Fiber-integrated 2D materials

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***Abstract*—In this paper we review our efforts to develop a range of functional in-fibre devices that draw on the unique optical properties of the 2D materials.**

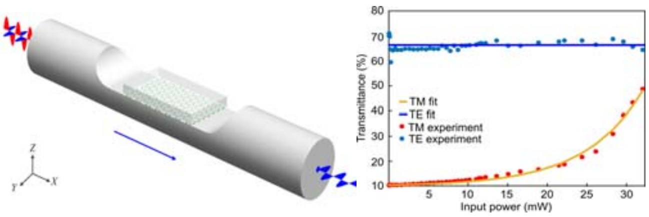
Keywords*—*Graphene; 2D Materials; Nonlinear Fiber Optics; Fiber Materials

I. Introduction

The incorporation of functional materials into the standard silica fiber geometry provides an efficient means of producing novel in-fiber devices. A noteworthy example of this is the rare-earth doped fiber amplifiers that power the internet [1]. More recently, there has been growing interest in integrating increasingly more exotic materials into fiber platforms, including the emerging class of two-dimensional (2D) materials [2,3]. However, one of the main challenges in working with these ultra-thin materials is how to increase the light-matter interactions without suffering from prohibitive loss penalties, thus allowing for the construction of efficient in-fiber devices. To this end, we have developed a customized side-polishing process to open up a low-loss interaction window within the cladding on to which the materials can be deposited. In this paper, we review some of the key device demonstrations that we have achieved using this approach, including ultra-broadband polarizers, all-optical modulators and highly nonlinear elements [4,5].

II. Results and Discussion

The side-polished fibers used in our work are fabricated using a block-polishing method that has been adapted to produce adiabatic transitions from the fiber's full circular geometry to the uniform D-shaped region. By retaining a small cladding buffer between the core and the polished surface, the insertion loss of the device is less than 1 dB, since the optical path of the core guided light is not broken. To enhance the light-matter interaction with the 2D material films, a high index polymer over-layer is added, which draws the mode towards the polished surface. Fig. 1(a) shows a schematic of our fiber-integrated 2D material devices. The transmittance response of the TE and TM modes for a graphene-based fiber, plotted as a function of increasing average power in Fig. 1(b), serves to illustrate both the polarization dependence and the nonlinear saturable absorption properties of the material.



(a) (b)

Figure 1. (a) Schematic illustration of our in-fiber structures. (b) Transmittance measurements as a function of power and polarization.

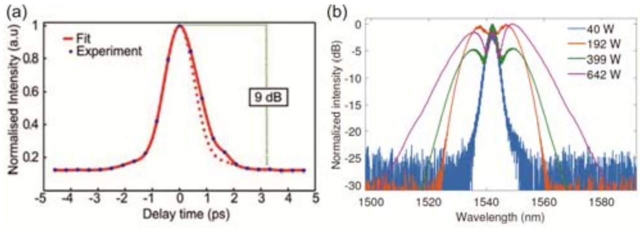


Figure 2. (a) All-optical modulation in a graphene-based fiber and (b) nonlinear spectral broadening in a MoS_2-based fiber.

By exploiting this design with different 2D materials, we have demonstrated a variety of all-optical functionalities. Fig. 2(a) shows an ultrafast modulator, which uses the saturable absorption properties of graphene, that recorded a record high value of the extinction ratio for an insertion loss of ~1 dB at the telecoms wavelength of 1550 nm [4]. Significantly, as graphene offers a flat absorption response over a very broad wavelength range, such modulators could be employed in sources covering the visible to the short-wave infrared [6]. Fig. 2(b) shows results of nonlinear broadening when propagating high power pulses inside a MoS_2-based fiber. This level of broadening (2.44 nm/mW) is remarkable considering the incredibly small volume of MoS_2 that the light is interacting with, and we estimate the effective nonlinearity in this device to be 1000 times larger than standard SMF [5].

III. Conclusion

We have presented a new fiber platform on which to exploit the exotic properties of the 2D material family. The unique device design results in robust, low-loss, high performance systems, laying a clear pathway for use in real-world applications.

IV. References

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