Ultra-Low Loss SiN Waveguide Platform for Integrated Passive and Active Components for Next Generation Photonic Integrated Circuits

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***Abstract*— The ultra low-loss SiN 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, gain, lasers, AWGRs, resonators, switches, vertical couplers and mode matchers and applications including lasers, adaptive dispersion compensators and optical gyros.**

I. Introduction

We describe progress towards reducing on-chip optical waveguide losses towards 0.45dB/m and the realization of long waveguide delays and other PIC elements that enable more complex PIC circuits based on Ultra-Low Loss Waveguide (ULLW) technology. This platform opens up a wide array of applications that will only utilize integrated optical circuits that are very low loss, perform equivalent functions at lower power consumption than electronic solutions, and offer small footprint and low cost. In this talk the ULLW platform, passive and active devices, and more complex PIC circuits and applications will be described.

II. Ultra-Low Loss (ULLW) Integration Platform

The ULLW design employs a silica-based planar waveguide with high aspect ratio Si3N4 core, low H absorption and bonded upper cladding to achieve a record low loss (0.045 ± 0.04) dB/m in the 1580-1610nm range [1][2][3]. The waveguides support very dilute modes using a high aspect-ratio stoichiometric Si3N4 core that minimizes scattering at the core-cladding sidewalls as shown in Figure 1a. Hydrogen impurities in the dielectric films are driven down through a combination of annealing and bonding of a thermally grown oxide upper cladding. A comparison of approaches for ULLWs is given in [4].

III. ULLW Passive and Active Devices and PICS

Table 1 summarizes a variety ULLW PIC elements and functions demonstrated to date. Ultra low-loss optical delay-lines have been fabricated including single-layer small-area coils [3][4], single layer coils with 90 degrees low-loss crossings [5], and large area coils with low loss stitching [6]. Longer delay and multi-layer function is achieved by moving these designs into a 3D stacked delay lines with only 0.5dB layer to layer coupling loss [7][8]. Other ULLW devices include a 16-channel 200GHz arrayed-waveguide grating (AWG) (de)-multiplexer [9], high-Q ring resonators [10] and extremely high polarization selectivity (>70dB) waveguides [11]. Grating filters and wavelength dependent mirrors have been implemented using periodic SiN sidewall gratings [12][13] that can be designed as extremely long gratings on-chip with low kappa and other properties difficult to achieve in high loss waveguides [12][13]. By incorporating a reactive co-sputtered erbium-doped aluminum-oxide layer with the ULLW, active waveguides with sufficient gain to achieve record low optical lasing thresholds has been demonstrated [14].

IV. ULLW PIC Applications

ULLW PICs enable a wide range of new 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 (Table 2). WDM DFB and DBR lasers have been demonstrated in the ULLW platform with record threshold powers and slope efficiency by combining active waveguides and sidewall gratings [15]. Due to the low thermal characteristics of glass the glass portion operates up to 400C [16]. True time delay (TTD) circuits have been fabricated by combining ULLW delays with thermally controlled 2x2 MMI switches [17]. 10-stage programmable matched optical filters can be used to replace power hungry DSPs for optical dispersion compensation, without a large optical power penalty, by using ULLW optical switches and long delay lines to realize tunable lattice filters [18]. A last example is chip-scale integration of interferometric optical gyros (iWog) where the optical delays are integrated on-chip instead of using a fiber coil and integrating the iWog optoelectronic front-end is achieved using a silicon photonics PIC [5][6][18][19].

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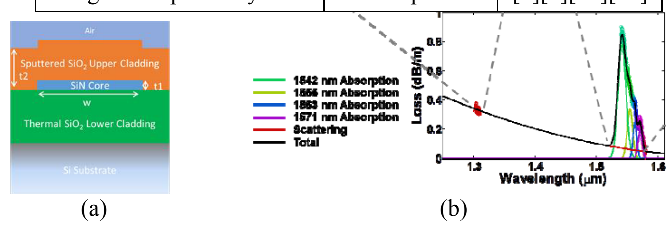
Table 1: PIC Elements

PIC Function	Figure Number	Reference
Passive Waveguide	1a, 1b, 1c	[1][2][3][4]
Delay Lines	1c, 1d	[3][4][5][6]
3D Stacked Delay Lines	1e	[7][8]
AWG	1f	[9]
Ring Resonator	1g	[10]
Waveguide Polarizers	1h	[11]
Waveguide Gratings	1i, il	[12][13]
Active Waveguides	1i, 1j	[14]

Table 2: PIC Applications

Application	Figure Number	Reference
Lasers	1k, 1l	[15][16]
True Time Delays	1m	[17]
Programmable Optical Equalizers	1n, 1o	[18]
Integrated Optical Gyros	1p	[5][6][18][19]



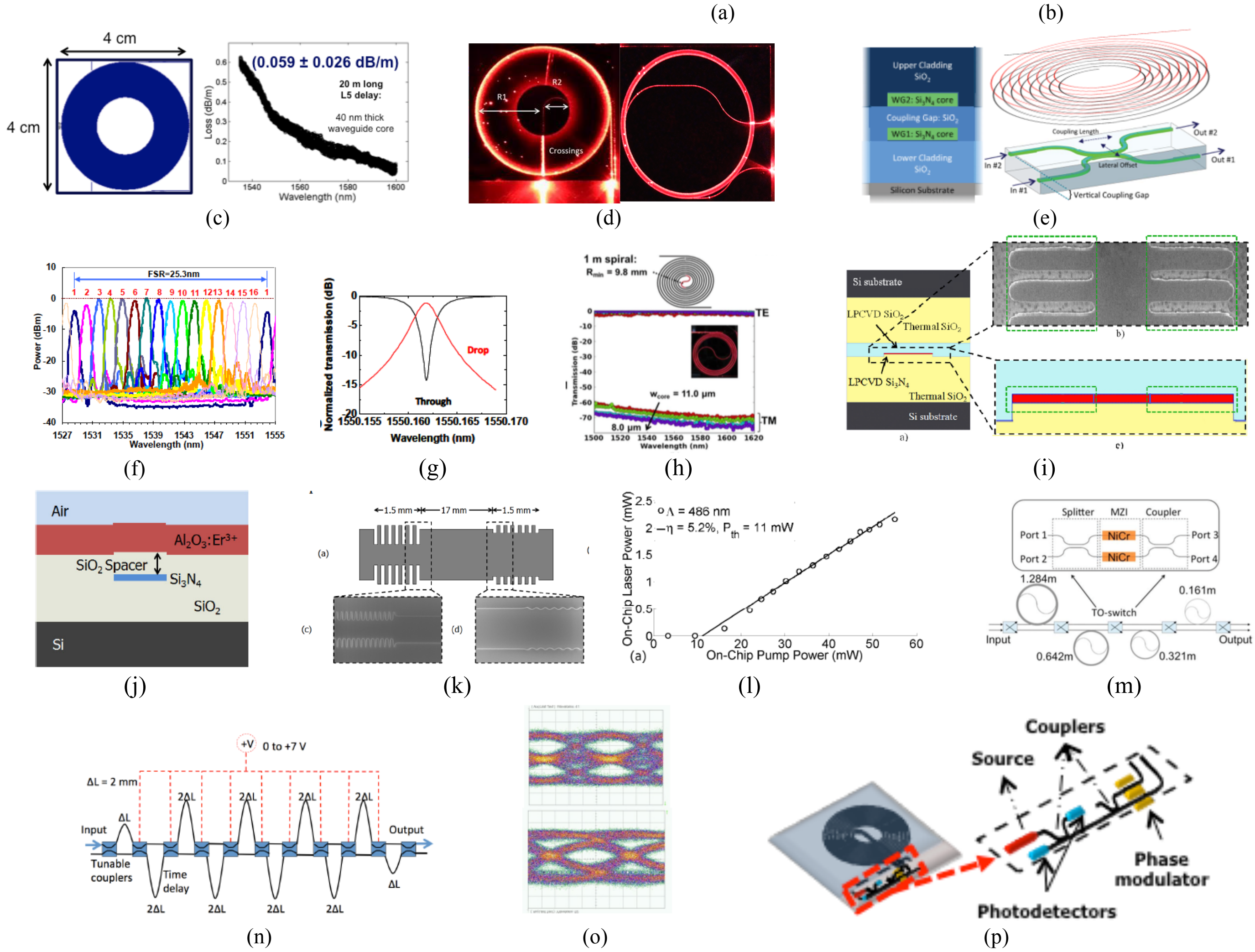


Fig. 1. (a) – (p). See Tables 1 and 2 for description.