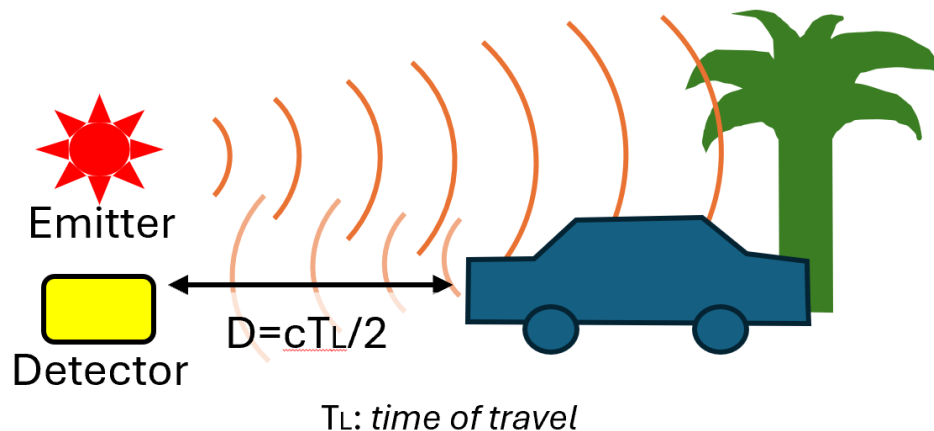


Designing LIDAR on a Chip

A Multiphysics Simulation Workflow for Integrated Photonics

Introduction

LIDAR (Light Detection and Ranging) has become a cornerstone technology for autonomous vehicles, enabling high resolution spatial mapping and object detection. As the industry pushes toward scalable, cost-effective solutions, **LIDAR on a chip** has emerged as a compelling alternative to traditional mechanical systems. Its advantages — compactness, robustness, and the absence of moving parts — make it an excellent candidate for large volume manufacturing.



However, achieving commercially viable on chip LIDAR requires careful optimization. Designers must minimize insertion loss, maximize output optical power, broaden beam steering range, and narrow the emitted beam. To meet these challenges, **reliable and specialized photonic simulation tools** are essential for reducing development cycles and ensuring high performance designs.

Overall Design and Simulation Strategy

To efficiently design a LIDAR-on-chip system, the device is decomposed into functional blocks, each simulated using the most appropriate tool from the **RSOFT Photonic Device Tools** suite:

- **Cascaded 1×32 splitter:** **BeamPROP BPM™**
BPM is ideal for 1×2 splitters due to little backward reflection and suitability for slowly varying structures.
- **Thermo-optical phase shifter:** **BeamPROP BPM™ + Multiphysics Utility**
BPM handles optical propagation, while the Multiphysics Utility computes temperature dependent refractive index perturbations.
- **Emitter (grating antenna array):** **FullWAVE FDTD™**
FDTD (Finite Difference Time Domain) is required for omnidirectional light propagation and accurate grating coupler modeling.

This modular approach ensures each component is optimized using the most accurate and computationally efficient method available.

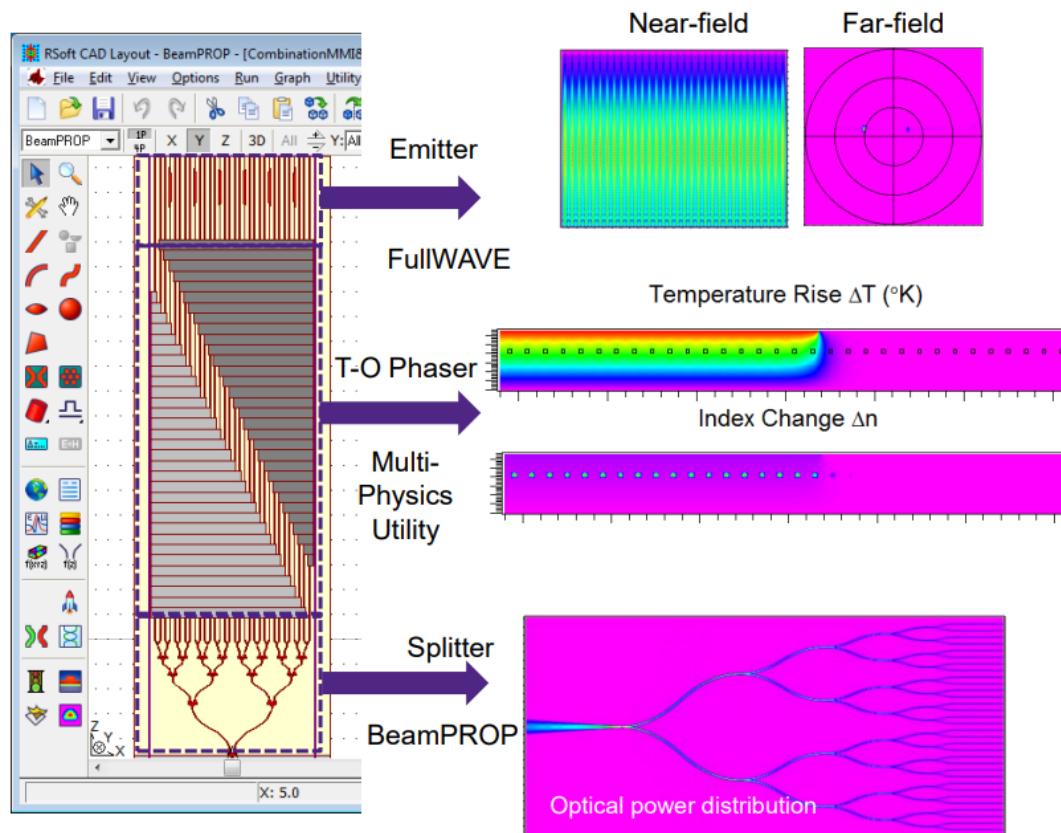


Figure 1. The overall design is composed of a splitter tree that could use either MMI or Ybranch splitters, then a thermo-optical phase shifter, and finally a collection of antennas for the emitter.

Step-by-Step Design of Individual Components

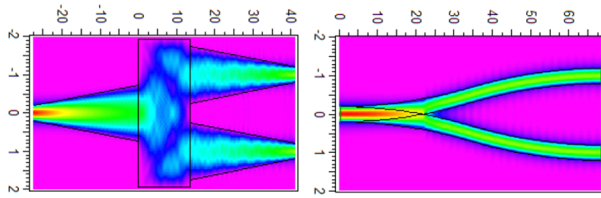
Power Splitter

A splitter tree is constructed using cascaded 1×2 splitters—either **MMI** or **Y-branch** designs.

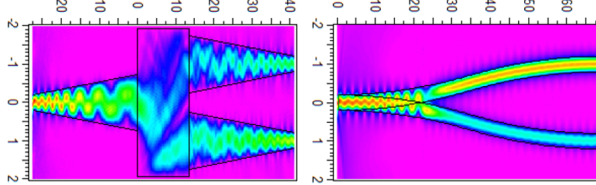
- **1×2 MMI splitters**
 - Low insertion loss (~0.3 dB)
 - Robust to asymmetric input
 - More complex to design
 - Wavelength sensitive, limited bandwidth, polarization dependent
- **Y-branch splitters**
 - Simple geometry (two S-bends)
 - Broadband and polarization independent
 - Higher insertion loss (~2 dB)
 - Less tolerant to asymmetric input

Both structures are well-suited to **BeamPROP BPM**, which solves one-way wave equations under assumptions of slow structural variation and monochromatic excitation.

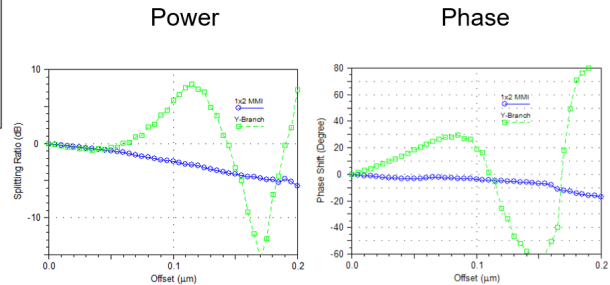
- Symmetric input



- Asymmetric input



- Sensitivity study

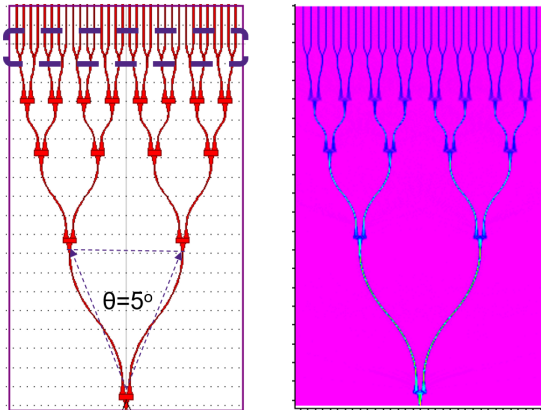


MMI is more tolerant and robust than Y-branch to asymmetric input, this is inherent to s-bends

Figure 2. Side-by-side comparison between MMI splitter and Ybranch.

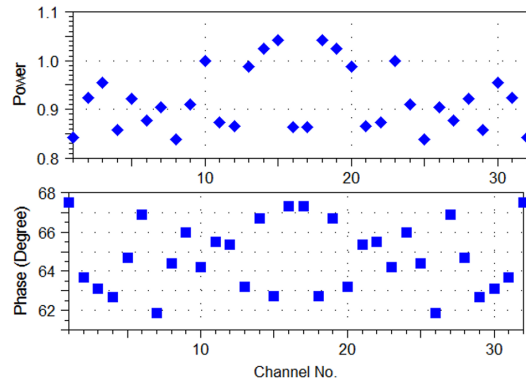
After optimizing width and length using 2.5D (2D-EIM) BPM, sensitivity analyses were performed for symmetric and asymmetric inputs. The final **1×32 splitter tree** uses four levels of 1×2 MMIs, followed by a fifth level of Y-branches where MMIs became too large to fit the remaining layout area.

Cascaded 1x2 splitters BeamPROP simulation



Y-branches are used in the last stage, MMI is too big to fit

Monitored power and phase



Some spread on uniformity is observed due to the asymmetric input from S-bends

Figure 3. Overall cascaded splitter with 1×32 branches.

Thermo-Optical Phase Shifter

Silicon's strong thermal sensitivity ($dn/dT = 0.00024/K$) enables phase tuning by heating waveguide arrays. Unequal heating introduces phase delays between channels, steering the output beam.

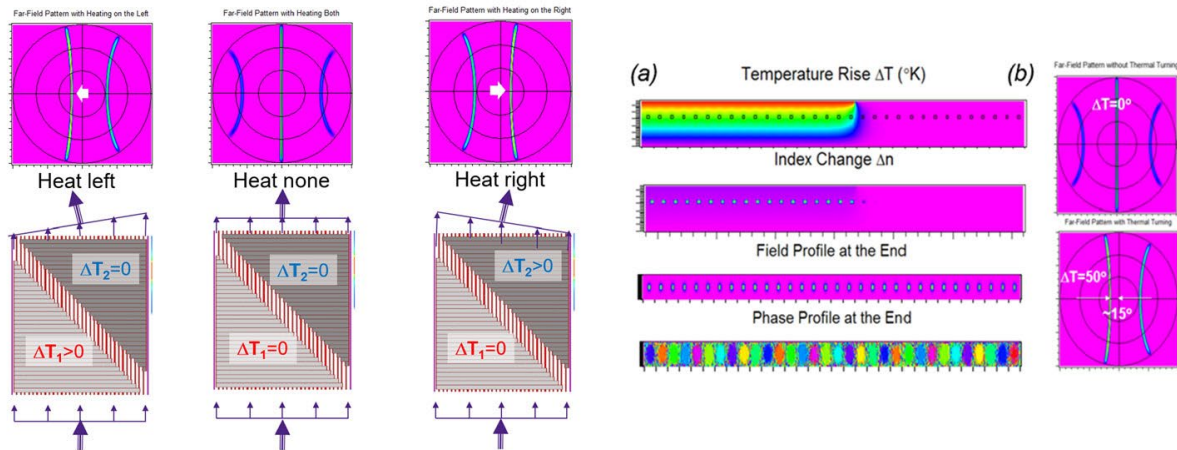


Figure 4. Thermal phase shifter simulated using BeamPROP BPM and Multiphysics Utility.

The workflow:

1. **Thermal diffusion equation** solved to obtain temperature distribution.
2. Temperature profile converted into refractive index perturbation.
3. BPM simulates optical propagation to compute amplitude and phase at the output.
4. Far-field analysis reveals the resulting beam steering.

For a temperature change of $\Delta T = 50^\circ\text{C}$, the phase difference between adjacent waveguides is **120°**. BPM predicts a steering angle of **15°**, matching the theoretical value:

$$\psi = \sin^{-1}(2\pi\Delta\Phi/\lambda) = 15^\circ$$

Emitting Gratings

To efficiently outcouple light (orthogonally) with minimal divergence, the grating must be **properly apodized**. FDTD optimization yields an optimal tapered width grating profile, normalized to the grating length (Fig. 5).

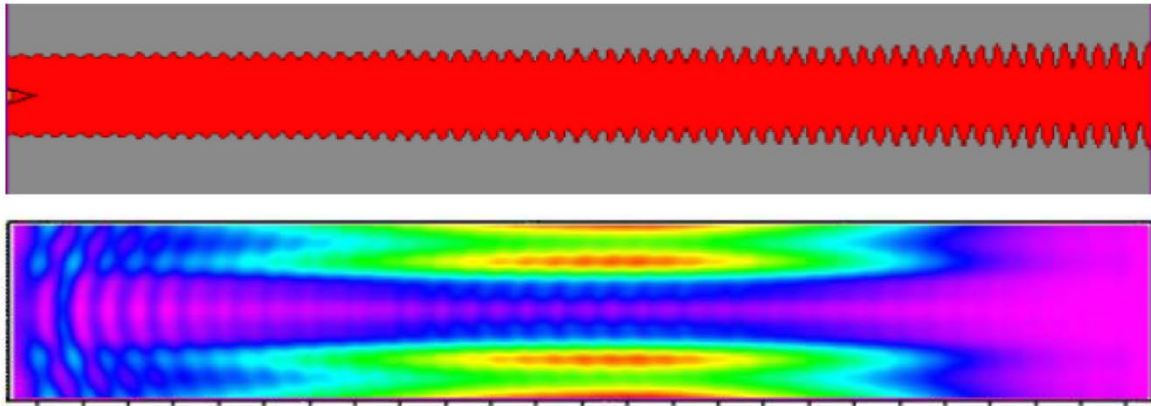


Figure 5. Optimized grating and emitted field

Full 32-channel FDTD simulation is computationally prohibitive (≈ 100 GB RAM few days' computation time). Instead, each waveguide input is simulated independently over a large domain (5-waveguide widths). The total near-field is obtained by coherently summing all individual near-fields (Figure 6b), and the far-field is computed from its transform (Figure 7).

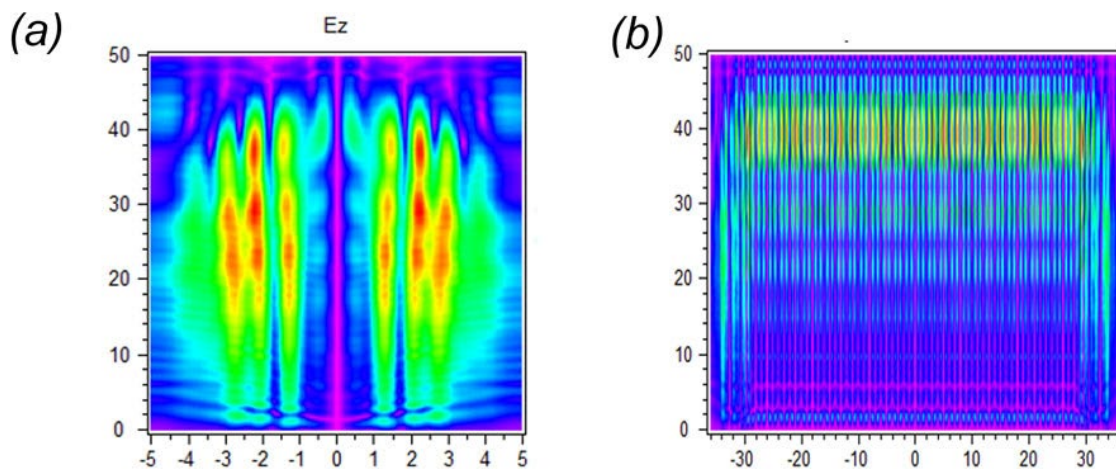


Figure 6. (a) Emitted near-field with input from a single waveguide; (b) Coherently combined near-field with inputs from every waveguide.

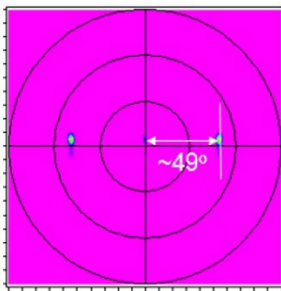


Figure 7. Emitted far-field

In figure 7, the first order diffraction angle is approximately **49°**, closely matching the theoretical prediction: -order diffraction angle is approximately

$$\sin^{-1}(l_0/D) = 50.8^\circ \text{ (at } \Delta\Phi=0^\circ \text{ and } \lambda=1.55\mu\text{m)}$$

Conclusion

RSoft tools provide a powerful and flexible environment for designing **integrated photonic LIDAR systems**. Because no single simulation method can accurately model every component, decomposing the device into functional blocks — and applying BPM, FDTD, and Multiphysics solvers where appropriate — is essential.

By combining **FDTD** for complex radiative structures with **BPM** for guided wave components, designers can thoroughly analyze system level performance while optimizing each building block for maximum efficiency.

If you're exploring integrated LIDAR architectures or evaluating photonic design workflows, feel free to ask about **trial access to these simulation tools** so you can experiment with your own designs.

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