January 15, 2004

Planar Lightwave Circuit Technology for Flexible and Precision Control over Fiber Launch Conditions

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Outline

- **Motivation for Controlling Fiber Launch Conditions**
- **Overview of Planar Lightwave Circuit (PLC) based designs for controlling fiber launch**
  - TOSA with integrated mode conditioner
  - Stand alone mode conditioner
- **Fiber launch capabilities of PLC based TOSAs**
  - Control of launch location
  - Control of spot size
  - Elliptical spot size launch
  - Off-normal angular launch
  - Two launch spots
- **Non-zero azimuthal "angular momentum" mode propagation characteristics**

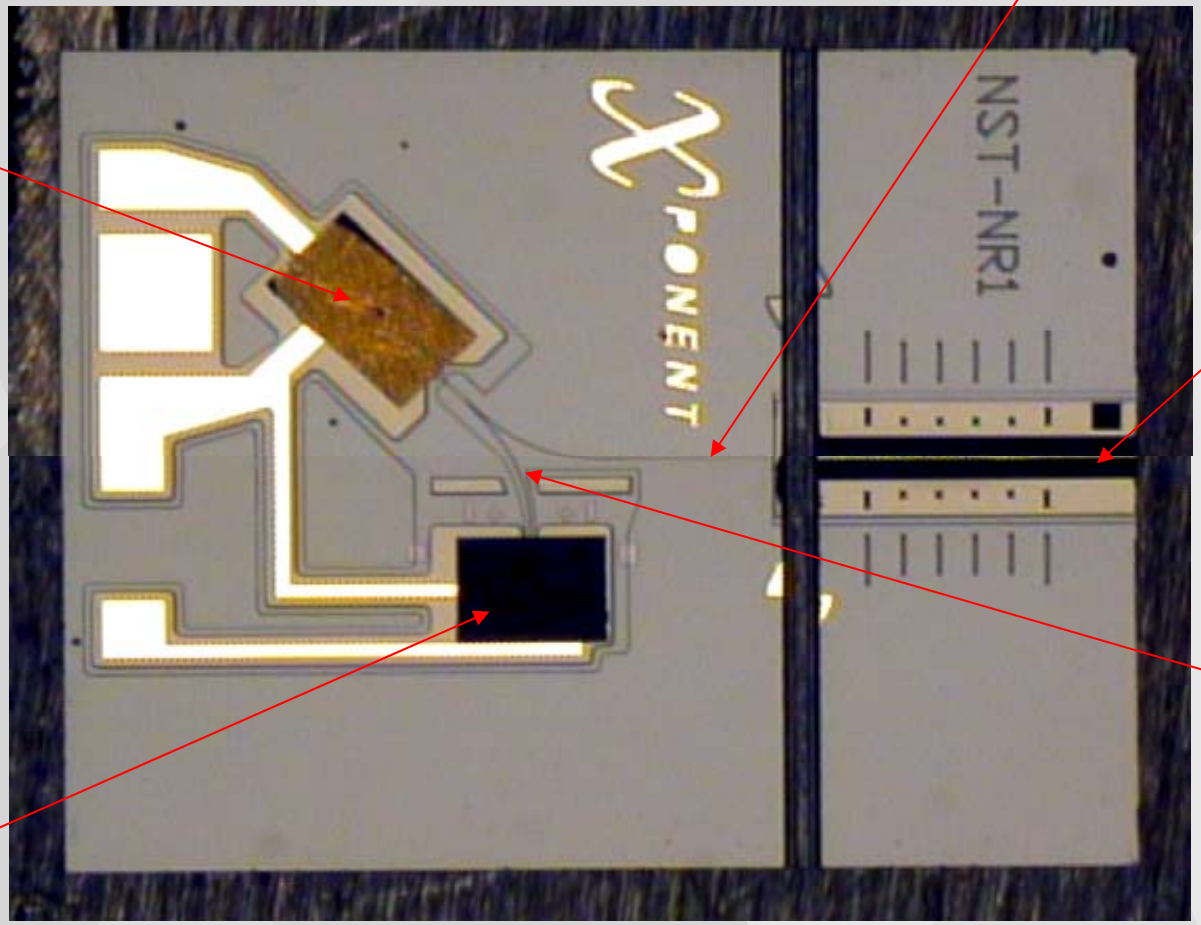
Launch Conditions and Bandwidth of Multimode Fiber

- Fiber bandwidth can be enhanced by controlling the excitation of spatial modes via control of the fiber launch conditions
- Most reports of bandwidth enhancement involve launching at a point radially offset from the center of the core
- PLC technology can easily achieve precisely controlled radially offset launch condition at no cost premium to a centered launch as well as many other launch conditions not readily attainable with alternate approaches
- By combining radial offset with angular offset, rays that propagate along nearly circular helical paths can be launched. Propagation characteristics of such modes with “angular momentum” are expected to be very different from conventional offset launch modes

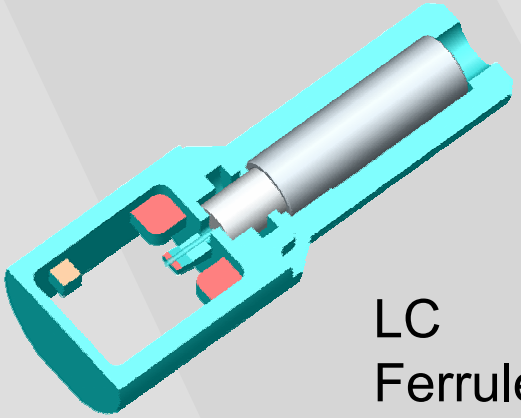
Key Elements of PLC Optical Circuit Board

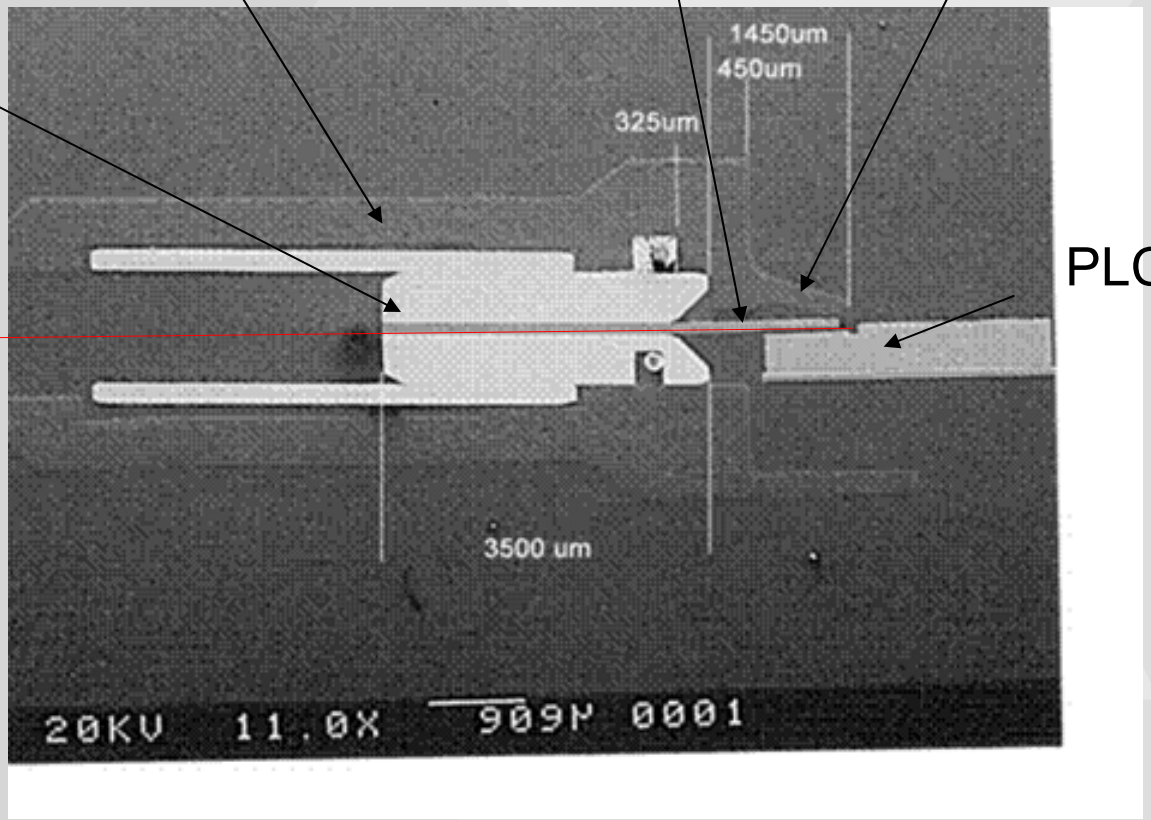
- Low loss optical waveguides
- Optical and electrical interface between laser and PD chips and optical waveguides
- Spot size conversion by tapering of waveguide core dimensions: Max size approx equal to SMF, min size about 2x2 μm, circular or elliptical profiles
- Low loss optical splitters and taps
- Waveguide bends
- Alignment of waveguides to precision etched V-grooves: approx 1 μm positional alignment accuracy, approx 0.02° angular alignment

1310 nm Fabry-Perot Laser Fiber Ready Optical Assembly

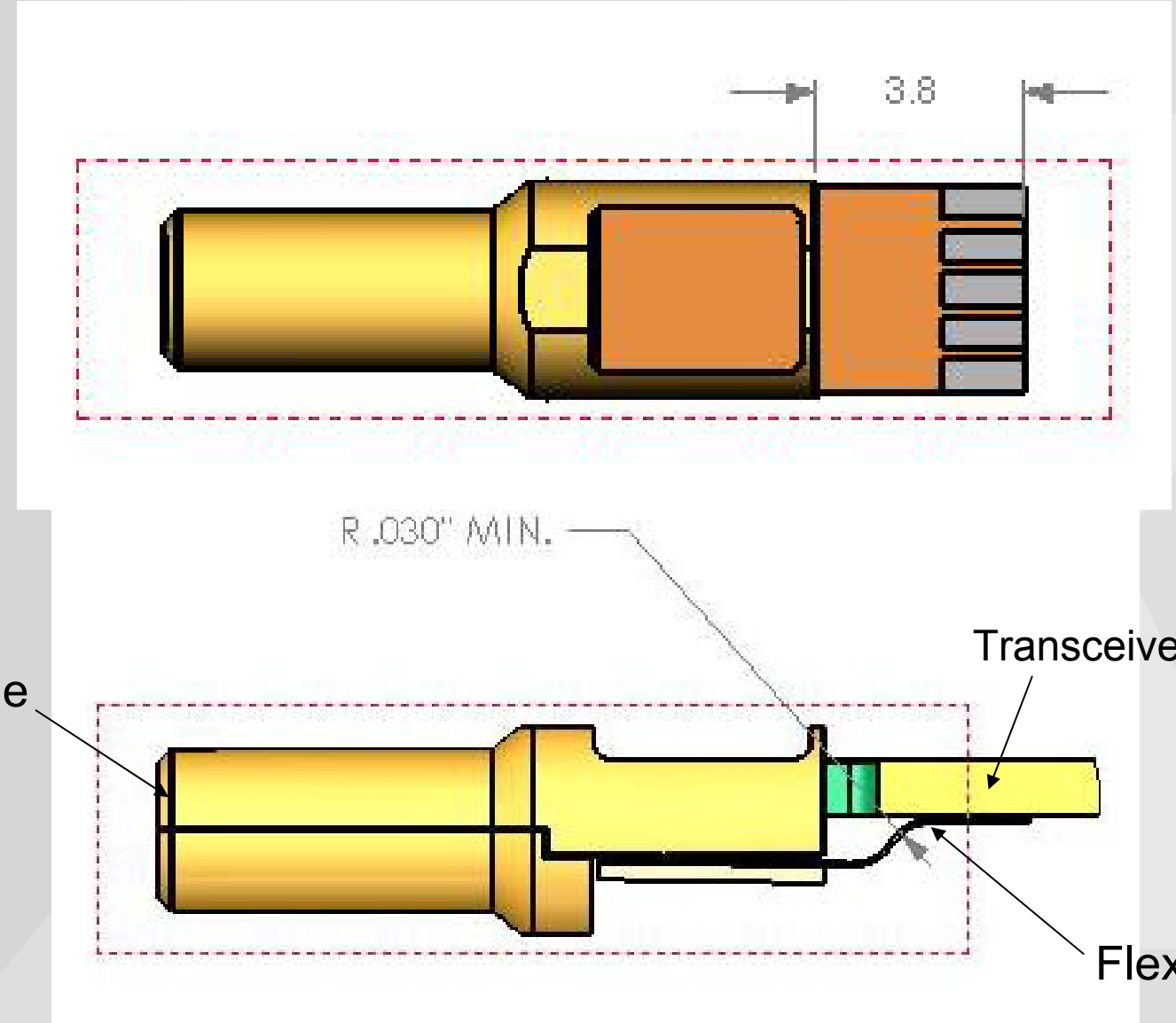


PLC Based TOSA Package Cross Section

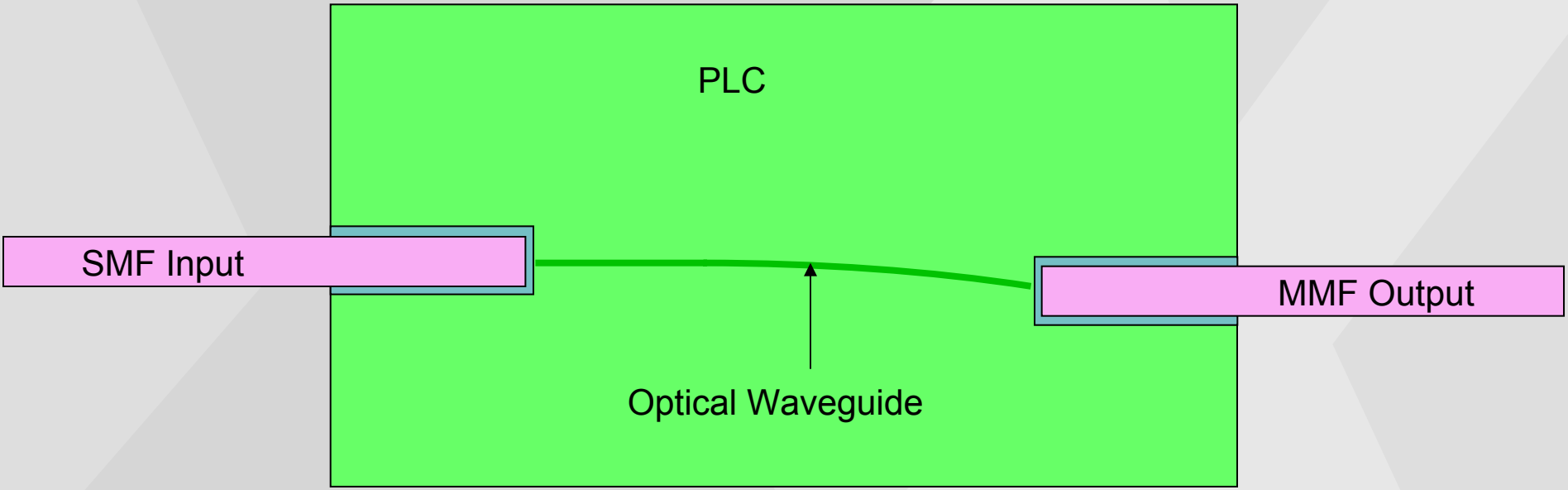




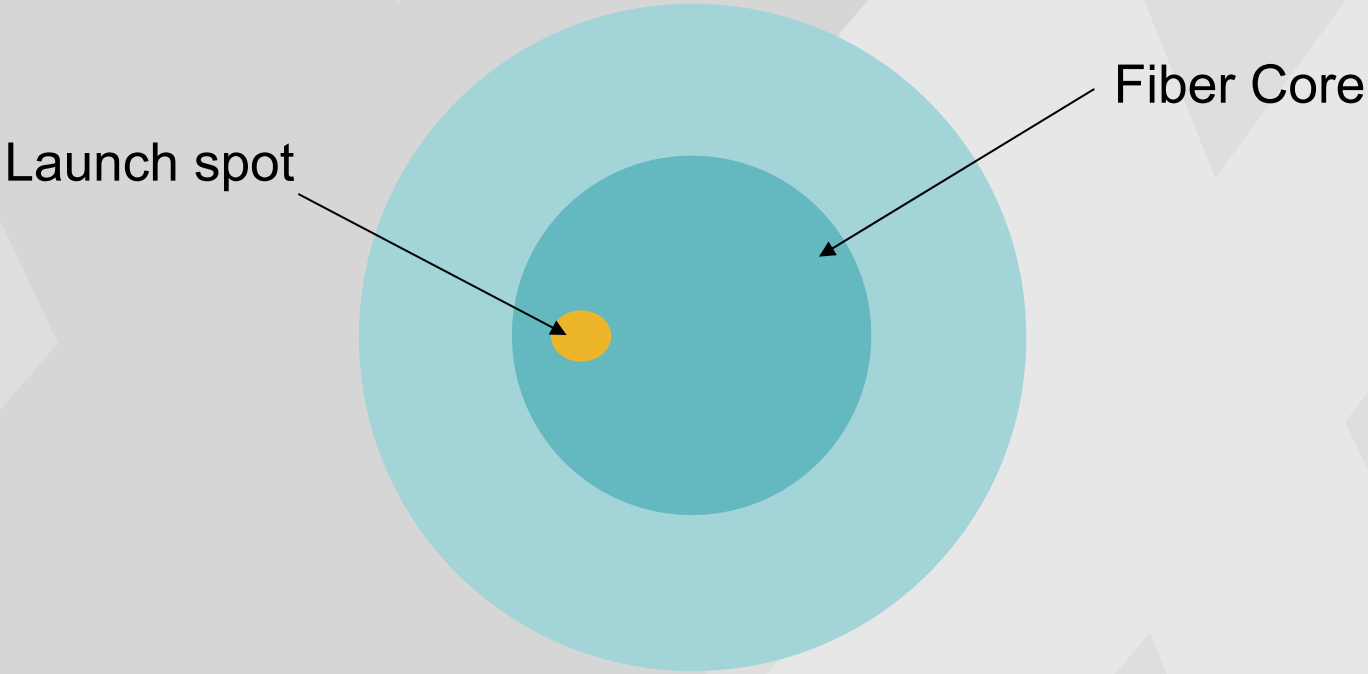
TOSA with Flex Circuit Input



Stand Alone PLC Mode Conditioner

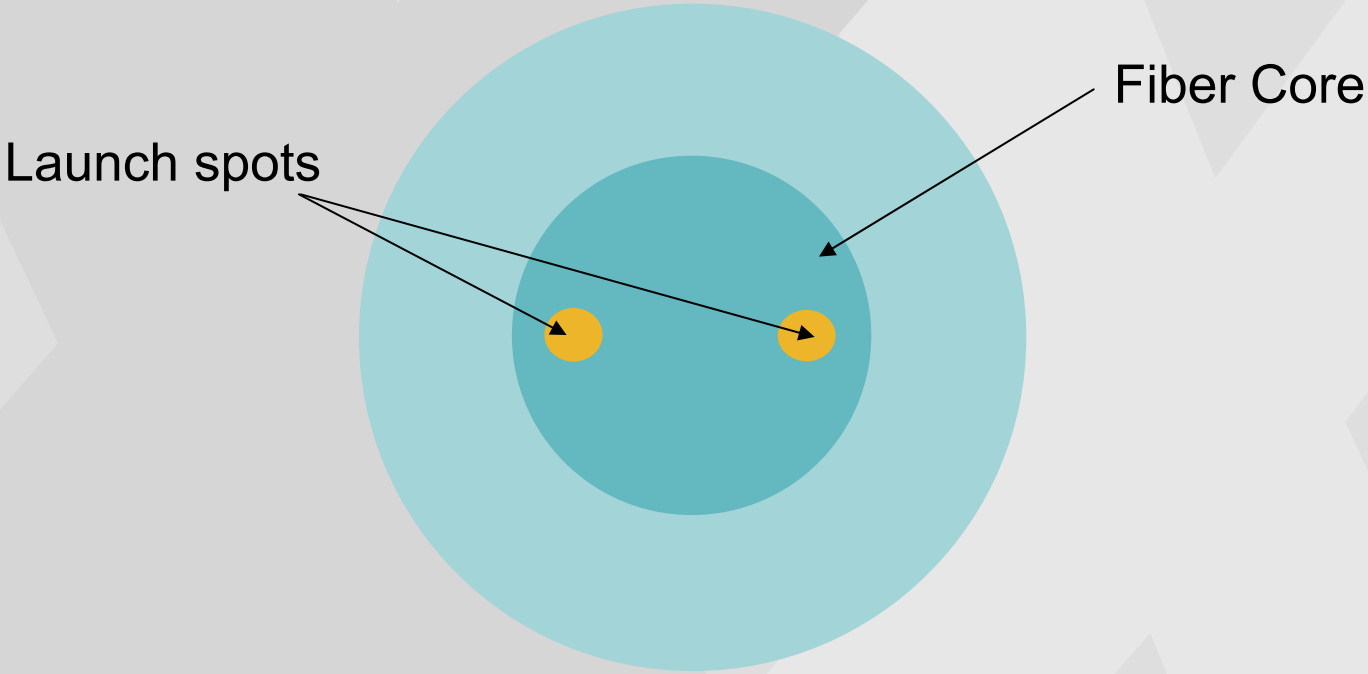


Precision Launch Implementations: Lateral Offset



Implemented by offsetting waveguide with respect to V-groove,
Spot size and angle of incidence can also be independently adjusted

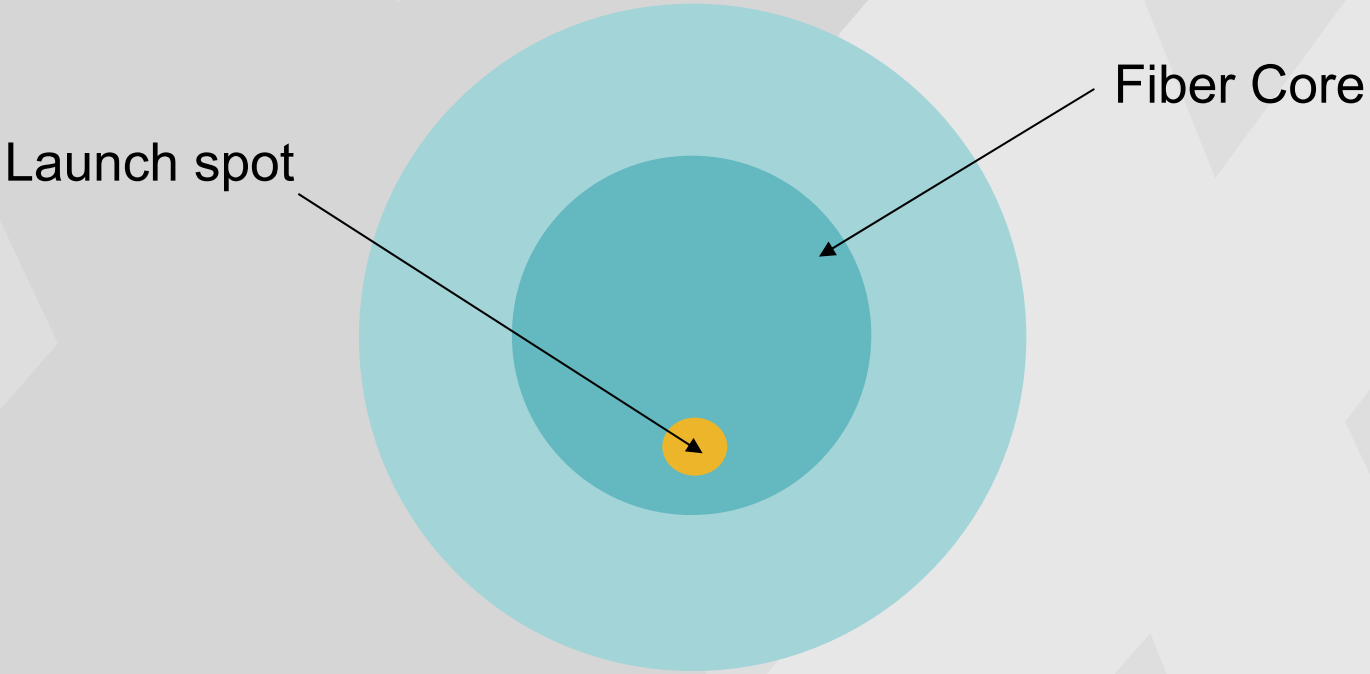
Precision Launch Implementations: Dual Spot Launch



Implemented by waveguide optical splitter and offsetting waveguides with respect to V-groove

Spot size and angle of incidence can be independently adjusted
Spots can have arbitrary phase relationships

Precision Launch Implementations: Vertical Offset



Implemented by over-sizing or under-sizing V groove width,
spot size and angle of incidence can also be independently adjusted
This configuration with off-normal incidence launches modes with high azimuthal mode number and low radial mode number with largely circular helical propagation and “angular momentum”

Launching of Modes with Angular Momentum

- Fiber supports modes with azimuthal phase that can vary in clockwise or counterclockwise fashion. Modes can also be described as superpositions of + and – azimuthal modes that have no net angular momentum
- Conventional centered and offset launch techniques generate symmetric levels for + and – angular momentum modes. Resulting superposition has zero net angular momentum
- Radial offset plus off axis angular launch results in modes with angular momentum.
- From a ray picture these modes spiral down fiber in circular helical trajectories (zero order radial modes) or elliptical for low order radial modes

Unique Properties with Nonzero Angular Momentum Modes

- **Modes have no power near center of fiber where largest index anomalies occur**
- **Angular momentum breaks degeneracy between modes with the same principle mode number**
- **Expected to suppress distributed coupling between modes within same principle mode group**
  - Likely has significant effect on nature of impulse response
  - May have significant effect on the level of modal noise

Summary

- Planar Lightwave Circuit technology allows for extremely precise control of fiber launch conditions
- Spot size, launch position, launch angle can be independently controlled
- Two (or more) launch spots can be implemented
- Allows for launching of modes with azimuthal angular momentum
- Flexibility and control of launch conditions may enable improvement of fiber bandwidth
- PLC circuits can be used as stand alone mode conditioner or integrated into TOSA
- Xponent is very interested in collaborations