Simulation of acousto-optical interaction in a Mach-Zehnder interferometer

The acousto-optical modulation of light in a Mach-Zehnder interferometer affected by a surface acoustic wave, is simulated by the finite element method. It is discussed how the modulation can be improved based on a parameter study of the geometry. Summary A new way to control and modulate light in waveguide structures is to let the light interact with surface acoustic waves (SAW) [1]. SAWs are elastic waves that propagate along a material surface, they consist of a longitudinal and a shear component and they have most of their energy density concentrated within one wavelength of the surface [2]. In [3] it is explained how a SAW can be employed to modulate the output light of a GaAs Mach-Zehnder interferometer (MZI) and experimental results with a relative modulation depth of 40% are presented. To modulate the light using a MZI a SAW is transmitted perpendicularly to the two waveguide arms and the elastic stress field from the SAW results in a periodic change of the refractive index and therefore a periodical phase change in the waveguide arms. At a wave crest the refractive index will increase and at a trough it will decrease. Thus, if the distance between the arms is chosen as an unequal multiple of half the SAW wavelength the light at the output waveguide will interfere constructively and destructively in a periodic way and the MZI can hence be used as an optical switch. To understand and improve the interaction of the elastic field from the SAW with the optical field in the waveguides a numerical model of the MZI is constructed. The generation of the SAW by interdigital transducers is studied using a 2D finite element model of a piezoelectric, anisotropic material implemented in the high-level programming language Comsol Multiphysics. By calculating the stresses in the waveguide arms introduced by the SAW the changes in refractive indices are obtained from Pockels constants. This model is then coupled to an optical model where the time independent wave equation is solved as an eigenvalue problem giving the effective refractive index of the lowest modes in the waveguide arms. Numerical results of the modulation for MZIs of both GaAs and Si are presented. Based on results from a parameter study of the geometry it is discussed how the acousto-optical modulation can be improved. References [1] M. M. de Lima Jr. and P. V. Santos, (2005), “Modulation of photonic structures by surface acoustic waves”, Rep. Prog. Phys., 68 1639-1701. [2] K.-Y. Hashimoto, “Surface acoustic wave devices in telecommunications modeling and simulation”, Springer, Berlin, 2000, ISBN 3-540-67232-X. [3] M. M. de Lima Jr., M. Beck, R. Hey and P. V. Santos, “Compact Mach-Zehnder acousto-optic modulator”, Applied Physics Letters, 89, 121104 (2006).