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Silicon-on-insulator (SOI) is a widely used material platform for making photonic integrated circuits that combine multiple components, such as waveguides, resonators, modulators, and splitters, into compact and scalable devices for applications such as sensing, imaging, telecommunication, and quantum networks. The device layer in the SOI wafer must be patterned to define the high index-contrast photonic structures, which can then be covered with glass to form embedded structures or be suspended by removing the oxide beneath. The suspended platform offers exciting possibilities of combining optical functionality with mechanical degrees of freedom [1, 2], either via the direct use of optical forces or by electromechanical actuation. The use of opto-electro-mechanical systems has the potential to replace thermo-optical and electro-optical actuation with a smaller footprint, lower power consumption, and higher speed for devices such as optical switches in programmable networks. An efficient interface to such a suspended platform is required, which calls for the development of efficient couplers to suspended waveguides. We present the recent development of a grating coupler that is suspended and fully etched to facilitate fabrication in a single lithography step in conjunction with the rest of the suspended photonic circuit [3]. We design the coupler for normal-incidence free-space coupling through an optical microscope to a rectangular suspended waveguide, which allows simple alignment and testing of suspended photonic circuit components. However, the vertical scattering angle does not automatically suppress back-reflection like the tilt-angle used in conventional fiber grating couplers [4], and thus it requires an explicit inclusion of back-reflection in the numerical optimization formulation. By treating all lines in the grating as design parameters, we have created a grating coupler optimized for C-band telecommunication wavelengths. The design optimization yields an aperiodic grating with good transmission of 21.8 %, minimal back-reflection of 0.2 %, and a 3 dB bandwidth of 75 nm. We fabricate the grating couplers, shown in Fig 1, on SOI wafers with a 220 nm device layer and 2 μm buried-oxide layer and perform an extensive experimental validation of the transmission and reflection characteristics for multiple photonic circuits. We present the applied characterization method, which uses a Fabry-Pérot resonator model in addition to windowed Fourier transforms, to understand and directly extract the reflections from the fringes in the measured transmitted power of the full photonic circuit.

References:

[1] T. H. Stievater, M. W. Pruessner, W. S. Rabinovich, D. Park, R. Mahon, D. A. Kozak, J. B. Boos, S. A. Holmstrom, and J. B. Khurgin, Appl. Opt. (2015), **54**, F164–F173.
[2] L. Midolo, A. Schliesser, and A. Fiore, Nat. Nanotechnol. (2018), **13**, 11–18, 276.
[3] S. E. Hansen, G. Arregui, A. N. Babar, M. Albrechtsen, B. V. Lahijani, R. E. Christiansen, and S. Stobbe, Opt. Express (2023), **31**, 17424-17436.
[4] D. Taillaert, P. Bienstman, and R. Baets, Opt. Lett. (2004), **29**(23), 2749–2751.

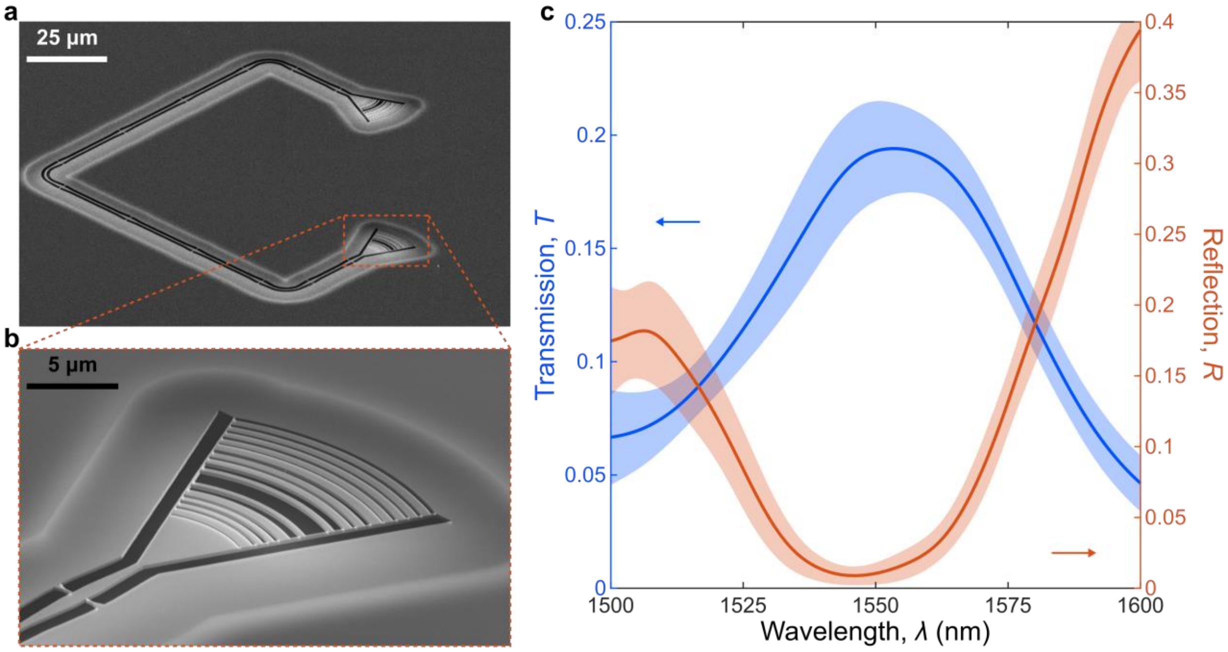

Figure 1. Fabricated grating coupler and measured performance. a, Scanning electron micrograph of suspended photonic circuit. b, Scanning electron micrograph of grating coupler. C, Measured transmission and reflection of grating coupler with the mean (solid line) and error (shaded area region showing the 95 % confidence interval).