a UW doctoral student of physics. "Photons are a natural choice for transmitting this quantum information because optical fibers enable us to transport

photons long distances at high speeds, with low losses of energy or information."

The researchers were working with excitons in order to create a [single photon emitter](#), or "quantum emitter," which is a critical component for [quantum technologies](#) based on light and optics. To do this, the team placed two thin layers of tungsten and selenium atoms, known as [tungsten diselenide](#), on top of each other.

When the researchers applied a precise pulse of laser light, they knocked a tungsten diselenide atom's electron away from the nucleus, which generated an exciton quasiparticle. Each exciton consisted of a negatively charged electron on one layer of the tungsten diselenide and a positively charged hole where the electron used to be on the other layer. And because opposite charges attract each other, the electron and the hole in each exciton were tightly bonded to each other. After a short moment, as the electron dropped back into the hole it previously occupied, the exciton emitted a [single photon](#) encoded with quantum information—producing the quantum emitter the team sought to create.

But the team discovered that the tungsten diselenide atoms were emitting another type of quasiparticle, known as a phonon. Phonons are a product of atomic vibration, which is similar to breathing. Here, the two atomic layers of the tungsten diselenide acted like tiny drumheads vibrating relative to each other, which generated phonons. This is the first time phonons have ever been observed in a single photon emitter in this type of two-dimensional atomic system.

When the researchers measured the spectrum of the emitted light, they noticed several equally spaced peaks. Every single photon emitted by an exciton was coupled with one or more phonons. This is somewhat akin to climbing a quantum energy ladder one rung at a time, and on the spectrum, these energy spikes were represented visually by the equally

spaced peaks.

"A phonon is the natural quantum vibration of the tungsten diselenide material, and it has the effect of vertically stretching the exciton electron-hole pair sitting in the two layers," said Li, who is also a member of the steering committee for the UW's QuantumX, and is a faculty member of the Institute for Nano-Engineered Systems. "This has a remarkably strong effect on the optical properties of the photon emitted by the exciton that has never been reported before."

The researchers were curious if they could harness the phonons for quantum technology. They applied electrical voltage and saw that they could vary the interaction energy of the associated phonons and emitted photons. These variations were measurable and controllable in ways relevant to encoding [quantum information](#) into a single photon emission and this was all accomplished in one integrated system—a device that involved only a small number of atoms.

Next the team plans to build a waveguide—fibers on a chip that catch single [photon](#) emissions and direct them where they need to go—and then scale up the system. Instead of controlling only one quantum emitter at a time, the team wants to be able to control multiple emitters and their associated [phonon](#) states. This will enable the quantum emitters to "talk" to each other, a step toward building a solid base for quantum circuitry.

"Our overarching goal is to create an integrated system with quantum emitters that can use single photons running through optical circuits and the newly discovered phonons to do quantum computing and quantum sensing," Li said. "This advance certainly will contribute to that effort, and it helps to further develop quantum computing which, in the future, will have many applications."

Other co-authors are Ruoming Peng, Xiaowei Zhang, Srivatsa Chakravarthi, Minhao He, Xiaodong Xu, Kai-Mei Fu and Ting Cao.

**More information:** Tunable phononic coupling in excitonic quantum emitters, *Nature Nanotechnology* (2023). [DOI: 10.1038/s41565-023-01410-6](https://doi.org/10.1038/s41565-023-01410-6) ,  
[www.nature.com/articles/s41565-023-01410-6](https://www.nature.com/articles/s41565-023-01410-6)

Provided by University of Washington

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