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Modelling and Experimental Investigation of Multicore Fiber Systems for Next Generation Optical Networks

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und Übertragungstechnik

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Abstract

In a little over 20 years, Internet has gone from a private network to global phenomenon, allowing the existence of platforms that enable and support economic, social, and political activities. Nowadays, optical communication technologies have to be able to keep up with the ever increasing data demands of such applications. In this regard, new alternatives of systems and optical fibers are being investigated so as to provide adequate answers to the questions of the near future.

Multicore fibers are one of the explored alternatives to upgrade the currently existing fiber networks. They are, in short, optical fibers that feature N optical waveguides (cores) encompassed by a single cladding structure, which are capable of transporting N different optical signals simultaneously. This overall increase in capacity comes at the expense of crosstalk–an undesired interaction among the optical signals.

This work focuses on the evaluation of state-of-the-art multicore fiber technology from the point of view of a communication system. For this purpose, the thesis is divided into three parts.

The first part of the work describes the development of a linear fiber model that can be used in simulations to estimate crosstalk levels of an arbitrary multicore fiber and their effect on the transmission performance of the system. At the time, this was the first complete description of a modelling approach for multicore fibers.

In the second part, 7-core components like amplifiers and fan-in/out couplers are presented and a fully integrated system is constructed for the first time. The performance of the communication system is evaluated by various experiments: reach, capacity, mixed transmission, real-time performance, among others.

Finally, in the third part of this thesis, components for a 32-core system are introduced and an experimental setup is constructed to demonstrate possible real-world implementations of the multicore fiber technology.

Zusammenfassung

In etwas über 20 Jahren hat das Internet sich von einem privaten Netz zu einem globalen Phänomen entwickelt, was die Existenz von Plattformen für die ökonomische, soziale und politische Aktivitäten ermöglicht und unterstützt. Heutzutage müssen die Technologien der optischen Kommunikation mit den immer weiter steigenden Datenanforderungen dieser Anwendungen mithalten. Insofern werden neue Systemalternativen und neue optische Fasern untersucht, damit diese Problematik der kurzfristigen Zukunft adäquat beantwortet werden kann.

Mehrkernfasern sind eine der untersuchenden Alternativen, um derzeitige Fasernetze zu aktualisieren. Sie sind im Prinzip optische Fasern, die innerhalb einer einzigen Mantelstruktur N optische Wellenleiter enthalten. Diese Wellenleiter ermöglichen die parallele Übertragung von N unterschiedlichen optischen Signalen. Die Kapazitätserhöhung jedes Linkes kommt jedoch mit dem deutlichen Nachteil des Übersprechens–eine unerwünschte Interaktion zwischen den optischen Signalen.

Diese Arbeit fokussiert sich auf die Auswertung des Stand der Technik bezüglich Mehrkernfasertechnologien in Bezug auf Kommunikationssysteme. Zu diesem Zweck ist die Doktorarbeit in drei Hauptthemen aufgeteilt.

Im ersten Teil wird die Entwicklung eines linearen Fasermodells dargestellt, das als Simulationstool zur Abschätzung der Größe des Übersprechens einer beliebigen Mehrkernfaser eingesetzt werden kann. Zusätzlich werden die Effekte des Übersprechens auf die Performance des ganzen Systems numerisch ausgerechnet. Zu seiner Zeit war dies die erste komplette Beschreibung eines Ansatzes zur Mehrkernfaser-Modellierung.

Im zweiten Teil werden die Mehrkern-Elemente präsentiert (z.B. Verstärker und Fan-in/out-Koppler), mit denen ein voll integriertes 7-Kern-System zum ersten Mal aufgebaut wird. Die Performance des Kommunikationssystems wird mithilfe mehrerer Experimente evaluiert: maximale Distanz, Kapazität des Systems, Echtzeit-Performance, usw.

Abschließend werden im dritten Teil dieser Arbeit die Elemente von einem experimentellen 32-Kern-System präsentiert, das verwendet wird, um mögliche reale Anwendungen von Mehrkernfasertechnologien zu diskutieren und zu analysieren.

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