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Molecular movies: how to make them and what are they good for?

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The rate of internal motion in small molecules is far too fast to be captured by conventional high speed cinematography. The scale of motion is determined by the molecular bond lengths (Angstroms) and binding energies (electron-volts) to be millionths of billionths of seconds (femtoseconds) or shorter. Yet, recent advances in laser technology have led to pulses of light so short and bright that for the first time we can consider lasers as strobe lights to make movies of internal motion in molecules. To interpret these stroboscopic motion pictures of the internal motion in atoms and small molecules, we must reconsider the concepts of motion and pictures on the quantum scale. Three kinds of laser sources are employed to capture this motion: Strong focused infrared lasers with pulse durations of a few femtoseconds; high harmonics sources of vacuum ultraviolet light, with pulses that can be shorter than one femtsecond; and femtosecond X-ray free electron lasers. I will show how these new tools are used together to track the internal motion in atoms and molecules, and reveal the underlying internal quantum mechanical mechanisms responsible for them.