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Dual wavelength vertical coupling for SHG in GaP microdisks

A. Lorenzo Ruiz¹, A. Beck¹, C. Cornet¹, Y. Léger¹

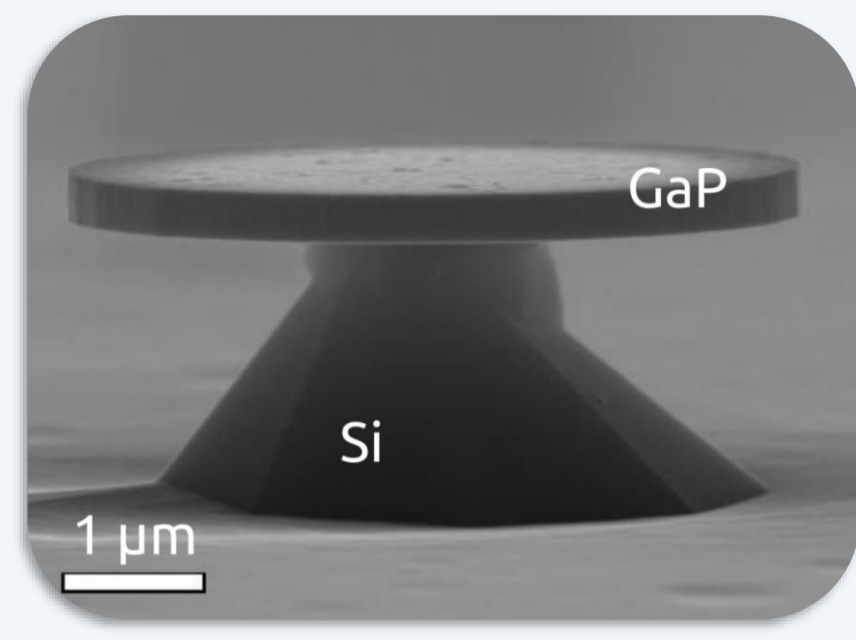
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Introduction

Wavelength converter is one of the essential blocks of photonic integrated circuits. One of most established configurations is based on χ^2 nonlinearities in microdisk resonators making use of the Whispering Gallery Modes (WGMs)⁽¹⁾

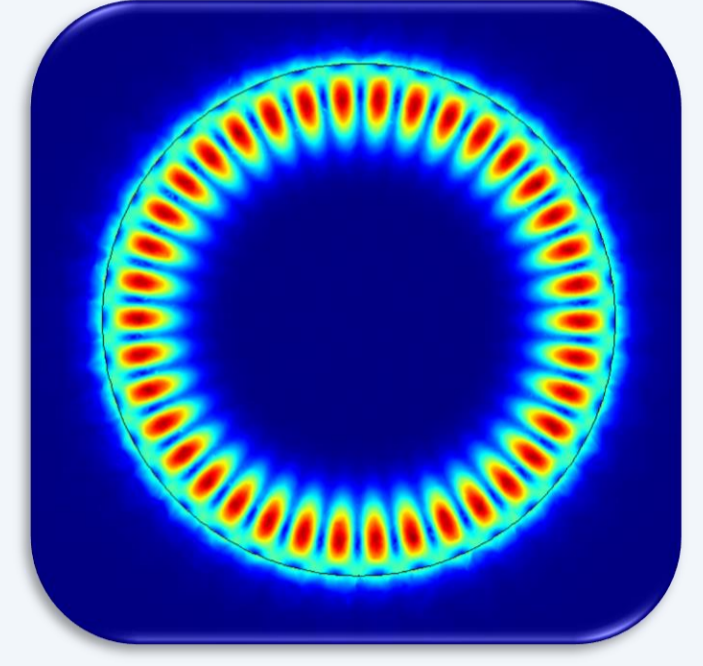
- III-V Semiconductors \rightarrow strong nonlinear properties and specific $\bar{4}$ quasiphasematching
- Challenging optical coupling, hard to couple two frequencies with the same system
- No study of different coupling schemes for nonlinear conversion in literature



SEM image of a GaP microdisk over Si made in the laboratory

The wavelength conversion (second harmonic generation):

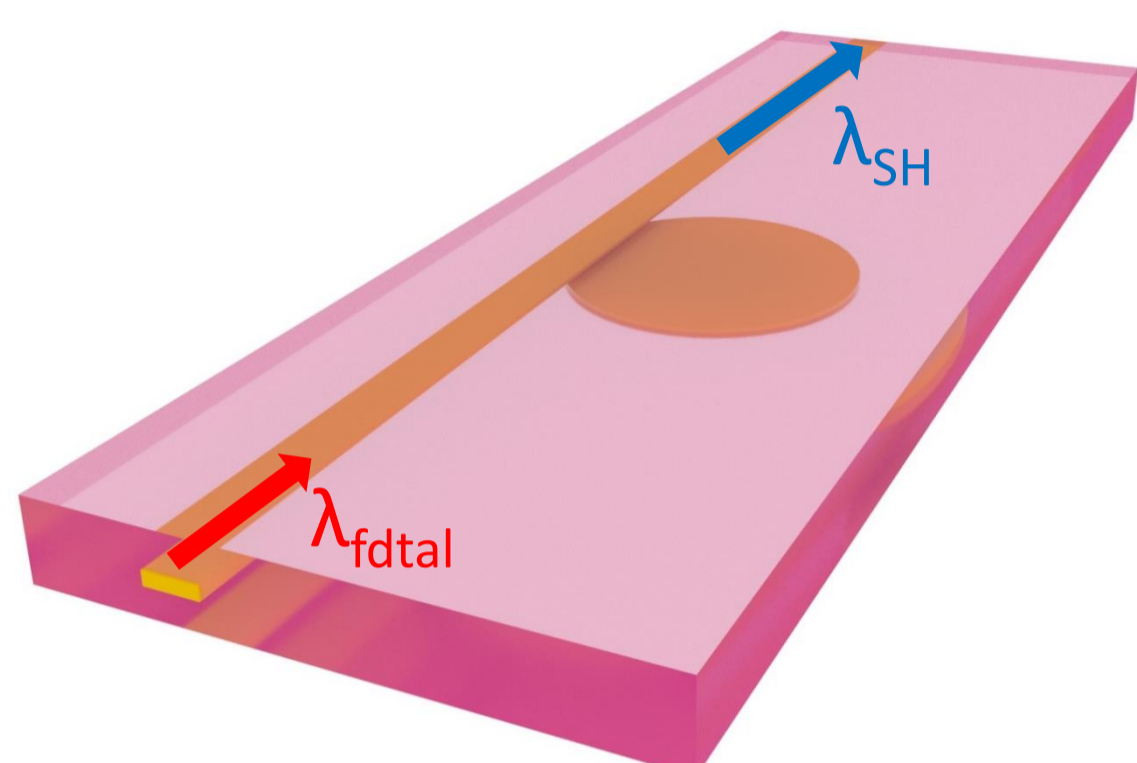
- Fundamental (Fdtal)=2 μ m \rightarrow Second Harmonic (SH)=1 μ m
- TE polarization \rightarrow TM polarization
- $\bar{4}$ Quasiphasematching possible for GaP microdisks⁽²⁾



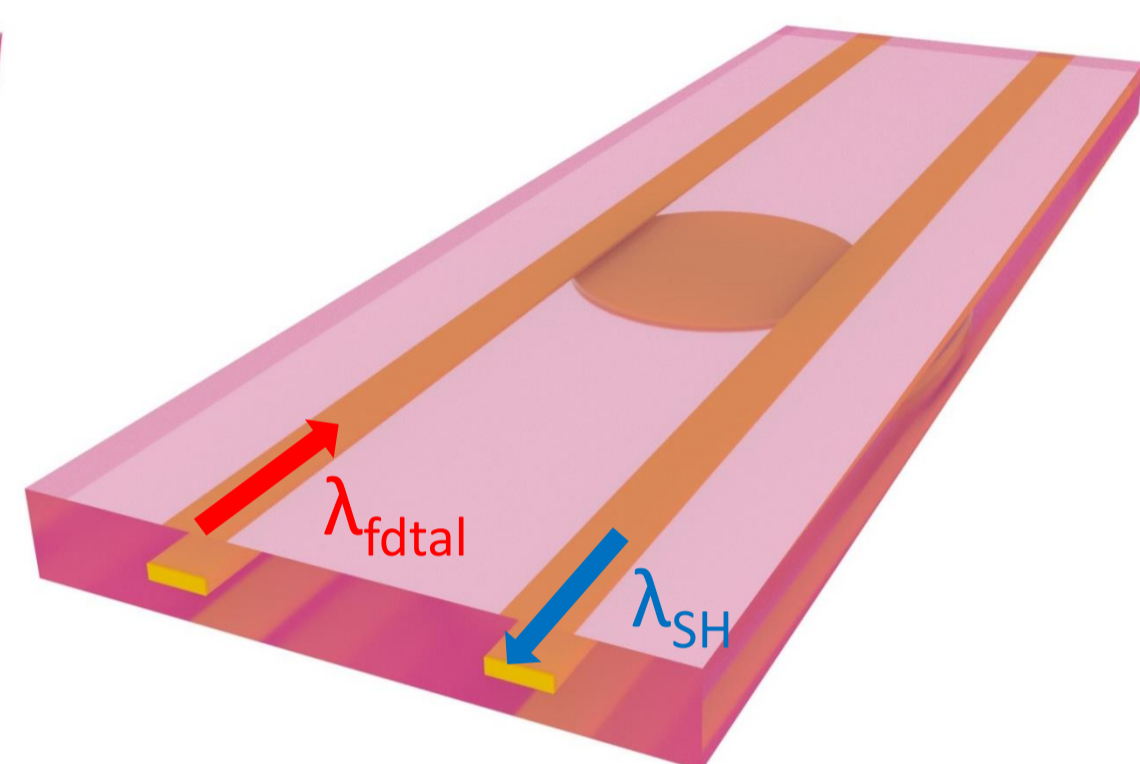
Planar electric field distribution of a WGM for a horizontal plane in a microdisk

Evanescent coupling configurations

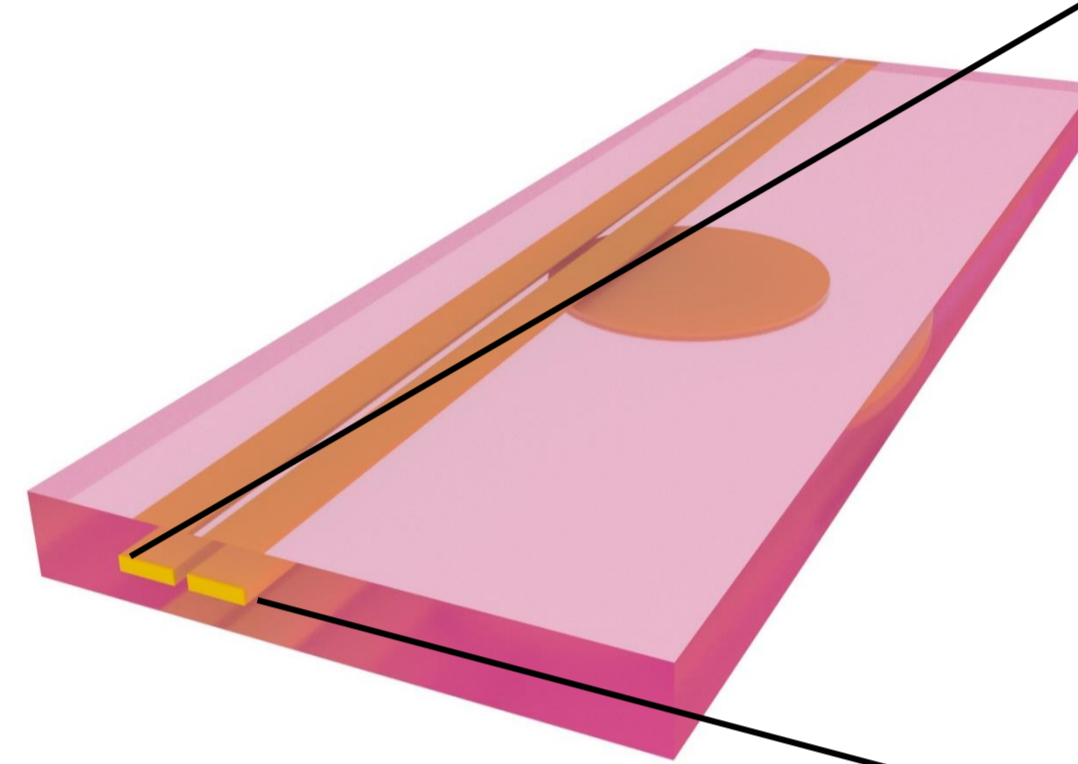
Three coupling schemes studied:



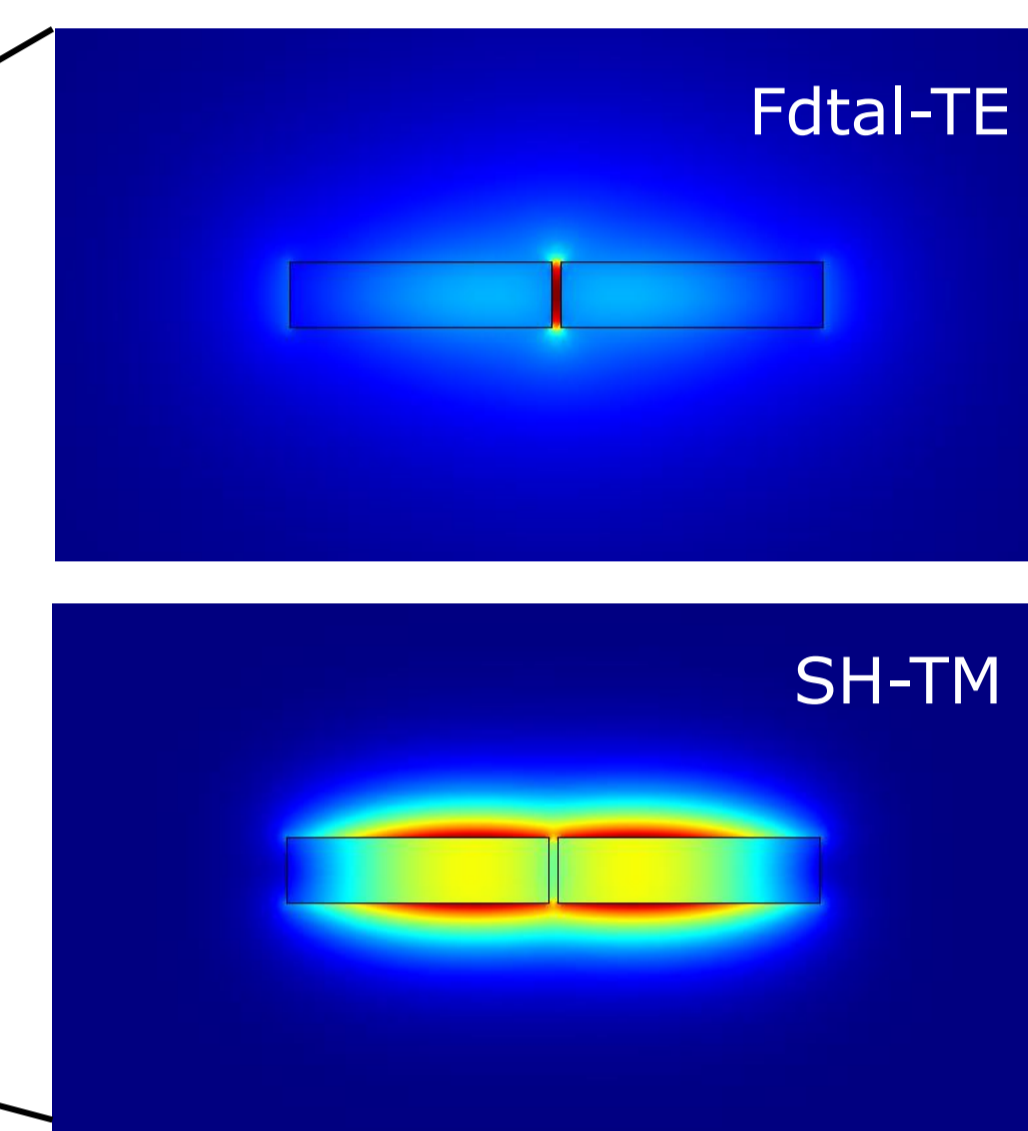
All-pass



Add-drop



Slit



Supermodes

Linear combination of single waveguide modes

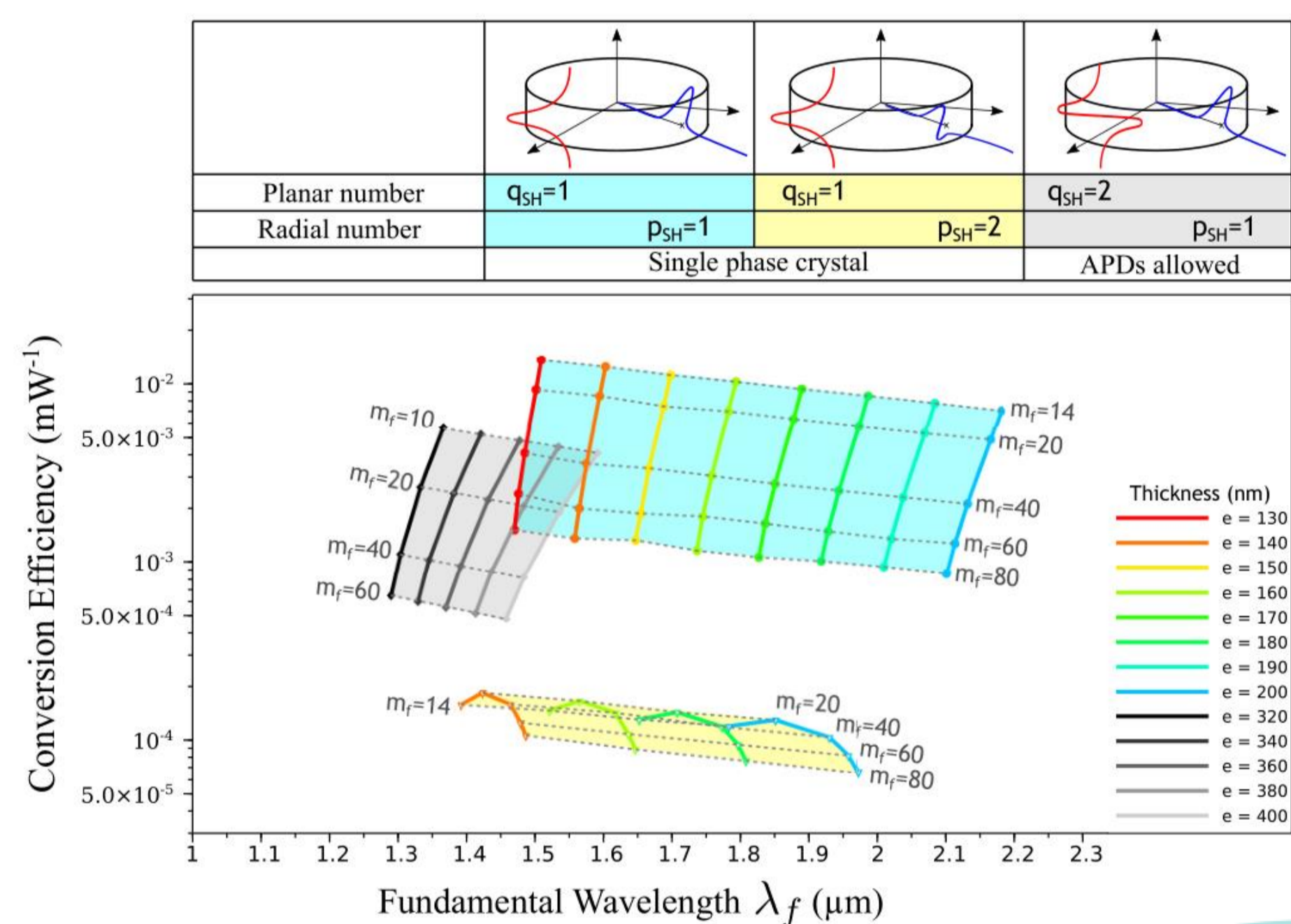
$$E = A(z)E_1 + B(z)E_2$$

$$H = A(z)H_1 + B(z)H_2$$

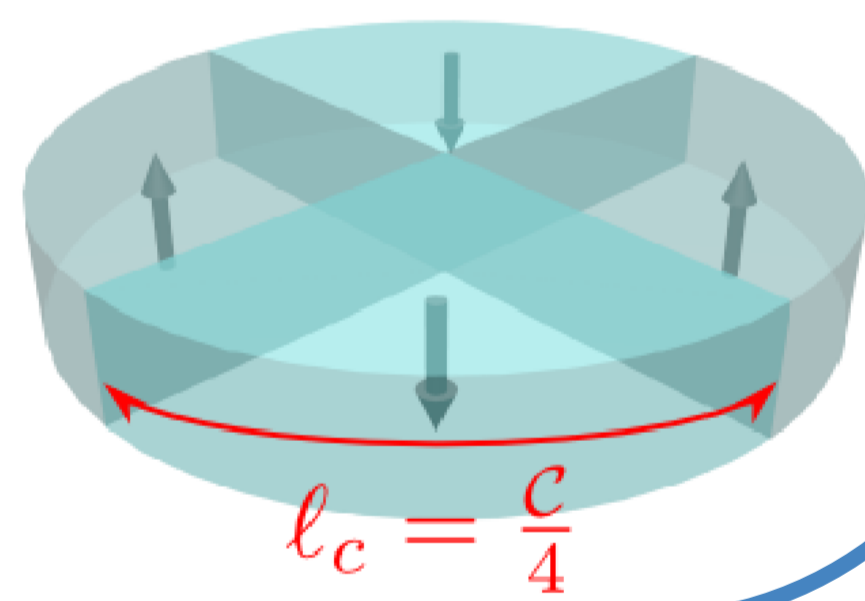
Achieve propagation constant engineering for TE and TM

$\bar{4}$ Quasiphasematching⁽³⁾

Possibility of QPM in circular microresonators

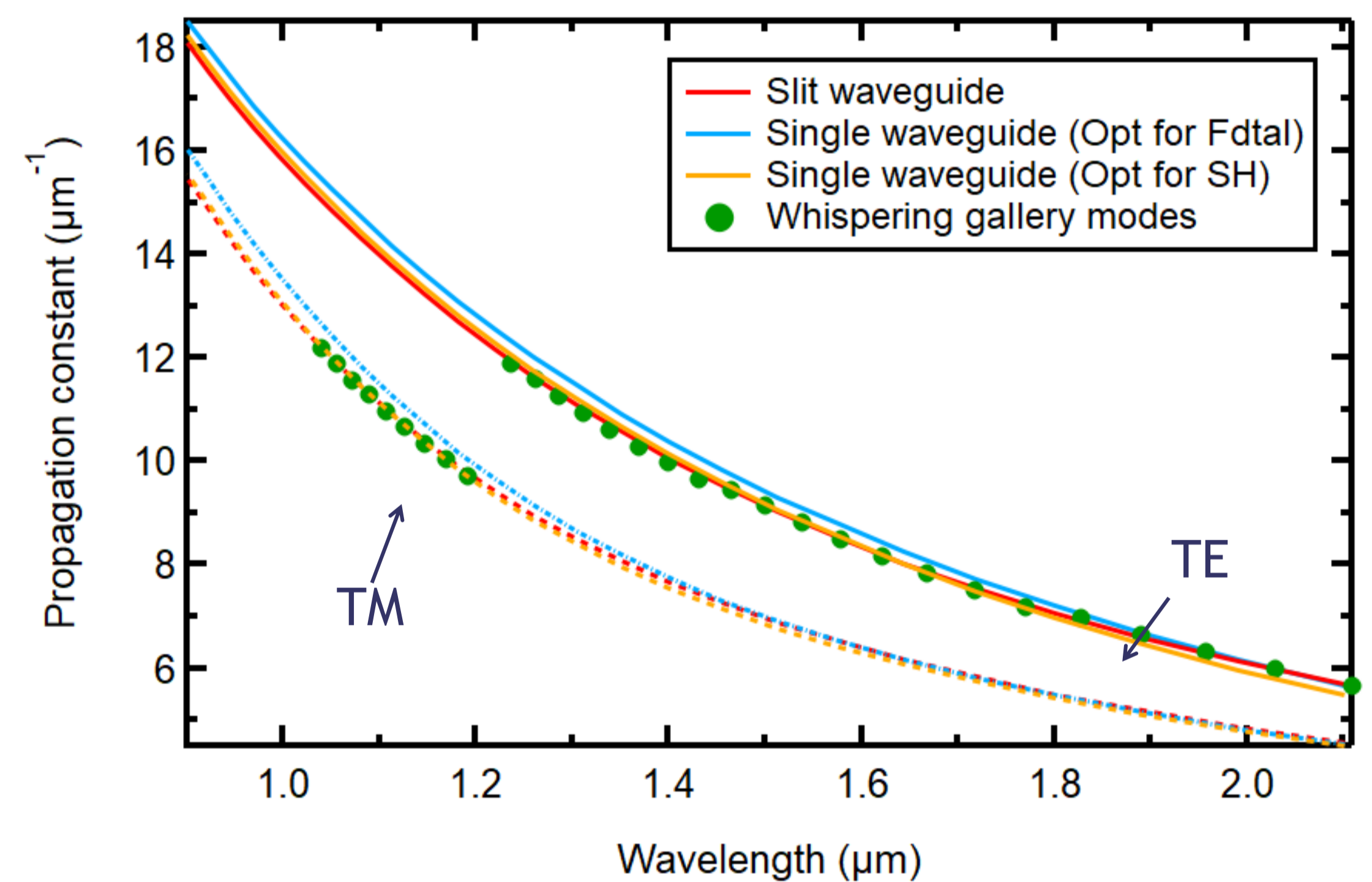


- Strict conditions:
 - $\Delta m = m_{SH} - 2m_{fdtal} = \pm 2$
 - $\omega = TE // 2\omega = TM$
 - Planar and radial numbers = 1



Study of dispersion

We calculate the dispersion curve for the three configurations

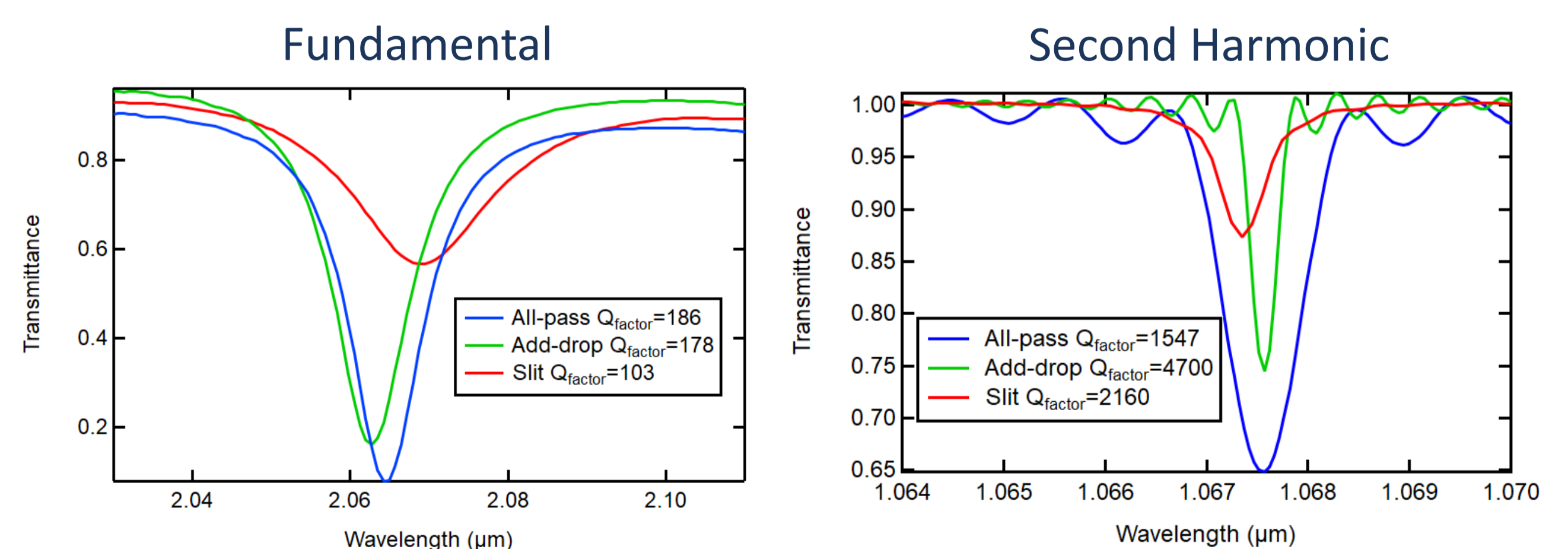


- Modal dispersion \rightarrow Impossible to couple both at once
- Slit size to control β separately
- Group index matching between guide and disk

Study of coupling

We compare the coupling for both wavelengths

- Different coupling regimes \rightarrow Undercoupling/overcoupling cases
- Waveguide vicinity \rightarrow high insertion losses
- Overcoupling regime well suited for pulsed excitation



Conclusion

- Comprehensive study of the different coupling configurations available
- Promising dual wavelength optical coupling scheme to microdisk resonators based on slit waveguide
- These configurations remain compatible with conventional semiconductor device processing

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(1) D. P. Lake et al. (2016) Efficient telecom to visible wavelength conversion in doubly resonant gallium phosphide microdisks. Appl. Phys. Lett. 108 031109

(2) P. Guillemé et al. (2016) Antiphase domain tailoring for combination of modal and $\bar{4}$ -quasi-phase matching in gallium phosphide microdisk. Opt. Express 24, 14608-14617

(3) P. Guillemé et al. (2017). Second harmonic generation in gallium phosphide microdisks on silicon: from strict to random quasi-phase matching. Semiconductor Science and Technology, 32(6), 065004