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Time-domain ptychography, from PIE to iPIE to pPIE

Spangenberg Dirk-Mathys*(1),Brügmann Michael(2),Rohwer G. Erich(1) and Feurer Thomas(2)
(1) LRI, Stellenbosch University, Private Bag X1, 7602 Matieland, South Africa; email: dspan@sun.ac.za
(2) IAP, University of Bern, Sidlerstr. 5, 3012 Bern, Switzerland; email: thomas.feurer@iap.unibe.ch

Ultrashort laser pulse characterization requires the reconstruction of the amplitude and phase of the electric field since no detector is fast enough for direct measurement. Several techniques for this purpose exists eg. FROG[1], SPIDER[2], MIIPS[3] and many more. Ptychography[4], a lens-less imaging technique that reconstructs the spatial phase from measured diffraction patterns, has recently been migrated to the time domain [5]. The temporal analogue of this technique uses measured spectrums for known relative time delays between a temporal object and a known probe to reconstruct the temporal object in the same manner. Pulse autocorrelation schemes requires using a probe derived from the pulse itself in order to determine the unknown pulse. In our application of time domain ptychography to the pulse characterization problem[6, 7], a known transfer function $h(t)$ is applied to the unknown input pulse $i(t)$ to generate a new probe pulse before multiplication with a time delayed input pulse as described by the relation,

$$I_n(t,\tau_n) = |\mathscr{F}\{i(t)\,[h(t)\otimes i(t-\tau_n)]\}|^2 \tag{1}$$

where $\mathscr{F}$ is the Fourier transform and the $\otimes$ is the convolution operator. Here it is possible to modify the PIE algorithm such that no knowledge of the temporal object and probe is needed only the modification to the temporal object as represented by the transfer function h(t). Further it is possible to modify the PIE algorithm in a similar fashion to handle a family of more complex measureable processes where the result is the multiplication of the electric field. Colinear measurements as described by the umbrella relation,

$$I_n(t,\tau_n) = \left|\mathscr{F}\left\{[i(t)\otimes h_n(t)]^2\right\}\right|^2, \tag{2}$$

of which for example MIIPS measurements are part of. We have modified the PIE algorithm to accomodate this family of pulse autocorrelation measurement. We refer to the modification of the algorithm as process PIE (pPIE). The modification requires knowledge of the process and incorporation of the new estimate by updating the function estimate with the known process.

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