Application Note
NuAPP-3

UHNA Fiber – Efficient Coupling to Silicon Waveguides

Submitted by Dr. Stefan Preble - Rochester Institute of Technology

Introduction:

The small mode field diameter of Nufern's Ultra-High Numerical Aperture (UHNA) fibers enables very efficient coupling to Silicon waveguides. In addition, UHNA can be fusion spliced directly to SMF28, providing a low-loss bridge from SMF28-to-Silicon with an overall coupling loss of less than 1.5dB (per connection) [1, 2, 3].

Silicon Photonic Chip connected to UHNA7 Fibers

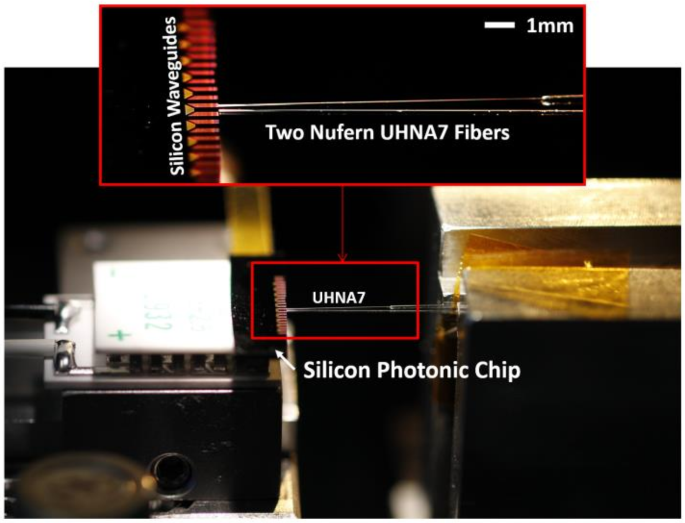

Image Courtesy of Stefan Preble - Rochester Institute of Technology

Two UHNA7 Fibers butt-coupled to Silicon Waveguides. The chip contains dozens of waveguide devices and the overall coupling loss (from laser to detector) between any input/output waveguide combination is measured to be <3dB.

Efficient Coupling to Silicon Waveguides:

Silicon Photonics is enabling the next generation of high performance transceivers by using standard integrated circuit manufacturing processes. The technology is also beginning to be used for a wide range of emerging applications, such as biological/chemical sensing, RF signal processing and optical interconnects. All of these applications require efficient coupling between traditional SMF28 fibers and the Silicon waveguides.

Nufern's series of UHNA fibers provide a low loss coupling interface to the small modes of Silicon waveguides. Specifically, the 3.2µm mode field diameter of UHNA7 closely matches the mode of an inverse tapered Silicon waveguide, which transitions from a ~150nm tip to a strongly confined single mode Silicon waveguide [width of ~500nm]. The cleaved UHNA7 fiber can be simply butt-coupled against a suitably prepared chip facet (cleaved, polished or etched) to achieve optimal coupling. By applying a modest force against the facet it is possible to maintain coupling indefinitely without any active feedback.

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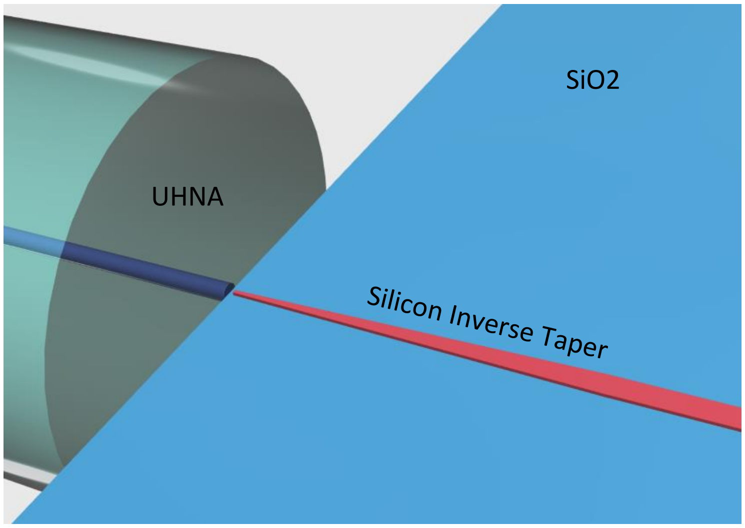
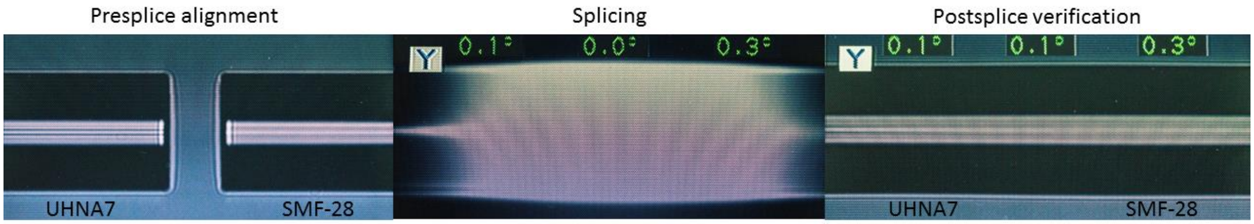
UHNA7 Fiber Butt-Coupled to a Silicon Inverse Tapered Waveguide



Optimal coupling was realized with an inverse taper with a 150nm wide tip transitioned to a final width of 500nm over 300μm length. The silicon is 220nm thick and the chip has a buried oxide of 3μm and is also clad with 3μm of SiO2 (not shown).

Fusion Splicing UHNA to SMF28:

Any small mode field diameter fiber would normally pose a problem with coupling to a larger mode field diameter fiber such as SMF28 because of the mismatch. The UHNA series of fibers solves this problem with a fiber core that will thermally expand upon fusion splicing. This expansion of the UHNA core allows the UHNA mode field to better match the mode field of larger core diameter fibers, creating an adiabatic taper in the UHNA fiber beginning at the splice point and decreasing back into the UHNA. This effective taper results in very high coupling efficiency between the two fibers and very low splice losses.



To achieve these low loss splices (0.1-0.2 dB loss), the splicing of UHNA fibers requires special treatment compared with standard optical fibers, namely a very long arc time to produce the proper length taper in the UHNA core. A splicing recipe that has been successful on a Fujikura FSM40S is as follows:

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Fujikura FSM-40S UHNA7 – SMF28 Splicing Parameters

Align: Core	Focus: Auto
ECF: Off	Auto Power: Off
Cleave Limit: 1°	Core Angle Limit: 1°
Cleaning Arc: 150 ms	Gap: 15 um
Gapset Position: Center	Prefuse Power: 20 bit
Prefuse Time: 180 ms	Overlap: 10 um
Arc1 Power: 20 bit	Arc1 Time: 18000 ms
Arc2: Off	Rearc Time: 800 ms
Taper Splice: Off	

Summary:

This application note has provided details on using Nufern's Ultra-High NA optical fibers as a low loss bridge from SMF28 to Silicon waveguides, including, a simple Silicon waveguide mode converter design and fusion splicing parameters that will minimize overall coupling loss.

UHNA Fibers:

Mode Field Diameter of Nufern UHNA Fibers at 1550 nm

UHNA1: MFD = 4.8 +/- 0.3 µm at 1550 nm	UHNA4: MFD = 4.0 +/- 0.3 µm at 1550 nm
UHNA3: MFD = 4.1 +/- 0.3 µm at 1550 nm	UHNA7: MFD = 3.2 +/- 0.3 µm at 1550 nm

References:

1. S. F. Preble, M.L. Fanto, J.A. Steidle, C.C. Tison, G.A. Howland, E.E. Hach III, Z. Wang, P.M. Alsing, "On-chip quantum interference from a single silicon ring-resonator source," Physical Review Applied 4, 021001 (2015).

2. J.A. Steidle, M. L. Fanto, C. C. Tison, Z. Wang, S. F. Preble, P. M. Alsing, High spectral purity silicon ring resonator photon-pair source, SPIE DSS 2015, Baltimore, MD (2015).

3. Data provided by Dr. Stefan Preble of the Rochester Institute of Technology.

Nufern offers a wide range of specialty fibers for industrial, medical, military, aerospace and scientific applications.

Our ongoing commitment to research and investigation with our customers promises a bright future with optical fiber technology.

We look forward to hearing from you.

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