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Unlocking Atomic Motion: Dielectric THz-Driven Accelerators for Ultrafast Electron Microscopy and Diffraction

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High-resolution electron microscopy (HREM) and ultrafast electron diffraction (UED) are crucial techniques in material science, biology, and chemistry. They enable researchers to visualize atomic structures and observe fastchanging processes, such as phase transitions, changes in molecular shapes, and chemical reactions, with high spatial and temporal accuracy. However, current electron sources have limitations regarding temporal resolution, brightness, and beam quality, which restrict their ability to effectively study ultrafast or fleeting phenomena in
complex systems.

Recent progress with Dielectric Terahertz-driven Accelerators (DTAs) provides a promising improvement. These compact devices operate within the THz range and use strong accelerating fields, exploiting shorter wavelength capabilities for particle acceleration and manipulation. Their design allows for the generation of high-quality electron beams. THz-linear accelerators can produce electron bunches lasting less than 100 femtoseconds, with an energy spread of less than 0.1%, very low transverse emittance (less than 0.1 nm·rad), and energies in the multi-MeV range.

Using these electron beams in HREM and UED would enable real-time imaging of atomic-scale movements with unmatched spatiotemporal resolution. In materials science, this advancement would permit direct observation
of rapid lattice changes and the movement of nanoscale defects. In biology, researchers could capture the motions of proteins or viral capsids with little radiation damage. In chemistry, they would allow for the visualization of transition states and reaction pathways as they occur. Therefore, THz-driven dielectric acceleration marks a significant advancement in fundamental research, providing access to beam qualities that were previously available only at huge facilities.

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