Tunable Quasi-Phase-Matching in Ion Implanted Silicon Waveguides

National Research Univ. of Electronic Technology[1], Moscow Inst. of Physics and Technology[2] °Nikolay Balakleyskiy [1], Yurii Kusnetsov[1], Nikolay Gerasimenko[1],

E-mail: balakleyskiy@gmail.com

Integrated silicon photonics is a rapidly growing technology area with applications reach from chip-to-chip interconnection to communication, sensing, light-field displays and numerous others. As a centrosymmetric crystal undoped silicon has third-order nonlinear susceptibility $\chi^{(3)} \sim 10^{-19}$ m^2/V^2 and large Kerr nonlinear coefficient. Nevertheless, second-order susceptibility $\chi^{(2)}$ would be highly desirable as it would allow the creation of electro-optic modulators and nonlinear waveguides.

In this article, we describe a CMOS compatible quasi-phase-matched (QPM) periodically ion-implanted silicon waveguide (Fig.1) for frequency conversion as well as for effective phase modulation and optical delay. Electric field-induced nonlinearity and QPM period can be tuned real-time by independently powered p-i-n junctions switching while extended frequency tuning achievable by geometry handling of p-n regions and ion implanted areas.

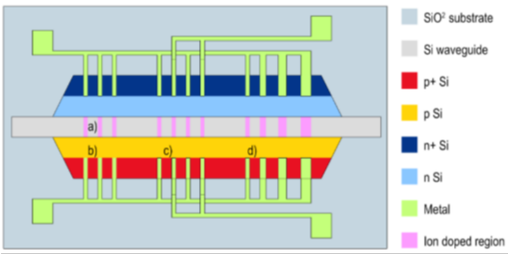

Fig.1 The design of a QPM Kerr effect based harmonic generator (a)– Ion doped waveguide core; (b) – constant electrical field period; (c) –adjustable field period. By powering both or only one of electric path the field period may be controlled; (d) - cascaded electrical field period for efficient multiwavelength conversion

Ion implantation is a common method for doping of silicon waveguides and may be done with a wide range of materials. Thus we can create metamaterials with local strain effects, enhanced carriers concentration and mobility, outstanding nonlinear properties and reduced optical losses. For example, SiN waveguide has low two photon absorption and equivalent $\chi^{(2)}$ of 0.3 - 3.7 pm/V, however nonlinear conversion, electro-optic modulation and detection hardly achievable simultaneously in the same waveguide. It can be overcome by selective ion doping of waveguide and thus creating local areas with controllable properties.

For nitrogen implantation in dose 10^{18} cm^{-2} and energy of 200 keV followed by 1000 C annealing our waveguide structure shows up to 148 pm/V $\chi^{(2)}$ nonlinearity and phase modulation efficiency less than VπL of 3 V*cm.