Out-of-plane fiber coupler for coupling to high-index-contrast waveguides

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Introduction

The problem
• the interface between a photonic crystal waveguide and the outside world is a serious problem
• huge mismatch between waveguide mode and fiber mode: 26dB coupling loss
• a spot-size converter is needed:
  • lateral (in-plane): easy
  • vertical (out-plane): not so easy

Our approach
• use a grating to couple light from/to a fiber perpendicular to the PIC
• use a spot-size converter in plane
• 1.55\( \mu \)m wavelength range
• TE-polarisation
• wafer scale, no need to cleave the devices for testing

Theoretical results

Basics
• in a coupler grating (grating period = \( \lambda/n \)), the first order diffraction can be used to couple out-of-plane
• short grating (approx. 10 \( \mu \)m long)
• high refractive index contrast: oxide cladding
• use rigorous electromagnetic modelling (2D) to optimize the grating parameters
• method: mode expansion with PML
• calculate coupling from waveguide to fiber
• optimize grating parameters
• computational model:

Simulation results

simple coupler grating: 20% coupling efficiency
coupler grating with parallelogramic teeth: 40%
coupler grating + reflector grating: 40%
structures with bottom reflector (2-pair DBR)
simple coupler grating: 40% efficiency to fiber
coupler grating + reflector grating: 75%

Experimental results

Measurements
• measure transmission from fiber to waveguide to fiber
• waveguide = SOI (205nm Si / 400nm SiO\(_2\))
• correction for substrate losses
• extract coupling efficiency from fiber to waveguide (coupling efficiency from fiber to waveguide is the same as coupling from waveguide to fiber)
• good alignment sensitivity
• don’t need to cleave/polish SOI

1D grating
• 15% efficiency (8.5dB coupling loss)
• wavelength range > 50nm
• good agreement theory-experiment

2D grating
• change DUV exposure dose -> change hole size
• optimum hole diameter = 380nm

Fabricated structures
• 1D grating in a ridge waveguide
• e-beam litho (Glasgow Univ. + COM)
• DUV-litho (IMEC Leuven)
• cross-section after etch:
  • shallow etch (50nm)
  • etch depth is critical

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