Modal multiplexing in highly overmoded optical waveguides

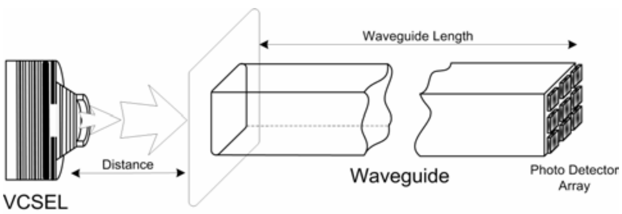
D. Lenz[1], B. Rankov[2], D. Erni[1], W. Bächtold[1] and A. Wittneben[2]

[1]Laboratory for Electromagnetic Fields and Microwave Electronics,
[2]Communication Technology Laboratory,
Swiss Federal Institute of Technology, ETH Zurich,
CH-8092 Zurich, Switzerland
lenz@photonics.ee.ethz.ch

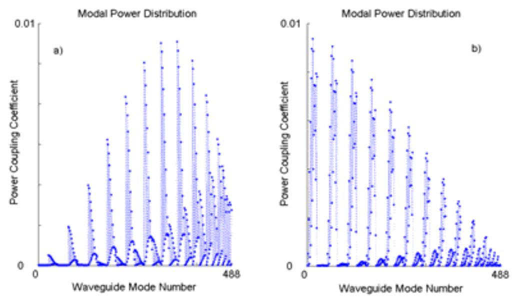
Optical transmission has become the future data communication technology on multi-layered Printed Circuit Boards (PCB's) to meet the increasing demand for communication bandwidth of modern multiprocessor systems [1]. For this reason optical waveguides are integrated into the boards using various technologies. For mass-producible board level interconnects only multimode waveguides are applicable due to the inappropriateness of clean room technologies and their relaxed tolerance requirements compared to singlemode technology. Such waveguides have very large cross sectional dimensions (100 × 100 µm) guiding up to several thousand modes. The drawback of multimode waveguides is the mode dispersion caused by the different propagation delays of the modes. Short distance optical interconnect systems for PCB applications are usually *single-input single-output* (SISO), *intensity-modulation/direct-detection* (IM/DD) systems using *Vertical-Cavity Surface-Emitting Lasers* (VCSEL) as light sources and are rather dispersion limited than noise limited.

However, highly-multimodal waveguides may also show some benefits. We propose a channel model that allows modal multiplexing by exploiting the orthogonality and the multitude of the modes while relating independent data streams to different mode groups. The information is therefore mapped into a finite number of spatially different field distributions, each consisting of a certain number of modes with distinctive modal amplitudes. A mode group is thus identified by its set of modal amplitudes. In order to excite and detect different field distributions, i.e., different mode groups, multiple sources and multiple detectors are required. The source is given by a VCSEL array or a single VCSEL with segmented contact geometry [2] both providing multimodal field distributions at the waveguide input. At the receiver side a photodetector array is assumed.

Using N data streams within a single waveguide allows the symbol duration to be relaxed by the factor N compared to a corresponding SISO system supporting the same overall data rate. This may help to overcome the limitation imposed by the *intersymbol interference* (ISI) stemming from mode dispersion. However, the reduced ISI must compete against an emergent *interchannel interference* (ICI) between different sub-channels. This interference is due to the impossibility to excite and detect entirely different mode groups and by mode coupling along the waveguide. The proposed quasi-analytic channel model considers the spatio-temporal evolution of modal power within the entire physical setting, i.e., the laser coupling to the overmoded rectangular waveguide, the propagation along an idealized straight waveguide channel and the coupling process between the waveguide and the different patches of the detector array.



System overview with VSCEL waveguide and photodetector.



Coupling coefficients for different sources: (a) LP_{01}^{C} (b) LP_{01}^{S}.

[1] Himmler, E. Griese, and J. Schrage. "*Modeling of Highly Multimodal Optical Interconnects for Time Domain Analysis*." *Digest of 2000 LEOS Summer Topical Meetings, Electronic-Enhanced Optics,* Aventura/FL USA, 2000.

[2] M. Jungo, D. Erni, and W. Bächtold, "Segmented VCSEL contact geometry for active coupling efficiency enhancement," *Workshop on Compound Semiconductor Devices and Integrated Circuits (WOCSDICE'03)*, May 26-28, Fürigen, pp. 67-68, Switzerland, 2003.