Optical limiting and noise suppression in fiber network through coherent control of absorption in plasmonic metamaterial

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Abstract: We demonstrate that in a nonlinear fibre optical network coherent interaction of light with a plasmonic metamaterial can be used for power-limiting as well as noise reduction applications.

Suppression of high intensity "light spikes" as well as noise reduction is essential in fibre telecommunication networks. Such functions of optical limiting and contrast enhancement are inherently nonlinear. Here we demonstrate experimentally how intensity-dependent optical phase shifts introduced by nonlinear optical fibres can be used to control absorption in a plasmonic metamaterial absorber to perform either optical limiting or enhancement of the intensity contrast between signal pulses and background noise.

Optical absorption of a lossy film of substantially subwavelength thickness can be controlled by counterpropagating coherent light waves, in principle from 0% to 100%. Destructive interference of both waves on the absorber results in perfect transparency as the light-matter interaction is prevented by electric field cancellation. Constructive interference of both waves causes enhanced absorption due to interaction of the absorber with an enhanced electric field. Preferential absorption of either high intensities (optical limiting) or low intensities (noise suppression) may thus be achieved if the intensity of light controls constructive and destructive interference on a thin absorber.

Here we exploit the nonlinear phase shift introduced by high intensity pulses propagating through a nonlinear optical fibre to control absorption in a plasmonic metamaterial absorber (Fig. 1a). A pulsed input signal is split along linear and nonlinear optical paths that recombine on a metamaterial absorber with an intensity-dependent phase difference. There are two regimes of operation. If the optical signals destructively interfere at low intensities resulting in low absorption, then the nonlinear phase shift resulting from increased intensity will increase absorption resulting in optical limiting. We observe that the output power stabilizes and then falls with increaseing input power for input peak powers of 130 – 170 mW (Fig. 1b). On the other hand, if the optical signals constructively interfere at low intensities resulting in high absorption, the nonlinear phase shift with increasing intensity will reduce absorption resulting in contrast enhancement. We observe that input pulses with 150 and 180 mW peak power (20% contrast) yield output pulses with 30 and 90 mW peak power (200 % contrast, Fig. 1c).

The experiments were conducted in a fibre-optic network with a plasmonic metamaterial consisting of a gold film of 70 nm thickness perforated with an array of asymmetrically split ring apertures on the core of a cleaved optical fibre (inset Fig.1a). The nonlinear optical fibre was a HNLF type (OFS) optical fibre of 299 m length with an effective nonlinear coefficient $\gamma=10.4(W*km)^{-1}$. All experiments were conducted at the 1550 nm telecom wavelength using 1 ps pulses with 10 GHz repetition rate and up to 1 W peak power in order to engage the fibre's nonlinearity, followed by attenuation to prevent optical damage to the metamaterial absorber.

In summary, we report all-optical power limiting as well as 10-fold contrast enhancement in a fibre-optic network based on use of fibre nonlinearities to modulate coherent absorption in a plasmonic metamaterial. Potential applications include optical damage prevention and signal-to-noise-ratio enhancement in all-optical signal processing and telecommunications networks.

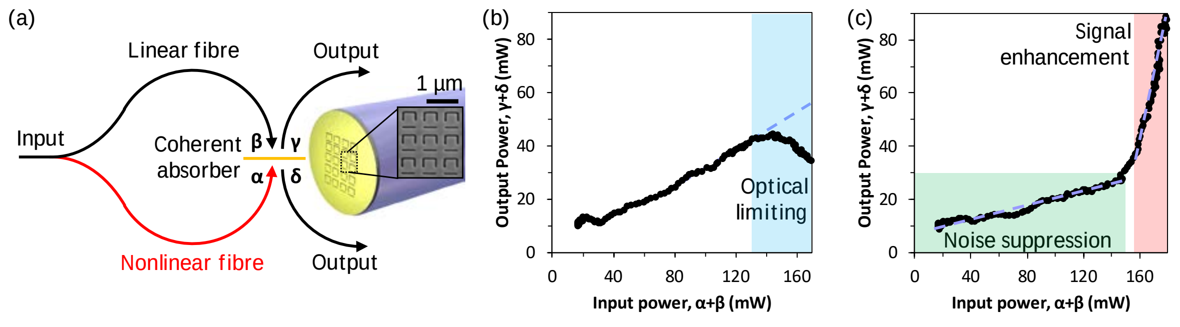

Fig. 1 Optical limiting and contrast enhancement based on nonlinear control of coherent absorption. (a) An input signal is split along linear and nonlinear optical paths that recombine on a metamaterial coherent absorber, such that the nonlinear phase shift controls absorption in the metamaterial. The inset shows part of the metamaterial on the core of an optical fibre. (b,c) Output power as a function of input power in regimes of (b) optical limiting and (c) contrast enhancement. All powers are peak powers of 1 ps pulses just before/after interaction with the metamaterial coherent absorber.