UNIVERSITÄT PADERBORN
Die Universität der Informationsgesellschaft

FAKULTÄT FÜR
ELEKTROTECHNIK,
INFORMATIK UND
MATHEMATIK

Abstract of the dissertation:

Optical coupling into multimode waveguides -
Wave theory analysis and a comparison to ray optical modeling

by Matthias Stallein

Embedding optical waveguides into Printed Circuit Boards (PCB) is an upcoming technology that is designated to meet the increasing demand for bandwidth. This new Electro Optical Printed Circuit Board (EOPCB) is a combination of electrical and optical layers resulting in a hybrid technology. Analog to existing layout software for Printed Circuit Boards, first design editors and simulation software for modeling optical waveguide layers are available. But these are entirely based on ray optical methods, whose scope of application has not yet been defined. The aim of this study is to verify the applied ray optical methods by comparing the results with those of a full-wave analysis. The focus is on modeling the coupling of optical waves with Gaussian intensity profile into cylindrical step-index fibers. Additionally the wave propagation in straight and circular bent slab waveguides is investigated.

The full-wave reference analysis for modeling the coupling process depends on classical mode theory and uses all propagating modes of the dielectric fiber. For the determination of the reflected and transmitted waves a perfectly conductive shielding encloses the fiber in a sufficient distance to the core. Thus a fully discrete mode spectrum allows to apply the method of mode-matching. The ray optical analysis particularly investigates whether it is advantageous to apply the Goos-Hänchen-Shift for the modeling of the coupling process. For a comprehensive study the axis of the incident Gaussian Beam is rotated or laterally shifted. As a main result it is shown, that a constant minimal Goos-Hänchen-Shift significantly reduces the average error in the ray optical model. Hence ray optical methods are qualified for the analysis of the coupling into multimode optical waveguides, even for waveguides with small diameters and only a couple of ten guided modes.

Analog results are obtained for planar slab waveguides, for which the propagation characteristics have also been analyzed. Using the straight waveguide there is a satisfying conformity between wave and ray optical results, as long as the model of the source is accurate. The major difficulty in modeling open bent waveguides is the continuous and nonorthogonal mode spectrum. Yet it is possible to separate a few quasi-guided modes, which relate to the guided modes of the straight waveguide and are suited to model the connections to straight waveguides. Once again the results of the wave and ray optical simulations agree on average.