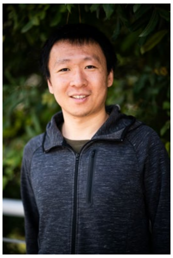
Quantum Free-Electron Radiation

Technion-Israel Institute of Technology, Israel

Xihang Shi
Email: xihangshi@technion.ac.il

Electron radiation technologies have been designed for decades by treating the electrons as classical point particles. This fact seems to violate the quantum uncertainty principle, which forbids particles from being simultaneously localized in space and momentum. Recent years have shown the examples of how the quantum framework contains exotic new phenomena altering classical electron radiation. For example, it has been shown that electron radiation depends on the entanglement between free electrons and the photons they emit. Here, we show how entanglement among electrons provides new degrees of freedom to control free-electron-light-matter interactions, manifested in wide ranges of photonics, from infrared photon polaritons to X-rays. In the full quantum framework, free electrons are spatially (transversely) and temporally (longitudinally) extended. The spatial and temporal structures of the wavefunction make the radiation process significantly more complex than that from a classical point charge. For example, radiation from a short electron pulse can undergo decoherence as the electron wavefunction broadens during propagation. Through engineering the electron wavefunction—for instance, through interaction with optical near-fields—one can manipulate the radiation. What is even more intriguing is that free electrons could excite quantum light directly, by utilizing post-selection of free electrons. These novel methods open possibilities for generating complex, ultrashort-wavelength quantum light, such as Schrödinger cat states.

Short Bio:



Xihang Shi received his PhD in Applied Physics from Nanyang Technological University, Singapore. He is currently a postdoctoral researcher at the Technion – Israel Institute of Technology, Israel. His research focuses on the quantum interactions between free electrons and nanophotonic materials. By bridging quantum electrodynamics, nanophotonics, and electron physics, his work facilitates the development of novel light sources—especially compact, coherent, and quantum X-ray sources, targeting spectral regions that are difficult to access with conventional optics.