Fibre-coupled photonic metadevices

Angelos Xomalis[1], Davide Piccinotti[1], Artemios Karvounis[1], Haojie Zhang[1], Vassili Savinov[1], Behrad Gholipour[1], Yongmin Jung[1], Anna C. Peacock[1], Eric Plum[1], Kevin F. MacDonald[1], David J. Richardson[1], Nikolay I. Zheludev[1,2]

1. Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, SO17 1BJ, UK
niz@orc.soton.ac.uk; www.nanophotonics.org/niz

2. Centre for Disruptive Photonic Technologies, School of Physical and Mathematical Sciences & The Photonics Institute, Nanyang Technological University, Singapore 637371, Singapore

Abstract: We report on metadevices realised by integration of functional metamaterials with single-mode telecoms fibres. These include plasmonic and all-dielectric nonlinear, nano-opto-mechanical and phase-change switching, dispersion manipulation and coherent absorber metadevices.

Fibre-optics, as for example in optical communications and fibre lasers, is an area where photonic metamaterials can have large commercial impact. Planar metamaterials covering areas comparable to an optical fibre core (~10 μm diameter for a single-mode fibre at wavelength of 1310/1550 nm) are readily achievable, however, fibre integration techniques and low-loss high-performance metamaterials are required.

We present a selection of fibre-coupled photonic metadevices, including (i) single-ended devices based upon metamaterial fabrication on the end faces of optical fibre, (ii) in-line metadevices wherein planar metamaterials are coupled to pairs of single-mode telecoms fibres – one on either side, and (iii) in-line metadevices where metamaterials are fabricated on the side walls of a side-polished fibres.

As illustrated by Fig. 1, examples include a nano-mechanical electro-optical light modulator consisting of electrostatically actuated nanowires made from indium tin oxide and silicon; an all-optical light modulator based on the nanomechanical nonlinearity of reconfigurable silicon meta-molecules; a spectral filter with a quality factor of 310 achieved by asymmetric structuring of a low-loss high-index dielectric (silicon) nanolayer; a nonlinear light modulator based on a nanostructured germanium film; a metadevice for performing all-optical logical operations and all-optical light modulation based on coherent perfect absorption in a gold metasurface (in principle operable with THz bandwidth and at arbitrarily low intensities); and a non-volatile switching device based on a germanium-antimony-telluride (GST) phase-change metasurface. Most structures are based on low-loss, high-index dielectrics and therefore avoid unwanted plasmonic losses, for the exception being the coherent absorption modulator, which exploits interference of coherent waves on a plasmonic absorber to achieve ultrafast control over light absorption ranging from coherent transparency to coherent perfect absorption.

In summary, we report proof-of-principle demonstrations of various single-ended and in-line fibre-coupled metadevices based on dielectric and plasmonic metamaterials for electro-optical and all-optical light modulation as well as data processing, filtering and switching applications.

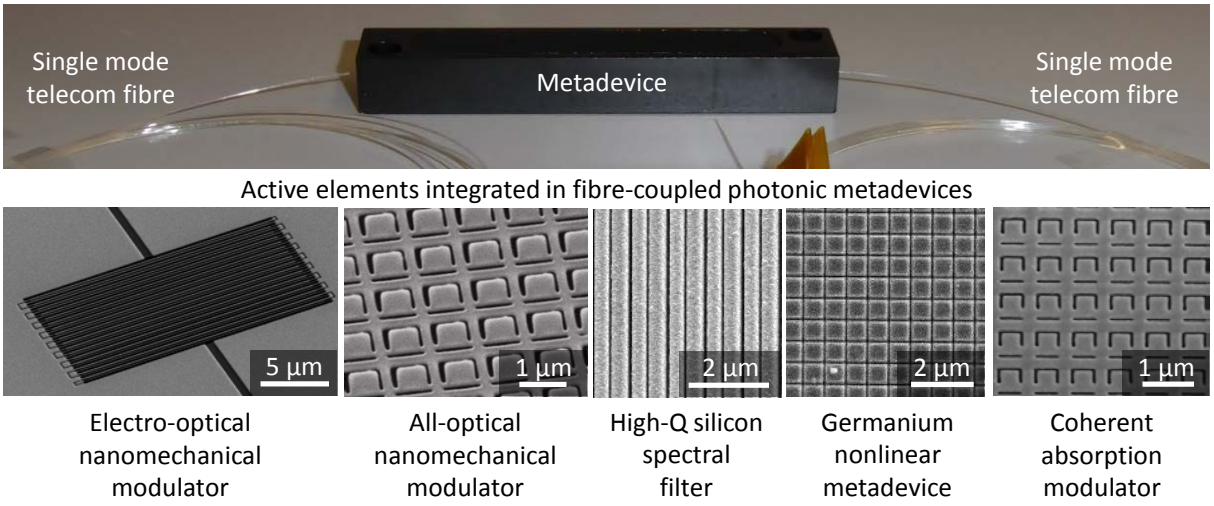

Fig. 1 Fibre-coupled photonic metadevice in protective housing and SEM images of dielectric and plasmonic active metamaterial elements of such metadevices for various light modulation and filtering applications.