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Abstract: We construct several examples showing that two distinct pulses can have identical intensity autocorrelations and power spectra, from which we infer that retrieval methods based on these two datasets alone produce ambiguous solutions.

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Because of the difficulty in resolving optical pulses on a femtosecond scale with electronic detectors, many techniques to indirectly obtain pulse shapes have been developed. Frequency-resolved optical gating is one of the most commonly used measurement methods [1]. It provides a two-dimensional dataset known to suffice for uniquely determining both amplitude and phase of a pulse. Nonetheless, aiming at less complex experimental setups and faster convergence of retrieval algorithms, some researchers have invented pulse-retrieval methods using one-dimensional datasets generated from conventional measurements, such as electric-field and interferometric autocorrelations [2-4]. These approaches, however, may raise nontrivial ambiguity problems unless sufficient data are involved.

Naganuma *et al.* used the interferometric autocorrelation function as the input to their iterative algorithm [2]. This is equivalent to three datasets: the electric-field autocorrelation (equivalently, the power spectrum), the intensity autocorrelation, and the second-harmonic-field autocorrelation, all of which are contained in the interferometric autocorrelation. Baltuska *et al.* exploited two traces, the fringe-averaged intensity autocorrelation and the power spectrum while Peatross *et al.* utilized only the intensity autocorrelation [3,4]. Unlike Naganuma¡s algorithm, the others are based on one or two input traces and can have room for ambiguity, despite the nonnegative-intensity condition. Theoretical approaches for this uniqueness problem reach different conclusions depending on their assumptions, such as the conditions of finite support, optical realizability, or analytic solutions [5]. In this paper, we explicitly construct examples demonstrating that retrieval from the (fringe-averaged) intensity autocorrelation and power spectrum [3,4] leads to ambiguous solutions, even under ideal (zero-noise) conditions. This result raises significant concerns about the validity of the retrieval procedures in [4], which are apparently still sometimes utilized in practice.

We adopt the following approach. We assume that two finite-supported datasets are available via the intensity autocorrelation and power spectrum.

(1) We first choose an asymmetric intensity profile $I(t)$ and then generate its autocorrelation $G_2(?)$.

(2) The Fourier transform of $G_2(?)$ gives $|\tilde{I}(?)|^2$, where $\tilde{I}(?)$ is The Fourier transform of $I(t)$. By setting the spectral phase of $\tilde{I}(?)$ to zero, we can derive a symmetric intensity profile with an autocorrelation identical to that of the original asymmetric intensity profile.

(3) We then assign a flat temporal phase to either the asymmetric or symmetric temporal field envelope and Fourier-transform it to find the resulting power spectrum $|\tilde{E}(?)|^2$. The temporal phase of one of the field envelopes is left unspecified at this point.

(4) Finally, we use Gerchberg-Saxton¡s method [6] or gradient-based methods to retrieve a temporal phase profile (for the pulse left unspecified in the previous step), consistent with both the intensity profile and power spectrum $|\tilde{E}(?)|^2$.

This results in a pair of pulses, one symmetric and one asymmetric, with identical autocorrelations and power spectra.

Figure 1 illustrates resultant traces in the case when the asymmetric pulse is assumed to have flat phase (Fig. 1(c)). The intensity autocorrelations of the symmetric field (output of the algorithm) and of the assumed asymmetric field are not distinguishable as shown in Fig. 1(a). Fig. 1(b) shows the two power spectra which are also identical within an error of 4.7¡ 10^{-4} but with two different spectral phase profiles. This error due to the stagnation of the algorithm is negligibly small and is believed to be limited by the reconstruction algorithm. The generated symmetric electric-filed envelope is plotted in Fig. 1(d).

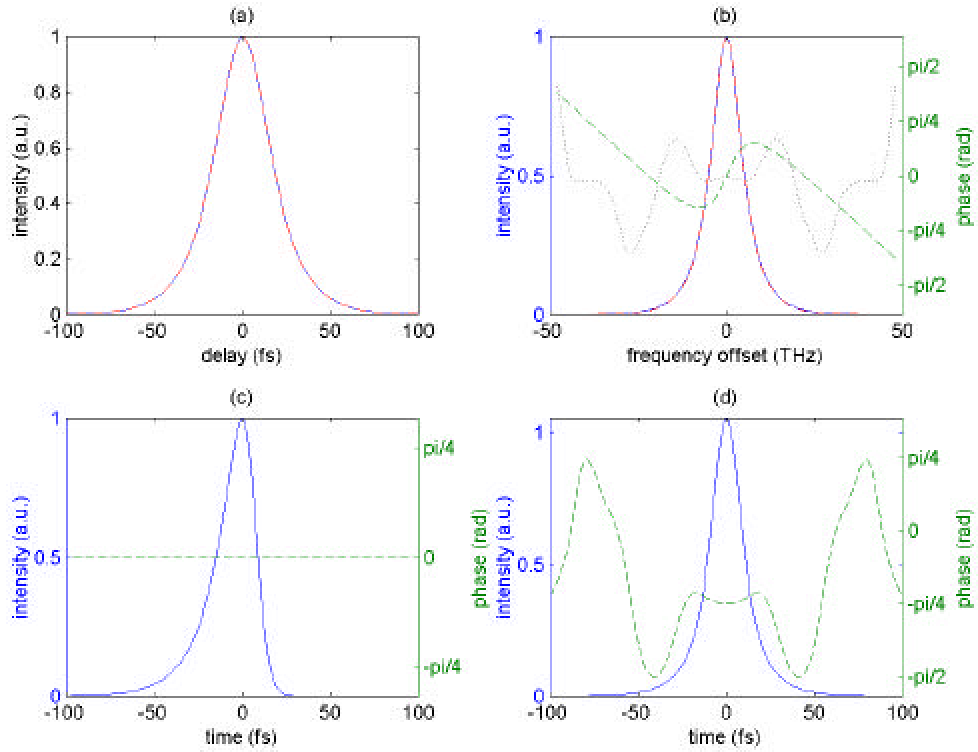

Fig. 1. Resultant traces when the asymmetric pulse is assumed to have flat phase. (a) Autocorrelation traces of asymmetric (solid) and symmetric (dash dot) pulses. (b) Power spectra of asymmetric (solid) and symmetric (dash dot) pulses and spectral phases of the same asymmetric (dashed) and symmetric (dotted) pulses. (c) Intensity (solid) and phase (dashed) of the asymmetric electric-field envelope. (d) Intensity (solid) and phase (dashed) of the symmetric electric-field envelope.

The graphs in Figure 2 result from the opposite case where the algorithm retrieves the phase of the asymmetric pulse (Fig. 2(c)) under the assumption that the symmetric pulse has flat phase (Fig. 2(d)). This example also gives identical intensity autocorrelations (Fig. 2(a)) and power spectra (Fig. 2(b)).

Through this analysis, we have illustrated the ambiguity of ultrashort pulse shapes retrieved from the intensity autocorrelation and power spectrum alone. In our talk we will also discuss other examples and compare the calculated interferometric autocorrelations of such symmetric-asymmetric pulse pairs, which are predicted to be distinct [2], in order to assess the degree to which they can be distinguished in a practical context.

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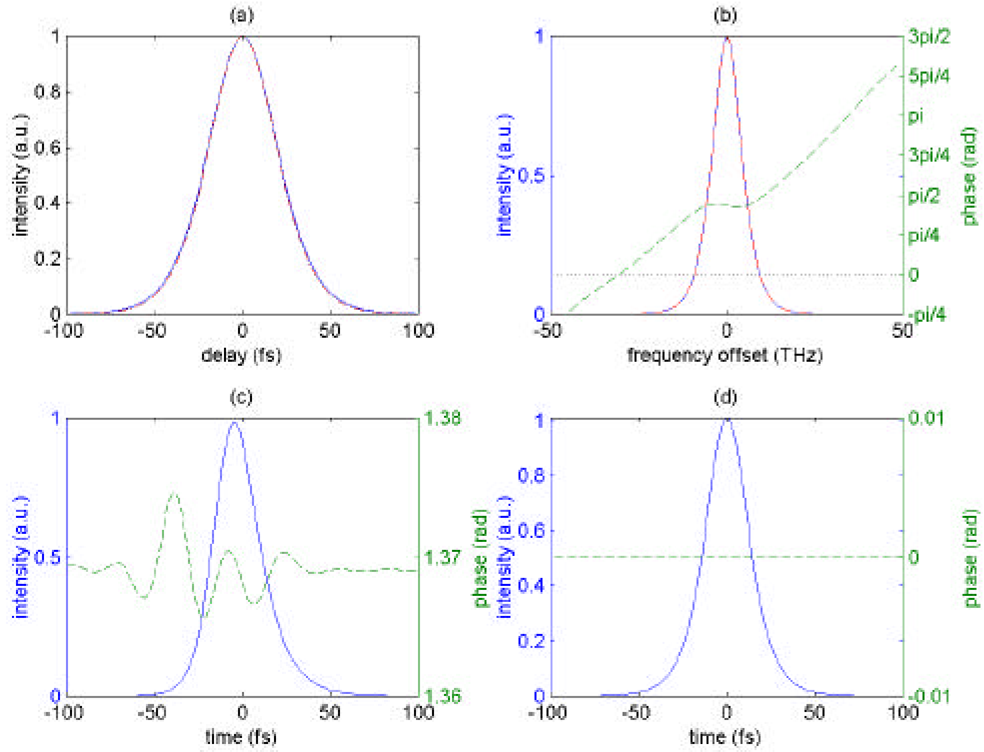

Fig. 2. Resultant traces when the symmetric pulse is assumed to have flat phase. (a) Autocorrelation traces of asymmetric (solid) and symmetric (dash dot) pulses. (b) Power spectra of asymmetric (solid) and symmetric (dash dot) pulses and spectral phases of the same asymmetric (dashed) and symmetric (dotted) pulses. (c) Intensity (solid) and phase (dashed) of the asymmetric electric-field envelope. (d) Intensity (solid) and phase (dashed) of the symmetric electric-field envelope.