Dissipative Optical Switch for Coherent Fibre Networks with 100 THz Bandwidth

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We provide the first demonstration of a high-bandwidth, low-intensity fiberized all-optical gate exploiting coherent absorption in a plasmonic metamaterial film. The fully packaged fiberized version of the switch has been tested to the bandwidth of 1 GHz while free-space versions of the gate have been shown to provide 100 THz bandwidth and to operate at arbitrarily low intensities. Our work illustrates how major bandwidth and energy challenges of optical telecommunications and information processing networks can be tackled by merging metamaterials and optical fibre technologies.

The metadevice exploits that strong light-matter interaction can be achieved with engineered metasurfaces that are thin compared to the wavelength. This creates the opportunity to place a metasurface at a node or anti-node of the standing wave formed by counter-propagating coherent optical signals (Fig. 1(a)), corresponding to negligible and enhanced light-matter interaction, respectively, e.g. 0% absorption and 100% absorption. This approach does not rely on nonlinear materials and therefore it can offer high optical contrast in combination with up to 100 THz bandwidth (plasmon lifetime) and arbitrarily low intensities down to the quantum regime. Nevertheless, it allows one optical pulse to be switched off by another and other essentially nonlinear functionalities enabling applications from all-optical amplification to all-optical logic gates. The device principle was tested successfully with 10 fs optical pulses as well as single photons.

Our fully packaged fiberized metadevice is based on a plasmonic metamaterial fabricated on the end face of a polarization-maintaining single-mode telecommunications fibre (Fig. 1(a)). The plasmonic nanostructure of 70nm thickness acts as switchable absorber, allowing the absorption of one optical pulse to be controlled by another coherent optical pulse. We demonstrate nonlinear input-output characteristics and all-optical logical data processing functions including NOT, AND and XOR (Fig. 1(b)) at kHz and GHz bitrates in a fibre network assembled from standard telecoms components at 1550 nm wavelength.

In summary, we report a first working prototype of a data processing metadevice that is compatible with existing optical telecommunications technology. We anticipate that such metadevices can provide solutions for low-energy all-optical information processing at up to 100 THz as well as quantum information networks.

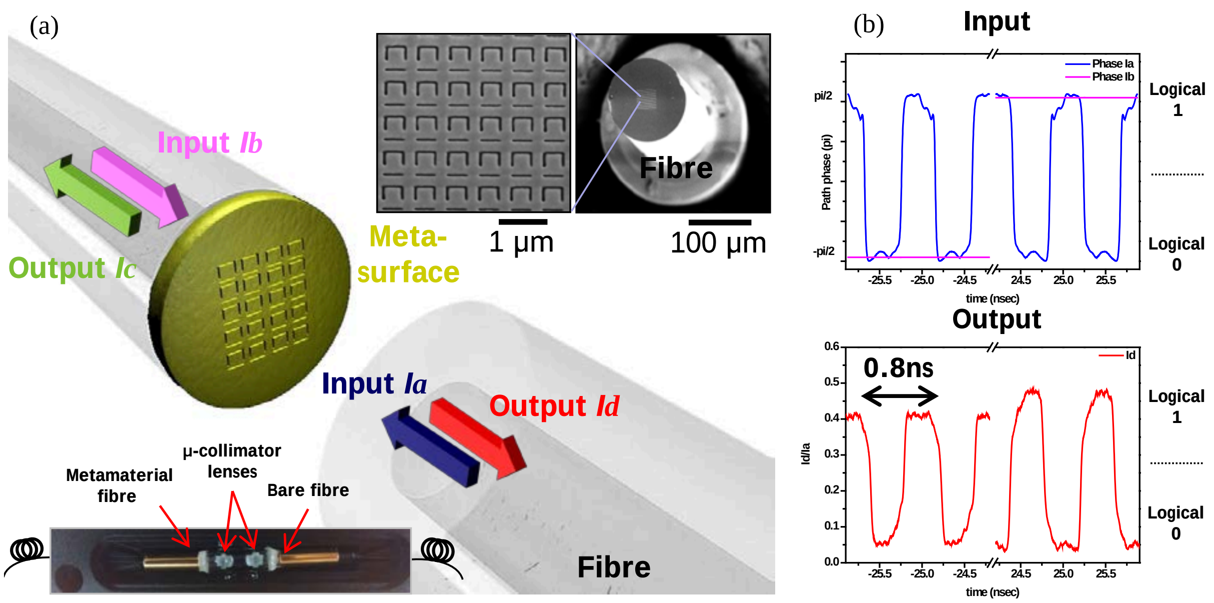

Fig. 1 (a) Schematic of the data processing metadevice based on coherent interaction of input light beams *Ia* and *Ib* on a plasmonic metamaterial absorber of 70 nm thickness (gold) fabricated on the end face of a telecoms fibre. Insets show scanning electron micrographs of the nanostructured fibre end and a photo of the assembled metadevice. (b) Experimental demonstration of an all-optical XOR operation between phase-modulated signals at a data rate of 1.2 GHz: High output (logical 1) results from opposite input bits and low output (logical 0) results from identical input bits.