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Ultra-broadband polarization beam splitter with a gradual anisotropy engineered subwavelength metamaterial

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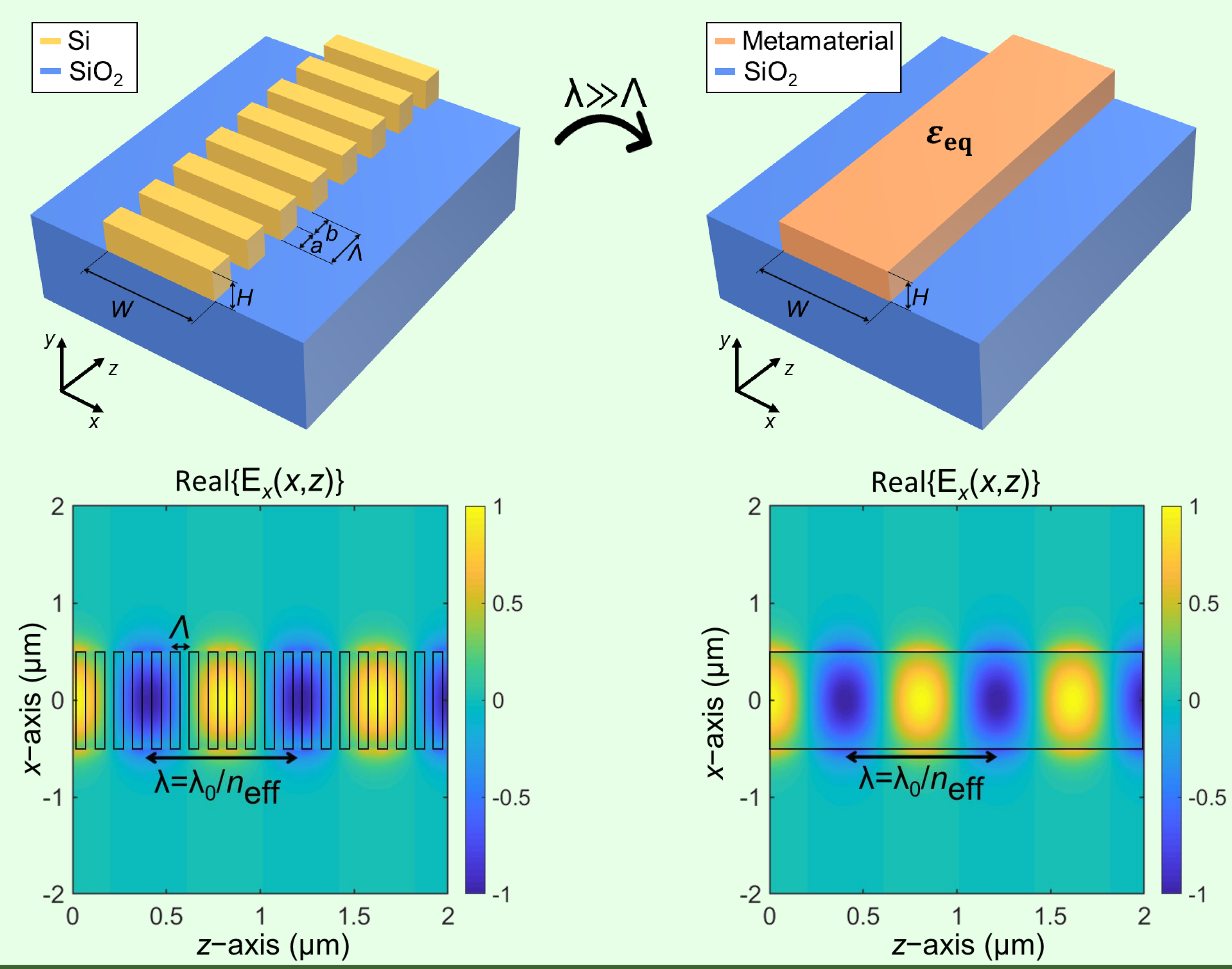
Summary

In this work we propose a polarization beam splitter based on an advanced SWG metamaterial topology which controls the propagation of multiple TE and TM modes at the same time. The proposed device achieves a simulated insertion loss <1 dB and extinction ratio >20 dB over a 400 nm bandwidth.

Silicon photonics and SWG metamaterials

- Silicon photonics is leading the landscape of integrated photonics, with Silicon-On-Insulator (SOI) platform having important commercial applications specially on the data/telecom industry [1].
- The huge success of SOI principally comes from its high integration density and the compatibility of the fabrication process of SOI chips with the CMOS process
- However, CMOS compatibility comes with the drawback of restricting the available materials to those compatible with the fabrication process, hindering the design of high-performance devices.
- Subwavelength grating (SWG) metamaterials circumvent the restriction on the available materials by behaving as homogeneous anisotropic material with tailorable optical properties [2].



The condition for a periodic structure to work as a homogeneous metamaterial is:

$$\Lambda < \lambda_0 / 2n_{eff}$$

The homogeneous metamaterial equivalent to an SWG structure is characterized by its permittivity tensor:

$$\boldsymbol{\varepsilon_{eq}} = \begin{bmatrix} n_{xx}^2 & 0 & 0 \\ 0 & n_{yy}^2 & 0 \\ 0 & 0 & n_{zz}^2 \end{bmatrix}$$

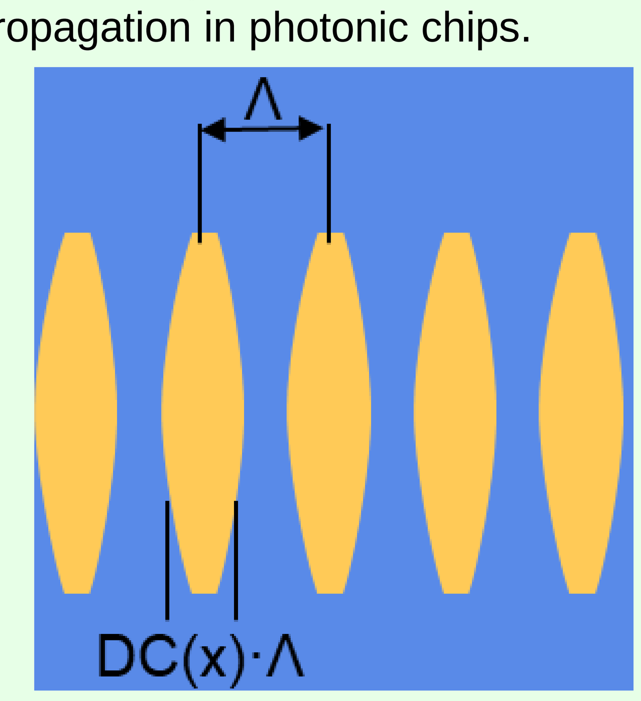
These tensor components can be calculated in a first approach as:

$$\boldsymbol{n_{xx}^2 = n_{yy}^2} = DC \cdot n_{Si}^2 + (1-DC) \cdot n_{SiO_2}^2$$

$$\boldsymbol{n_{zz}^{-2}} = DC / n_{Si}^2 + (1-DC)/n_{SiO_2}^2$$

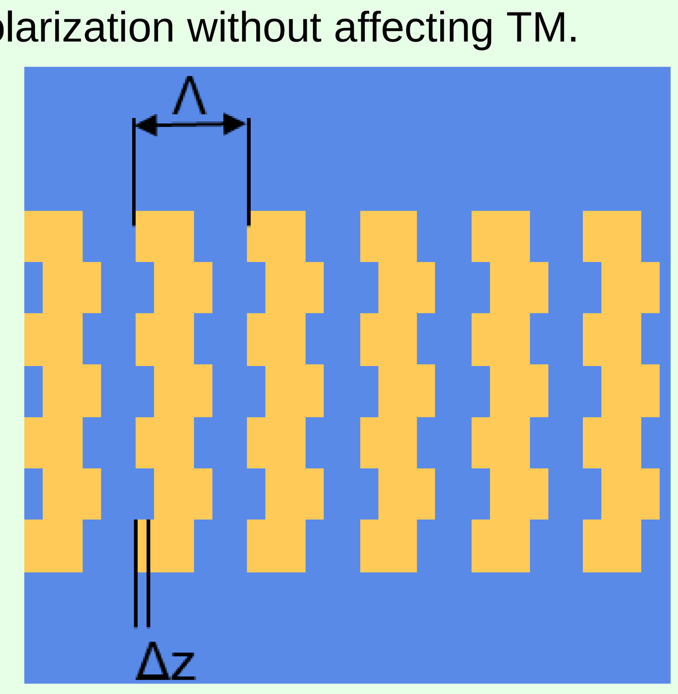
Advanced SWG metamaterials topologies

- Gradual subwavelength gratings [3] offer virtually complete control over light propagation in photonic chips.



$$\boldsymbol{\varepsilon_{eq}} = \begin{bmatrix} n_{xx}^2(x) & 0 & 0 \\ 0 & n_{yy}^2(x) & 0 \\ 0 & 0 & n_{zz}^2(x) \end{bmatrix}$$

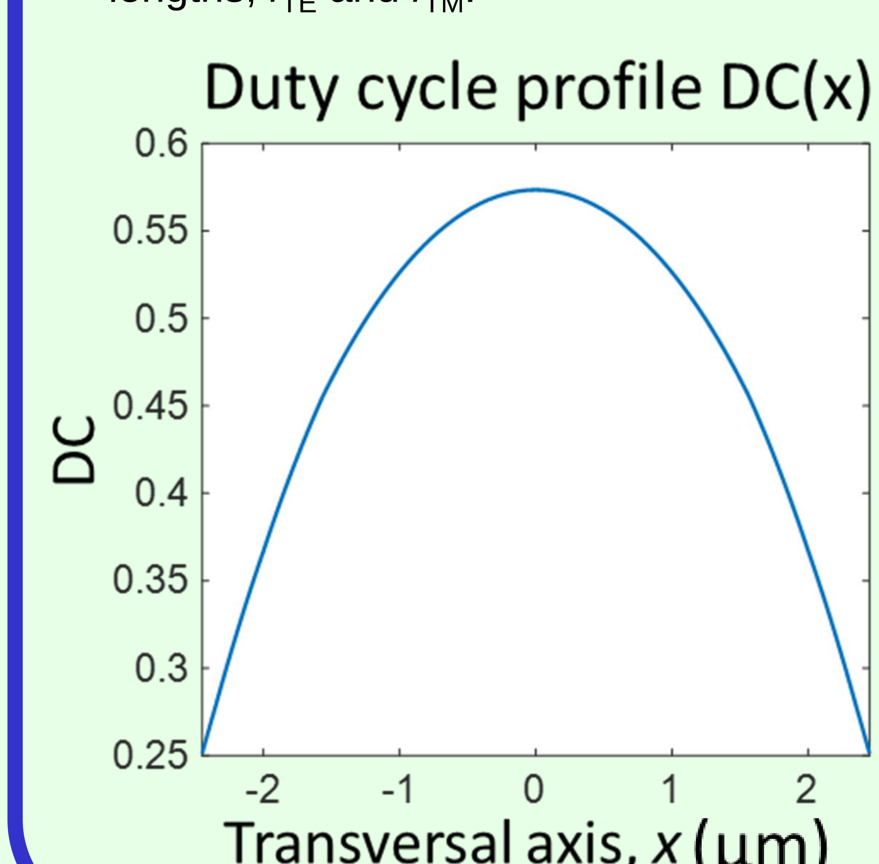
- Bricked subwavelength gratings [4] are auspicious structures to control the TE polarization without affecting TM.

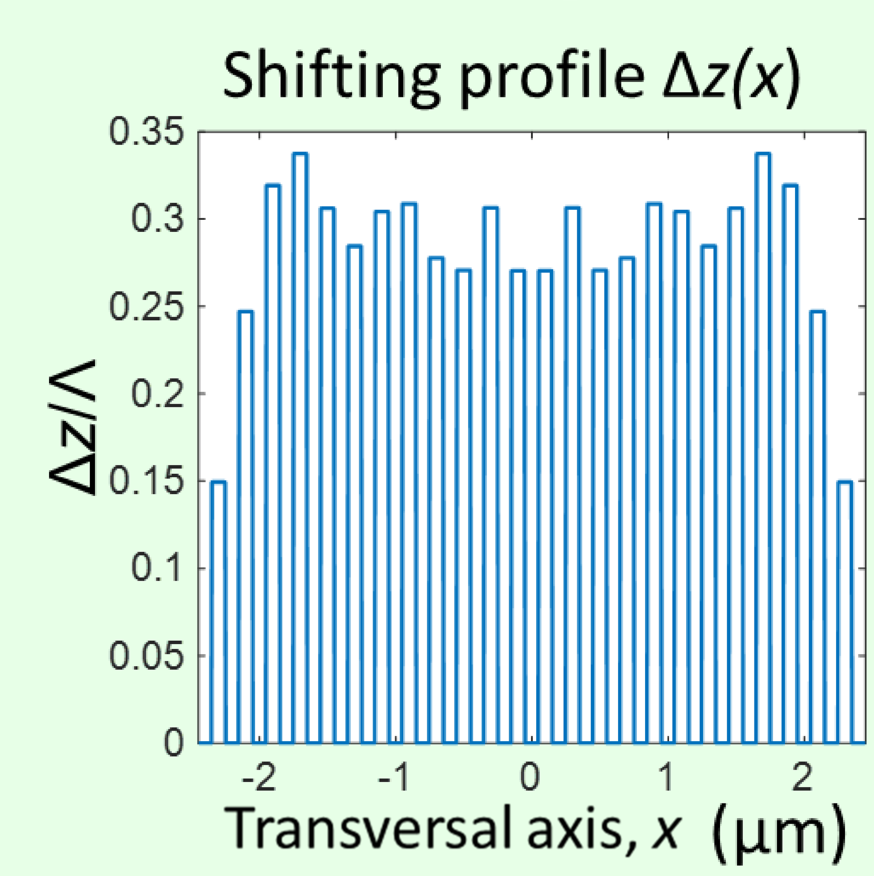


$$\boldsymbol{\varepsilon_{eq}} = \begin{bmatrix} n_{xx}^2(\Delta z) & 0 & 0 \\ 0 & n_{yy}^2 & 0 \\ 0 & 0 & n_{zz}^2(\Delta z) \end{bmatrix}$$

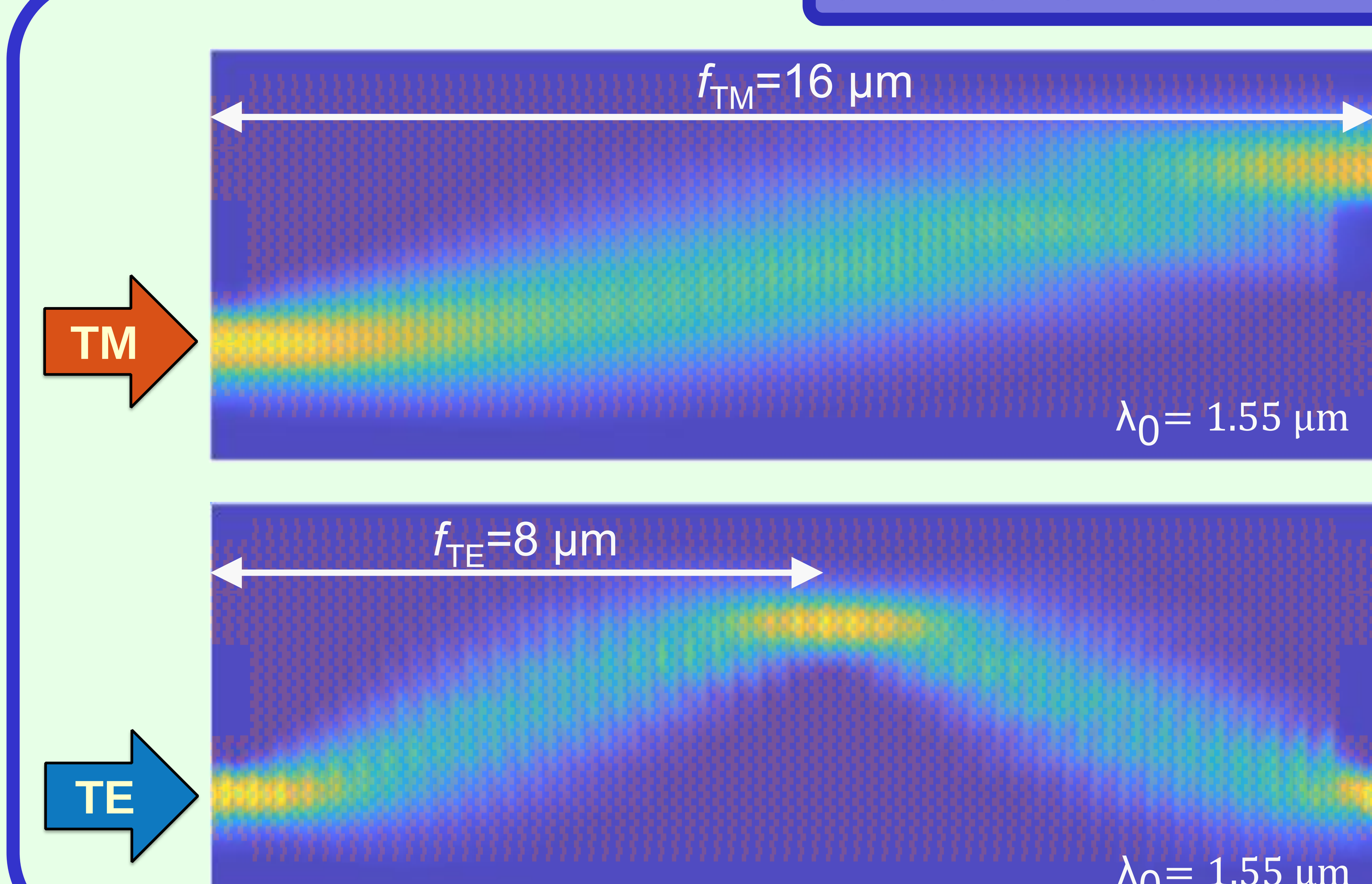
Design of a GRIN bricked lens

- The gradualness profile on the duty cycle, DC(x), enables the implementation of a GRIN lens working for both polarizations with focus lengths, f_{TE} and f_{TM}.
- The shifting profile of the bricked topology, Δz(x), enables the tuning of the TE focal length, enabling to satisfy the polarization splitting condition: $2f_{TE} = f_{TM}$



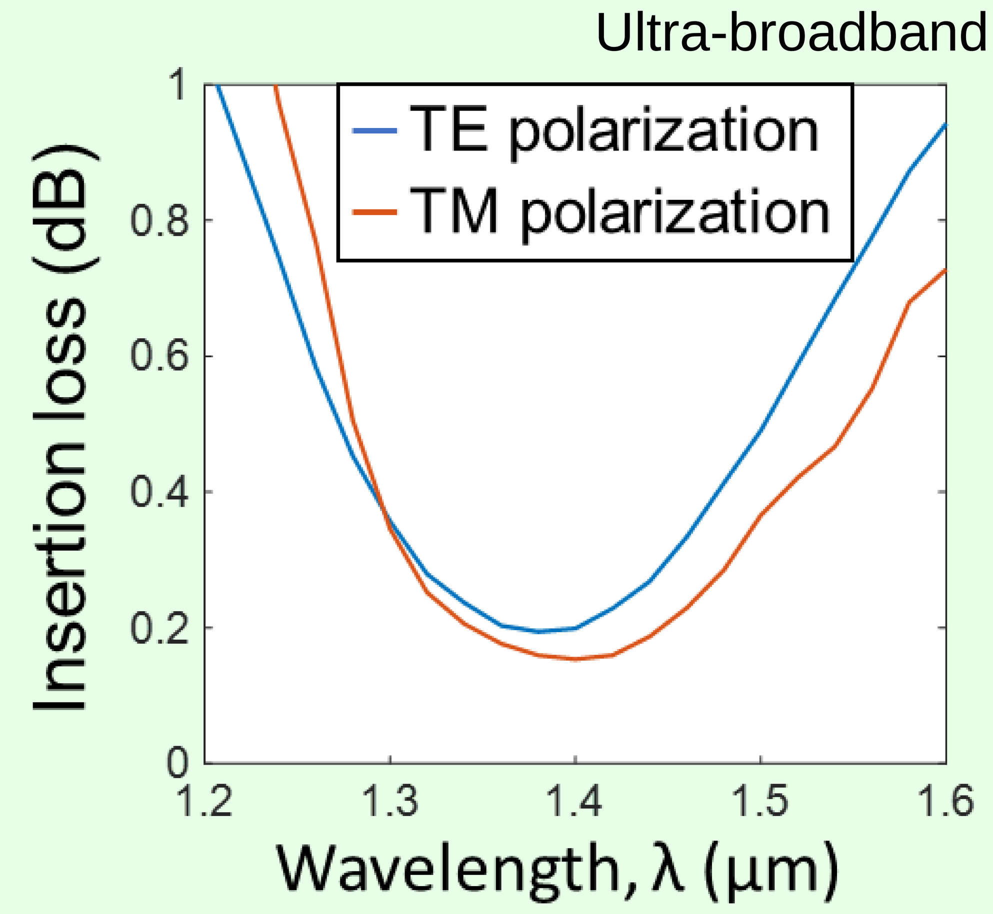


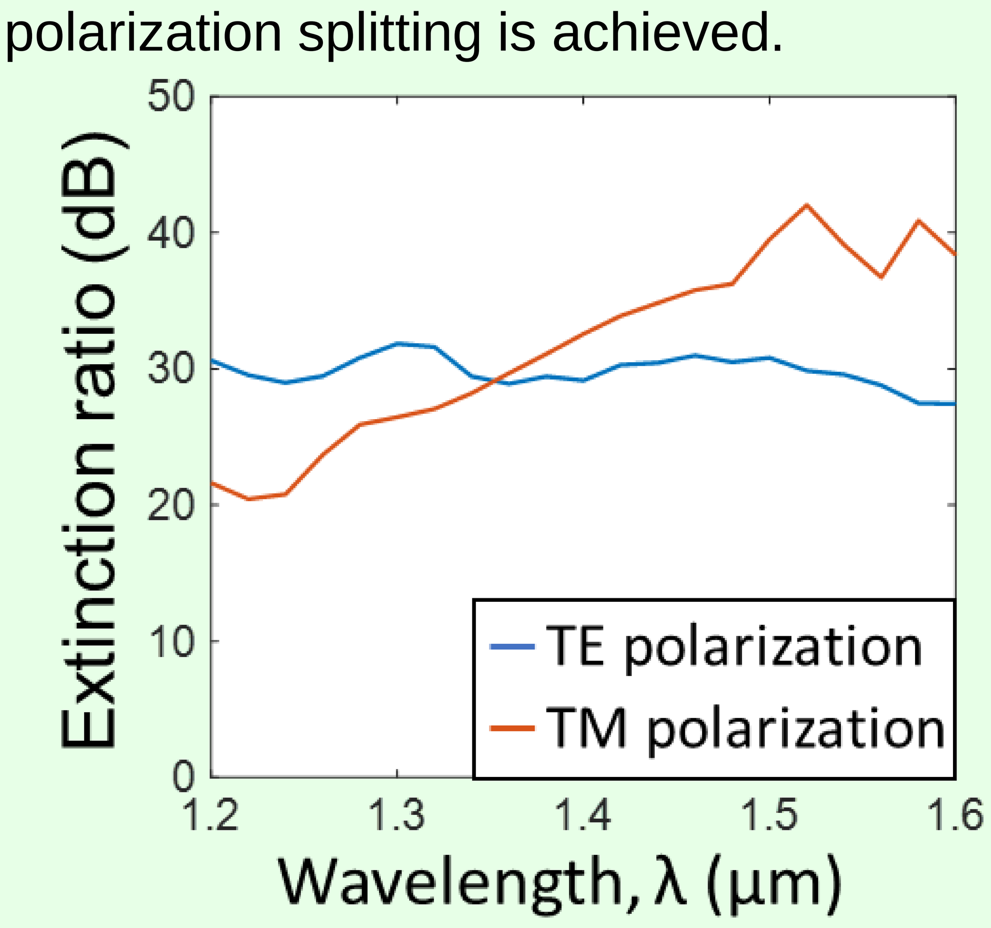
Simulation of a GRIN bricked lens polarization beam splitter



The focus length of GRIN lenses is wavelength independent!!!

Ultra-broadband polarization splitting is achieved.





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