

# 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.