

Optical poling of silicon nitride waveguides for enhanced effective $\chi^{(2)}$

Camille-Sophie Brès, Edgars Nitiss

Ecole Polytechnique Fédérale de Lausanne (EPFL), Photonic Systems Laboratory, CH-1015 Lausanne, Switzerland

camille.bres@epfl.ch

Abstract: The integration of both second and third order nonlinearities in CMOS compatible platform can open new opportunities for integrated nonlinear optics. In this talk, we will cover recent work on optically inducing second order nonlinearity in silicon nitride waveguides and the characterization of the effect. © 2019 The Author(s)

OCIS codes: (190.4390) Nonlinear optics, integrated optics; (190.2620) Harmonic generation and mixing; (130.3120) Integrated optics devices

Silicon Nitride (SiN) is now one of the most widely utilized and mature platforms for development of optical waveguide devices due to its CMOS compatibility as well as exceptional linear and nonlinear optical properties. High refractive index, low absorption in the visible and infrared spectral regions and high third-order nonlinearity in SiN has enabled its use in multiple applications such as optical frequency comb generation [1–3], spectroscopy [4] and entangled photon-pair generation [5] to name a few. Completely new horizon of applications could be unveiled if $\chi^{(2)}$ nonlinearity would be present in SiN waveguides. Even though SiN does not exhibit second order nonlinear optical properties due to its amorphous nature, an effective $\chi^{(2)}$ in SiN waveguides can be induced by symmetry breaking at interfaces [6–9] or, as very recently shown, by performing all-optical poling [10–12]. The later method has been used to achieve maximum effective $\chi^{(2)}$ to about the order of pm/V [11,13]. It has been recognized that during all-optical poling the second-order nonlinearity and quasi-phase-matching is built up due to the coherent photogalvanic effect [14] in which a harmonic space-charge modulated $\chi^{(2)}$ grating quasi-phase matches the pump and its second-harmonic (SH). This effect was also demonstrated and studied in SiO₂ optical fibers three decades ago [15–17]. Contrarily to optical fiber, self-organized $\chi^{(2)}$ gratings integrated devices build up much faster under orders of magnitude less pump power, by leveraging their enhanced spatial confinement, and larger $\chi^{(3)}$, thus also leading to higher effective $\chi^{(2)}$.

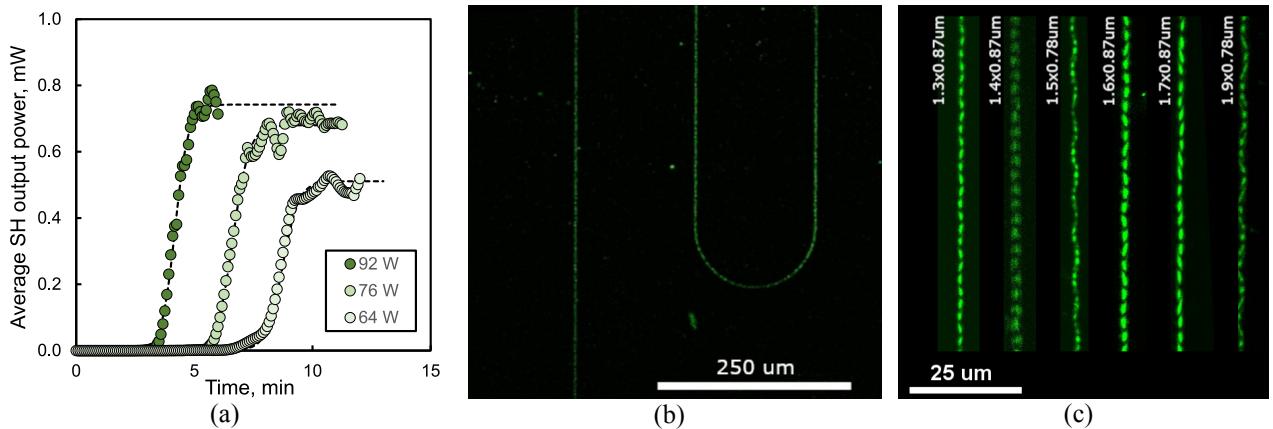


Fig. 1. (a) Measured average SH output power growth in time during all-optical poling of a 4 cm long SiN waveguide at different coupled pump peak power (pump wavelength 1550 nm, 5 MHz repetition rate and 1.25 ns, 1.5 ns, 1.75 ns pulse width respectively). (b) TPM image of a poled SiN waveguide. (c) TPM image of $\chi^{(2)}$ gratings in SiN waveguides with different dimensions.

Despite numerous papers on the subject of self-organized $\chi^{(2)}$ gratings in silica fibers, there are still several open questions on the effect in general and in SiN in particular. Here we study the properties of $\chi^{(2)}$ gratings by optical means. We investigate the growth and maximum conversion efficiency of $\chi^{(2)}$ gratings prepared in waveguides with different geometries and under different pumping conditions (Fig 1a). The waveguides are of various lengths, from 2.2 cm to 5.8 cm in, arranged in meanders (Fig 1b). We observe that growth speed and saturation depends on the

pump power as well as the waveguide lengths. We also use two-photon microscopy (TPM) to directly image the $\chi^{(2)}$ grating (Fig 1b and 1c) and provide evidence on mode matching conditions responsible for grating formation. A strong response is measured after poling of the waveguide with clearly identifiable periods. The retrieved grating periods change with waveguide dimensions, as expected from theoretical calculations of the effective refractive indices.

This work is supported by the European Research Council (ERC) under grant agreement ERC-2017-CoG 771647-PISSARRO. The authors thank Dr. M. Pfeiffer, C. Herkommer and the K-lab of Prof. Kippenberg at EPFL for the SiN waveguides.

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