Efficient fiber-optical interface for nanophotonic devices: supplementary material

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1. SUPPLEMENTARY INFORMATION

For all measurements we assume perfect reflection from the Bragg mirror ($\eta_m \equiv 1$) and we correct for the independently calibrated beamsplitter ratio ($\eta_{bs} = 0.99$) and the FC-FC fiber coupling (with a typical value of $\eta_{FC} = 0.89$). We note that our results for η_c are conservative since we observe a small amount of scattering from the entrance Bragg mirror ($\eta_m < 1$) and did not account for propagation losses through the $\simeq 5$ m of fiber. We estimate these combined losses to be on the percent level, however, our current method has not sufficient accuracy to determine η_c to a higher precision.

Aside from the high coupling efficiency another important property of the coupler are its possible reflections. If light is reflected from the fiber-waveguide interface rather than the Bragg mirror this could affect measurements performed in reflection, such as the fiber-wg coupling efficiency characterization performed here, or quantum optics experiments. In order to characterize spurious reflections from our coupler we perform a measurement using a critically-coupled double-sided cavity. In the absence of cavity losses the reflection vanishes on resonance (enabling us to measure spurious reflections from the coupler) and the cavity is fully reflective off resonance (enabling us to measure the fiber-wg coupling efficiency as described above and in the main text). We choose a low quality factor ($Q \simeq 2000$) in order to minimize the effect of cavity losses and detach the cavity from the chip to avoid additional reflections from the chip. For this specific device we achieve a slightly sub-optimal coupling efficiency of $\eta_c = 0.87$ and for TE-polarized light (see figure S1) we observe an on-resonance reflection of $2.0(4) \times 10^{-3}$. Addi-

tionally, we do not observe any reflection ($0.1(3) \times 10^{-3}$) of the fiber tip when no cavity is attached. Finally, in an independent measurement using TM-polarized light we measure a reflectivity of $4(1) \times 10^{-3}$. These values set an upper limit of the reflection from the coupler since we have assumed a perfectly symmetric cavity, no cavity losses, perfect polarized probe light and no reflection of TM-polarized light by the Bragg mirror. Here, we have assigned the polarizations based on maximum and minimum reflection from the Bragg mirror which is designed to have a band gap for TE-polarized light at 780 nm.

In order to align the relative fiber-waveguide position we mount the fiber under an angle of $\sim 10 - 20^\circ$ and align the fiber with respect to the waveguides under an optical microscope using a three axis translation stage with micrometer and piezo control. When the fiber is brought into contact with the waveguide, they stick together, allowing stable alignment to be maintained over long periods of time. They can be released from each other by pulling them apart with the translation stage, apparently without damage. While we have not investigated the mechanism of the sticking, we note that "stiction" is very common and has been extensively studied in the context of micro- and nano-mechanical systems.

We obtain the optimal fiber-waveguide coupling by adjusting the fiber position, optimizing for the reflected power. Typically, the optimal coupling is achieved by slightly lifting the fiber off the chip which we attribute to the waveguide bending and aligning with the angle-mounted fiber taper. The procedure to detach cavities from the chip and attach them to the fiber taper is as follows: we break off and pick up a waveguide using a

tungsten tip and transfer it to the fiber tip in free space using three axis translation mounts for both the fiber and tungsten tip. We move the waveguide using the tungsten tip while optimizing for optimal reflection.

Fig. S1. Spurious reflections from coupler. Reflection spectrum of a critically damped cavity (*Inset* shows full spectrum) for TE-polarized light (red) and for the bare fiber taper without a cavity attached (green).