Long, stitch-free slot waveguide for IR-sensing applications using e-beam lithography

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Electron beam lithography (EBL) remains one of the most popular methods for fabricating nanoscale structures providing high resolution, flexibility in pattern geometries and, in most cases, acceptable patterning times. A recent application in which EBL systems are used is to fabricate slot waveguide[1] structures for on-chip absorption spectroscopy, which provide strong light-matter interaction for sensing but require patterns with large in-plane aspect ratios. As such structures are typically much larger than the addressable area of the EBL, they are commonly fabricated by dividing the pattern area into smaller write fields, and stitching them together, with the drawback of introducing stitching errors. In on-chip absorption spectroscopy, one of the main sources of noise are etalon features in the measured spectra (also referred to as interferometric noise) due to reflections from defects that are introduced during fabrication. These are in the case of EBL largely caused by write-field stitching errors. Moreover, the imperfections produced by stitching errors increase waveguide propagation loss as they increase scattering during transmission. The Raith e_line EBL system provides a fixed beam moving stage (FBMS) mode that can produce long lines without stitching errors.[2] However, the FBMS mode also has inherent limitations one being that each FBMS structure can only have a fixed width. Therefore, it cannot be used in combination with structures that have variable widths, such as tapered structures.[3] Furthermore, since each FBMS element is patterned as a whole, the patterning time increases with increasing size of the element and system drift due to e.g., temperature variation can result in stage and consequently pattern placement drift. For slot waveguide pattern with lengths in the range of cm but slot width of 150 nm, such pattern placement errors have sever effects on the intended optical application.

In this work, the Raith e_line FBMS mode is used to pattern 1 cm long slot waveguides with s-bend tapered couplers as shown in figure 1. The fabrication method solves two major limitations of the FBMS mode, namely the requirement for fixed width structures and the incidence of stage placement drift for patterns involving elements of different widths. The structures were realized by using a fixed width path to create both the tapered coupler, which has variable width, and the slot waveguide. In the mask design, one FBMS path with a width of 150 nm is used to define the entire structure, which helps to minimize random pattern positioning errors caused by factors such as thermal drift. The remaining large areas are then patterned by using a wider width FBMS path. The fabrication method can be applied to a much longer waveguide structure.

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Acknowledgements: This work was supported by Tromsø Research Foundation (project ID 17_SG_JJ), the Research Council of Norway (grants no. 262608 and 295864), and the European Research Council (grant no. 758973).

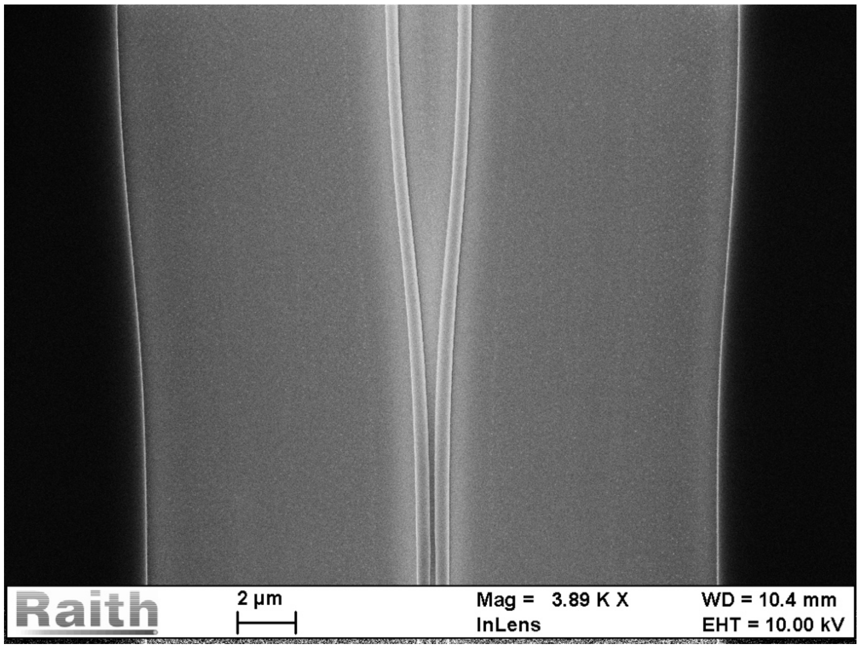

Figure 1: SEM image of the fabricated structure which shows one of the couplers and the slot waveguide.