Electron-beam lithography of photonic waveguides: measurement of the effect of field stitching errors on optical performance and evaluation of a new compensation method

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Direct write electron beam lithography is the most flexible and straightforward way to pattern optical waveguides with sub-300 nm critical dimension, as the DUV steppers required for optical patterning with such resolution are out of reach for most photonic foundries or research laboratories. However, devices with optical waveguides are relatively large (several millimetres) and the pattern extends over several fields that are stitched together by the lithography system with typical accuracy between 20 nm and 60 nm. Understanding the effect of field stitching errors on light propagation in fabricated waveguides is critical in order to obtain a better quality control and the optimal method to correct stitching errors for the fabrication of optical circuits. Some methods are available for correcting potential field stitching errors during patterning but they involve reducing the writing current to overlap areas with partial dose, resulting in a significant increase of the write-time.

In the present work we report on the fabrication of SOI-based photonic waveguides with intentional stitching errors of predefined amplitudes and orientation (*Figure 1*). The number of errors along the waveguides was chosen to produce a measurable optical effect. The optical losses were measured for both the TE and TM polarizations and compared to the results of Finite Difference Time Domain (FDTD) simulations.
As shown in *Figure 2*, for uncorrected writing, stitching errors of 50 nm in both horizontal and vertical directions results in additional loss of ~20 dB and the 450 nm waveguides become nonconductive when the amplitude of the stitching errors reaches 75 nm.

A method for stitching error compensation by multi-pass writing of the pattern in the area of the field boundaries is proposed. This method does not require reducing the write current and was used to correct the artificial stitching errors introduced. Measurements of optical losses for the waveguides after correction show a clear improvement (*Figure 2*).

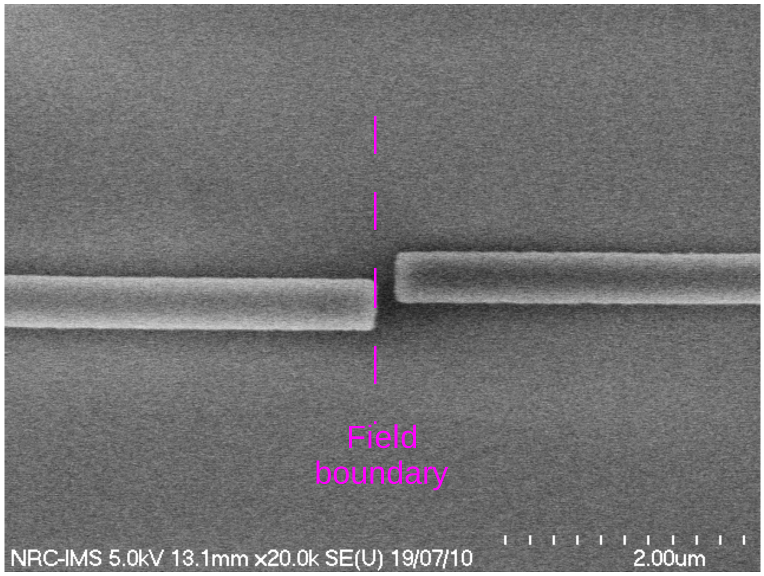

Figure 1: SEM micrograph of a 450-nm wide waveguide in SOI made with intentional field stitching error of 200 nm in both horizontal and vertical directions

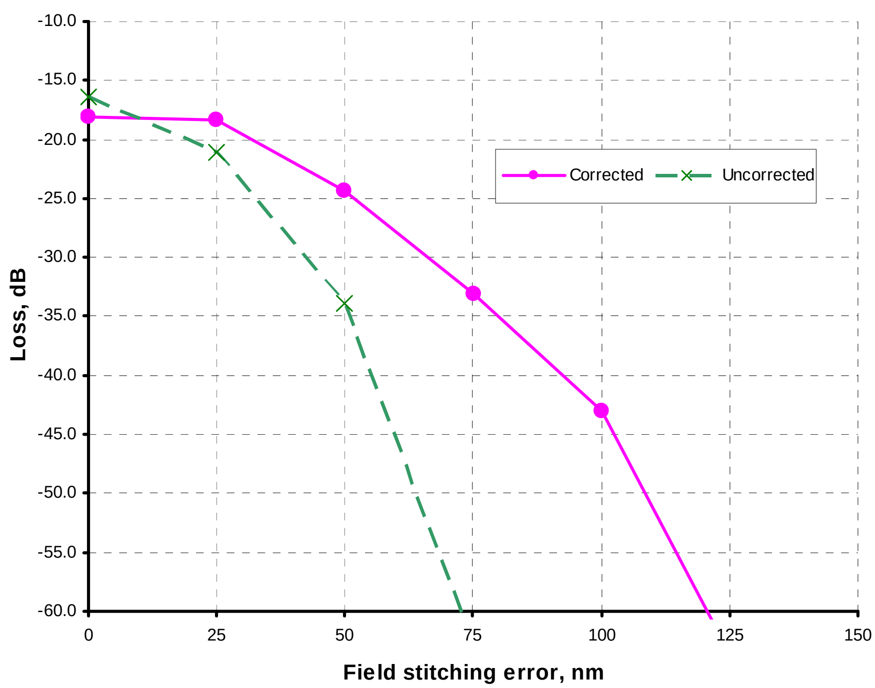

Figure 2: Optical loss combined for TM and TE polarizations in straight 450-nm waveguide in SOI, plotted vs. the amplitude of intentional stitching error for corrected and uncorrected e-beam writing