Design and simulation rules for printed optical waveguides with implemented scattering methods in CAD and raytracing software

F. Loosen*, C. Backhaus*, N. Lindlein*, J. Zeitler**, J. Franke**
** Institute of Optics, Information and Photonics,*
Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)
*** Institute for Factory Automation and Production Systems,*
Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU)
mailto: florian.loosen@fau.de

The printing process of Polymer Optical Waveguides (POWs) is a new and uncharted research topic in which the DFG founded research group OPTAVER is involved. The main goal of the group is to build up the whole manufacturing process of such waveguides, from the design, over the simulation, to the fabrication. Therefore it is necessary to investigate a new manufacturing chain.

1 Introduction

The main reason to investigate new fabrication processes for waveguide production is the request making simpler and more favorable solutions. This also fulfilled the effort for new technologies, e.g. Industry 4.0 [1] and Internet of Things applications. These include new optical bus-couplers (shown in fig.1) for data communication technology [2]. A new approach is to print these Polymer Optical Waveguides (POWs).

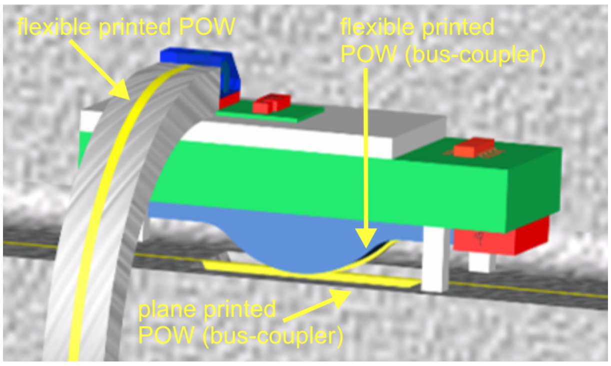

Figure 1: *3D drawing of a optical bus-coupler with a flexible and a plane waveguide part and the flexible connection to the optical bus-coupler with printed POWs.*

2 Waveguide design

The waveguide design respectively the geometry of the waveguide structure depends on the fabrication process. First experimental printing tests show that the polymer material for the core forms a semi circular cross section (because of the adhesion force of the printing material for the core printing), that is shown in fig.2. For that, the shown geometrical parameters are very important to describe the whole waveguide structure. Through the use of conditioning lines (ridges) [3] on the sides of the waveguide, the aspect ratio can be substantially influenced to increase the waveguide height. But the choice of materials (refractive indices, permeability, and material quality of core and cladding material) have a significant impact on the quality of the transmitted signal through the waveguide.

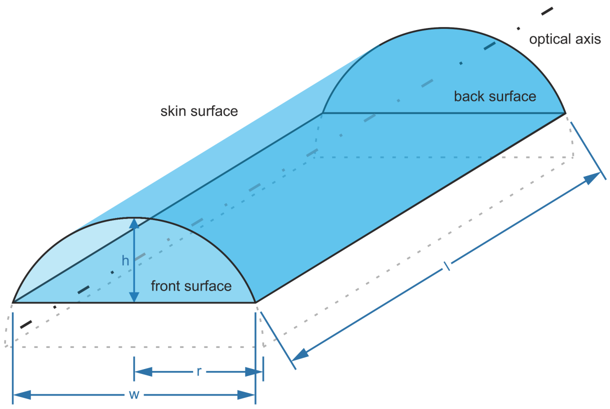

Figure 2: *3D sketch of the geometry of the core of the printed POW, with marked parameters (radius r, width w, height h, and length l) for the CAD design.*

Another important parameter of these printed POWs is the roughness between core and cladding material. This surface roughness impacts scattering of an incident ray which interacts with this boundary layer.

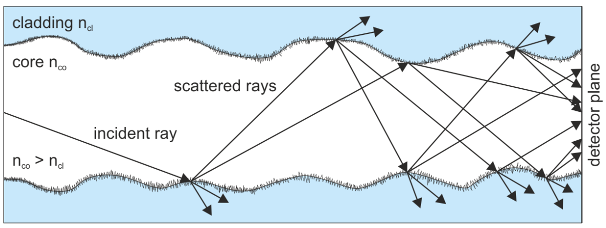

Figure 3: *Principal sketch of the printed POW for a better description of the scattering process induced by the boundary layer between core and cladding material.*

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For this special case (fig.3), standard non-sequential raytracing methods must be extended with scattering algorithms [4]. It should be noted that this approach is only possible for highly multimode waveguide simulation.

3 Monte Carlo raytracing

One approach is to use the perturbation theory to generate scattering power spectra for each incident ray which interacts with the rough surface [5]. For the description of the rough surface an exponential autocorrelation model can be used [6]. At this model, the heights of the surface are normally distributed. The Monte Carlo approach that will be used, picks up a diced angle combination out of the calculated scattering power spectra (calculated with the 1. order perturbation theory) and assigns all incident power to that scattered ray minus the transmitted power (for the reflection case) or vice versa. This diced ray which angle combination is selected out of the calculated distribution function (weighted according to their probability) is the starting point (incident ray) for the next calculation (intersection with the interlayer) loop. The non-sequential raytracing algorithm calculates the propagation of all rays through the designed waveguide in consideration of scattering.

4 Linking parameters

For the linking process between the mechatronic design system MIDCAD (Mechatronic Integrated Device Computer-Aided Design) for the construction and placement of such waveguides and other mechatronics at 3D dimensional surfaces and the raytracing software RAYTRACE (both software packages are in-house software) many different parameters are needed [7]. This includes, for example, different light sources (from ideal, over LEDs, to laser light), entering of the waveguide parameters (see therefore chapter 2), optical bus-couplers, and different detector types. Hence, not only the geometrical (CAD) parameters are important, but especially the physical parameters for the optical simulation process are of special interest. Fig.4 shows a flow chart of the engineering routine of the manufacturing process of POWs, that includes the feedback loop for the design and simulation process and all interfaces between the involved software and hardware tools. Thereby, the complete process chain of the waveguide manufacturing can be represented.

5 Summary

In this proceeding, a sub-activity of the DFG founded research group OPTAVER (Optische Aufbau- und Verbindungstechnik für baugruppenintegrierte Bussysteme) is shown. The design and simulation process of such printed POWs is a big and challenging task to build up the „manufacturing process“ and give the designer a feedback about the optical quality of the waveguide. This requires a priori knowledge about the fabrication process and the material properties. This new approach fulfil the requirements and the wish for new data communication solutions.

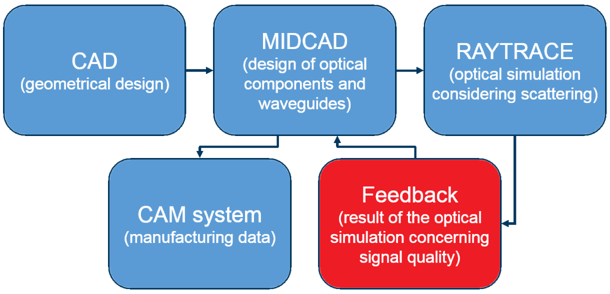

Figure 4: *Flow chart of the engineering routine of the manufacturing process of POWs, from the design, via the simulation (includes the feedback loop), to the fabrication.*

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6 Bibliography

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