# Self-aligned InP polarization converters for monolithic polarization-multiplexed PICs

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**Abstract:** We review our recent progress in the development of the half-ridge InP/InGaAsP polarization converters, which can be fabricated by a simple self-aligned high-yield process and monolithically integrated with other active InP components. High polarization conversion efficiency over 96%, low insertion loss below 1 dB, wavelength insensitivity, and monolithic integration with semiconductor optical amplifiers are demonstrated experimentally.

## 1. Introduction

With the increasing demand for data capacity in the optical networks, use of polarization multiplexing in conjunction with digital coherent technology has become the standard choice for the spectrally efficient long-haul and metro transmission. As 100G dual-polarization quadrature phase shift keying (DP-QPSK) and 16 quadrature amplitude modulation (DP-16QAM) technologies have been developed extensively, there is a growing interest to realize more compact and lower-cost InP-based photonic integrated circuits (PICs) that support polarization-multiplexed signal formats without using bulky optics [1,2]. To this end, simple scheme of manipulating the polarization state inside InP-based PICs is essential.

While various types of InP PC based on asymmetric waveguide structure have been proposed and demonstrated to date [3-6], monolithic integration of PCs with active photonic components, such as laser diodes (LDs) and semiconductor optical amplifiers (SOAs), has been a challenging issue. This is mainly because most of these PCs exhibit relatively large structural mismatch with standard ridge waveguides, which generally leads to large coupling losses. In addition, these schemes often require non-standard fabrication processes, such as slanted dry etching, and/or strict lithographic alignment, which may not be compatible with general LD fabrication procedures.

We have recently proposed and experimentally demonstrated a half-ridge InP/InGaAsP PC, which particularly suits the integration with LDs and other active components owing to its ridge-like structure and simple self-aligned fabrication process [7,8]. In this talk, we review our recent progress in the development of the monolithic InP PCs for polarization-multiplexed PIC applications. In particular, we present our first demonstration of half-ridge InP PCs monolithically integrated with a multiple-quantum-well (MQW) SOA.

## 2. Half-ridge InP polarization converter

Figure 1 shows the schematic of the proposed half-ridge InP/InGaAsP PC. It exhibits an asymmetric structure, having a shallowly etched ridge profile on one side and a deeply etched high-mesa profile on the other side [7]. Due to the asymmetric cross section, electric and magnetic fields of the two

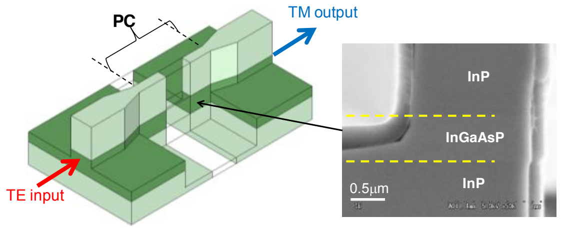


*Fig. 1: Schematic of half-ridge InP/InGaAsP PC and SEM image of the fabricated device [8].*

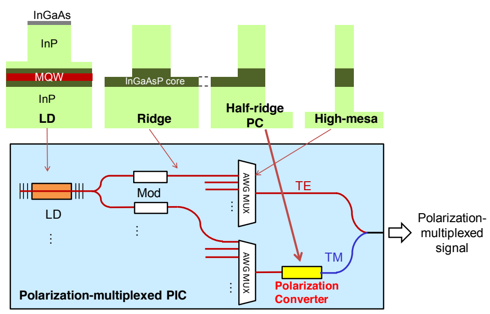


*Fig. 2: Schematic of polarization-multiplexed PIC.*

lowest-order eigenmodes are tilted from the vertical axis. With a proper choice of the waveguide width and etching depth, these two eigenmodes can be adjusted to have the electric/magnetic field tilted approximately by ±45° [7]. In such a case, incident light with TE (or TM) polarization state excites the two eigenmodes with an equal magnitude. After propagating half a beat length, these eigenmodes recombine into the orthogonal, i.e. TM (TE) polarization state. Owing to the thick InP upper cladding and the half-ridge structure, these modes have large overlap with the TE and TM modes in a symmetric ridge waveguide, which allows low-loss integration with standard ridge LDs and SOAs as shown in Fig. 2.

We have successfully fabricated the half-ridge PCs integrated with symmetric ridge waveguides by using a simple self-aligned high-yield process without the need for any critical lithographic alignment [8]. With a 150-µm-long PC, we have demonstrated TE-to-TM conversion efficiency higher than 96% and insertion loss of less than 1 dB over a broad wavelength range covering from 1510 to 1575 nm. We have also numerically studied the fabrication tolerance of this PC, and demonstrated that it could be extended further by an optimal design [9].

### 3. Monolithic integration of half-ridge InP polarization converter with SOA

To demonstrate feasibility of monolithic integration with active components, we have fabricated a PIC shown in Fig. 3, where an MQW SOA is monolithically integrated with half-ridge PCs of different lengths ($L_{PC}$). Fig. 4 shows the measured optical power of the TE and TM components of the output light from two different ports with and without PC. We see that the TE-mode light amplified by the MQW-SOA is effectively converted to TM mode by the PC section. We have thus demonstrated simultaneous emission of both the TE- and TM-mode light from a single InP PIC.

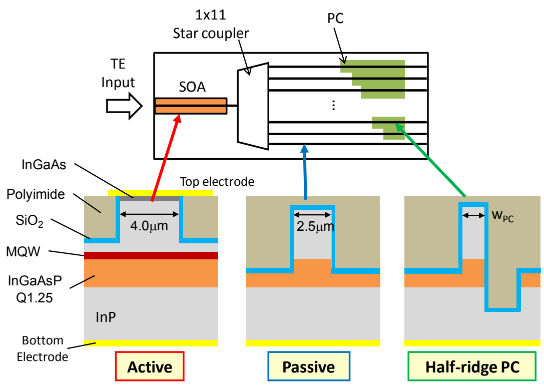


*Fig. 3: Schematic of the fabricated PIC with half-ridge PCs and MQW SOA integrated on a single chip.*

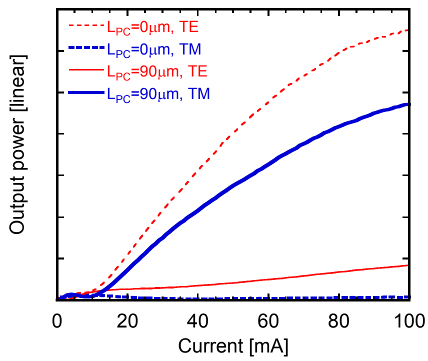


*Fig. 4: Measured output power of the TE (red) and TM (blue) components of the light from the ports with PC (solid lines) and without PC (broken lines).*


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