Phase-Sensitive Parametric Mixing for Temporal-Domain Pulse Shaping

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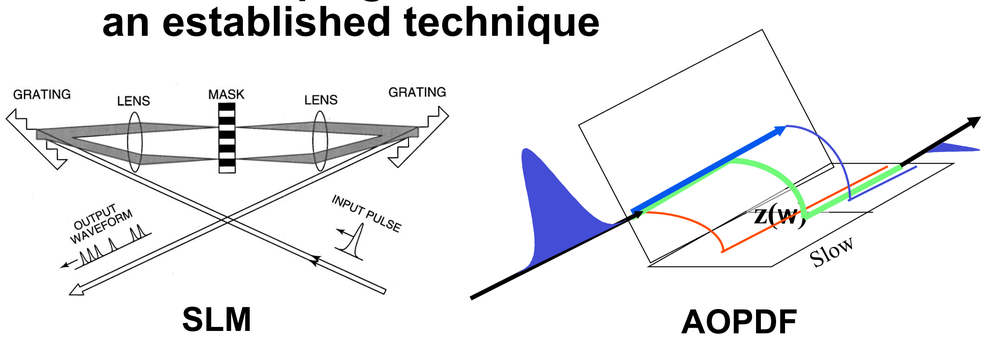
***Abstract:** Fourier domain pulse methods have been successfully applied to numerous applications where they enabled important advances in producing and understanding ultrafast phenomena. However, passive pulse shaping by amplitude and phase manipulation in the spectral domain exhibits certain limitations, which are manifested particularly in pulse shaping scenarios in which pulses exhibit inconvenient Fourier representations. An alternative approach to Fourier domain shaping is proposed, based on the ubiquitous nonlinear three-wave mixing interaction. Of particular interest is the optical parametric amplifier operated in the phase-sensitive mode (PS-OPA). While the OPA is usually used in a phase-insensitive mode as a power amplifier, its operation as a phase-sensitive amplifier (PSA) offers an attractive set of features for temporal pulse shaping. Unlike pulse shaping methods used to date, the approach proposed here can broaden the spectral bandwidth of the initial pulse, similar to self-phase modulation (SPM). In contrast to SPM process, however, the PS-OPA exhibits both the amplitude and the phase cross-modulation. We demonstrate that the PS-OPA at optical frequencies is realizable in standard nonlinear crystals, offering additional attractive possibilities such as phase amplification when compared to phase-insensitive configurations.*

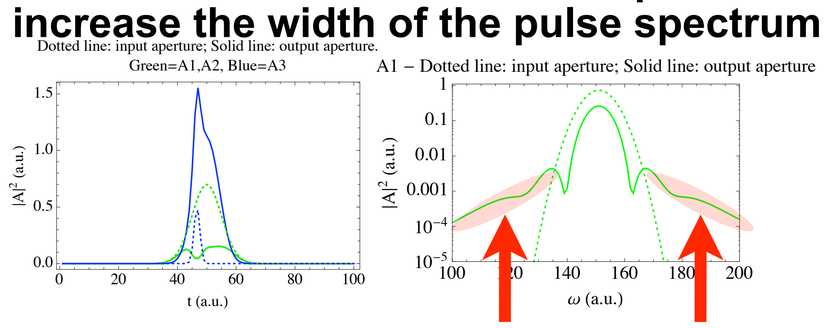
Pulse shaping in the Fourier domain is an established technique



SLM **AOPDF**

A. M. Weiner, Rev. Sci. Instrum. **71**, 1929 (2000).
P. Tournois, Opt. Comm. **140**, 245 (1997)
F. Verluise, V. Laude, Z. Cheng, Ch. Spielmann, P. Tournois, Opt. Lett. **25**, 575 (2000).

Passive Fourier-domain techniques do not increase the width of the pulse spectrum



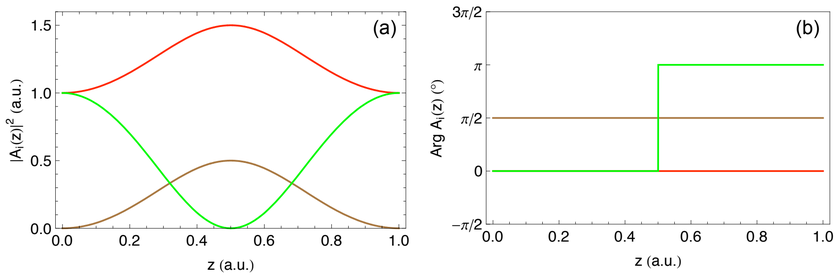
Phase-sensitive parametric amplification generates additional frequencies, unlike shaping in Fourier space.

Temporal pulse shaping via three-wave mixing goes beyond the capability of Fourier pulse shapers.

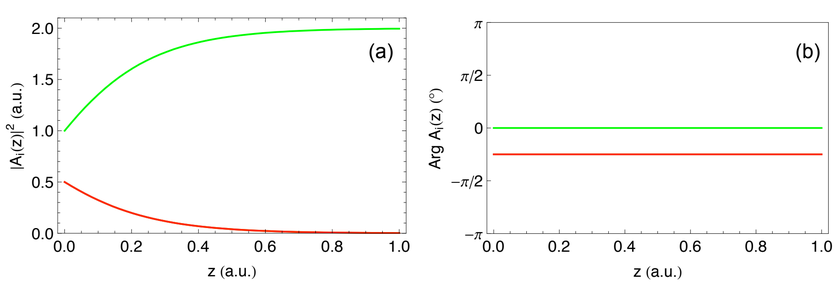
Phase-sensitive TWM features:

- operates in configuration space (x,t)
- utilizes a nonlinear process
- active: can redistribute energy in different frequencies
- can access regimes with inconvenient Fourier representations
- requires interferometric timing

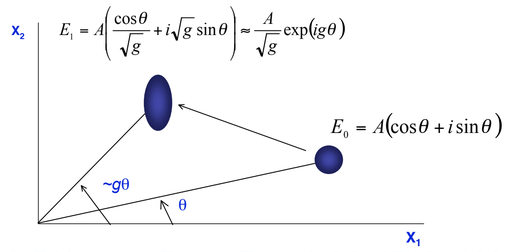
Phase insensitive TWM (PI-TWM)



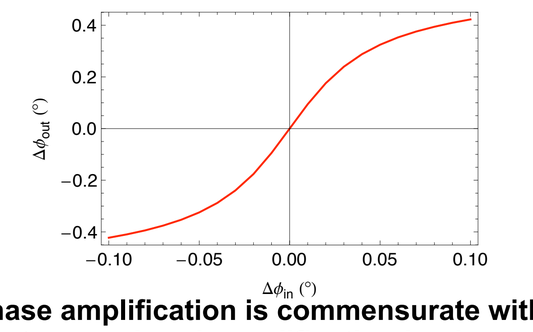
Phase sensitive TWM (PS-TWM)



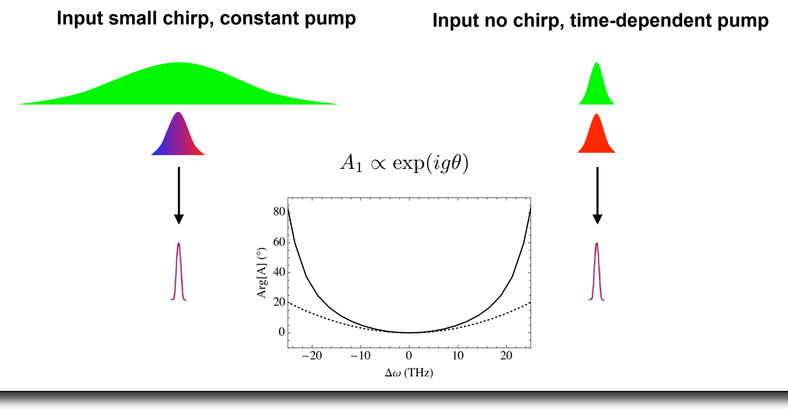
Phase amplification



G. M. D'Ariano, Phys. Rev. A **54**, 4712 (1996).



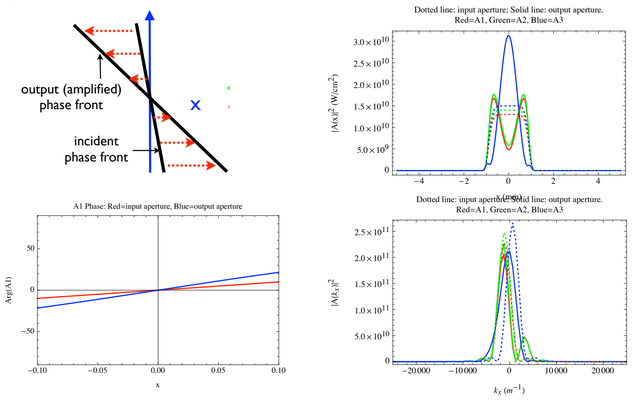
Phase amplification is commensurate with photon number deamplification in phase sensitive TWM.



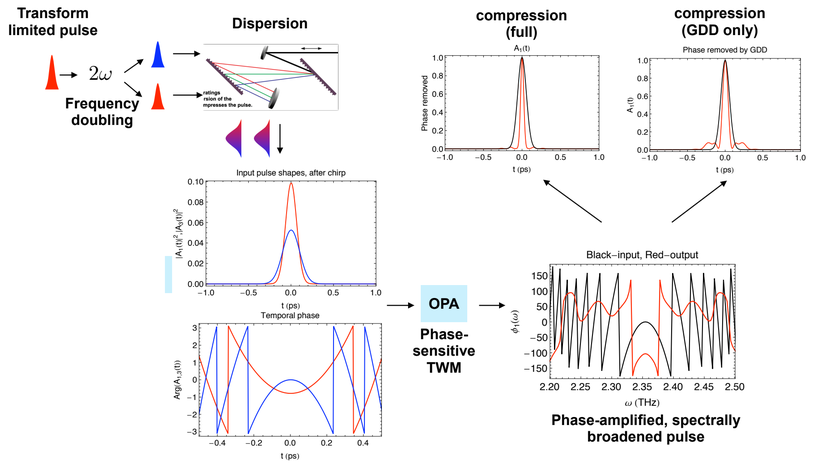
Position-variable phase amplification can be used for angular amplification

Consider the simplest case of a plane wave incident on an infinitely large aperture.

The phase difference between signal/idler and the pump wave will amplify the phase profile, resulting in angular amplification.

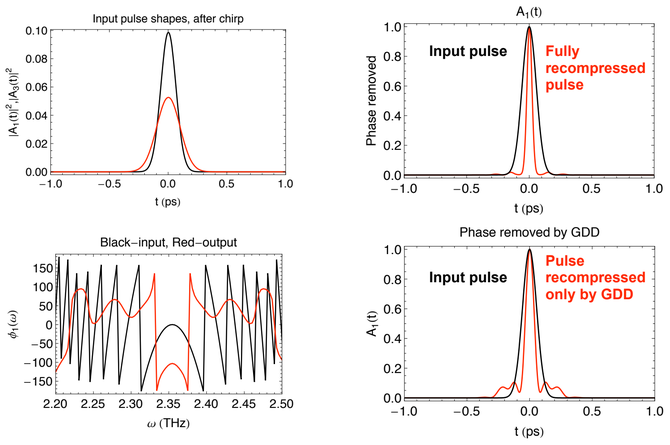


Example of the reduction of pulse duration by use of PS-TWM

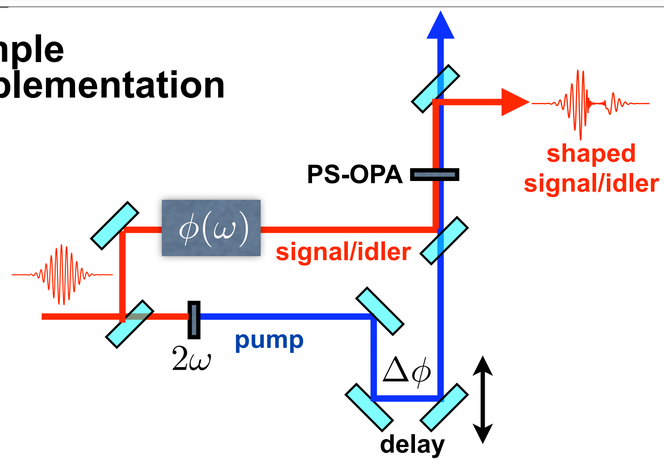


Example of the reduction of pulse duration by use of PS-TWM

$\lambda_{1,2} = 800\ nm, \lambda_3 = 400\ nm$
$\Delta\lambda_{1,2} = 10\ nm$
$GDD_1 = 1.8 \times 10^4\ fs^2$
$GDD_3 = 3.6 \times 10^4\ fs^2$



Simple implementation



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