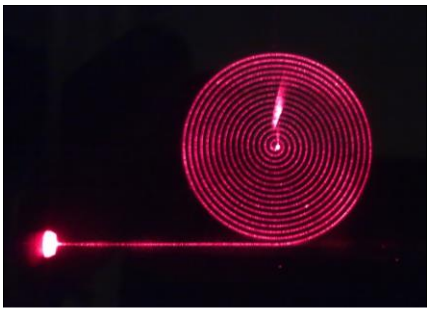
Si_3N_4 waveguide technology for broadband and ultra-low-loss photonic integrated circuits

Martijn J. R. Heck

Department of Engineering, Aarhus University, Finlandsgade 22, 8200 Aarhus, Denmark
e-mail: mheck@eng.au.dk

Traditionally, routing, switching and filtering functions for communications are performed by photonic integrated circuits (PICs) fabricated on a silica or silicon nitride based platform [1]. In such a platform, doped silica, silicon oxynitride (SiON), or stoichiometric silicon nitride (Si_3N_4) is used for the light guiding core, embedded in a silicon oxide upper and lower cladding. Only passive components and thermo-optic tuners are available.
The reason for the widespread use is the low intrinsic material loss over a wide wavelength range, from the ultra-violet to the mid-infrared. Traditionally, doped silica and SiON were the preferred solutions, as the waveguide core index can be tuned by material composition. This allows for low-index contrast waveguides, e.g., 0.3% - 3% [2], thereby minimizing scatter losses.
The interest in silicon nitride waveguide technology has significantly increased recently, due to its potential compatibility with CMOS fabrication technology. Si_3N_4 has a relatively large index contrast with the oxide cladding. This allows for small waveguide cores and tight bending radii, with a potential for large-scale photonic integration. Another benefit of this tight confinement is the optimization of nonlinearities. Silicon nitride resonators have been used for comb generation [3] and frequency doubling [4]. At first sight, silicon nitride might not seem like a good approach for low-loss waveguide design. This is due to the high index contrast with silicon dioxide and, hence, the large scattering. However, it has been shown that the lowest loss waveguides can be made using very thin silicon nitride waveguides of only 30 nm – 40 nm thin [5] (Figure 1). The CMOS-compatibility of the process also allows for further integration with silicon photonics, leading to highly functional and high-end PICs [6].



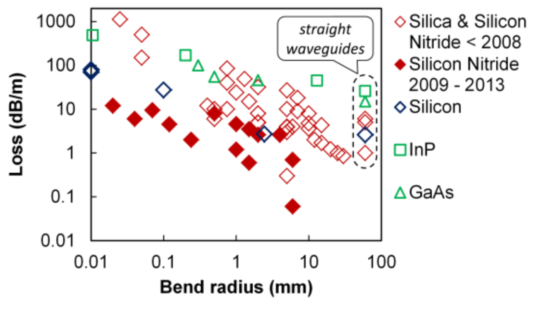


Figure 1. (left) Silicon nitride waveguide in a spiral layout, showing red light propagation. (right) Overview of waveguide propagation loss as a function of bend radius. Data for silica and silicon nitride before 2008 (red, open), recent silicon nitride (red, solid), silicon (blue), indium phosphide (green squares), and gallium arsenide (green triangles) are given [7].

References

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