The Abdus Salam
International Centre
for Theoretical Physics
50th Anniversary 1964-2014

2572-19

Winter College on Optics: Fundamentals of Photonics - Theory, Devices and Applications

10 - 21 February 2014

Simulations Laboratory

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Simulation lab

POLARIZATION CONVERTERS

Introduction

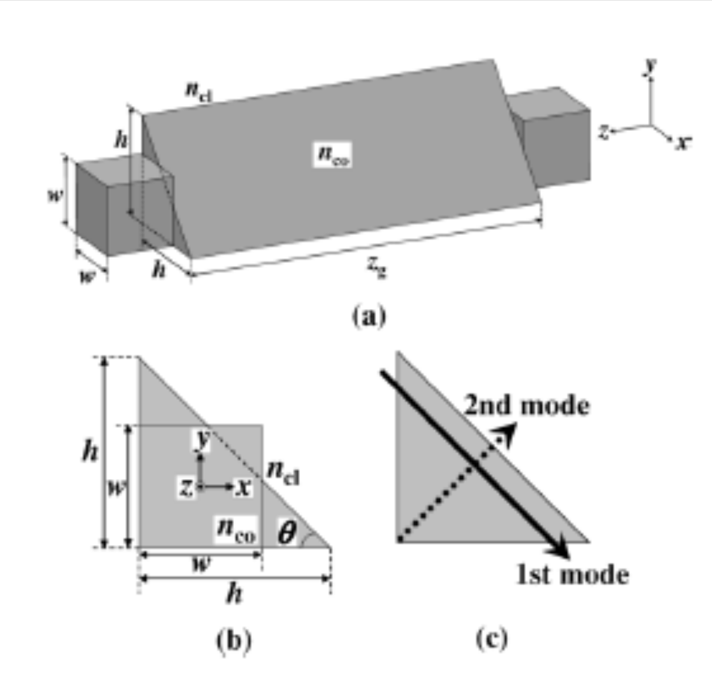
- Silicon photonics have shown remarkable capabilities to implement a wide variety of devices, such as WDM components, spectrometers, sensors, nonlinear devices, etc.

- SOI presents high birefringence → Most devices are designed to work for a single polarization

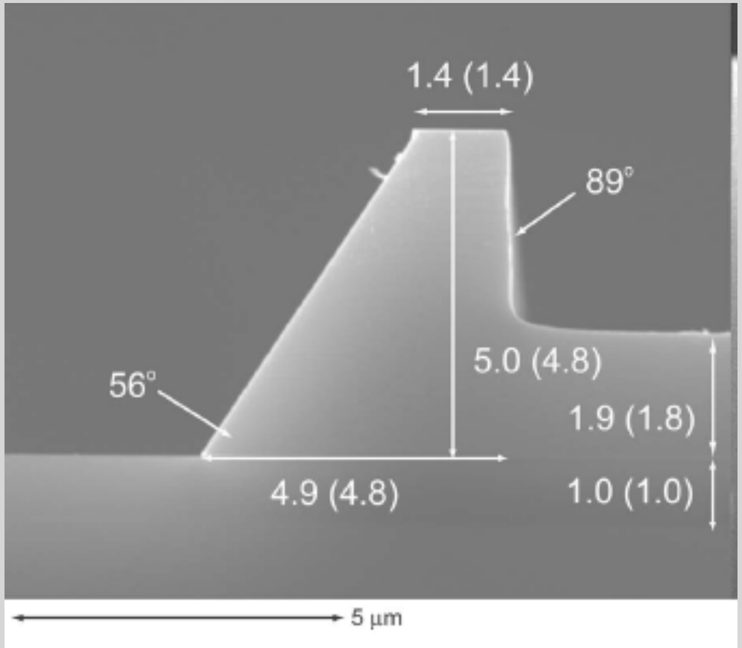
- There is a need for compact polarization diversity schemes, with polarization splitters and rotators as the keys components

Examples of Polarization Converters in SOI

Slanted waveguides



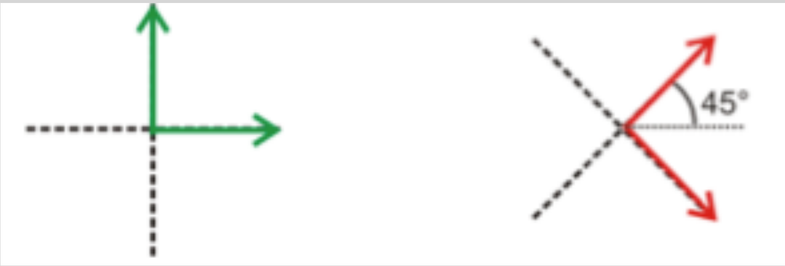
J. Yamauchi et al, Journal of Lightwave Technology 26, 1708 (2008)



C. Brooks et al, Optical Engineering 454, 044603 April 2006

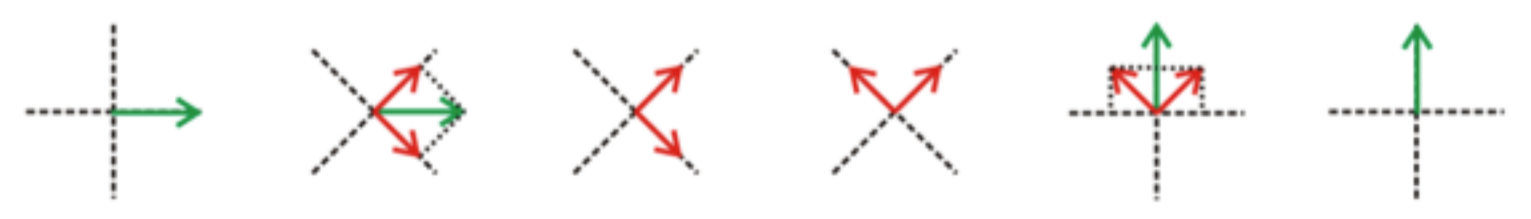
Hybrid Modes

- Hybrid modes: Polarization angle rotated 45°



- The two hybrid modes have different propagation constants, resulting in full mode conversion at each half-beat length:

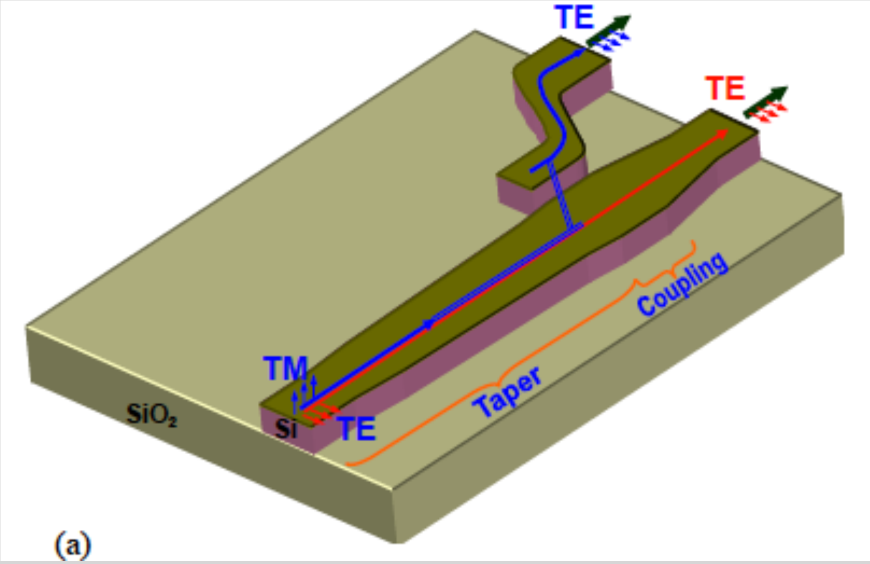
$$L_{1/2}=\pi/(\beta_1-\beta_2)$$



Waveguide Transition Converter Transition Waveguide

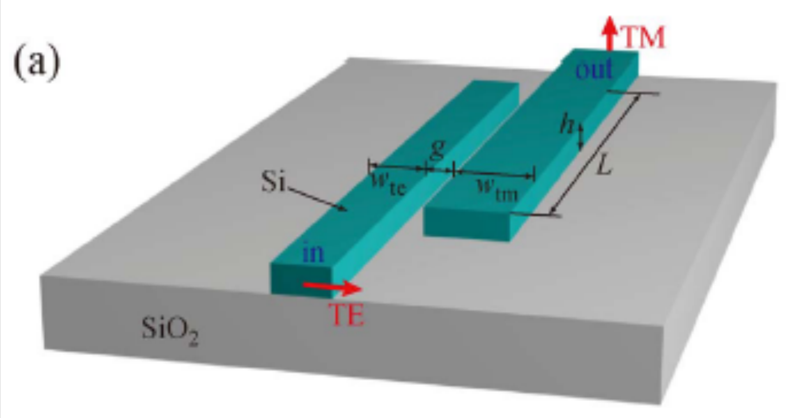
Some Polarization Converters in SOI

Asymmetrical Coupling



Theoretical length = 100 µm
Conversion efficiency close to 100%

L. Liu et al, Optic Letters 36, 1059 (2011)

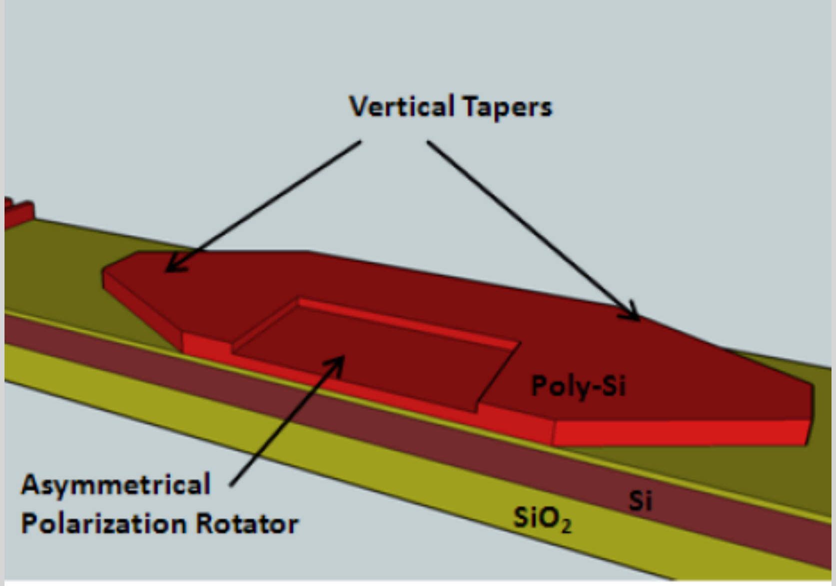


Theoretical length = 44 µm
Conversion efficiency = 92%

L. Liu et al, Optic Letters 36, 1059 (2011)

Examples of Polarization Converters in SOI

Different Etch Depths



Conversion Length = 9µm

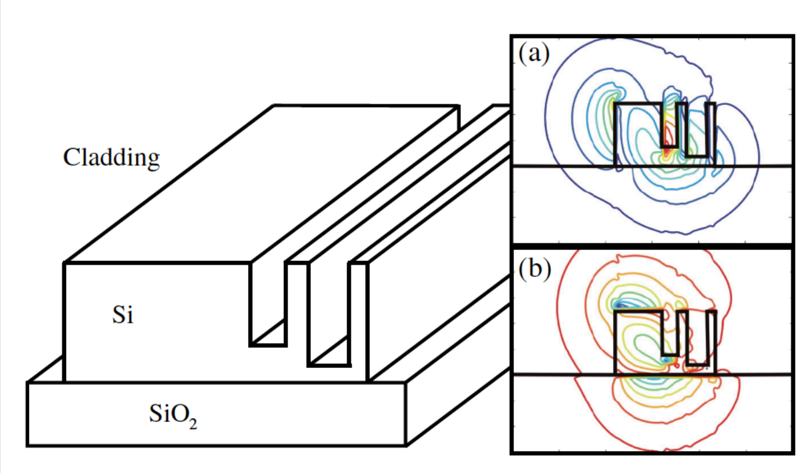
D. Vermuelen et al, Seventh International Conference on Group IV Photonics, Beijing, China, September 2010, paper WC6

Our Goal

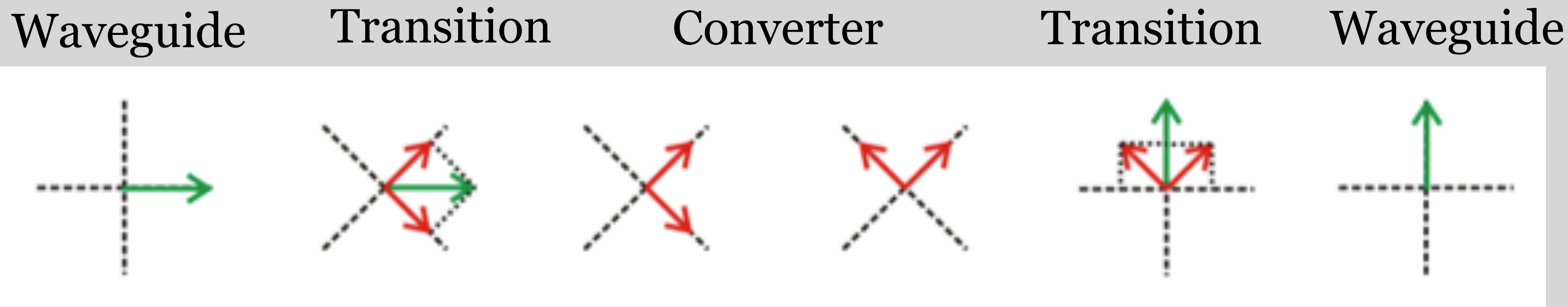
- Devices with slanted walls or multiple etch depths achieve the shortest conversion lengths, but are difficult to fabricate.
- We want to design a polarization mode converter:
  - Very short conversion length
  - Single etching step
  - High conversion efficiency

Proposed Structure

- Wire waveguide with two longitudinal trenches
- Two perpendicular hybrid modes are supported
- We can implement different depths with RIE Lag effect

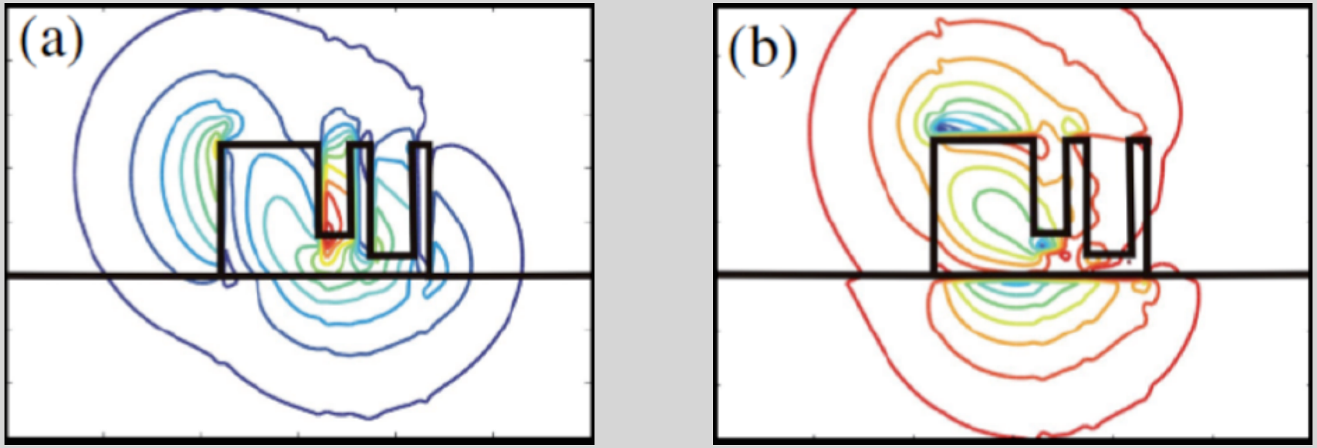


A. V. Velasco, M. L. Calvo, P. Cheben, A. Ortega-Moñux, J. H. Schmid, C. Alonso Ramos, Í. Molina Fernandez, J. Lapointe, M. Vachon, S. Janz,, D.-X. Xu, **Opt. Lett 37, 365 (2012).**



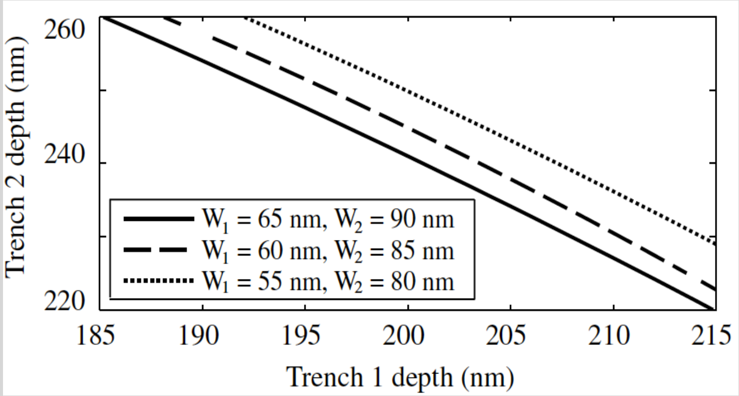
Hybrid modes

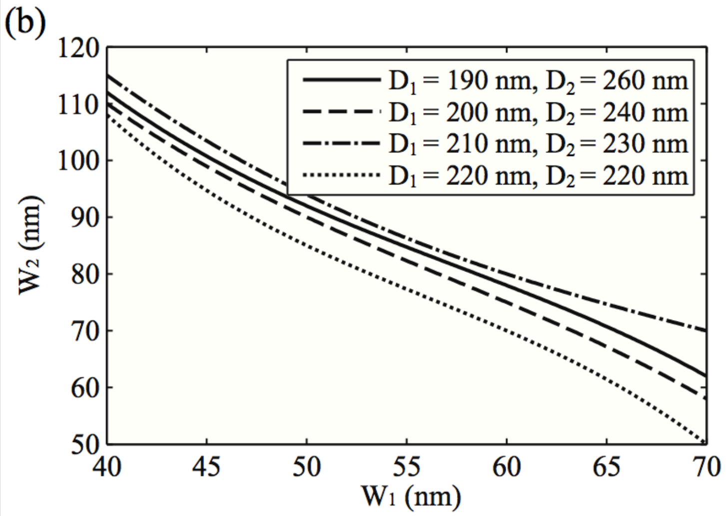
- All the requirements are achieved by choosing the width and depth of the two trenches



- Many combinations of widths and depths result in hybrid modes rotated 45°

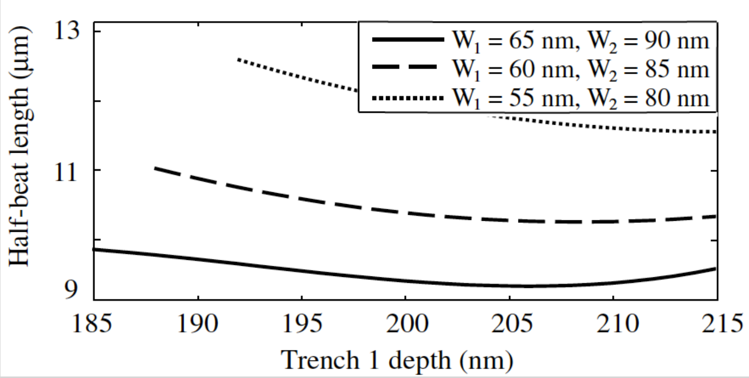
Design and Simulations

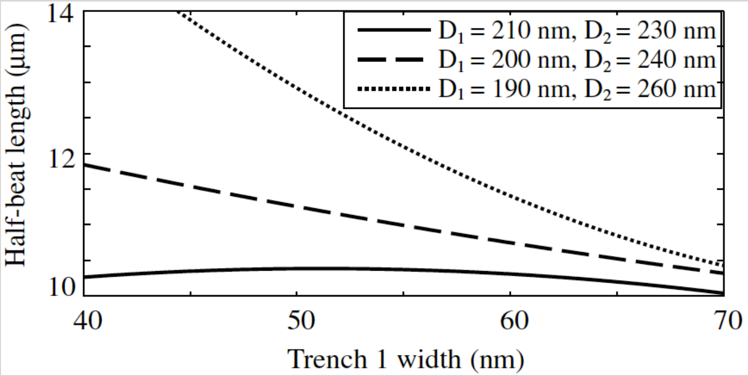




- We find different solutions with simulation software to find the relations between the parameters
- Greater trench widths require shallower trench depths
- If the size of a trench increases, the size of the other trench decreases

Design and Simulations





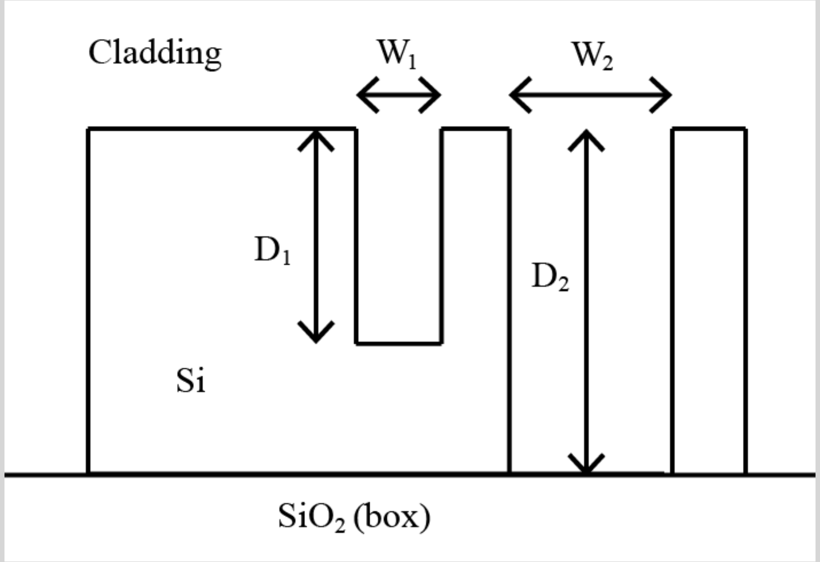
- We can optimize the parameters of the design to minimize conversion length

$$L_{1/2}=\pi/(\beta_1-\beta_2)$$

- However, not all the theoretical parameter combinations can be fabricated

RIE Lag effect

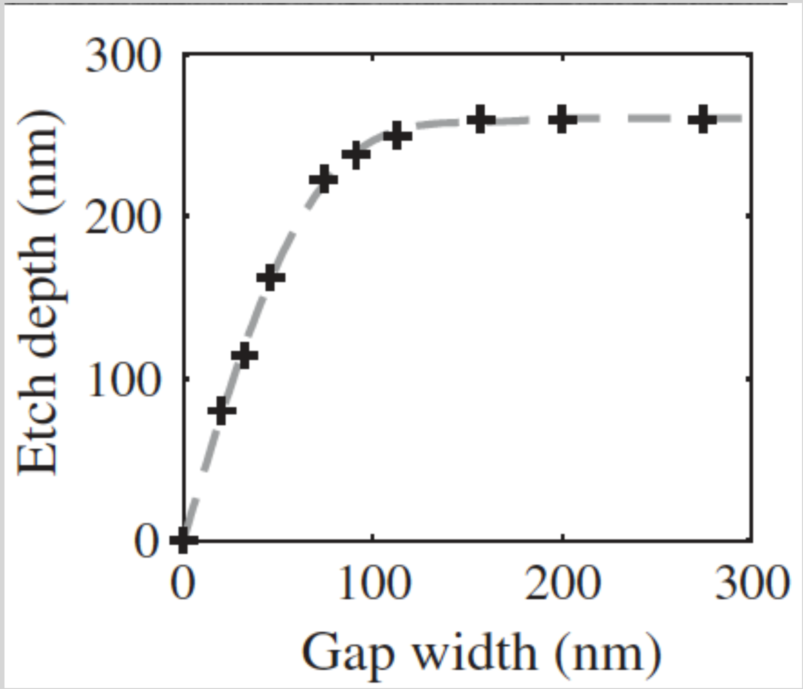
- How to implement different depths with a single etch step?



- Reactive Ion Etch Lag:
  - Large features are fully etched
  - If the features are too narrow, the etch is only partial

B. M. Holmes et al, IEEE Photonics Technology Letters 18, 43 (2006)

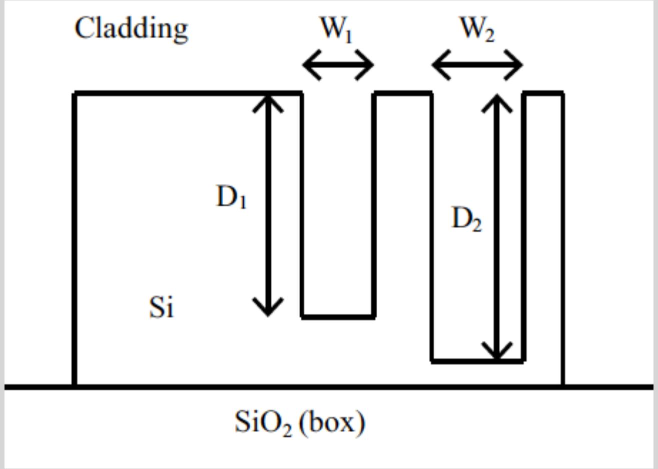
RIE Lag effect



- We can characterize this RIE Lag effect and find width/depths combination that can be fabricated
- For widths below 140 nm, etch depths starts to decrease
- The final design results from the intersection of this curve and the possible combinations that achieve hybrid modes at 45°

B. M. Holmes et al, IEEE Photonics Technology Letters 18, 43 (2006)

Final Structure

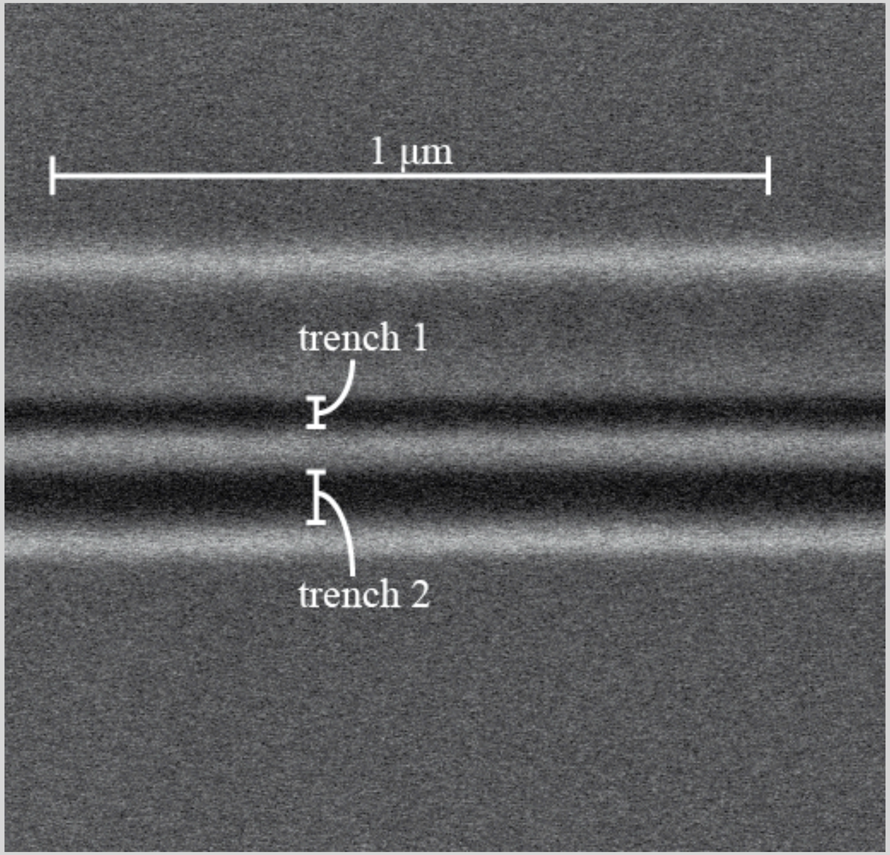


- Waveguide width: 450 nm
- Waveguide depth: 260 nm

- Trench widths: 60 nm and 80 nm
- Trench depths: 210 nm and 230 nm

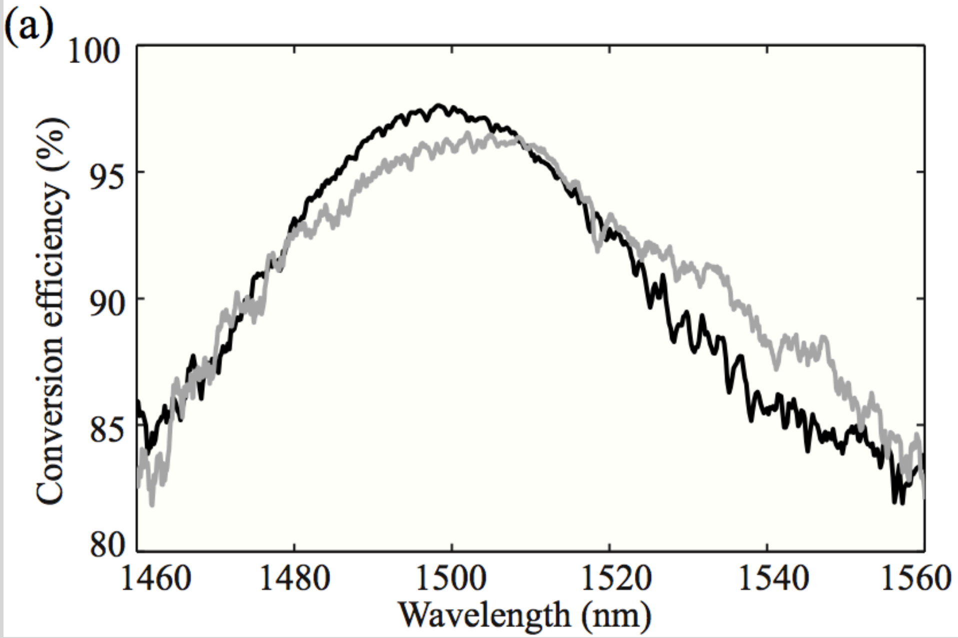
- Device length = **10 µm**
- Adaptation sections were included to smooth the transition

Fabrication



- SEM image of the fabricated device
- Single patterning step with electron beam litography

Experimental Results



$$\eta_{TE-TM} = \frac{P_{TM}}{P_{TM} + P_{TE}} \times 100\%$$

- Peak conversion efficiency (TE to TM): **97.5%**
- Extinction Ratio: **16 dB**
- **90%** conversion bandwidth of 47 μm

Let’s design our own