Directly recording diffraction phenomena in time domain

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Diffraction phenomena are traditionally studied with steady-state or monochromatic illumination. However, describing diffraction effects for ultrashort pulses—ideally of a single-cycle—is surprisingly simple, because in this case the light fields before and after diffraction are well localized in space and time. Diffraction in the time domain can simply and elegantly be described using the so called boundary wave diffraction theory, which is not widely known though it dates back to the times of Thomas Young (see references in [1]). In this paper we report results of our pioneering study of the diffraction of ultrashort pulses from various optical elements, which were recorded with ~5 \(\mu\)m spatial and ~5 fs temporal resolutions using the technique SEA TADPOLE. Briefly, this technique involves sampling the wavefield at different distances \(z\) with a single-mode optical fiber and then interfering it with a reference pulse in a spectrometer to reconstruct \(E(t,x,y,z)\) for every spatial point [2].

We have measured the spatiotemporal field of ultrashort pulses behind circular holes, an opaque disk (see Fig. 1.), circular gratings, an axicon lens, annular slits and etc. The latter two elements actually generate “non-diffracting” and non-spaying Bessel-X pulses—a typical representative of the so-called localized waves [3]—which propagate superluminally as was first demonstrated in [4].