

Article Overview

High-precision fiber couplers operate by carefully matching optical modes and minimizing alignment mismatches to achieve efficient light transfer between fibers or between fibers and photonic devices.

Basic Operating Principle

High-precision fiber couplers are designed to transfer light efficiently from one optical fiber to another or from a fiber to a photonic chip. The core principle involves mode matching, where the optical mode of the input fiber is aligned with the mode of the output fiber or waveguide to minimize coupling loss. This requires precise control over the mode field diameter (MFD), polarization, and spatial alignment.

Mode Matching and Alignment

Efficient coupling is achieved by optimizing the dimensions of the mode converter or waveguide taper so that the optical mode expands or contracts to match the fiber mode. For example, increasing the mode diameter at the interface can increase alignment tolerance, reducing sensitivity to lateral or angular misalignment. Gaussian beam propagation principles are often used to model and optimize the coupling efficiency, taking into account radial, axial, and angular mismatches.

Polarization and Depolarization Control

High-precision couplers often use polarization-maintaining (PM) fibers to preserve the polarization state of light. The design ensures that light does not depolarize as it couples into the chip or another fiber, which is critical for applications requiring stable polarization. Pre-fusion and post-fusion measurements of polarization extinction ratio (PER) are used to verify that polarization is maintained during the coupling process.

Fabrication Techniques

Several fabrication methods are employed to achieve high-precision coupling:

- o Fused fiber couplers: Fibers are thermally tapered and fused to bring cores into intimate contact, allowing controlled power splitting.
- o Lithographically defined mode converters: On-chip waveguides and mode converters are precisely patterned to match fiber modes, often using SiO₂ or Si₃N₄ layers.
- o Free-form micro-optics: Advanced 3D micro-optics designed using Fermat's principle can create broadband, low-loss couplers between standard fibers and high-index-contrast waveguides.
- o Large-mode-diameter designs: Increasing the MFD reduces sensitivity to angular misalignment and

improves coupling efficiency, sometimes achieving efficiencies above 95% .

Efficiency Optimization

High-precision couplers aim to maximize optical power transfer while minimizing losses due to misalignment, scattering, or mode mismatch. Techniques include:

- o Lateral and angular offset optimization
- o Use of high numerical aperture (NA) objectives for mode collection
- o CO₂ laser fusion for permanent fiber-chip attachment
- o Broadband design to maintain efficiency across a wide wavelength range

Summary

The principle of high-precision fiber couplers relies on careful mode matching, precise alignment, polarization control, and advanced fabrication techniques. By optimizing these factors, couplers achieve high efficiency, low loss, and robust performance, which are essential for fiber-optic communication, photonic integration, and precision sensing applications .

This research demonstrates a method for the repeatable passive fiber optic coupling of single-mode waveguides with

When an input optical signal is introduced with sufficiently low power levels (i.e., at linear regime), they can divide themselves equally

One important issue of silicon photonics that comes with its high integration density is an interface between its high

A fiber coupler is defined as a device that enables the coupling of light between two single-mode fibers, achieved by

Polarization-Maintaining Fused Couplers represent a significant advancement in fiber optic technology, serving as

Fused couplers are made by joining two independent optical fibers, which work on the basic principle of coupling between parallel

A system connection may require either a fiber optic splice, connector, or coupler. One type of system

connection is a permanent

An ideal polarization-maintaining coupler should have a high polarization extinction ratio (usually >20 dB) and a precisely controllable

In this paper, a 2D fiber array coupler with high coupling efficiency and high precision positioning is designed and

PM fiber couplers represent the convergence of materials science, precision engineering, and photonic innovation. As

Fiber couplers or nonlinear fiber couplers or directional couplers possess more than one single-mode optical fibers placed parallel to

Dichroic couplers can be used to combine a pump and a signal input for a fiber amplifier, or to remove

The temperature-insensitive fused-tapered fiber coupler can find important application in optical precision measurement

Actually, even after 25 years of existence of low-loss glass fibers, the coupling efficiency remains the biggest concern

calable and broadband coupling scheme for this platform is therefore of paramount importance. Leveraging two-photon

Fiber connections such as connectors and splices and the associated intrinsic and extrinsic losses are described. The

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