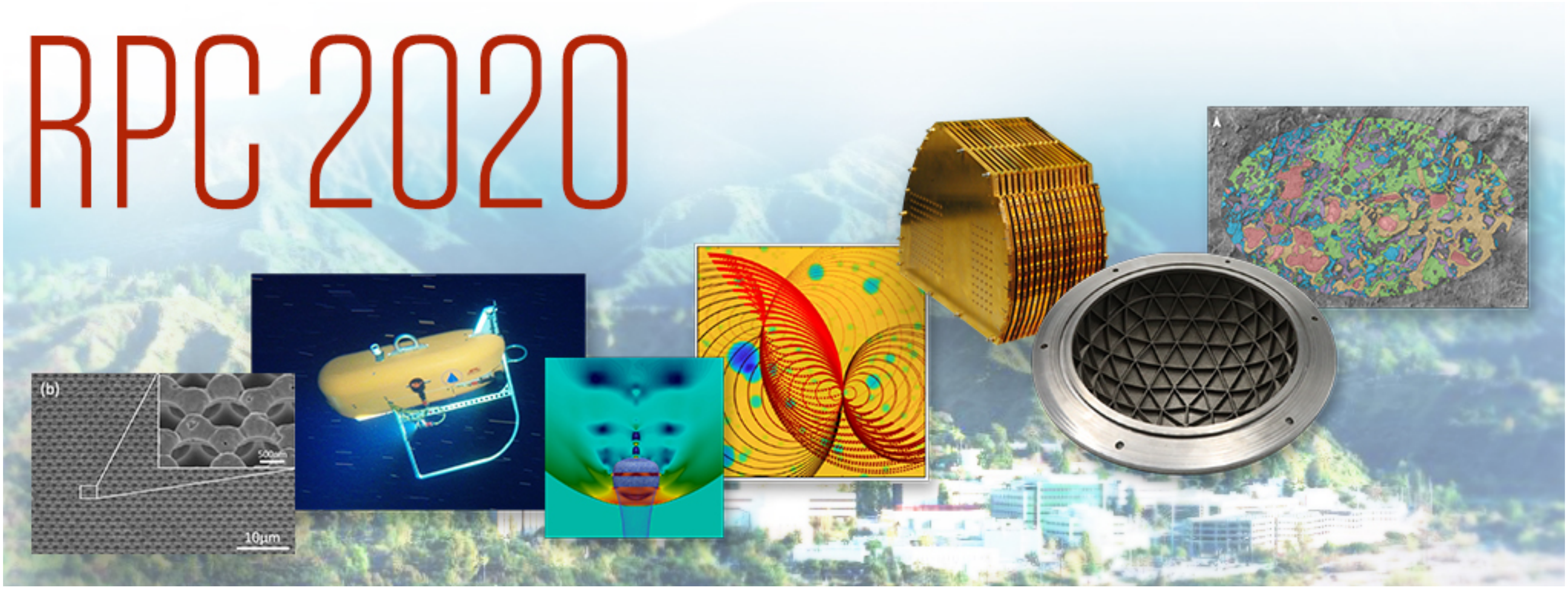

Virtual Research Presentation Conference

Multi-Layer Grating Couplers for Broadband LP-mode Demultiplexing

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Program: Spontaneous Concept

Assigned Presentation # RPC-098

Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

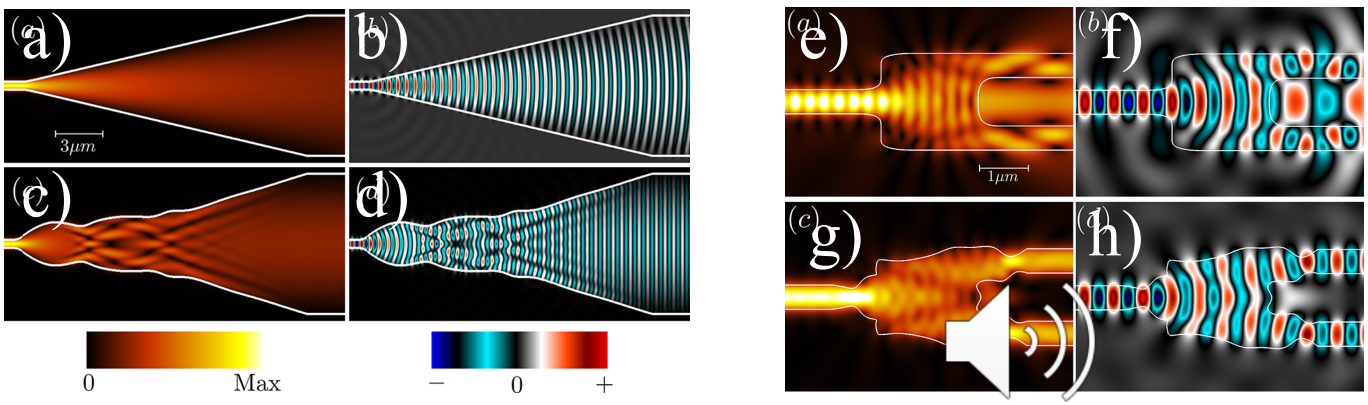
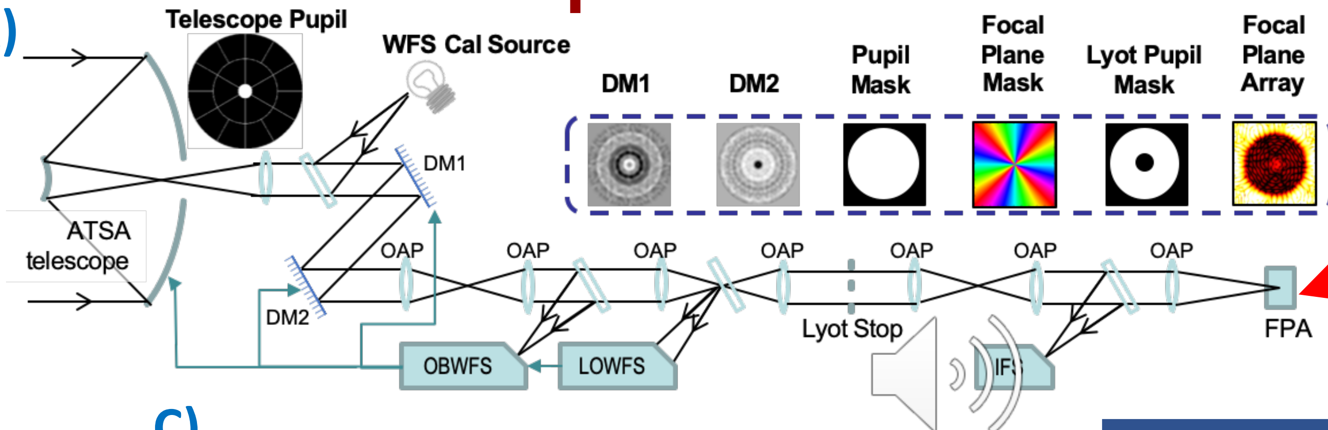


Figure: *Optimal photonics through inverse design and state of the art integral equation Maxwell solver ([1], C. Sideris et al, ACS Photonics, 6, 2019)* **(a-b)** Initial design of an adiabatic taper achieving only 49% efficiency; (a) modulus and (b) electric field real part). **(c-d)** Inverse designed solution achieving 99% efficiency (modulus (c) and real part (d)). **(g-h)** Analogous figures for a power splitter, with the initial and final designs achieving <30% and 99.6% efficiency respectively.

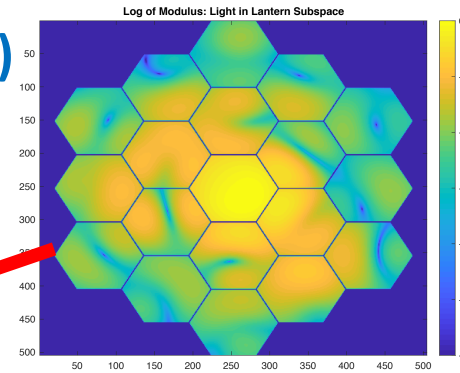
Abstract Our objective was to design a new multi-layer grating coupler for broadband LP-mode demultiplexing, optimized with a state-of-the-art integral equation method Maxwell solver in an inverse photonics design framework. Grating couplers provide one way to couple incident light into waveguides which can then be routed to integrated photonic devices (integrated circuits and/or arrayed waveguide gratings). Photonic devices will typically have high throughput over a limited wavelength range, so that building up coverage over a science driven bandpass requires spectral demultiplexing of the incident light into separate channels. We explored the novel idea of stacked layers of grating couplers, with each layer designed to couple to a narrow wavelength band, providing overall broad wavelength coverage. The focus of this proposal involved two-dimensional optimization as a first step – future work will involve fully three-dimensional optimization also including spatial arrays of the couplers designed here for fundamental, and higher-order, LP-mode spatial/spectral de-multiplexing for subsequent photonic integrated circuit "computing" on chip.

Problem Description

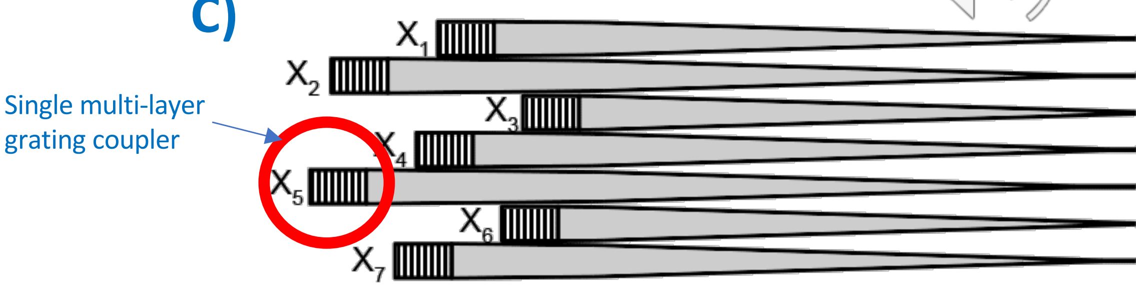
A)



B)



C)

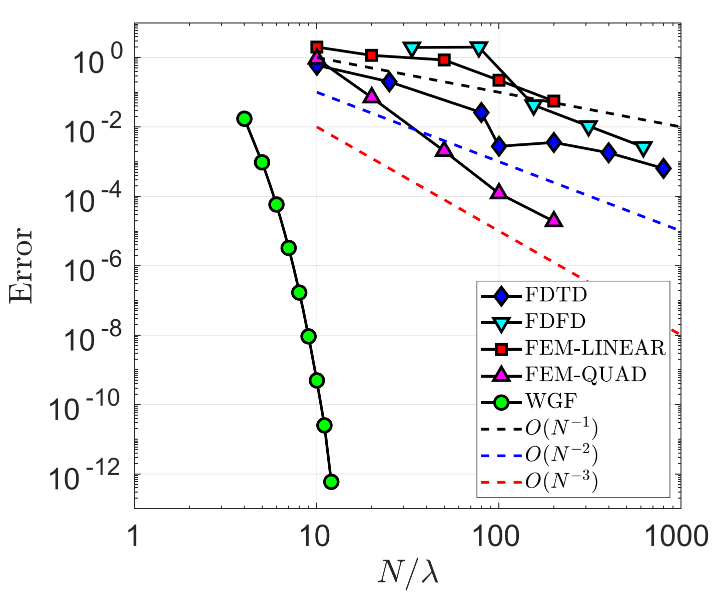


Integrated photonic devices on the same chip, which can include (but not limited to):

- Photonic integrated circuits
- Arrayed Waveguide Grating spectrometers

A) The optical path from a segmented aperture telescope through a coronagraph [2]. **B)** Simulated focal plane diffraction pattern (modulus shown) for an aberrated wavefront due to telescope primary mirror segment piston errors, overlaid on a hexagonal spatial array of lenslets. **C)** An example spatial array of grating couplers, here showing a 1-ring spatial array, which would sit underneath the lenslets in fig. B above. Near normal incidence light couples into the grating couplers and through the adiabatic tapers, routing the light into downstream photonic devices on the same chip. ***Our inverse designed multi-layer grating coupler can feed multiple narrow band channels to downstream photonic devices, enabling overall broadband photonic instrument concepts.***

Methodology



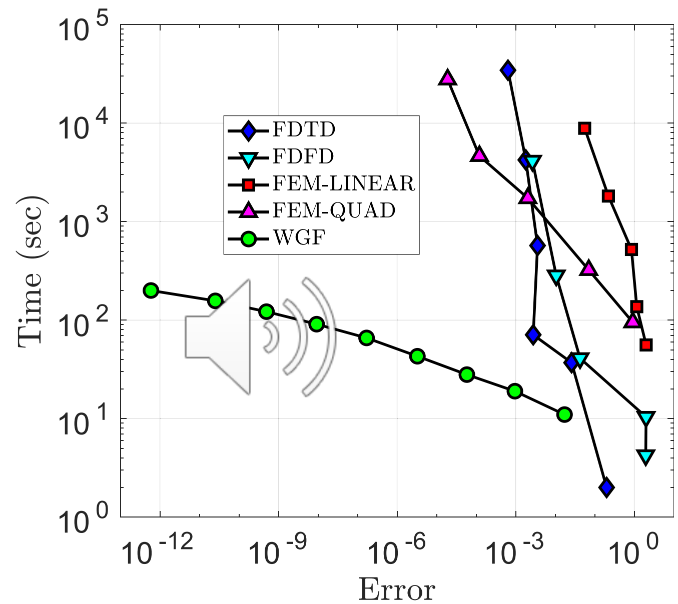
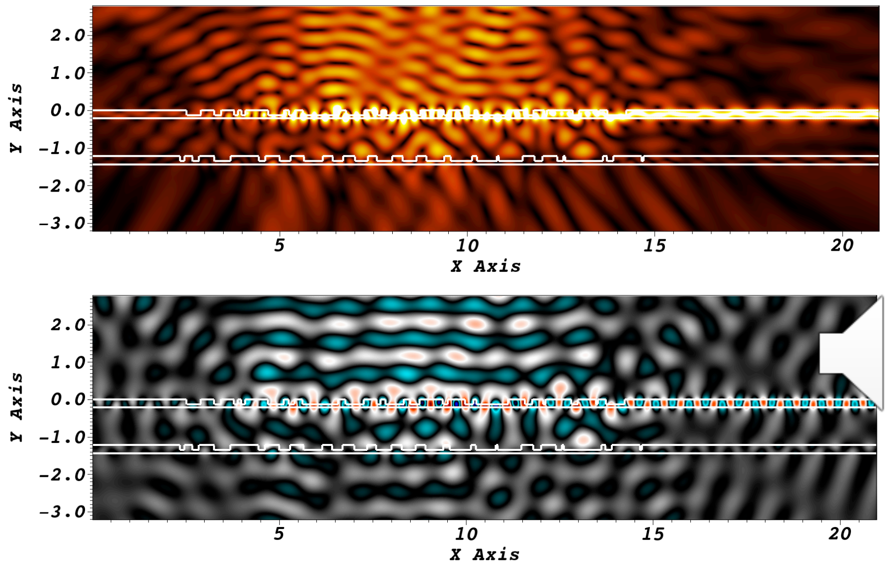


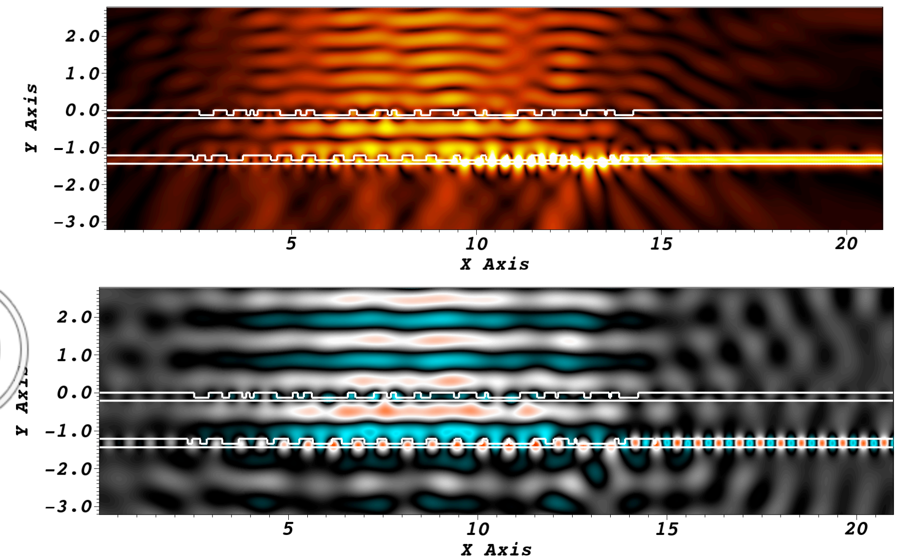
Figure: Error for the integral equation Maxwell solver (green points) compared to Finite Difference Time Domain (FDTD) and other numerical methods with respect to (left) number of points per wavelength and (right) time required. ([1] C. Sideris et al, ACS Photonics, 6, 2019)

Innovation of the approach: We use a state-of-the-art integral equation Maxwell solver [1], orders of magnitude faster and more accurate than Finite Difference Time Domain (FDTD) solvers, enabling high fidelity fields to be solved at each step of an inverse photonics design optimization. The speed and accuracy of the solvers enable optimization directly in terms of high-dimensional device (geometric) parameter spaces, resulting in novel, non-intuitive, photonic device designs. The framework allows objective functions including rewards for robustness to fabrication errors. The optimization involves an adjoint method gradient descent, converging to local objective function minima. Good feasible solutions are discovered with an ensemble of random initial designs.

Results



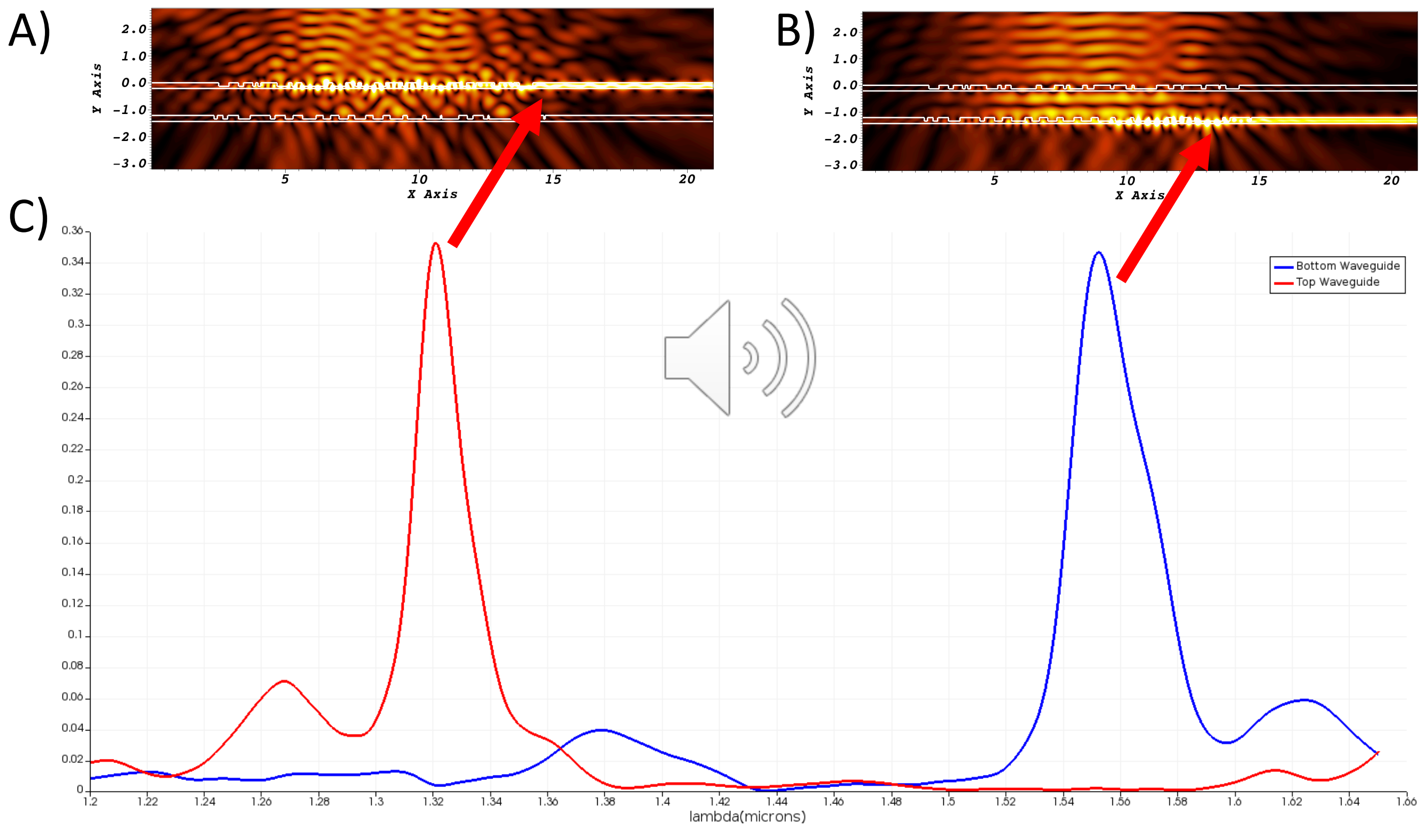
The modulus (top) and real part (bottom) of the field at ***1.31 micron strongly coupling to the top*** *grating coupler as designed.*



The modulus (top) and real part (bottom) of the field at ***1.55 micron strongly coupling to the bottom*** *grating coupler as designed.*

Inverse design of both the top and bottom grating couplers was used to optimize the geometric parameters of the grating coupler "teeth" width and spacing to couple to 1.31 micron in the top layer, and 1.55 micron in the bottom layer, as shown in the figures above. Notice that the inverse designed top and bottom couplers successfully allow wavelengths other than 1.31 micron (coupling strongly to the top layer) to pass through the top layer and strongly couple to the bottom layer. ***This provides an example of the innovations waiting to be discovered with inverse design of photonics, enabling non-intuitive and novel methods of spatial and spectral mode de-multiplexing.***

Results



A) *The modulus of 1.31 microns, and* ***B)*** *1.55 micron, showing the fields strongly coupling to the top and bottom grating couplers respectively.*
C) *The frequency response of the fields showing the spectral response function of the inverse designed multi-layer grating couplers.*

Publications and References

[1] C. Sideris, et al., *"Ultrafast Simulation and Optimization of Nanophotonic Devices with Integral Equation Methods",* ACS Photonics, 6, 2019.

[2] C. Lawrence, et al, Astro2020 White Paper, “Active Telescopes for Future Space Astronomy Missions”.