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Joseph F. Keithley Award For Advances in Measurement Science Talk: Beyond the Fringe: measuring ultrafast optical pulses using spectral interferometry

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The ability to completely characterize ultrashort electromagnetic pulses has revolutionized the field of ultrafast optics, enabling both new technology and new science. The aim of pulse characterization is to infer the electric field of the pulse from measurements of quantities that rely on standard (relatively slow) photodetectors. Since the field is a fundamental entity in Maxwell's theory, it contains the most information one may obtain about a system probed by an optical pulse, and is, in this sense, much more valuable set of data than a measurement simply of the pulse energy or even the spectral or temporal intensity, Pulse measurement methods may be categorized as spectrographic and tomographic, by which the time-frequency phase space of the pulse is mapped, or interferometric, by which the phase is determined directly. Interferometry provides a sensitivity and robust approach affording a rapid, direct reconstruction algorithm that gives a provably unique solution to the complete space-time field. An important class of self-referencing interferometric are those based on spectral shearing, whereby two frequency shifter replicas of the test pulse are generated encoding the spectral phase derivative in the spectral interferogram resulting from their superposition. The nonlinear implementation of this approach is called spectral phase interferometry for direct electric-field reconstruction (SPIDER). SPIDER has shown itself to be an adaptable and robust method, gaining widespread application in all areas of ultrafast optics, from nonlinear microscopy to attoscience. Some essential concepts and history of the field will be presented, along with recent developments, illustrating applications in ultrafast source diagnosis and certification, dynamical spectroscopy, coherent control, imaging and materials processing.