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English translation from Chinese

Quantum recoil in free-electron interactions with atomic lattices

A research group led by Nanyang Asst Prof Wong Liang Jie from Nanyang Technological University, Singapore has made an achievement in demonstrating quantum recoil in the interaction between free electrons and atomic lattices. The research was published in the Nature Photonics journal on Jan 19, 2023.

The researchers demonstrated quantum recoil experimentally, showing that this quantum electrodynamic effect is not only observable at room temperature, but also robust in the presence of other electron scattering mechanisms. By scattering free electrons off periodic two-dimensional atomic sheets of van der Waals materials on a desktop platform, the group demonstrated that only quantum recoil theory could accurately predict X-ray photon energies. The team showed that quantum recoil could be so large that classically predicted X-ray photons were emitted as extremely low-energy photons.

The research team envisions quantum recoil as a means of precisely controlling the energy spectrum of outgoing photons and electrons, and points out that quantum recoil can be tailored through a range of parameters: electron energy, atomic composition and tilt angle of the van der Waals material. The group's results pave the way for a desktop room-temperature platform to exploit and study quantum electrodynamic effects in electron-photon interactions.

It is understood that light emitted by charged particles is the basis of many scientific phenomena and technological applications. Classical theory determines the emitted photon energy by assuming an undeflected charged particle trajectory. In 1940, Ginzburg pointed out that this assumption breaks down when considering quantum electrodynamics, and there is a shift in photon energy from the classically predicted value (known as quantum recoil). Since then, quantum recoil during free electron luminescence, including Cherenkov radiation and Smith-Purcell radiation, has been well studied theoretically, but experimental evidence remained inconclusive.

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