Modelling of Time-varying Phenomena in Electroabsorption Modulators

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Modern RF electroabsorption modulators are important devices as they directly determine the bandwidth, speed and operational frequency of dense wavelength division multiplexing (DWDM) and optical time division multiplexing systems (OTDM). In these systems they are commonly used for short pulse generation, data encoding and clock recovery. In order to enable systems achieve higher speed, bandwidths and lower costs an efficient modelling tool that would enable deeper insight into the physical behaviour of the modulator and its existing problems and limitations is needed.

The principal operation of a RF electroabsorption modulator relies on the interaction of the optical electromagnetic wave with the time-varying medium whose complex dielectric constant is modulated by a microwave wave. The optical wave is confined by a complex semiconductor geometry and the modulation of the dielectric constant is done in a relatively small region of a multiple quantum well (MQW). It is well known that a temporal change of the dielectric permittivity in an open and semi-open medium causes transformation of the original plane wave into reflected and transmitted waves of different frequencies and same wave numbers [1, 2]. In the time-varying waveguide the change of the permittivity directly affects not only the frequency of the incident wave but also the spatial distribution of the wave which further complicates the problem.

One of the major limitations in the performance of RF modulators is the temporal variation of the frequency and this is measured through the chirp parameter.

Numerical methods such as the Finite Difference Time Domain (FDTD) and the Transmission Line Modelling (TLM) method can in general be used to model time-varying phenomena but they do not allow for the physical investigation of the problem. On the other hand exact analytical methods have been confined to a few special cases of infinite and semi-infinite media [1, 2] and slab waveguides [3].

This paper investigates a semi-analytical Time Domain Spectral Index (TDSI) technique [4] that enables efficient modelling of propagation of the optical signal through a time-varying rib waveguide and is suitable for predicting the chirp parameter. For the complex case of a time-varying dielectric waveguide, invariant in the z-direction, the solution of the wave equation yields waves (incident and reflected) having new frequencies and preserved wavenumbers. The new spatial wave distribution of the secondary waves is obtained by reversing the original spectral wave problem of the TDSI and solving for a new frequency. The amplitudes of all incident and reflected waves are solved using the Galerkin approach with triangular and Gaussian basis functions. The method is verified for cases of temporal dielectric change in an open region and a slab waveguide and then extended to include an air-clad waveguide. The method is applied to model the chirp parameter in a typical electroabsorption waveguide.

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