(Advanced) Practical Course "Optical Information Transmission"

At the latest since the introduction of the World Wide Web, our information society has become accustomed to exchanging high volumes of data worldwide quickly and cost-effectively. Criteria such as capacity and speed of network connections have become economically essential location factors. Optical information transmission plays a central role in this.

Optical information transmission systems are mainly used in telecommunications networks or large corporate networks where conventional methods reach their performance limits. However, the annual increase in the volume of data transmitted worldwide, e.g., smartphones, video streaming, and social networks, is shifting optical information transmission more and more toward end users, making Passive Optical Networks (PON) the next generation of access networks.

The goal of this lab practical is to teach students of the physics department the theoretical as well as practical fundamentals of optical information transmission using fiber optic transmission systems as an example. The laboratory practical course is divided into three main areas.

1. Main focus

1.1 Fiber optic transmission link

The optical signal can be affected by various linear and nonlinear effects of a fiber optic transmission link [1, 2, 3]. Therefore, different degradations such as losses (scattering, attenuation, coupling, and curvature losses) and dispersion (chromatic, mode, polarization mode, and material dispersion) as well as nonlinear degradations such as four-wave mixing, self-phase, and cross-phase modulation will be elaborated first. This is followed by an experimental investigation of transmission losses on a fiber optic transmission link. Using optical time domain reflectometry (OTDR) and a power meter, the transmission losses of a fiber optic transmission link will be determined. The backscatter curve of the fiber optic transmission link will be specifically manipulated by different fiber types, fiber splices, fiber bends, and connectors and the resulting results will be discussed.

1.2 Components of a fiber optic transmission system

The aim is to give an overview of the different passive and active components of a fiber optic transmission system. First, the transmitter and receiver side, modulators, couplers, optical amplifiers, polarization controllers, isolators, circulators as well as fiber Bragg gratings (FBG) will be worked out theoretically. At the beginning of the practical part, the spectra of different sources will be measured experimentally, the signal transmission behavior of a Mach-Zehnder modulator will be determined, and FBGs will be fabricated and investigated. The fabrication will be done by writing a periodic refractive index change in photosensitive optical fibers using an excimer laser.

1.3 System Design and Multiplex and Modulation Formats

In this focus area, concepts of optical transmission systems are to be dealt with. First, different multiplexing techniques and modulation formats will be elaborated. Furthermore, all parameters important for system design such as line budget, bit error rate (BER), jitter, eye diagram, signal-to-noise ratio, and receiver sensitivity will be treated [4]. Subsequently, the fiber-optic transmission system is characterized.

The transmission system is characterized. Among other things, the dependence of the bit error rate and the eye diagram on the attenuation of the transmission system is evaluated.

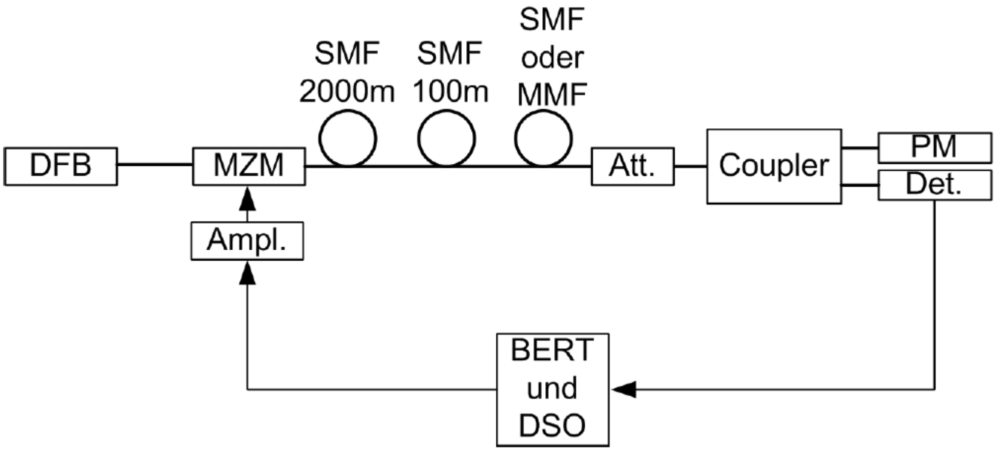

Figure 1: Experimental setup optical transmission system DFB: DFB- Laser; MZM: Mach-Zehnder Modulator; Ampl.: RF-Amplifier; SMF: Single-Mode Fiber; MMF: Multi-Mode Fiber; Att.: Attenuator; Det.: Detector; BERT: Bit Error Rate Tester; DSO: Digital Sampling Oscilloscope; PM: Power meter

2. preparation tasks

2.1 Explain the difference between a single-mode and a multi-mode fiber (number of modes and dispersion).
2.2 What are the refractive index profiles of a polarization-maintaining and a bend-insensitive single-mode fiber?
2.3 What types of scattering occur in optical fibers?
2.4 What is a pulse OTDR and how does it work? How is the spatial resolution of an OTDR calculated?
2.5 What are FBGs and how are they fabricated? Where are FBGs used in OTDR?
2.6 Explain how a Mach-Zehnder (MZ) interferometer works.
2.7 How is the coherence length of a light source calculated?
2.8 Describe mathematically the principle of a direct as well as a homodyne receiver.
2.9 Which multiplexing techniques exist for OKT?
2.10Which modulation formats exist for OKT?
2.11Please describe the operation of a sampling oscilloscope.
2.12What is an eye diagram and what statements does it allow?

3. Literature for preparation

1. Olaf Ziemann, „POF-Handbuch: Optische Kurzstrecken-Übertragungssysteme", Springer-Verlag Berlin Heidelberg, 2007
2. Fedor Mitschke, „Fiber Optics: Physics and Technology“, Springer-Verlag Berlin Heidelberg, 2010
3. E. Voges, K. Petermann, „Optische Kommunikationstechnik – Handbuch für Wissenschaft und Industrie“, Springer 2002
4. Dennis Derickson, „Fiber optic test and measurement", Hewlett-Packard Company, Prentice Hall PTR, 1998
5. http://www1.hft-leipzig.de/bunge/E_HSOTS-files/Skript_HSOTS.pdf