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Compact, Low Loss Edge Couplers for Hybrid Integration of Blue Lasers

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Photonic integrated circuits (PICs) operating at blue wavelengths hold immense promise for applications ranging from quantum optics to biomedical detection [1]. While silicon nitride (Si_3N_4) platforms are widely employed for visible wavelengths [2], achieving full integration of blue lasers into a Si_3N_4 platform remains a significant challenge. The major limitation arises from the high aspect ratio of horizontal to vertical dimensions of the laser spatial output profile, imposing stringent requirements on the edge coupler design. To address this, we propose a compact, low loss (< 3 dB per facet) fork-shaped edge coupler, specifically designed for a gallium nitride (GaN) laser chip operating at 488 nm, providing a promising solution for the hybrid laser integration with flip-chip bonding [3].

The proposed fork-shaped edge coupler (Fig. 1 (b),(c)) consists of two parts: 7 small inverse taper tips designed to have a good spatial overlap with the laser mode to ensure a high coupling efficiency and a large taper structure serving as a spot size converter to guide light into the single-mode waveguide. Mode fields calculated by 3D FDTD simulations are shown in Fig. 1 (e1)-(e4), corresponding to the locations along the structure indicated in Fig. 1 (c). Fig. 1 (d) displays the incident facet of the edge coupler. The edge couplers are fabricated in a 110 nm thick LPCVD Si_3N_4 layer and have a bottom and top SiO_2 cladding of 2.0 and 0.64 µm, respectively. The devices are fabricated using electron-beam lithography and reactive ion etching, and side-polishing is employed to reduce the surface roughness of the end facet to increase the coupling efficiency. The coupling efficiency from the laser chip to the single mode Si_3N_4 waveguide is measured by active alignment of the laser chip to the edge coupler, and the feedback is obtained by vertical fiber coupling with a characterized grating coupler (Fig. 1 (a),(f)). The simulated and measured edge coupling losses for varying inverted taper tip widths are illustrated in Fig 1 (g). The best coupling loss of 2.1 dB per facet is obtained for a tip width of 150 nm.

In conclusion, we have demonstrated a compact, low loss fork-shaped edge coupler specifically designed for a GaN laser chip at 488 nm, achieving a coupling loss of 2.1 dB per facet. This device represents a significant step towards the development of hybrid integrated blue lasers on a Si_3N_4 platform via flip-chip bonding, enabling scalable integration of laser sources and facilitating practical applications at visible wavelengths.

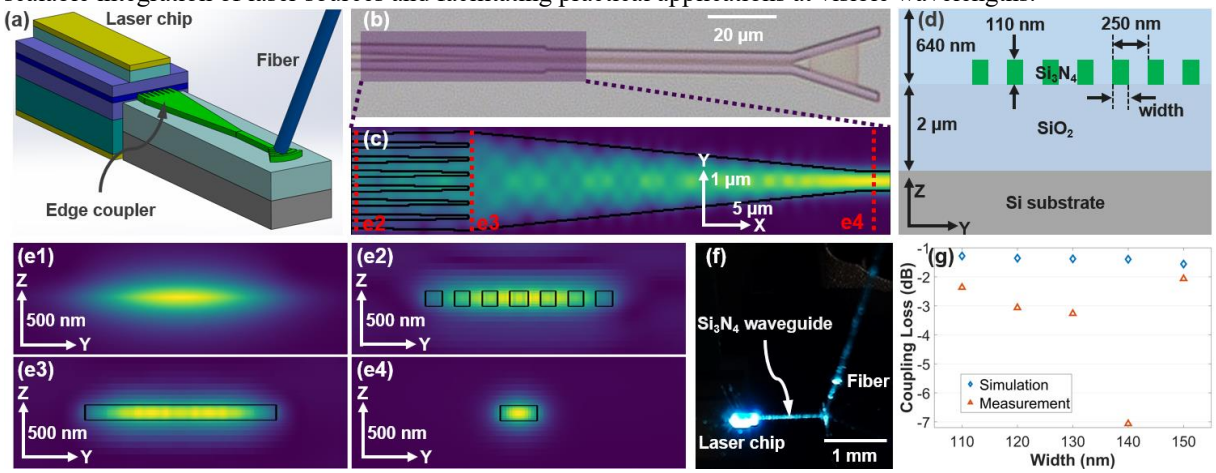

Fig. 1 (a) Schematic of the edge coupling between laser chip and Si_3N_4 chip. (b) Microscope image of a device with a fork-shaped edge coupler as input port and a grating coupler as output. (c) FDTD simulation of the edge coupling at the wavelength of 488 nm. (d) Cross-section of the end facet of the fork-shaped edge coupler, illustrating the varying tip width. (e) Simulation of the mode profiles from (c): (e1) laser spot profile, (e2) mode profile of multiple tips, (e3) mode profile of wide taper and (e4) mode profile of single mode waveguide. (f) Photograph of the coupling experiment. (g) Measurement and simulation results of the edge coupling loss with respect to various tip widths.

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