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Beam Steering Device with Sub Micrometre Precision

**Simone CARDARELLI*, Nicola CALABRETTA, Domenico D'AGOSTINO,
Ripalta STABILE and Kevin WILLIAMS**

COBRA research institute, Eindhoven University of Technology

* s.cardarelli@tue.nl

Abstract: A lateral beam steering device based on electro-optic effects in an InP/InGaAsP expanded mode waveguide has been designed, simulated and tested. Experimental results confirm that sub-micron precision beam movement is achieved at the output facet of the device. A total tuning range of 0.8 µm has been measured.

The ability to move the location of an optical beam from inside an integrated photonic circuit offers opportunities from automated optical alignment in packaged parts to beam scanning and metrology. So far external optics has been used to align the mode exiting an optical chip to the subsequent micro-optics either by means of precision placement of micro-optics and fibers, the use of intricate micro-scaffolds[1], or micro-electro-mechanical systems[2] (MEMS).

In this work we propose and demonstrate an on chip optical beam steering device based on Electro-Optic effects in InP/InGaAsP materials which allows a single lobed beam to be moved across the output facet of a waveguide, with sub-micron precision. The schematic of the device is shown in figure 1a. The structure consists of a multimode ridge waveguide which is connected via a long adiabatic taper to a single mode laser source. Two twin electrodes are symmetrically placed on top of the widened waveguide. A beam propagating in this structure can be continuously displaced across the output facet by tuning the amplitude of the reverse bias voltages applied to one or other of the two electrodes. The principle of operation is based on the refractive index perturbation. In order to design the device, a numerical tool has been employed that integrates DEVICE software (Lumerical) for the electrical simulation, MATLAB for the Electro-Optical simulation and FIMMPROP (Photon Design) for the optical propagation. The device cross section is first defined in terms of epitaxial layers, etch profiles and electrodes geometry to compute the electrical field and the carrier density for different bias voltages. The refractive index and loss are subsequently defined for multiple 2-D cross sections to enable 3D optical field propagation calculations.
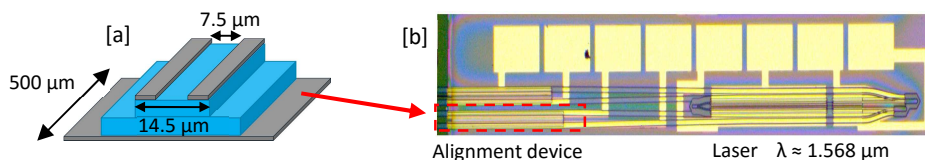
Fig. 3. a) 3D schematic of the steering device; b) Microscope photograph of circuit.

Figure 1b shows a picture of the photonic integrated circuit (PIC) fabricated from SMART Photonics foundry. The PIC includes three blocks; 1) the prototype device (red dashed box), composed of a 14.5 μm wide and 500 μm long multimode waveguide with two electrodes along the 500 μm length, spaced by a 7.5 μm gap for electrical isolation; 2) a coupled cavity laser[3] which is used as a high spectral purity on chip light source; 3) an 800 μm long linear taper connecting the 2 μm wide output waveguide of the laser to the multimode waveguide of the steering device. The device has been tested by mean of a near field measurement setup; the beam at the chip output facet has been magnified by an 100X objective and imaged with an IR camera (320x256 pixels) which is placed at 140 cm from the chip. The magnification enables a 50 nm near field discretisation.

Figure 2 shows the predicted and measured performance in terms of beam movement. For simulations, the maximum applied voltage is -12 V for both left and right electrode, enabling the beam peak to scan across the device facet from -2.6 μm to 2.6 μm relative to the waveguide center. Experimental comparison is performed over the limited range 0V to -4V since a residual leakage path limits the maximum voltage for the first prototypes. When -4 V is applied to the right electrode the beam peak moves of 0.8 μm and 1.1 μm respectively from experiments and simulation results.
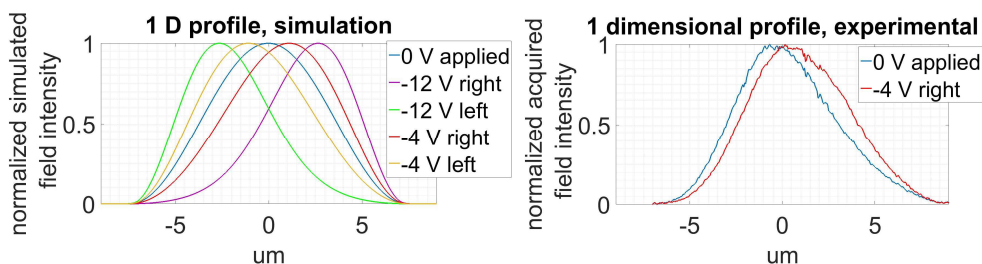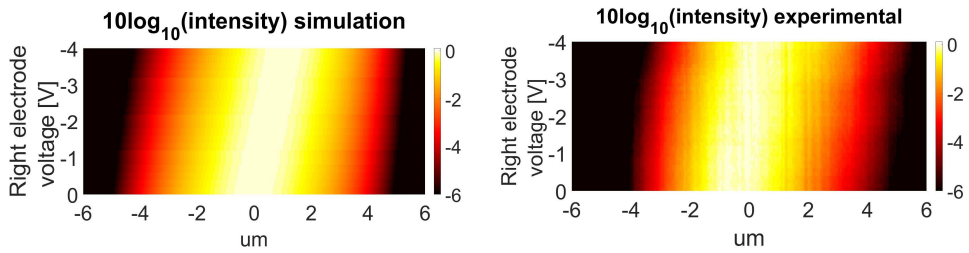

Fig. 4. Optical intensity profiles for different voltage settings. The curves are normalized to their peak value.

Figure 3 shows the colormaps of the intensity profiles, measured and simulated, for up to -4 V applied to the right electrode. The colormaps clearly show that the steering direction is well predicted from the simulation and that continuous tuning is achieved.

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Fig. 5. intensity colormaps for voltage steps of 0.1 V.

In conclusion we have demonstrated an on-chip lateral and continuous beam movement of 0.8 μm with sub-micrometer precision. Simulations indicate that a larger tuning range may be expected with improved electrical isolation.

References

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