UNIVERSITÄT PADERBORN
Die Universität der Informationsgesellschaft

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FAKULTÄT FÜR ELEKTROTECHNIK, INFORMATIK UND MATHEMATIK

Optische Nachrichtentechnik und Hochfrequenztechnik
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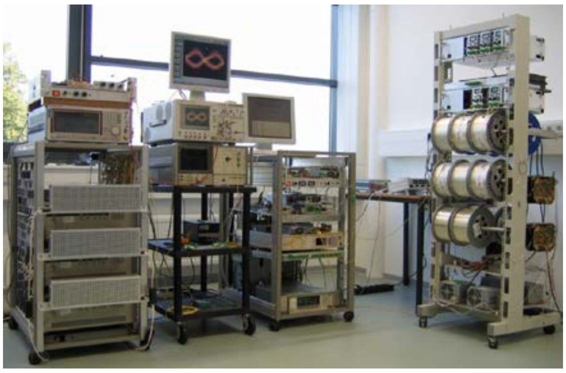
About Attoseconds, Kiloradians/s and Terabit/s: Modulation and Equalization of Optical Data Signals

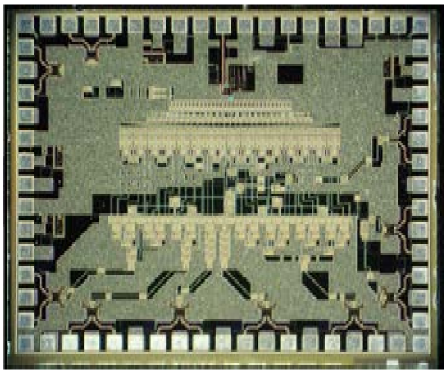
Optical communication utilizes lightwave guides made from silica glass for information transmission in the worldwide data and telephone net. The attenuation of the glass fiber for laser light with wavelength 1.5 micrometers is so small that after 100 km 1/100 of the transmitted light power is still available. The bandwidth is about 10% of the lightwave frequency, i.e. about 20 Terahertz (20,000,000,000,000 cycles per second). This is almost 1000 times as much as the whole radio frequency spectrum including microwave links. About 4 Terahertz can be exploited very cost-effectively with the help of optical amplifiers. These superb properties of glass fibers have made possible the worldwide web and cheap telephone conversation. The growth of the data traffic is enormous, about 50% per year. Network operators and industry strive at using available and new glass fiber links most effectively and cost-efficiently, from which we derive our fields of work:

Compensation of linear optical distortions – Just as a short earth quake agitates a distant seismometer for a longer time short data pulses are temporally dispersed in glass fibers by **chromatic dispersion**. Neighbor pulses overlap and become undetectable. For equalization (compensation) we measure the dispersion with an extremely cost-effective method which detects repeated, regular light pulse propagation delay changes with an accuracy of **100 attoseconds** (0,000.000.000.000.000.1 seconds). Due to unwanted elliptical rather than circular fibercore cross-sections the light pulses are subject to another dispersion that depends on the polarization direction. We have compensated this **polarization mode dispersion** at the receive end using an integrated optical Lithium Niobate component which we have proposed. We have implemented **optical polarization controllers** with an unrivaled tracking speed of up to **140 kiloradians/s**, corresponding to more than 10000 full polarization rotations per second (spin-off Novoptel GmbH, 2010).

Advanced optical modulation formats – With **2 polarization directions and ≥4 phases and amplitudes** of the light we transmit in each data symbol ≥16 different states rather than the traditional 2 (light on/off). This way we have set up a capacity world record of **5,94 Terabit/s** (5,940,000,000,000 bit per second) over a 324 km distance (2005) and, with fast polarization control, a bitrate world record of **200 Gigabit/s** over a 430 km distance for a single channel (2010). Rather than – as there – in interferometers the 4 phase states can also be demodulated synchronously in **coherent optical superheterodyne receivers**, which increases sensitivity and makes it possible to compensate signals distortions very cost-effectively. We have demonstrated such a system for the first time worldwide with standard lasers, have equipped it with an electronic polarization control and enhanced it for 2 polarizations, with a tracking speed of **40 kiloradians/s**. For electronic signal processing we have implemented a microelectronic **5-Bit analog-to-digital converter with 12,5 GHz sampling frequency** and a digital signal processor. This coherent optical transmission technique has revolutionized long-distance optical data transmission.

Right: Realtime transmission of 5,940, 000,000,000 bit/s over 324 km in optical C band





Left: Electronic analog-to-digital converter circuit for processing of detected data symbols

Bottom: Book

Deutschland Land der Ideen
Ausgewählter Ort 2011

GERMANY AT ITS BEST
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Left: The innovation award 2008 of the Land Nordrhein-Westfalen in the category innovation was awarded to Reinhold Noé und Ulrich Rückert.