18. Development of birefringence free ridge waveguides for waveguide isolators

Sponsors:
DARPA, FA8750-04-1-0134

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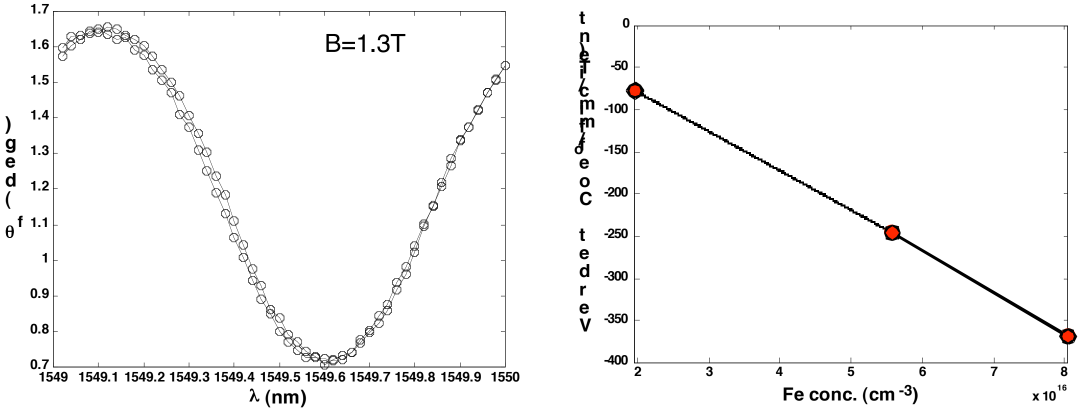
Waveguide isolators/circulator that can be easily integrated with other components are essential to large scale photonic integration. These components provide functionality that cannot be achieved in integrated circuits today. They also enable complex circuit design by isolating or 'buffering' various parts of a circuit.

The Faraday rotator is the key component for this kind of device. This project is to fabricate such a device on InP, the substrate for semiconductor lasers and optical amplifiers. InP is doped with Fe. Magnetic dopants couple to the free carriers in a semiconductor to dramatically enhance the Faraday rotation due to interband transitions. The free carrier concentration can be reduced along with free carrier absorption. In this way it is possible to *simultaneously* enhance the magneto-optical activity and reduce the optical absorption of a semiconductor.

InP doped with an Fe concentration of 2.9×10^{16} cm^{-3} was measured. At 1550 nm, the Verdet coefficient is 23.8 °/cm/T, which indicates a significant improvement due to the Fe. In InGaAsP, which is lattice matched to InP and normally used as the active layer for semiconductor lasers and amplifiers, this effect is even more significant. The bandgap of InGaAsP is much closer to the 1.55µm wavelength used for telecommunications than the InP bandgap (0.9µm). Operating closer to the bandgap will enhance the Faraday rotation.

Fig.1 (a) shows the Fabry-Perot spectrum of the Faraday rotation in a 0.5µm-thick Fe-doped InGaAsP film on a 350 µm-thick Fe doped InP substrate. Fig.1 (b) shows the Verdet coefficient for $InGa_{.29}As_{.63}P$ (bandgap=1.3 µm) versus Fe concentration at 1.55 µm. The Verdet coefficient scales linearly with Fe doping, and it is two orders of magnitude larger than that of Fe doped InP. It also surpasses the Verdet coefficient of YIG (434445455) by a factor of 2.



(a) (b)

Fig. 1 (a) Fabry-Perot spectrum of the Faraday rotation in 0.5 µm-thick Fe-doped InGaAsP film on a 350 µm-thick Fe-doped InP substrate. The magnetic field is 1.3 T. (b) Verdet coefficient for Fe-doped InGaAsP vs. Fe concentration at 1.55µm

A Faraday rotator requires very low waveguide birefringence for efficient conversion between TE and TM, which determines the polarization rotation. The waveguide is designed to be 1.4μm wide and 2.5μm deep. The waveguide birefringence is measured at different wavelength. The minimum birefringence is measured to be less than 10^{-5} at 1540nm. This is sufficient to achieve the required 45 degree rotation with the measured InGaAsP Verdet coefficient.

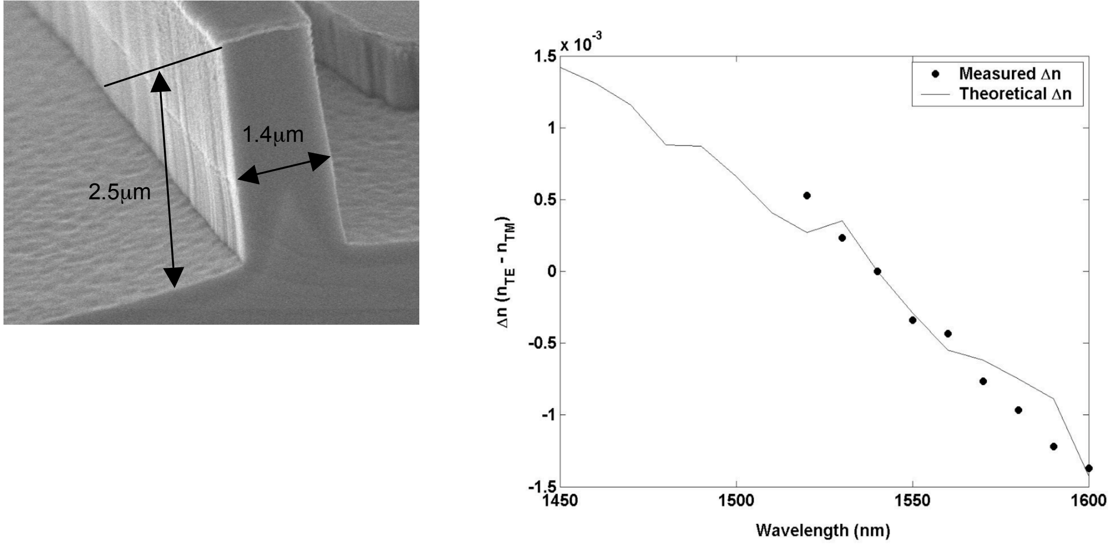


Fig. 2 Birefringence of the waveguide vs. wavelength. The solid line is a theoretical calculation and the dots are experimental data.

These data shows that it is possible to fabricate an isolator on a magnetically doped InP/InGaAsP structure. The structure has the advantage of being fully integratable with laser and other photonic circuit components. A fully integratable, polarization independent optical isolator/circulator design has been proposed. It requires one ion implantation step and two etch steps for fabrication. The device includes 3dB couplers, waveguide half plates and waveguide Faraday rotators.