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Ultrafast Quantum Optics for Femtochemistry and Biological Applications

Friday, June 27, 2025 11:30 AM (30 minutes)

Advancements in quantum optics and squeezed light generation have transformed various domains of quantum science and technology. However, real-time quantum dynamics remain an underexplored frontier. Here, we extend quantum optics into the ultrafast regime, providing direct experimental evidence that quantum uncertainty is not a static constraint but evolves dynamically with the system's state and interactions. Using ultrafast squeezed light generated via a four-wave mixing nonlinear process, we observe the temporal dynamics of amplitude uncertainty, demonstrating that quantum uncertainty is a controllable and tunable physical quantity. This offers new insights into fundamental quantum mechanics in real-time. Additionally, we demonstrate control over the quantum state of light by switching between amplitude and phase squeezing. Our ability to generate and manipulate ultrafast squeezed light waveforms with attosecond resolution unlocks exciting possibilities for quantum technologies, including petahertz-scale secure quantum communication, quantum computing, and ultrafast spectroscopy. We also introduce an ultrafast quantum encryption protocol leveraging squeezed light for secure digital communication at unprecedented speeds. This work paves the way for exploring quantum uncertainty dynamics and establishes the foundation for the emerging field of ultrafast quantum science.

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