Fiber-to-chip coupling using fiber lens

One of the common challenges in silicon photonics and integrated optics is coupling light in and out of an optical chip. To achieve high coupling efficiency, the fiber mode has to match the mode of the waveguide on the chip. However, fiber mode is much larger than the mode of a conventional waveguide. For example, in silicon photonics, the mode field diameter of the SMF-28 fiber is ~10 µm at 1550 nm, while the mode size of photonic wire is only several hundred nanometers. The same relation between fiber mode and waveguide mode exists in the visible range.

An easy way to increase coupling efficiency is to use fiber lens. Fiber lens focuses light into the small focal spot. The focal spot has a better match with the waveguide mode, making the coupling efficient. Conventional fiber lens is made out of a glass fiber itself, which has a low index of refraction. The use of such lens requires an air gap between the lens and the photonic chip. The main advantage of the lensed fiber coupling is that it increases coupling efficiency without the need for any modifications to the photonic chip itself. However, there are some problems. The main issue is that the focal spot from the fiber lens is usually still bigger than the mode of the photonic wire. Therefore, the coupling efficiency does not get close to 100%. In addition, the reflection from the chip edge is coupled back into the fiber. The back reflection is extremely undesirable for many integrated optics applications.

aBeam's high refractive index lens offers a unique solution to this problem. Using aBeam's fiber imprint technology, lens structure can be made out of high refractive index material. Our high refractive index lens can now be used inside an adhesive and produce a diffraction limited focal spot. Immersion usage brings many attractive advantages including; decreased focal spot size by a factor of ~ 1.5, nearly doubling the coupling efficiency, as well as significantly reduced back reflection. See below comparison between conventional and immersion edge coupling techniques.

Conventional vs. Immersion edge coupling

Conventional fiber lens

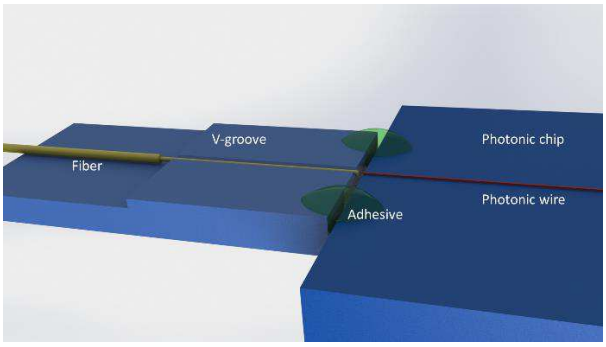

Figure 1. Typical configuration of fiber-to-chip coupling using fiber lens. The tip of the fiber has to be kept clean from the glue.

Immersion compatible fiber lens

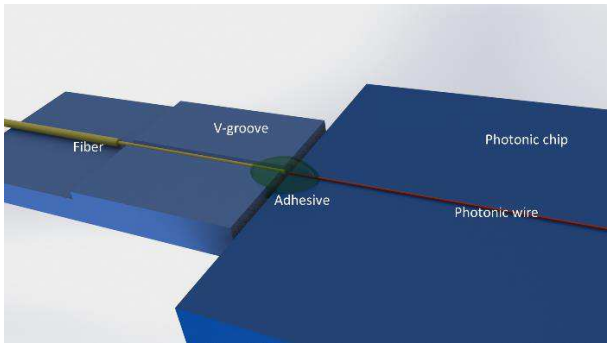

Figure 2. Fiber-to-chip coupling using high refractive index lens. Adhesive covers the point of coupling and acts as immersion.

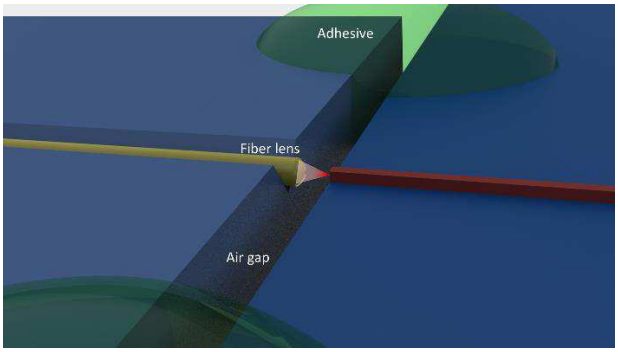

Figure 3. Close view of fiber lens coupling.

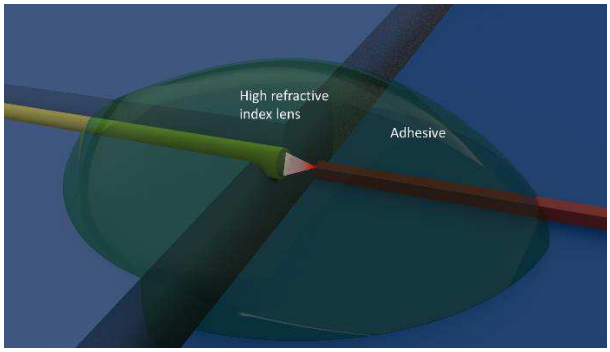

Figure 4. Close view of immersion coupling with high refractive index fiber lens.

Challenges:

- Focal spot size is not small enough. Coupling efficiency is limited.
- Air gap leads to mechanical instability.
- Harmful back reflection from the photonic chip.

Advantages:

- Smaller focal-spot size by ~ 1.5 times.
- Greater coupling efficiency; up to 2x.
- Improved mechanical stability.
- Significantly reduced back reflection due to immersion; less than 1% reflection.

aBeam's unique capability:

For this application to work, lens's refractive index has to be much higher than that of immersion medium to focus light efficiently. Conventional fiber lens will not work due to low contrast in refractive indices. Using aBeam's fiber imprint technology, the lens can have a high refractive index, making this application possible for the first time!