

Waveguide Loss & Curvature Perspective

1. Why Curvature Matters

In integrated photonic waveguides, optical loss is strongly influenced by local curvature. Excessive curvature introduces radiation loss, mode mismatch, and increased sensitivity to fabrication variations.

2. Curvature Definition

For a parametric curve $r(t) = (x(t), y(t))$, curvature $\kappa(t)$ is defined as

$$\kappa = |x'y'' - y'x''| / (x'^2 + y'^2)^{3/2}.$$

Optical loss increases rapidly with curvature.

3. Cubic Bézier Advantage

Cubic Bézier curves provide continuous first derivatives and smooth tangent evolution, avoiding sharp corners and abrupt curvature transitions.

4. Two-Segment S-Bend

The S-Bend is constructed using two cubic Bézier segments joined at a midpoint, ensuring tangent continuity and reduced radiation loss.

5. Inflection Point

Curvature smoothly changes sign at the inflection point, enabling adiabatic mode evolution.

6. Effective Bend Radius

An effective local bend radius $R_{\text{eff}} = 1/\kappa(t)$ is used to ensure curvature remains above critical loss thresholds.

7. Manufacturing Robustness

Smooth curvature improves OPC convergence, reduces line-edge roughness impact, and increases yield robustness.

8. Summary

Cubic Bézier S-Bends minimize curvature peaks, reduce optical loss, and provide manufacturing-friendly geometry.