Characterising Solitons with Tuneable Multi-peak Spectra

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Conventional optical solitons are pulses formed by the balance of anomalous 2nd order dispersion (β_2) with the nonlinear Kerr effect in a medium. However, in the last decade, mounting interest in solitons generated using higher even-order dispersion has been prompted by the experimental discovery of pure-quartic (4th order dispersion) solitons [1]. For example, appropriate combinations of higher dispersion orders produce dispersion relations with multiple peaks. The resulting solitons comprise separate spectral components, which beat to generate oscillatory temporal solutions. In a previous study [2], the analysis of such pulses was limited to the case where all dispersion peaks have the same local curvature (i.e. β_2) and wavenumber (red curve, Fig. 1(a)).

We explore the regime where this is not true and again find soliton solutions with several spectral components. For a fixed dispersion relation, these pulses form a family whose characteristic property is that their relative spectral component intensity depends on the pulse power. To show this, we simulate two pulses from the same three-peaked dispersion relation where the two side peaks are raised by 0.5 km^{-1}, but all peaks share the same curvature, $\beta_2 = -4$ ps^2/km (red curve, Figs. 1(b), 1(c)). These pulses were chosen to differ in peak power, increasing from 1.7 W to 3.4 W in their temporal profiles from Figs. 1(e) to 1(f). Indeed, this causes an increase in the relative intensity of the central spectral component (blue curve, Figs. 1(b), 1(c)). By studying the limit where the middle spectral pulse becomes arbitrarily small, we can also predict the existence of critical points, below which, the pulse power is too low to sustain it. We thus see that dispersion relations with multiple peaks generate families of multi-frequency optical pulses whose members are distinguished by tuning their power.

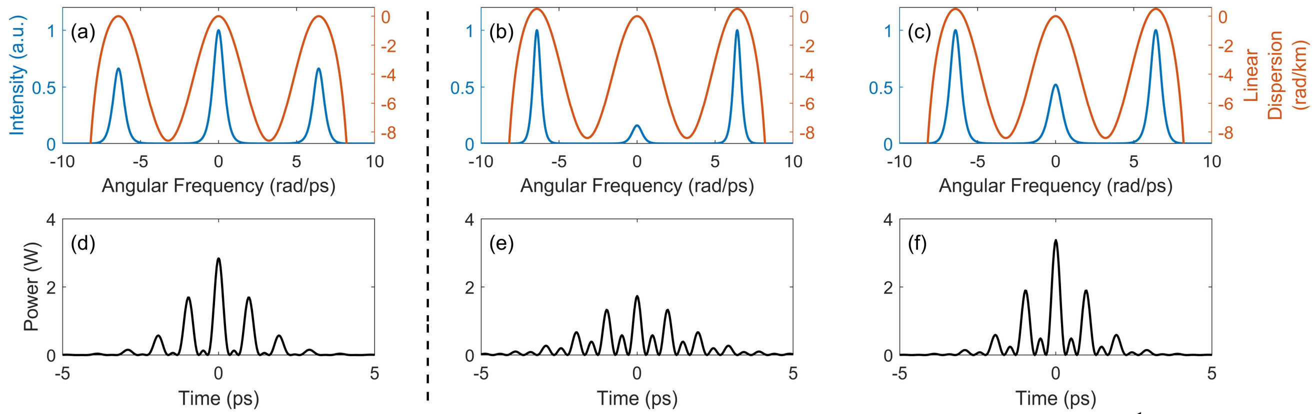

Fig. 1. Dispersion relations (red) with (a) equal peaks and, (b,c) side peaks raised by 0.5 km^{-1}, and produced soliton spectra (blue). Temporal profiles for the spectra given in (a-c) are shown in (d-f) respectively.

[1] A. Blanco-Redondo, *et al*., *Nat. Commun*. **7**, 10427 (2016).

[2] J. P. Lourdesamy, *et al*., *Nat. Phys*. **18**, 59 (2022).