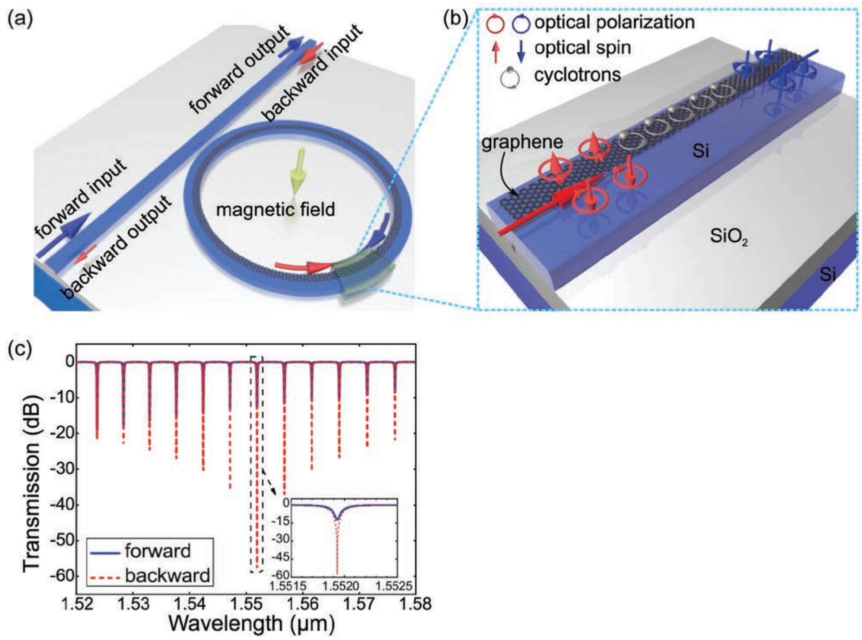
NON-RECIPROCAL DEVICES

Hybrid Graphene/Silicon Integrated Optical Isolators

Optical isolators are a type of non-reciprocal device that allow for unidirectional light transmission by breaking time-reversal symmetry.[1] In traditional optics, such devices can easily be implemented using the Faraday rotation effect of magneto-optical garnets. Incorporating isolators into an integrated platform poses problems, however, because of the large lattice mismatch and thermal incompatibility between the magneto-optical garnets and the substrate.

Graphene, a monolayer of carbon atoms, exhibits an enormous magneto-optical effect that can be utilized to construct optical isolators.[2] To date, most graphene-based optical isolators have employed an out-of-plane scheme, with light propagating in a direction normal to the graphene sheet.[3,4] This scheme not only suffers from a short interaction length, but also is difficult to implement in planar photonic circuits on a chip, where light propagates in parallel with the graphene sheet.

This year, we proposed a hybrid integrated graphene/silicon isolator by exploiting photonic spin–orbit coupling together with graphene's magneto-optical effect.[5] Owing to the photonic spin–orbit interaction, the magnetically induced cyclotrons in the graphene nanoribbon experience different photonic spin for light propagating in opposite directions. As a result, graphene's magneto-optical property induces a difference in the effective refractive index of the forward- and backward-propagating light, causing the non-reciprocal transmission spectrum required for an optical isolator. An optical microring cavity resonantly enhances the non-reciprocal effect (see figure).



(a) Proposed hybrid graphene/silicon integrated optical isolator consisting of a photonic bus waveguide and a microring resonator. A patterned graphene nanoribbon covers the inner top surface of the silicon waveguide of the microring. (b) Zoomed-in section of the isolator, showing mechanism of the nonreciprocal optical transmission. (c) Calculated forward and backward light transmission spectra of the proposed device at temperature of 77 K and magnetic field of 8.4 T.

A large extinction ratio can be achieved in the transmission spectra at a resonant wavelength under the critical-coupling condition. At a temperature of 77 K and magnetic field of 8.4 T, our proposed device can achieve an extinction ratio of roughly 45.3 dB, with a reasonable insertion loss of around 12.3 dB, at a wavelength of 1552 nm. Such integrated non-reciprocal devices based on 2-D materials should find great promise and numerous applications in next-generation on-chip photonic systems. OPN

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