Optical pulse transforms using tapered optical fibres

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A common problem in optics is optical pulse transformation which can be done in either the spatial or the temporal domain. In the spatial domain, beam reshaping has many different solutions from holography and phase plates to using a simple lens. Similarly in the temporal domain different solutions such as fibre Bragg gratings can be used to alter the profile of a pulse, producing square or parabolic pulses from a sech-shaped input for example. A common feature of all these schemes is the linear nature of the transformation which means that no new frequency components are introduced and thus for a transformed limited input pulse the transformed pulse will always be longer. If pulse compression and reshaping is desired then nonlinear effects must be introduced and in this paper I look at how to design long fibre tapers in order to control the output pulse characteristics in the nonlinear regime.

In a tapered optical fibre the pulse envelope obeys the usual nonlinear Schrödinger equation with varying coefficients[1]:

$$i\frac{\partial\psi}{\partial z} - \frac{\beta_2(z)}{2}\frac{\partial^2\psi}{\partial t^2} + i\frac{\alpha}{2}\psi + \gamma|\psi|^2\psi = 0 \quad (1)$$

where the normalised pulse envelope is given by ψ while the effect of tapering is included in the position dependent dispersion coefficient β_2. The problem of pulse transformation then can be restated as whether or not a dispersion profile exists that transforms a given input pulse shape into a desired output one. Due to the nonlinear nature of the problem numerical methods must be used and I used a genetic algorithm to find the optimised dispersion profile for a variety of desired pulse shapes[2].

In order to compare results with previous results I examined the generation of parabolic pulses. Such pulses form naturally in a normal dispersion fibre amplifier and various schemes have been proposed to generate them in passive dispersion fibres[3]. Using the standard transformation between gain and dispersion variations for the NLSE, parabolic pulses should form in an exponentially decreasing dispersion varying fibre. In contrast the optimal dispersion profile that I find is shown in Fig. 1(b) which shows that the dispersion initially decreases and then increases again near the end. The misfit parameter for this parabolic pulse is several orders of magnitude better than that previously published illustrating the power of this method. I have also looked at generating square pulses and a typical result is shown in Fig. 1(c). Here the abrupt change in the electric field is hard to create due to the finite bandwidth of the input source and so the transformation is not as successful as the parabolic pulses.

In conclusions I have presented a new method for temporally transforming the shape of optical pulses using nonlinear propagation in dispersion varying optical fibre tapers. Compared to other linear methods nonlinear propagation allows the generation of new frequencies and thus this method can create shorter pulses than the input pulses. A genetic algorithm is used to solve the nonlinear optimisation problem with excellent results.

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[1] G. P. Agrawal, "Nonlinear Fiber Optics" Academic Press, 2001.
[2] N. G. R. Broderick, "Method for pulse transformations using dispersion varying optical fibre tapers" Opt. Ex. **18** pp 24060 (2010).
[3] C. Finot *et al.* "Optical parabolic pulse generation and applications", IEEE J. Quant. Elect. **45** pp 1482 (2009).

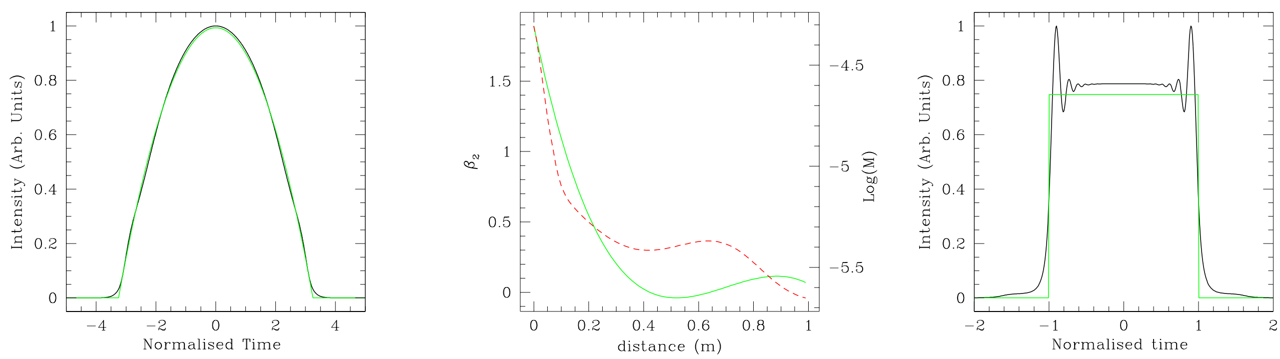

FIG. 1. (a) Parabolic pulse and associated fit (green line). (b) Optimised dispersion profile and associated misfit (red line), (c) Square pulse generation attempt.