Temporal reflection in a nonlinear photonic integrated circuit

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There is much current interest studying temporal analogs of optical reflection and refraction in optical fibers [1]. These dynamics describe the processes where ultrashort pulses undergo large frequency shifts at a temporal index barrier, closely related to the concept of the optical event horizon [2].

In this work, we report experimental signatures of multiple temporal reflections enabled by dual-wavelength pumping of a high-index doped silica glass integrated waveguide [3,4]. By employing stabilized and synchronized Ytterbium and Erbium femtosecond lasers operating at 1040 nm and 1550 nm respectively, we demonstrate temporal reflection of the 1040 nm pulse interacting with the 1550 nm soliton barrier. These reflections induce significant frequency shift, which show good agreement with numerical simulations and phase-matching theory. Furthermore, the temporal reflection dynamics are shown to generate additional resonant radiation components, effectively broadening the supercontinuum bandwidth.

Figures 1(a) and 1(b) illustrate the waveguide cross-section and dispersion profiles for TE and TM modes, and Fig 1 (c) shows the dual-pump experimental setup. Short pump pulses at 1040 nm and 1550 nm are coupled into a 50 cm long spiral waveguide, with electronically controlled time delay between the two pulses. Figures 1(d) and 1(e) show the output spectra from experiment and numerical simulations respectively, plotted in false color as a function of delay between the input pulses. As the delay approaches zero, the pulses interact strongly through cross-phase modulation (XPM), resulting in significant frequency chirp on both pulses and temporally-localized spectral peaks associated with reflection-induced resonant radiation seen at around 722 nm in experiments and 735 nm in simulations. Note that we also observe a non-temporally-localized spectral peak around 710 nm corresponding to the dispersive wave (DW) emitted by the 1550 nm soliton under single-pump conditions. These results can be interpreted physically through the simulated spectral and temporal evolution maps in Figs 1(g-h) and also by the phase-matching curves in Fig. 1(f). The yellow curve in Fig. 1(f) represents the frequency shift induced by temporal reflection, while the red curve corresponds to the dispersive wave (DW) emitted by the 1550 nm soliton under single-pump conditions [4].

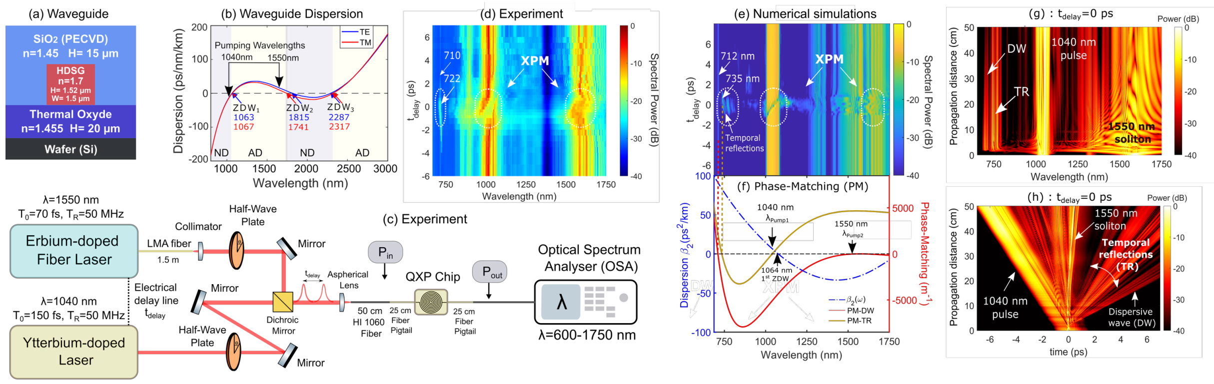

Figure 1: (a) Waveguide cross-section. (b) Group-velocity dispersion of TE and TM modes. (c) Schematic of dual-pumping experiment. Experimental (d) and numerical (e) output spectra for dual-pumping at 1040-nm and 1550-nm as a function of delay (t_{delay}) between the two pump pulses. (f) Dispersion curve (left axis, blue curve) and phase-matching curves (right axis) for resonant radiation: (i) at 735 nm from temporal reflection (TR) (yellow curve) and (ii) at 712 nm from dispersive wave (DW) emission by the 1550-nm soliton at 712 nm (red curve), (g) and (h) : spectral and temporal evolutions along the waveguide showing the temporal reflections of the 1040-nm pulse on the 1550-nm soliton index barrier.

References

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