Modelling of Polymer Taper Waveguide for Optical Backplane

Atef M. Rashed and David R. Selviah

Department of Electronic and Electrical Engineering
University College London
Torrington Place, London WC1E 7JE, United Kingdom

a.rashed@ee.ucl.ac.uk   d.selviah@ee.ucl.ac.uk

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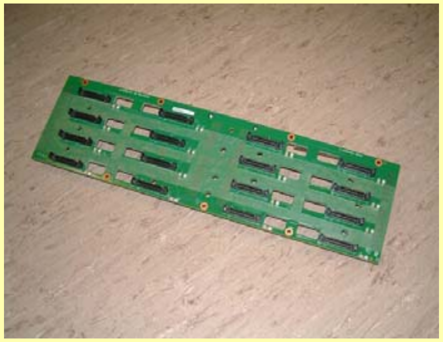
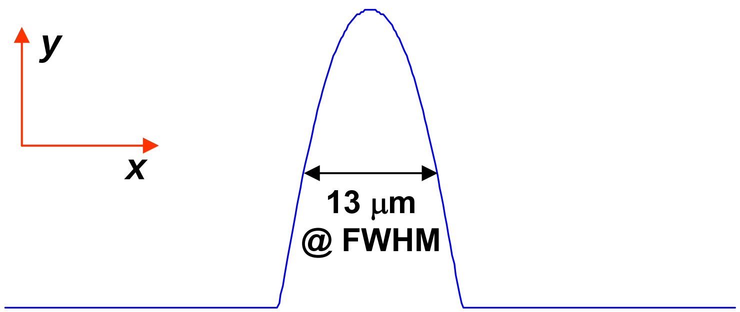
Optical Backplane



- Complex, high capacity data storage units involve different levels of communication such as board-to-board, rack-to-rack and cabinet-to-cabinet.
- With data rates in the range of 10 Gb/s the electrical interconnects are a bottleneck because of the cross talk and EMI.
- Optical backplanes using optical waveguide interconnects offer many advantages such as high distance bandwidth product, immunity to EMI and light weight.
- Polymer waveguides are easy to integrate within the FR4 PCBs.

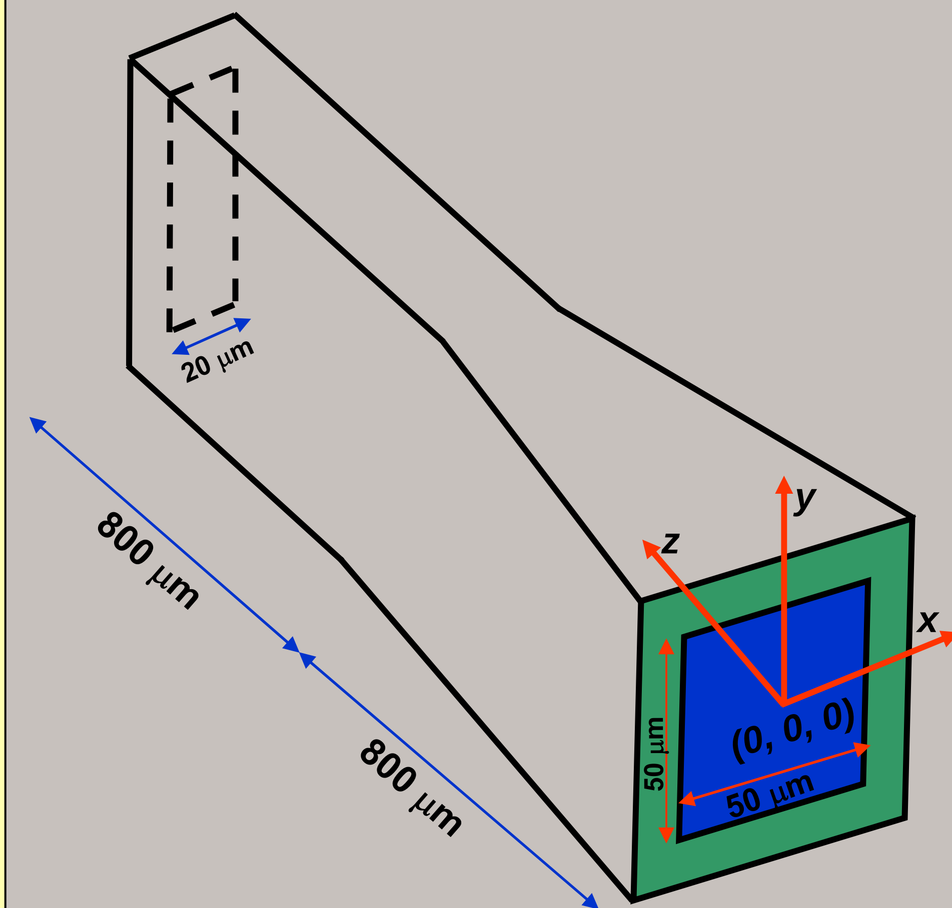
Polymer Taper Waveguide

- Tapered waveguide with wider input aperture provides the optimum solution for wide tolerance to source misalignment and excellent modal behaviour.
- Half taper angle ≈ 1°.
- Core input and output cross sections are 50x50 and 20×50 μm, respectively.
- 2% step index profile with $n_{core} = 1.54$.



VCSEL fundamental mode

- The fundamental mode of a 20 μm aperture VCSEL emitting at 850 nm is used as the source located at (0, 0, 0).



Schematic of taper waveguide

Waveguide Model Using FD-BPM Technique

Helmholtz Equation for the field *u*:

$$\frac{\partial u}{\partial z} = \frac{i}{2\beta}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \left(\frac{4\pi^2 n^2(x,y,z)}{\lambda^2} - \beta^2\right)u\right)$$

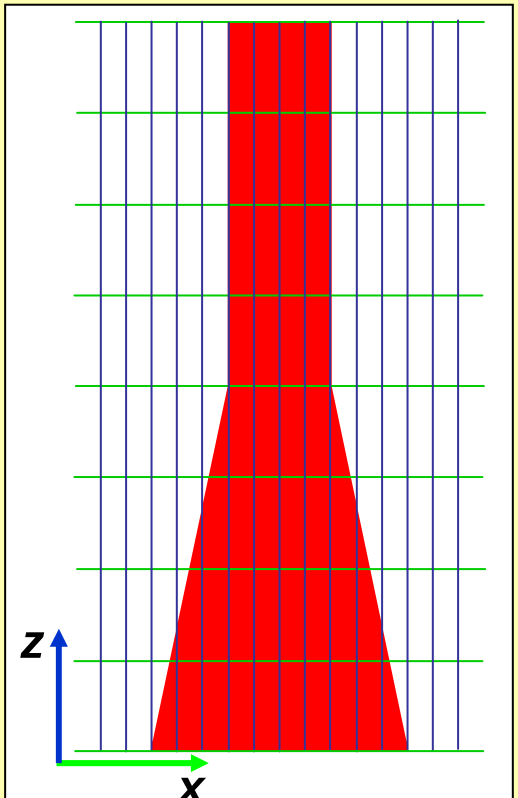
- **β is the propagation constant for the fundamental waveguide mode.**

- **A 3D mesh is created with step sizes $\Delta x = \Delta y = 0.2\ \mu$m and $\Delta z = 1\ \mu$m.**

- **The second order partial derivatives are replaced by their finite difference approximation.**

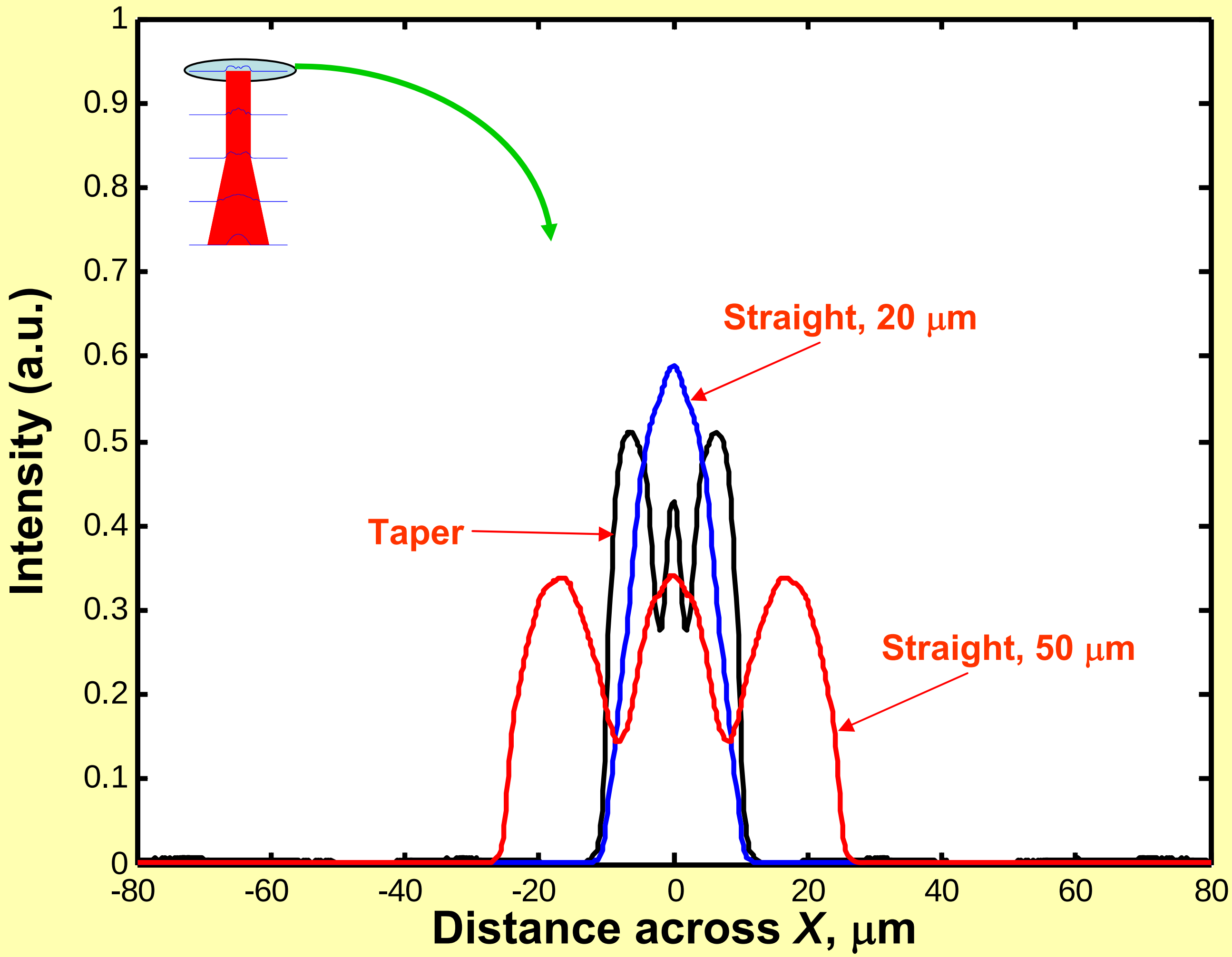
- **Both sides of the equation are then integrated.**

- **The resulting tridiagonal system of linear equations is solved iteratively and the field is determined for each step along the *z*-axis.**



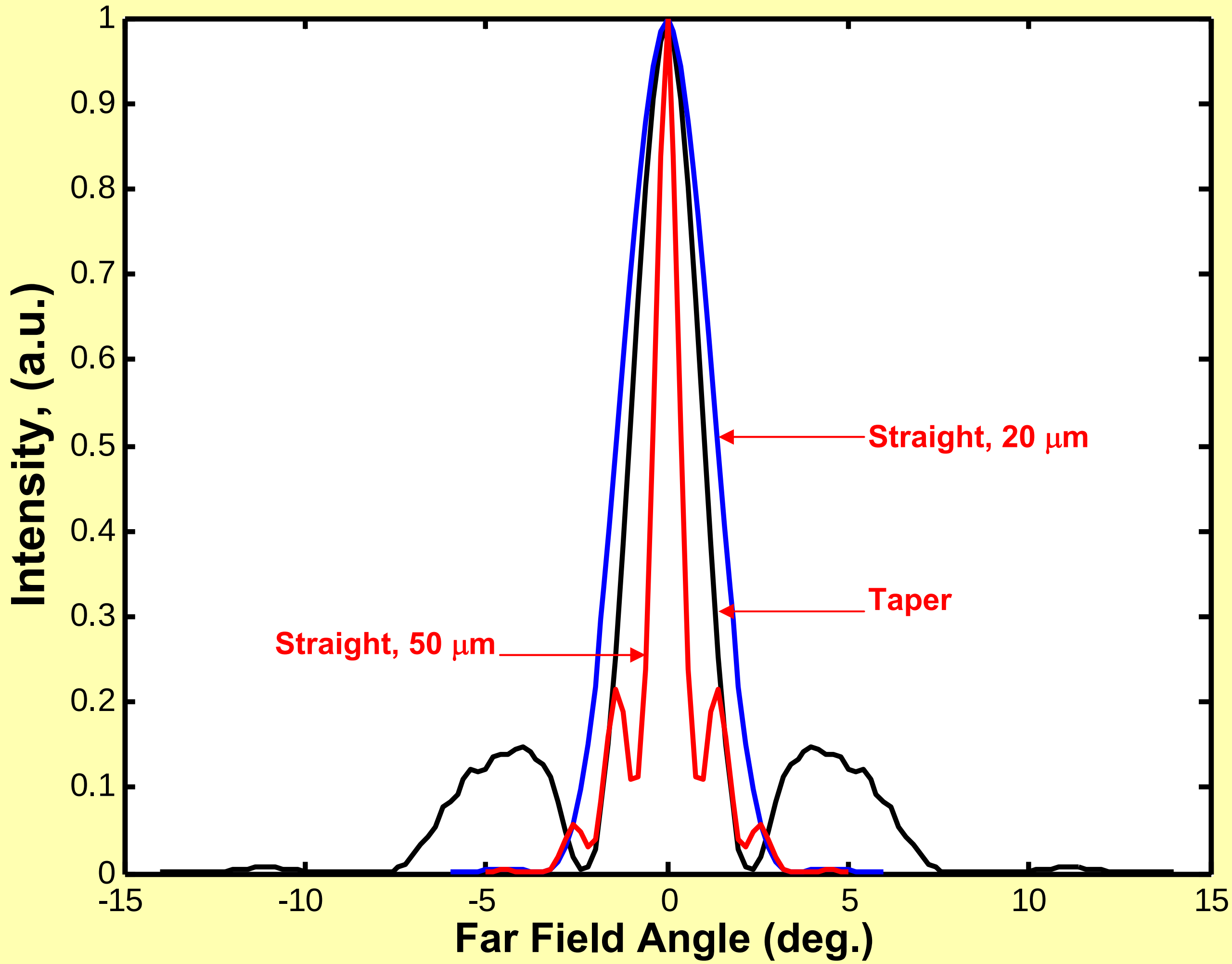
Top view of the waveguide with schematic of the mesh

Output Lateral Near Field



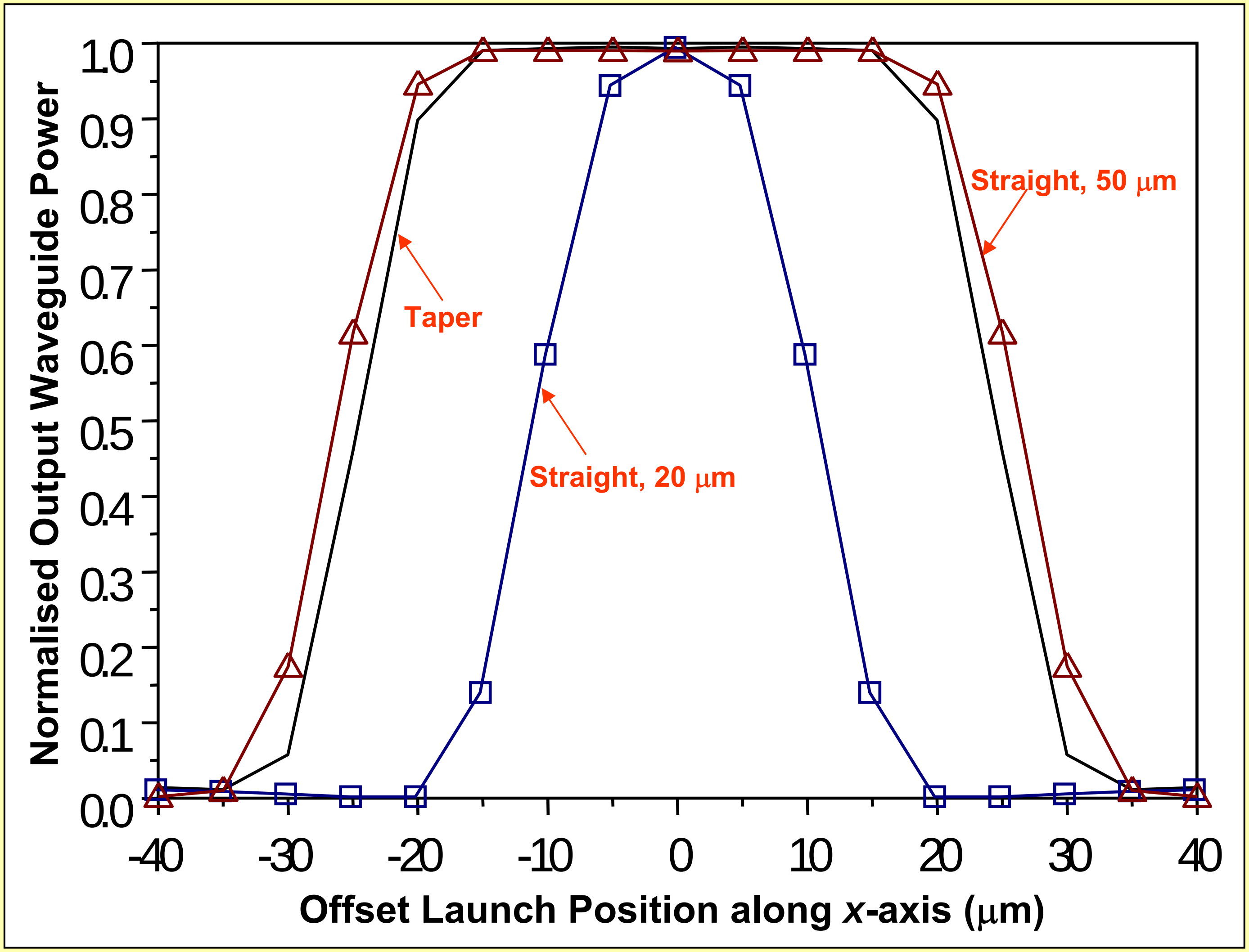
- Tapered waveguide provides near field of 19.2 μm at fwhm near, 29% broader than 13.6 μm of the straight narrow waveguide.
- The near field pattern of the straight wide waveguide exhibits multilobe feature with about 45% modulation depth.

Lateral Far Field



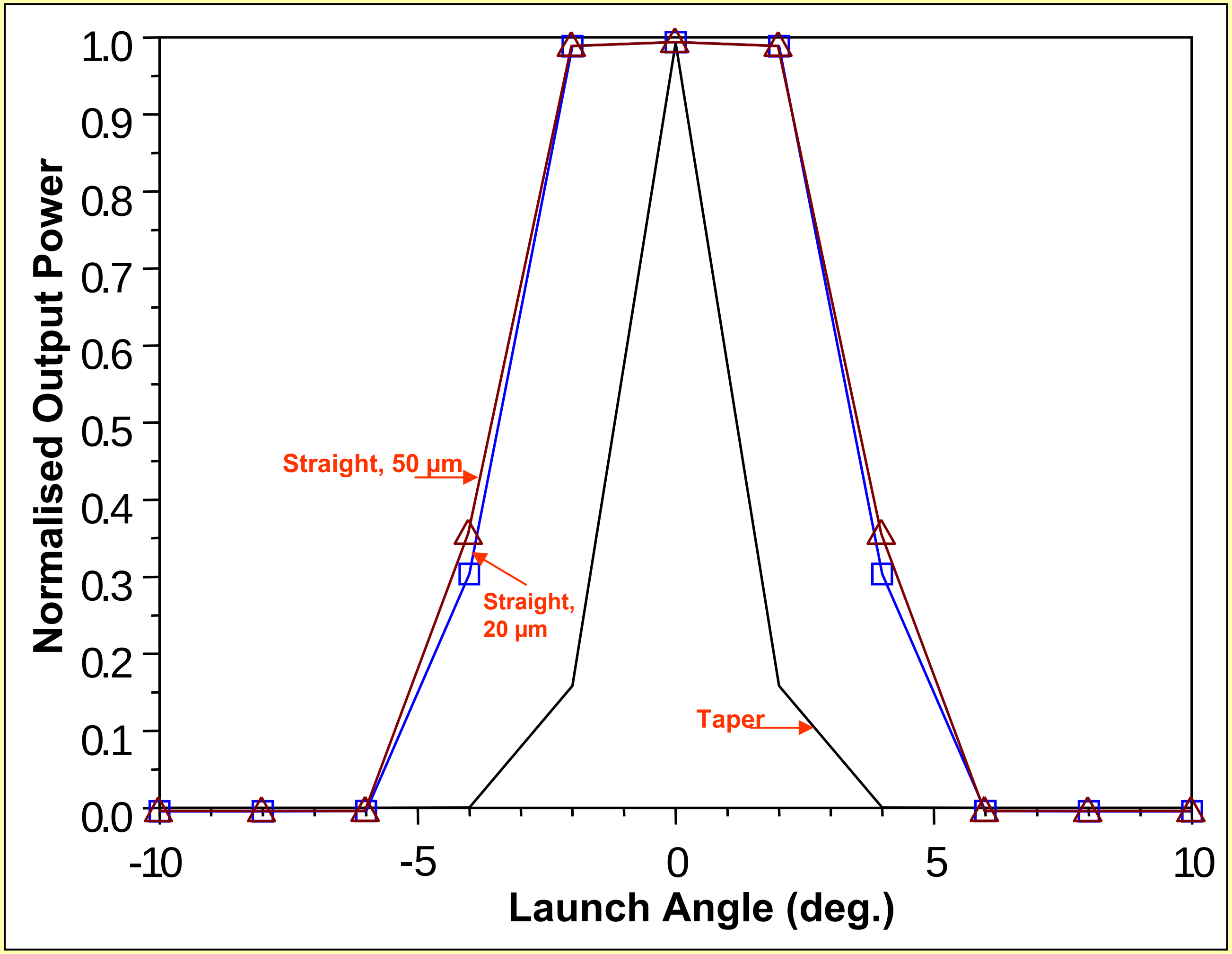
- FWHM of the far field patterns are 2.1°, 2.8° and 0.8° for the tapered, narrow and the wide straight waveguides, respectively.
- Tapered waveguide shows 25% improvement of the far field over the narrow one with less than 15% power in side lobes.

Source Horizontal Misalignment



- **Output power tolerance to misalignment is more dependant of waveguide width than the taper section.**
- **Taper maintains output power within 90% of its optimum value for ±20 μm misalignment in *x* direction.**

Source Angular Misalignment



- Launch angle in *xz*-plane and measured from *z*-axis clockwise.
- Up to 99% of output power could still be achieved within ±2° source misalignment for straight waveguides.
- For the same range taper waveguide is less efficient due to the reflection off the tapered sides.

Conclusions

- Optical backplanes with polymer waveguides interconnects are viable solution for the EMI problems of the copper tracks in electrical backplanes at 10 Gb/s data rate.
- Taper waveguide with wider input aperture is a compromise between narrow and wide straight waveguides in terms of the output power and the modal behaviour.
- Taper waveguide provides better modal behaviour and higher coupling efficiency represented by 29% broader near field and 25% narrower far field than the narrow straight waveguide.
- The wide straight waveguide exhibits multimodal near field pattern and ≈ 25% of sidelobes power in far field pattern.
- The 50 μm input width of the taper waveguide maintains at least 90% of output power for ±20 μm source misalignment in *x* direction.
- The straight waveguides perform better than the tapered one with respect to angular source misalignment due to reflection off the tapered sides.

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