Ultra-Low Loss Si3N4 Waveguide Passive and Active Next Generation Photonic Integration for Optical Gyroscopes and Communications Applications

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The ultra low-loss Si3N4 waveguide platform has yielded a wide range of passive and active components that open up new PIC applications. Devices and applications including long delays, 3D stacking, gratings, filters, erbium amplifiers switches, vertical couplers and optical gyros, lasers and adaptive dispersion compensators.

I. Ultra-Low Loss (ULLW) Passive and Active Devices

The ULLW design employs a silica-based planar waveguide with high aspect ratio Si3N4 core to achieve a record low loss (0.045 ± 0.04) dB/m [1]. The waveguides support dilute modes using a high aspect-ratio stoichiometric Si3N4 core that minimizes scattering at the core-cladding sidewalls (Fig. 1a). Ultra low-loss optical delay-lines have been fabricated including single-layer small-area coils [1], single layer coils with 90 degrees low-loss crossings [2], and large area coils with low loss stitching [3] (Fig. 1b). Longer delay and multi-layer function is achieved by moving these designs into a 3D stacked delay lines with 0.5dB layer to layer coupling loss[4][5] (Fig. 1c). Other ULLW devices include grating filters and wavelength dependent mirrors using periodic Si3N4 sidewall gratings [6] (Fig. 1d) that can be designed as extremely long gratings on-chip with low kappa. By incorporating a reactive co-sputtered Al2O3-Er3+ layer with the ULLW, active waveguides can be realized [7] (Fig. 1e).

II. Integrated Optical Gyros

Chip-scale integration of interferometric optical gyros where the optical delays are integrated on-chip instead of using a fiber coil are designed to reach a detection limit of 19°/hr/√Hz (Fig. 1f). The operating principle is identical to the FOG where two counter-propagating light signals experience different phase shifts proportional to the rotation rate and the desired signal is measured by interfering these signals on a photodetector. Preliminary results for an integrated 3-meter long Si3N4 waveguide coil are reported in [2] with minimized scattering and reflection impairments can reach down to 19°/hr/√ Hz for a loss of 1dB/m and 4.2°/hr/√ Hz for a loss of 0.1dB/m.

III. Communications Applications

ULLW PICs enable a wide range of communications applications at the chip-level and offer solutions to handle functions normally done with electronics into the optical domain in order to save power and space. WDM DFB and DBR lasers have been demonstrated with record threshold powers and slope efficiency by combining active waveguides and sidewall gratings [7]. Due to the low thermal characteristics of glass laser performance with small threshold and wavelength shifts have been reported t0 400C [8]. True time delay (TTD) circuits have been fabricated by combining ULLW delays with thermally controlled 2x2 MMI switches [9]. 10-stage programmable matched optical filters can be used to replace power hungry DSPs for optical dispersion compensation [10] (Fig. 1g).

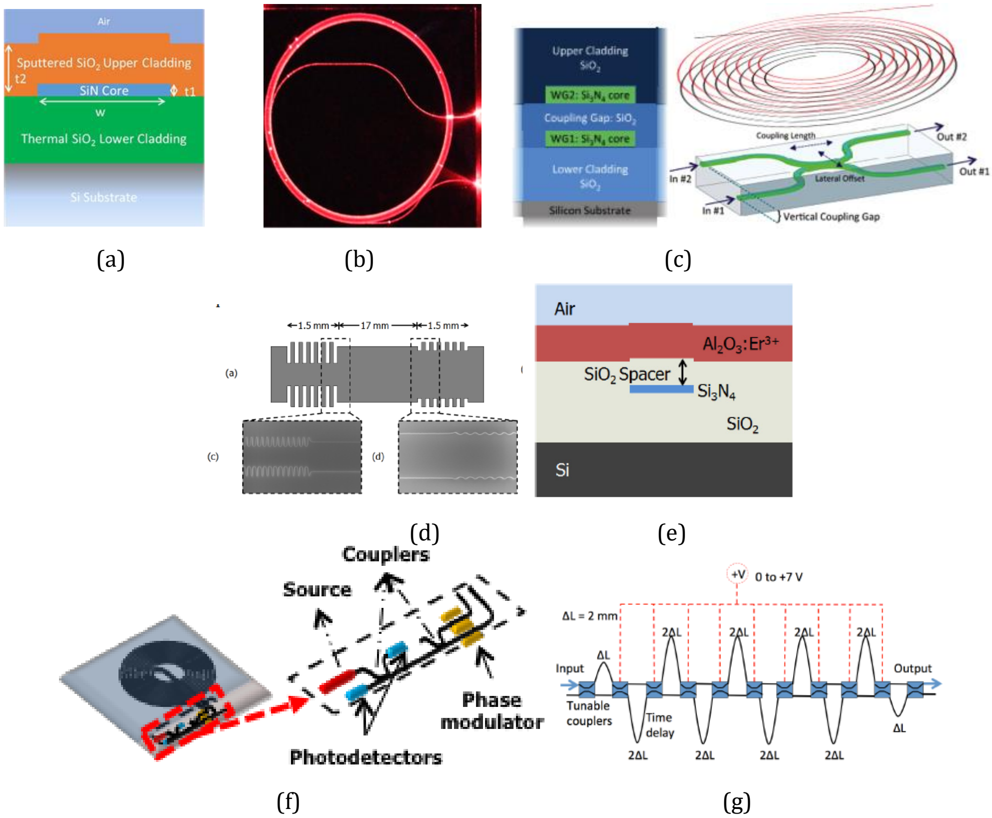

Fig. 1. (a-c) ULLW passive waveguide design, large area coils and 3D stacking. (d-e) Sidewall gratings, active erbium design and lasers. (f-g) Integrated optical gyro and dispersion compensator applications.

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