Max-Born Institute
for Nonlinear Optics and
Short Pulse Spectroscopy

Optical Transistor: From Optical Event Horizons to Rogue Waves

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Abstract

We demonstrate that the properties for the concept of an optical event horizon are naturally given in the supercontinuum (SC) generation process when fundamental solitons (FS) interact with surrounding dispersive waves (DW). Under certain conditions this interaction leads to strongly accelerated solitons with extremely high peak powers. Using the underlying mechanism in a deterministic way makes an all-optical control of light pulses possible. This can be done in a very efficient and versatile manner with the opportunity to overcome the main limitations for realizing an optical transistor.

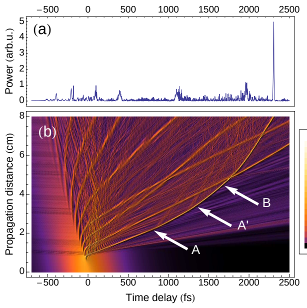
Emergence of a giant soliton

Non-envelope propagation model for ultrashort pulses with dispersion and Kerr nonlinearity provides the minimum set of optical effects necessary for the formation of rogue waves

$$i\partial_z \mathcal{E}_\omega + |\beta(\omega)|\mathcal{E}_\omega + \frac{3\omega^2\chi^{(3)}}{8c^2|\beta(\omega)|}(|\mathcal{E}|^2\mathcal{E})_\omega = 0$$

Pulse electric field $E(z,t) = \mathrm{Re}[\mathcal{E}(z,t)]$.

SC generation by soliton fission



Typical temporal SC evolution in a photonic crystal fiber with one ZDW.

One wave is exceeding the average wave crest by more than a factor of three.

Parabolic trajectory of one FS with strong increase of the peak power between A and B.

A, A': FS-DW interaction with conditions for an optical event horizon.

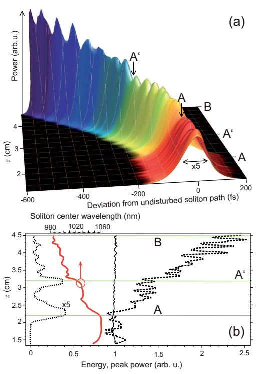
Isolation of the energy transfer between the DWs and the champion soliton

$I_{1,2}$ are finite and proportional to the time-averaged photon flux and power, respectively:

$$I_1 = \sum_\omega \frac{n(\omega)}{\omega}|\mathcal{E}_\omega|^2$$

$$I_2 = \sum_\omega n(\omega)|\mathcal{E}_\omega|^2$$

Development of $\lambda_0(z)$ (red line), pulse energy $\propto I_2$ (black line), and peak power $P_0(z)$ (dashed line). Energy content of the dispersive wave (dotted line).



Collaborations

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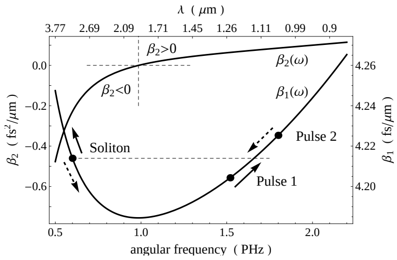
Key conditions for optical Event Horizon

Group velocity dispersion β_2 and relative group delay β_1 of fluoride glass.



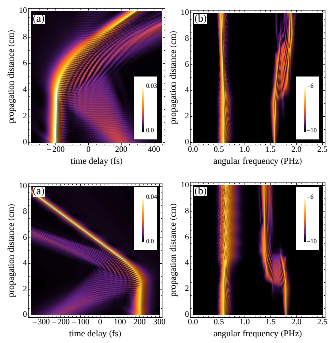
Nonlinear refractive index change due to an intense soliton.

Frequency combinations for a soliton and a control pulse with nearly equal group velocities.

=> Extending the interaction length for an enhanced XPM

All-optical control with an Event Horizon

Manipulation of a strong soliton signal by a much weaker control pulse



Faster control pulse
Redshift of the signal; energy from signal to control pulse.
=> Switch Off

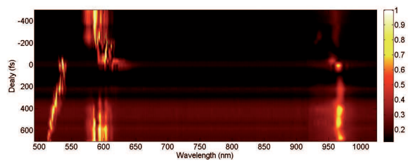
Manipulation of the soliton strongly depends on the induced frequency shift which can be adjusted by the control pulse parameter

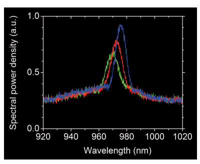
Faster signal pulse
Blue shift of the signal, signal is compressed.
=> Switch On

Concept for an optical Transitor fulfilling all Miller criteria

Experimental verification

Wavelength switch induced for a FS and a DW with a power ratio 4:1





Variation of the time delay between a faster control pulse and a signal. Strong blue shift for the control pulse and a small red shift for the signal.

Publications

- A. Demircan, Sh.Amiranashvili, G. Steinmeyer *'Controlling light by light with an optical event horizon'*. Phys. Rev. Lett. **16**,163901 (2011).
- A. Demircan, Sh. Aminarashvili, C. Bree, Ch. Mahnke, F. Mitschke, G. Steinmeier *'Soliton acceleration by dispersive waves: a contribution to rogue waves?'*, Phys. Rev. Lett. (2011), submitted.
- Sh.Amiranashvili, A. Demircan *'Hamiltonian structure of propagation equations for ultrashort optical pulses'*. Phys. Rev. A **82**, 013812 (2010).