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Sculpting pulses in space and time to control ultrafast dynamics[1]

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Because of the energy-time uncertainty principle, ultrashort pulses need a wide spectral bandwidth. In the near-infrared, ultrafast pulses can have bandwidths of more than 100 nanometers. But bandwidth is not enough: the actual shape of the pulse depends critically on the phase of the spectral components. Typically, ultrafast laser beams are aligned for perfect spatial registration of the spectral components. However, in recent years, our group and others have found that the spatial and temporal properties of the pulse can be controlled by carefully manipulating the directions and overlap of the spectral components (the spatial chirp). For example, the pulse can be focused simultaneously in the spatial and temporal domains, leading to extreme localization of the intensity along the direction of the beam. This has numerous applications in micromachining, microscopy, and laser surgery. We are also considering applying these techniques to generating high-order harmonic and attosecond pulses. The control of "spatial chirp" can also be extended to novel beam geometries, such as Bessel-Gauss and vortex beams.

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