Inverse-design in large photonic gratings enabling efficient photonic-to-free-space mode coupling

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COMSOL Conference
October 7-8, 2020

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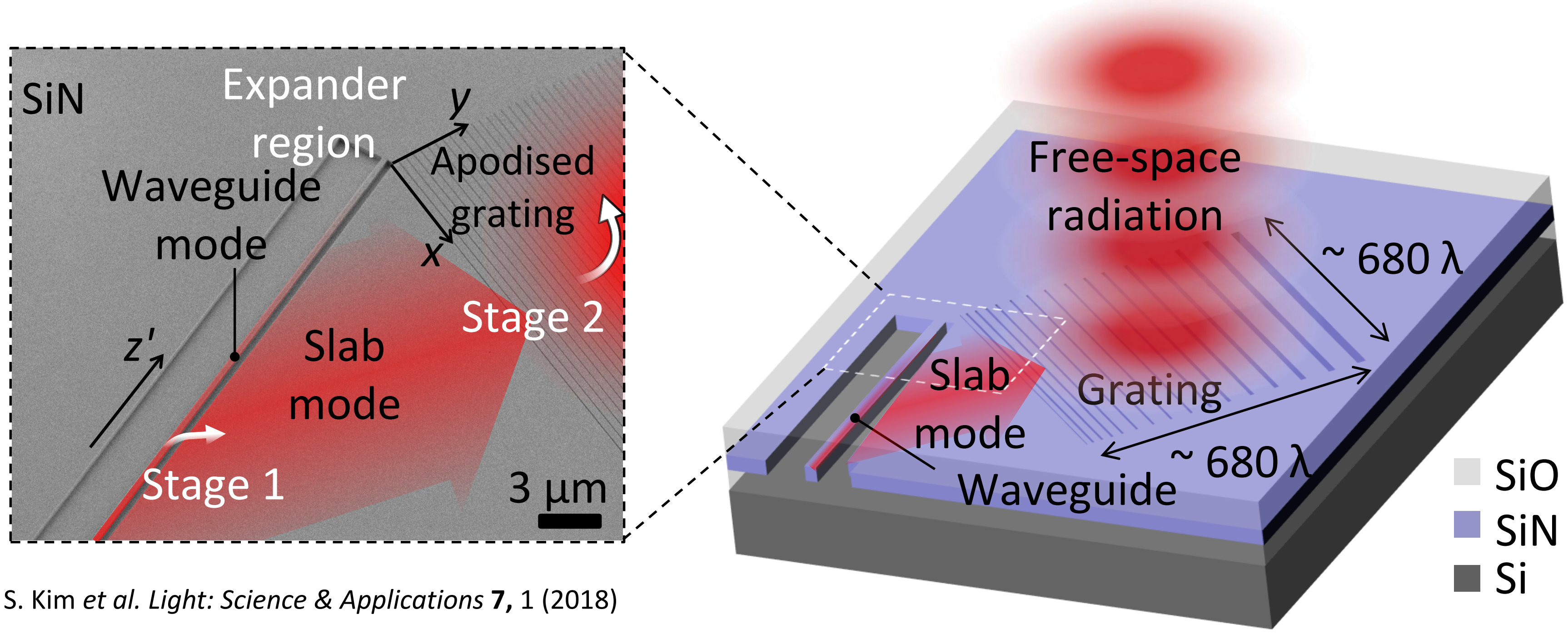
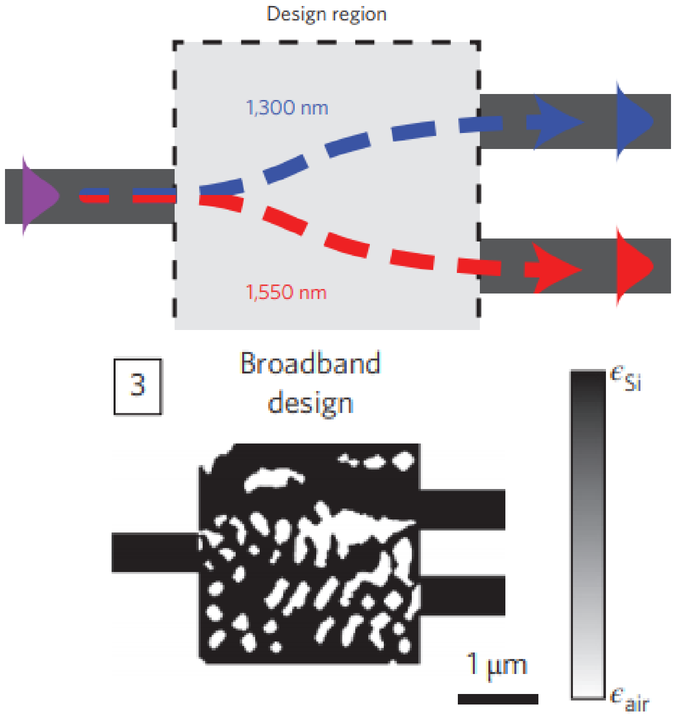
Designing Extreme Mode Converters



S. Kim *et al. Light: Science & Applications* **7,** 1 (2018)

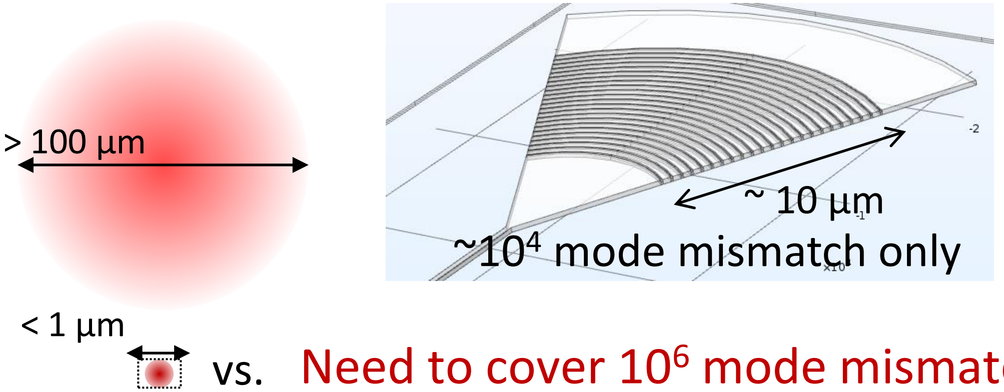
Inverse design based on continuously varying material properties



Harsh trade-off between computational resources/time and size of the design domain

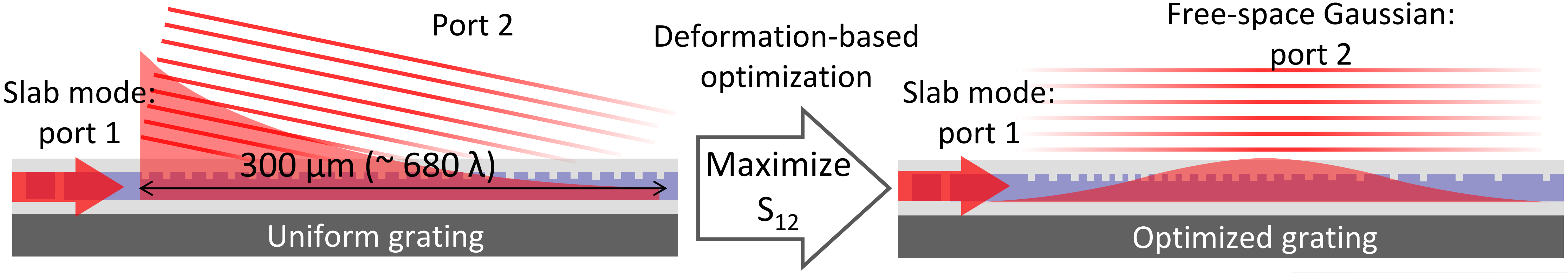
Piggott AY et al. *Nature Photonics* **9,** 374 (2015)

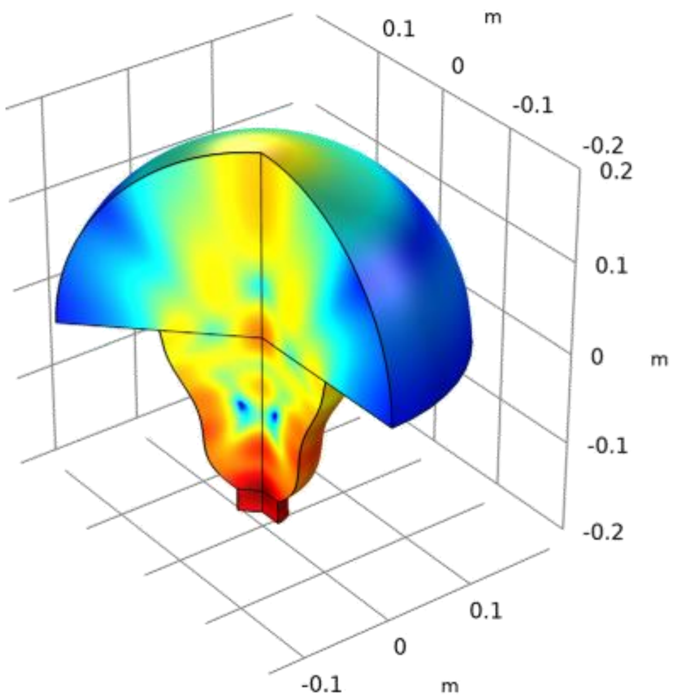
Conventional grating couplers



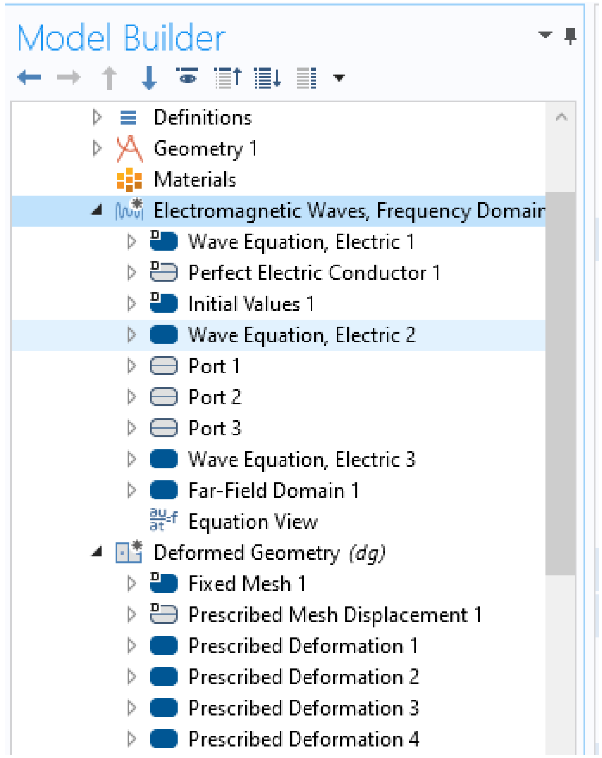
vs. Need to cover 10^6 mode mismatch

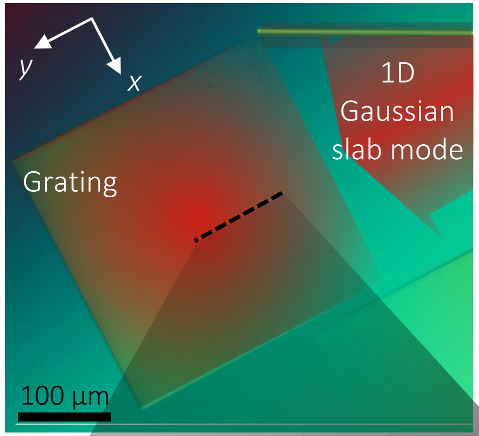
Our framework: Deformation-based inverse design

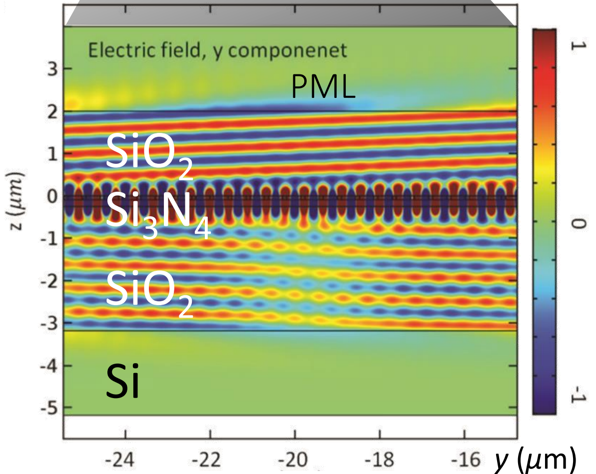




comsol.com/optimization-module







- Duty cycle defines local coupling efficiency
- Period changes to maintain phase constant

Setting Deformation-based optimization

SNOPT. Objective function

Optimization Solver

Method:

SNOPT

Optimality tolerance:

0.2

Study step:

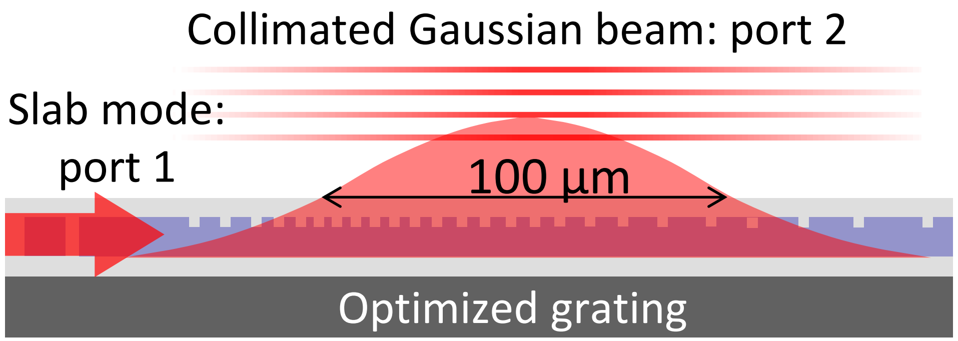
Frequency Domain

Maximum number of model evaluations:

700

Objective Function

Expression	Description	Ev
10*log10(realdot(comp1.ewfd.S12,comp1.ewfd.S12))	S-parameter, dB, 12 com...	F
(wg0/20e-6-5)	width forcing	F



Control variables & Parameters

Control Variables and Parameters

Parameter name	Initial value	Scale	Lower bound	Upper bound
wg0	35e-6	100e-6	30e-6	100e-6
d0	0.0021618	0.4	-0.4	0.4
d1	0.58706	1	-0.1	1
d2	0.092279	0.1	-0.1	0.1
d3	-0.021815	0.1	-0.1	0.1
d4	-0.01474	0.05	-0.1	0.1
p0	437.68e-9	10e-9	420e-9	445e-9
p1	-3.1115e-4	0.01	-0.03	0.03
p2	-0.008	0.01	-0.03	0.03
p3	-0.002651	0.01	-0.03	0.03
dy	1.23E-1	0.1	0.04	0.15
ctrG	0	0.1	-0.3	0.3
dSi	2.9084e-6	0.05e-6	2.8e-6	3.0e-6

Constraints

Constraint

Ψ dut

Bounds

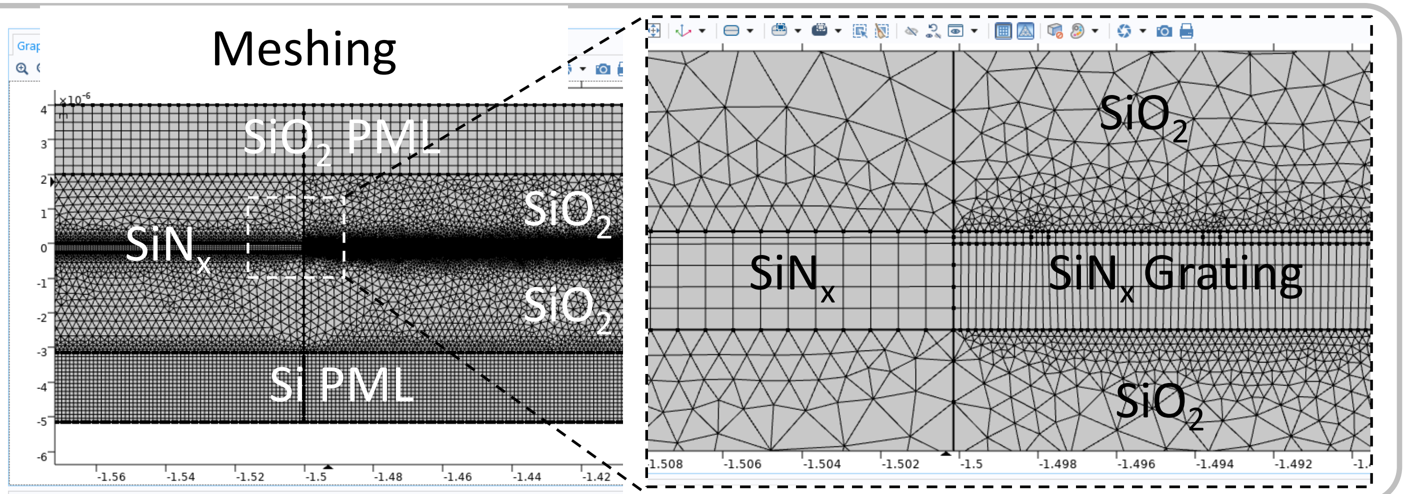
☑ Lower bound

0.1

☑ Upper bound

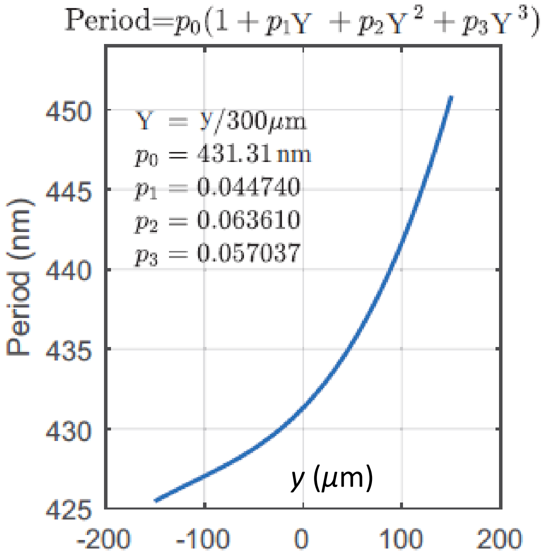
0.8

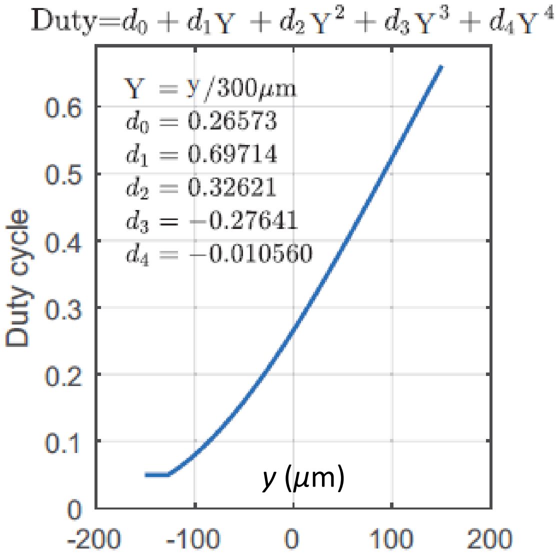
Discretization

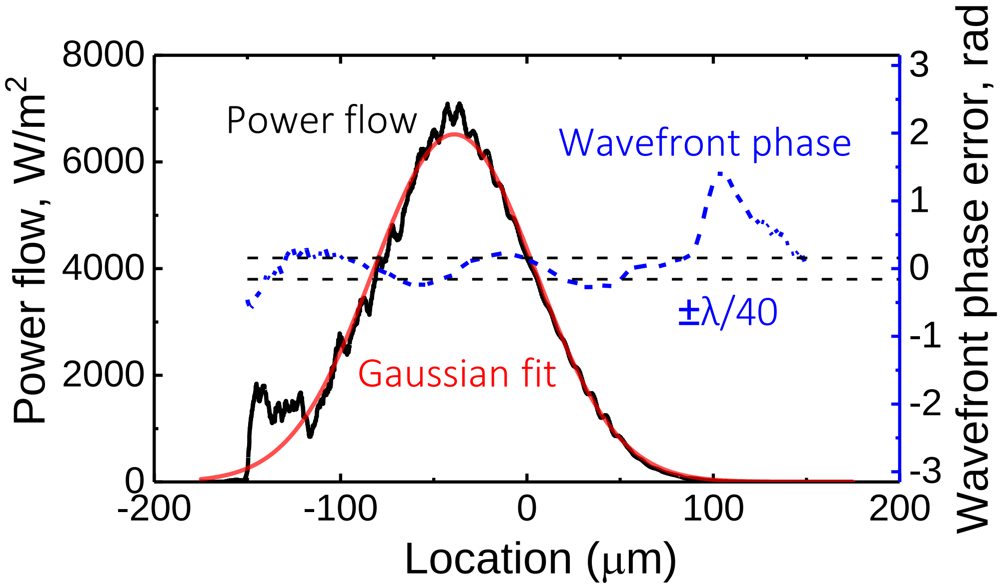


Ex.1: Wide collimated Gaussian beam at finite-angle

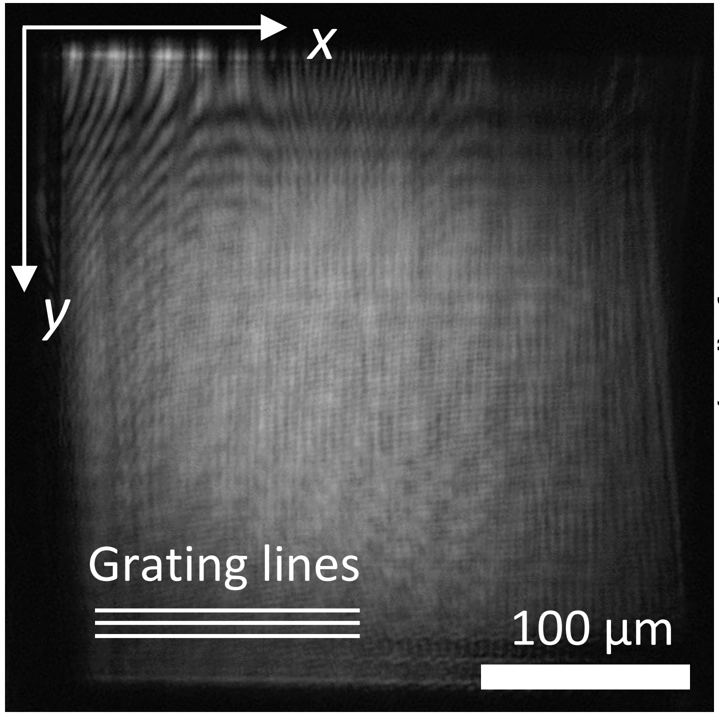
FEM simulations

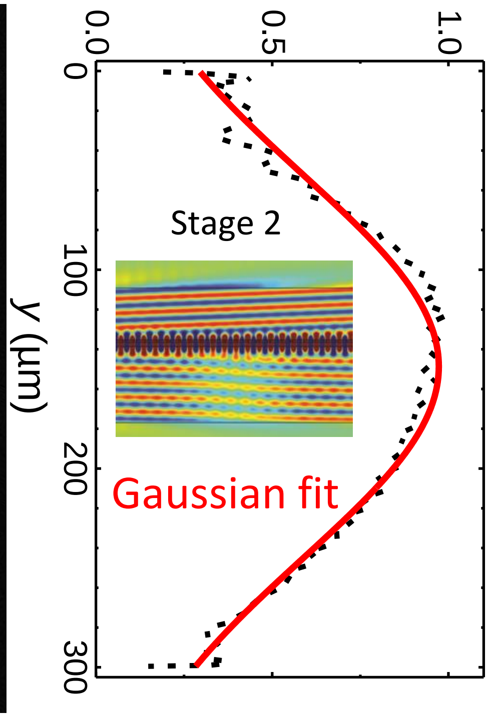




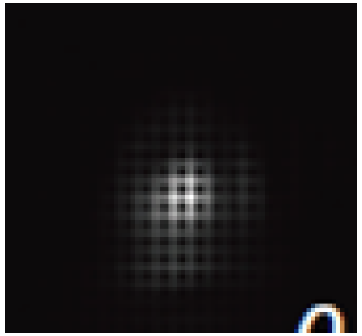


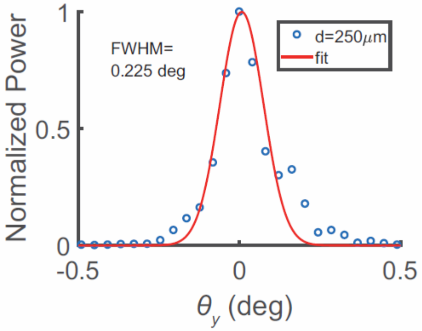
Experiment





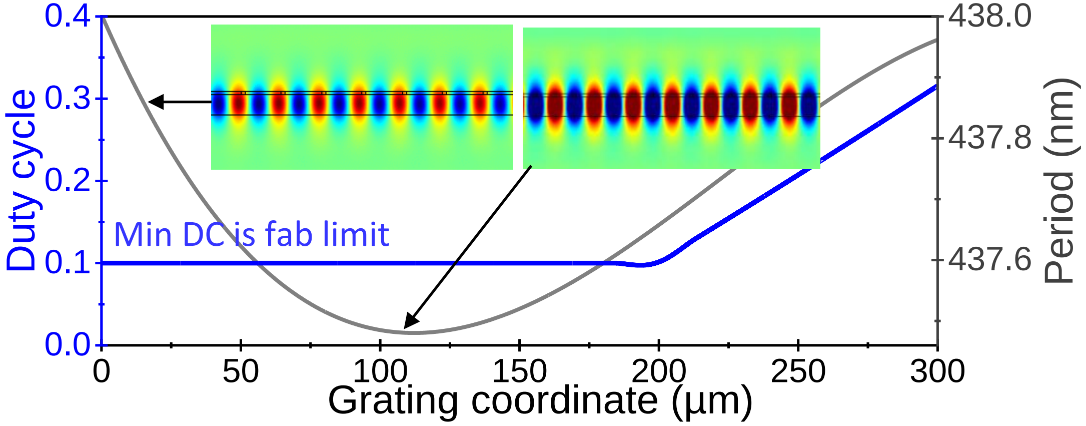
Near-diffraction-limited Gaussian

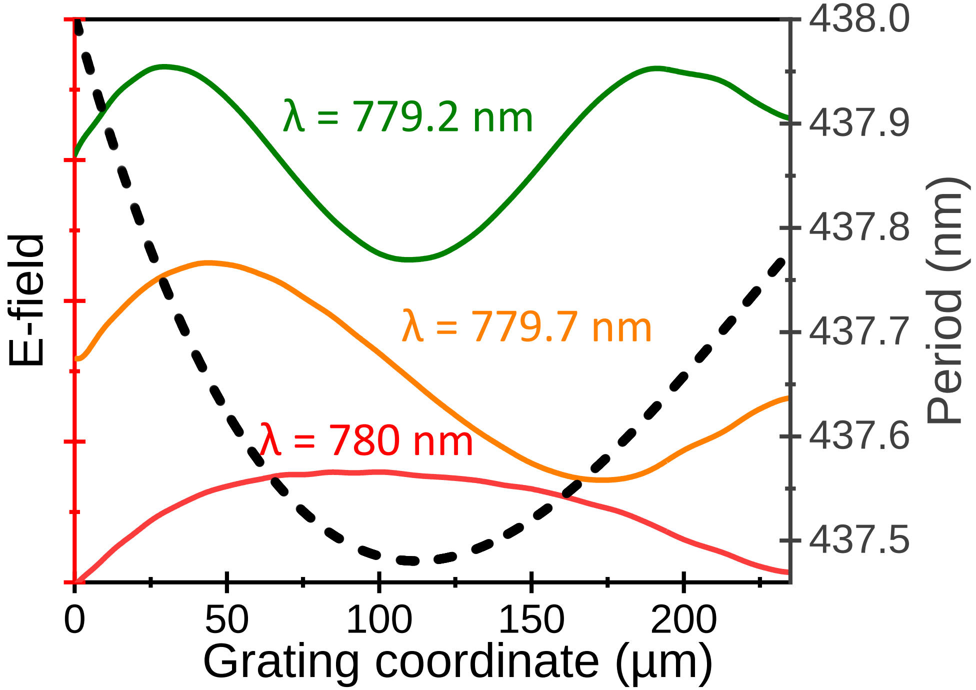




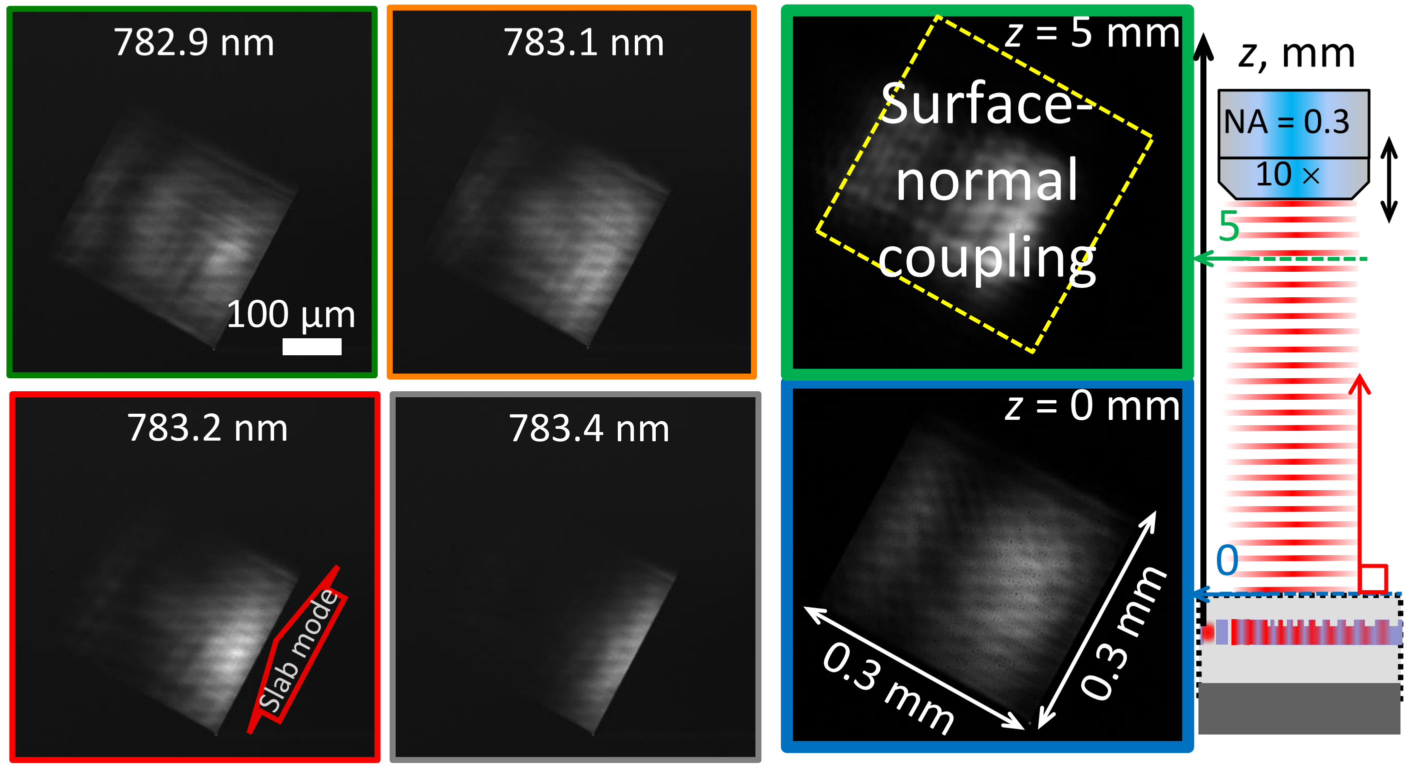
Ex.2: Surface-normal collimated Gaussian beam

FEM simulations:
Slow-light resonant grating



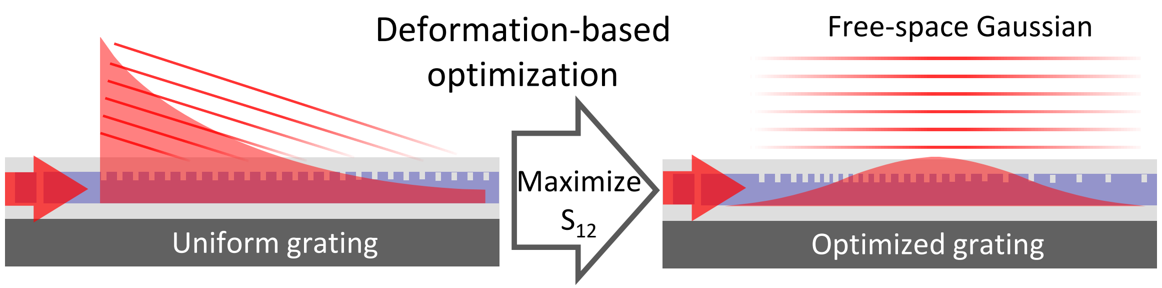


Experiment

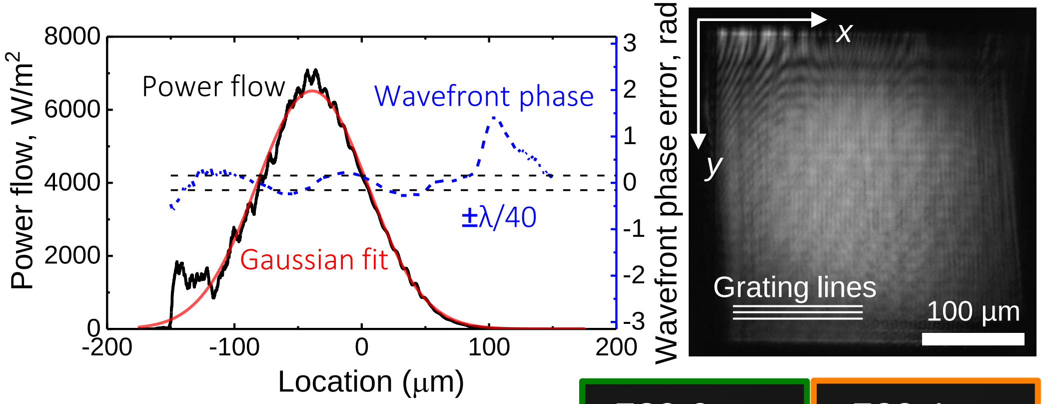


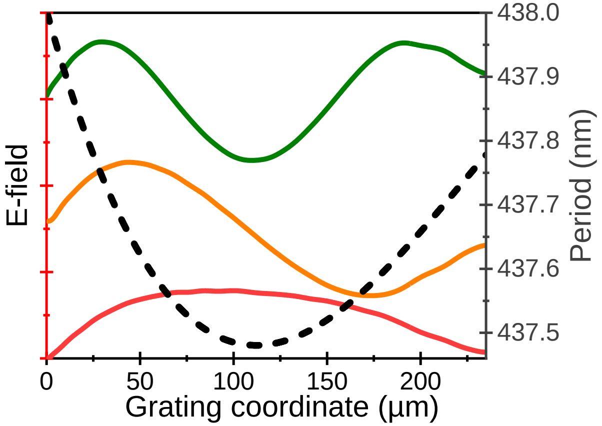
Conclusions

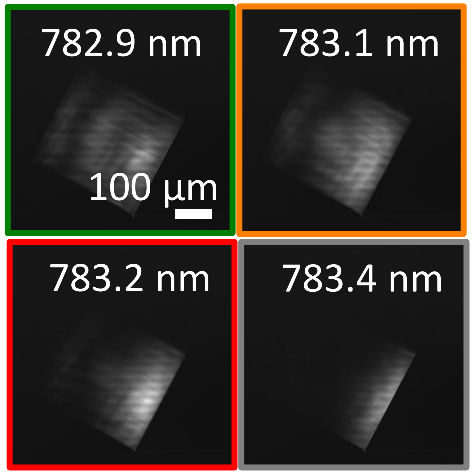
1. Developed deformation-based optimization framework for bridging the scale mismatch of 10^5 times in modal area, projecting 160 µm wide 2D free-space Gaussian beam;



2. Design can be adapted for visible, telecom, and UV wavelengths;
3. Waveguide-to-free-space calculated coupling conversion is 70 %
4. Well controlled light intensity, phase, and polarization
5. Discovered new operational mode (resonant grating)







Acknowledgements

This work has been conducted at PML, NIST using CNST NanoFab facilities. Dr. Alexander Yulaev acknowledge support under the Professional Research Experience Program (PREP), administered through the Department of Chemistry and Biochemistry, UMD.

Publications

A. Yulaev *et al. ACS Photonics* **6,** 2902 (2019)
S. Kim *et al. Light: Science & Applications* **7,** 1 (2018)
A. Yulaev *et al. CLEO: Science and Innovations,* OSA, (2020)

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