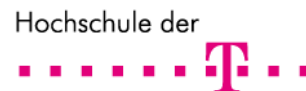


Breaking the Gigabit Barrier

New Gbit/s POF standard for home networking:
New possibilities for automotive applications

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Ohm-Hochschule Nürnberg



Basic facts about the group and the goals

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- ▶ 1 Gbit/s over up to 50 m
 - ▶ 1-mm standard step-index POF (IEC 60793-2 A4a.2)
 - ▶ eye safety, easy installation...

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 - ▶ 1-mm standard step-index POF (IEC 60793-2 A4a.2)
 - ▶ eye safety, easy installation...
- ▶ Goals:
 - ▶ definition of „VDE Anwenderregel“ for Gigabit Ethernet over POF
 - ▶ contributions to standardization bodies like, e.g., ETSI, IEC, IEEE

Participants (selection)

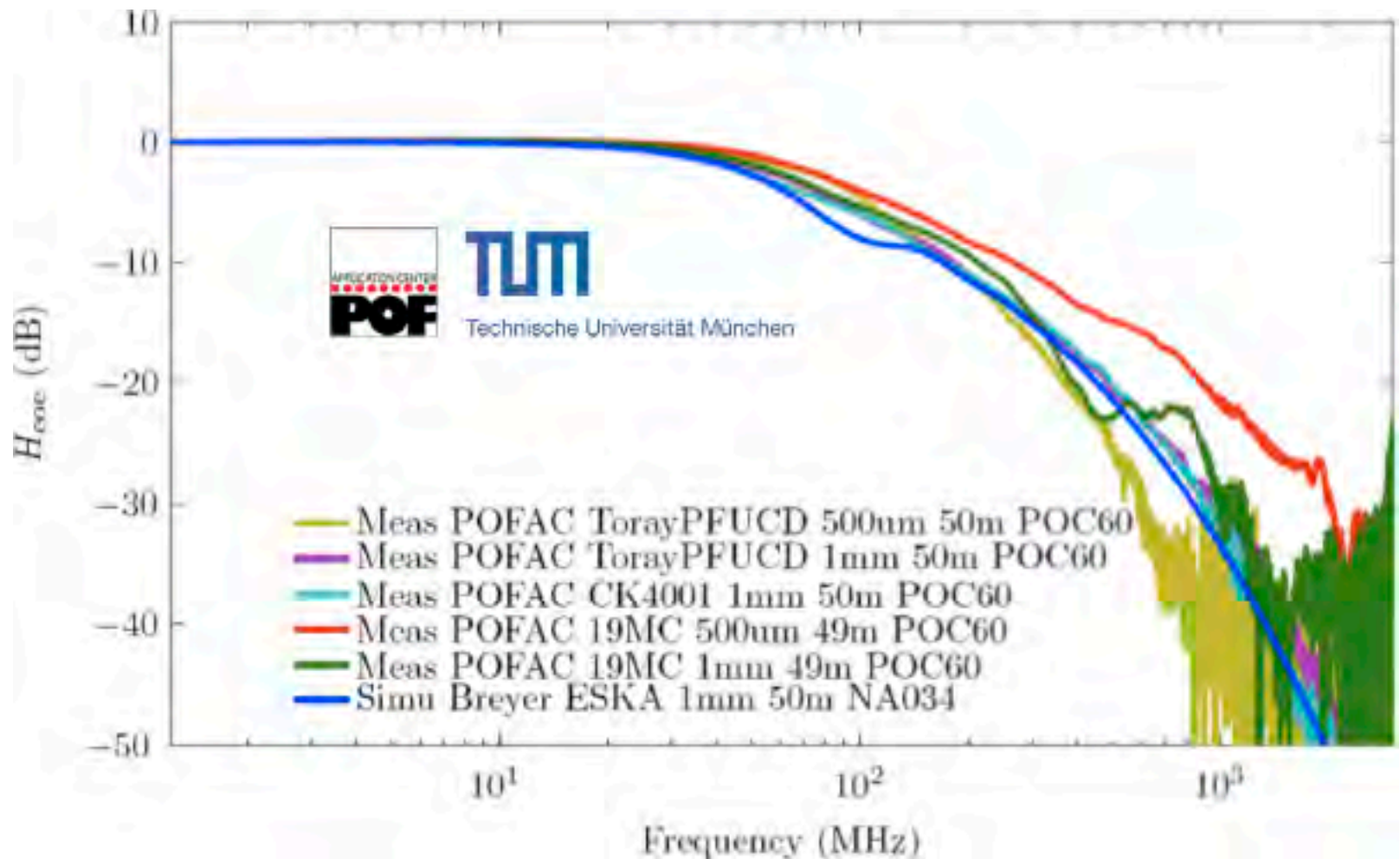


Convincing cabling solutions



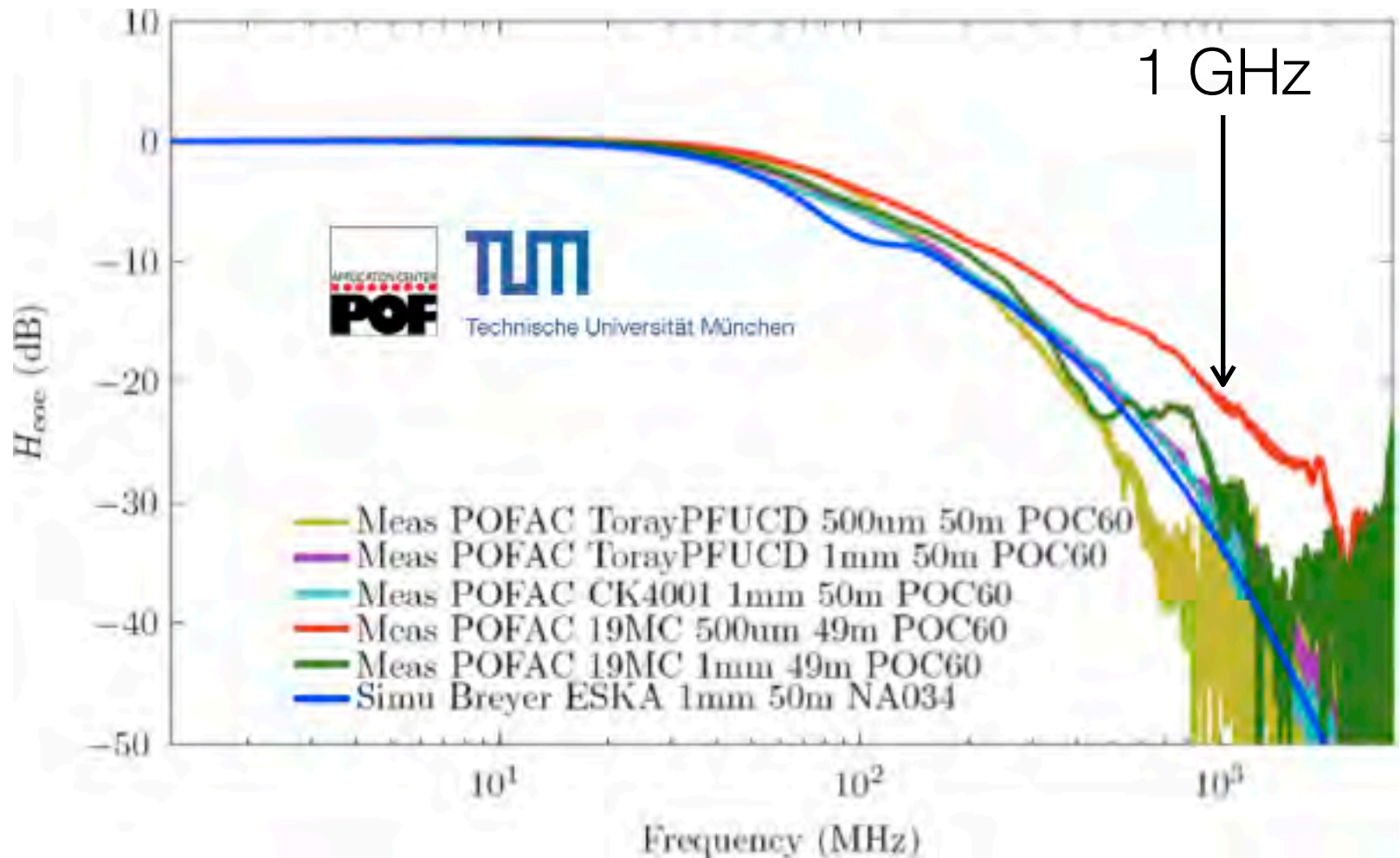
Main issues

Bandwidth of the POF



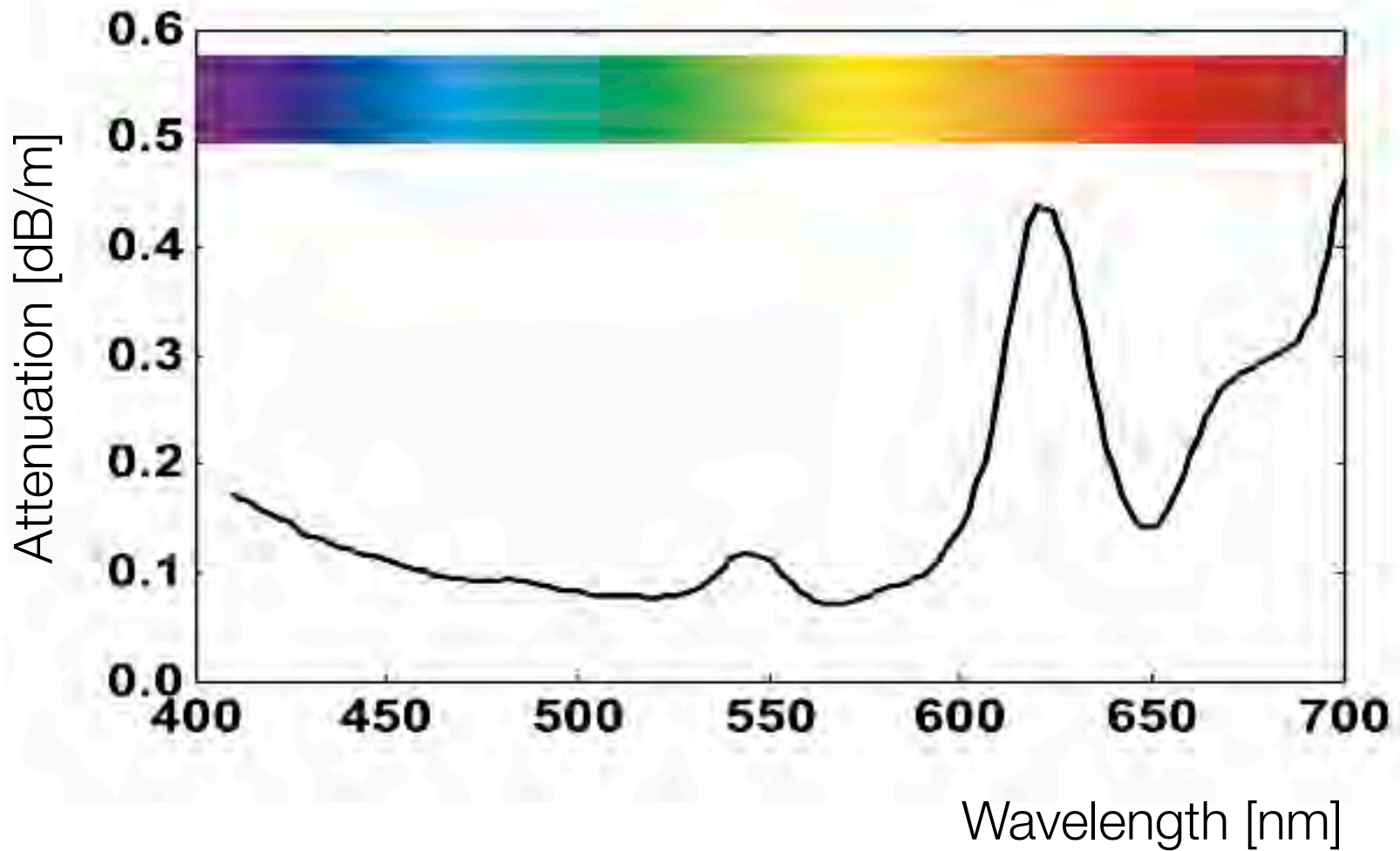
electrical frequency response of 50m POF channel

Bandwidth of the POF

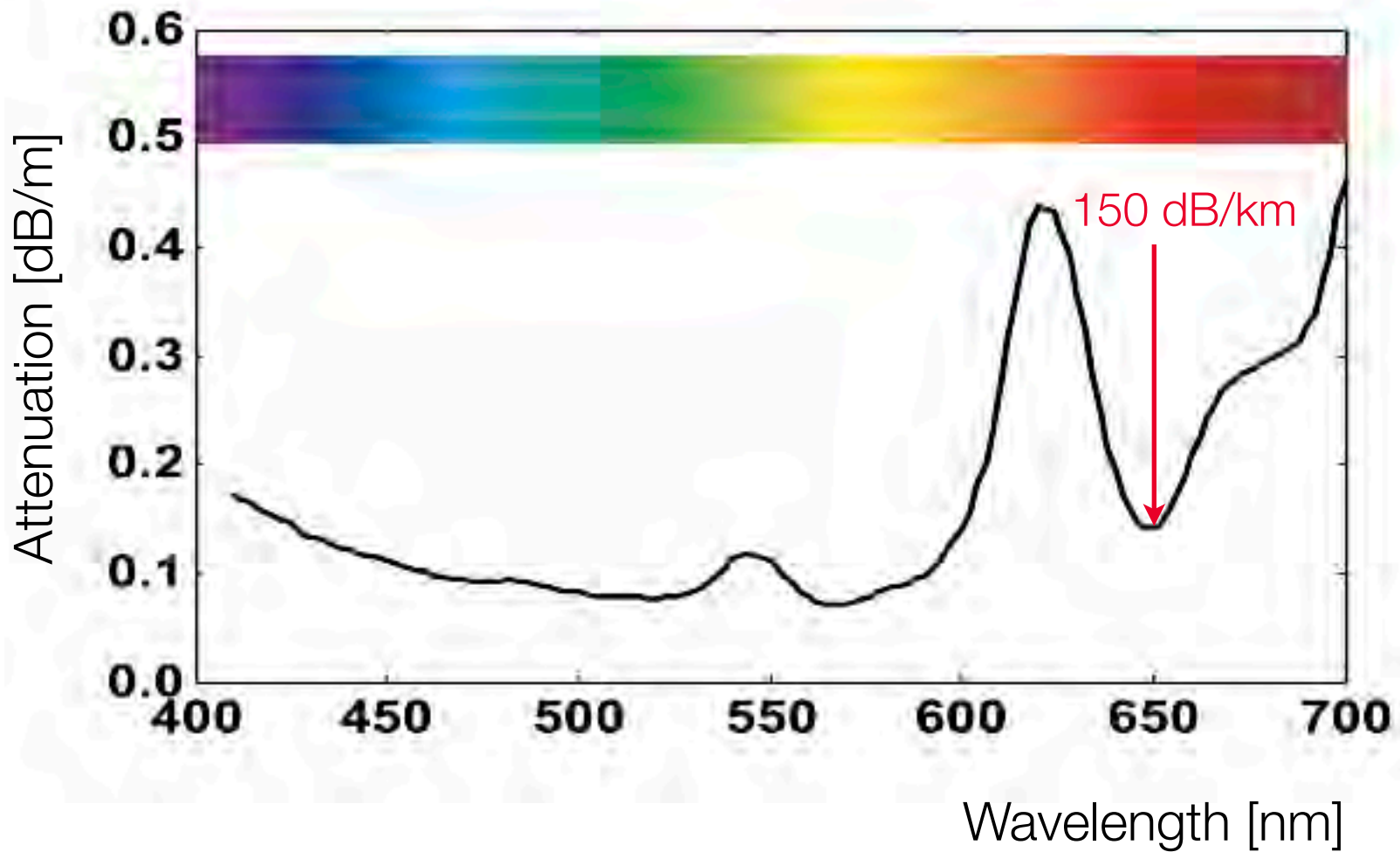


electrical frequency response of 50m POF channel

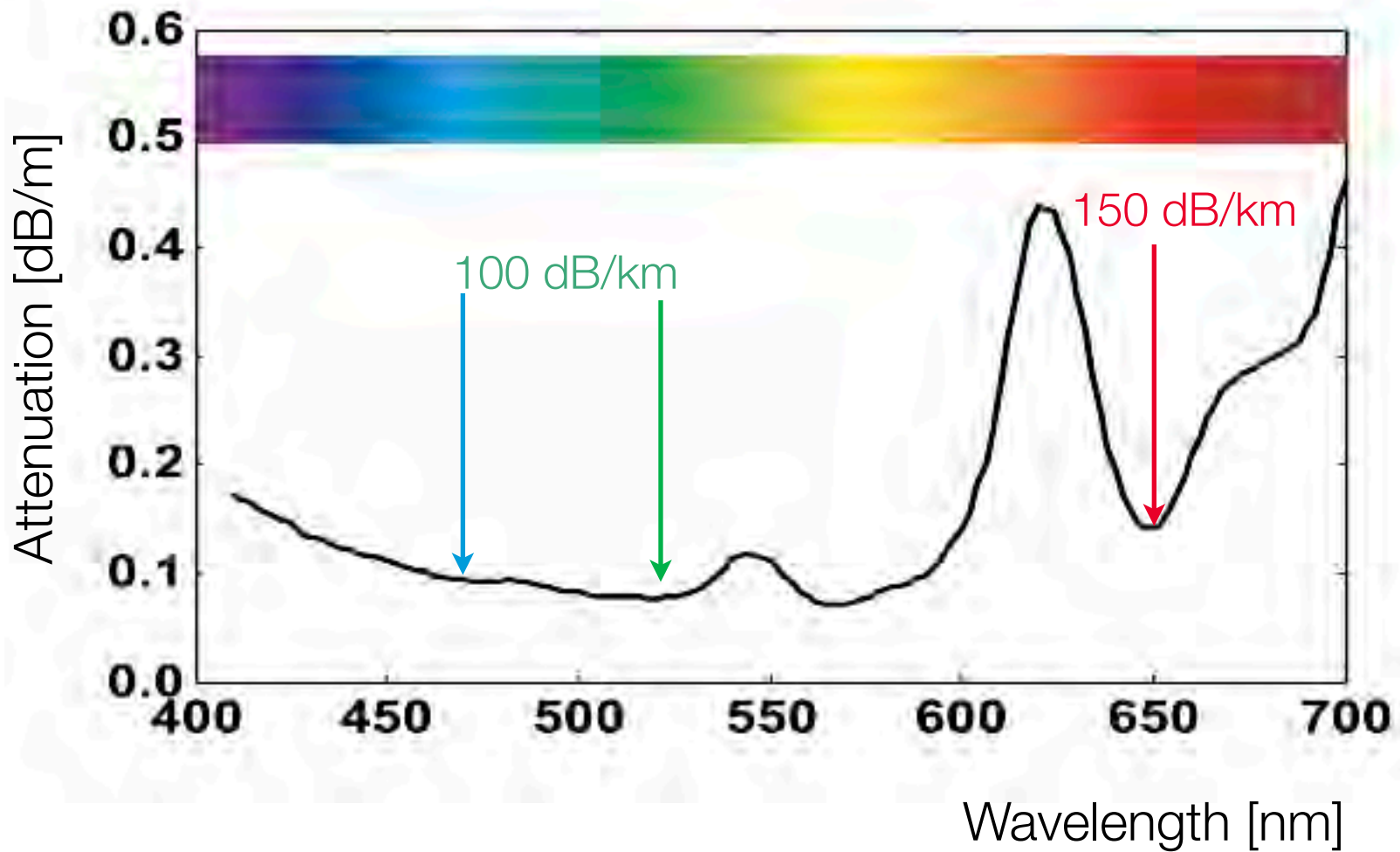
Attenuation of the POF



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Attenuation of the POF



Power Budget (working numbers)

- ▶ **fiber coupled launch power 0.0 dBm**
 - ▶ Tx aging/temperature -3.0 dB
 - ▶ 50 m fiber attenuation -9.0 dB
 - ▶ spectral loss -3.0 dB
 - ▶ two connectors (2 dB each) -4.0 dB
 - ▶ photodiode coupling -2.0 dB
 - ▶ margin -3.0 dB
-
- ▶ **required sensitivity -24.0 dBm**

the same for in-car distances (10 m)

- ▶ **fiber coupled launch power 0.0 dBm**
 - ▶ Tx aging/temperature -3.0 dB
 - ▶ 10 m fiber attenuation -2.0 dB
 - ▶ spectral loss -3.0 dB
 - ▶ two connectors (2 dB each) -4.0 dB
 - ▶ photodiode coupling -2.0 dB
 - ▶ margin -10.0 dB
-
- ▶ **required sensitivity -24.0 dBm**

...with relaxed requirements for Tx/Rx

- ▶ **fiber coupled launch power** **-3.0 dBm**
 - ▶ Tx aging/temperature -3.0 dB
 - ▶ **10 m fiber attenuation** **-2.0 dB**
 - ▶ spectral loss -3.0 dB
 - ▶ two connectors (2 dB each) -4.0 dB
 - ▶ photodiode coupling -2.0 dB
 - ▶ margin -3.0 dB
-
- ▶ **required sensitivity** **-21.0 dBm**

Transmitter

Transmitter

- ▶ **LED**

- ▶ robust, but slow and non-linear

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▶ **RC-LED**

- ▶ faster, good compromise, but availability?

Transmitter

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- ▶ faster, good compromise, but availability?

▶ **VCSEL**

- ▶ linear, but lifetime, eye safety, availability
- ▶ difficult driver circuitry

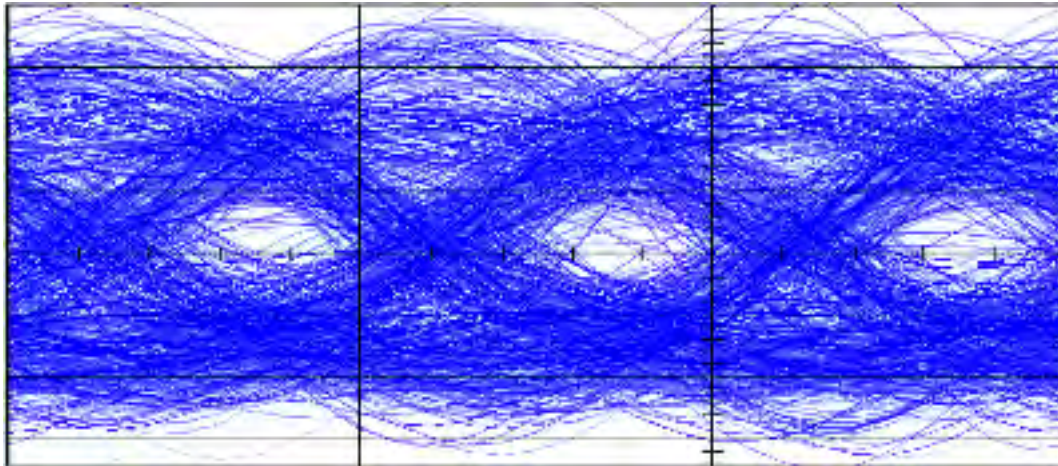
Modulation schemes

Non-Return to Zero (NRZ) with equalisation

- ▶ sampling rate full 1 Gbit/s
- ▶ only two levels, no nonlinearity issues
- ▶ sophisticated equalisation (dynamic range)

Non-Return to Zero (NRZ) with equalisation

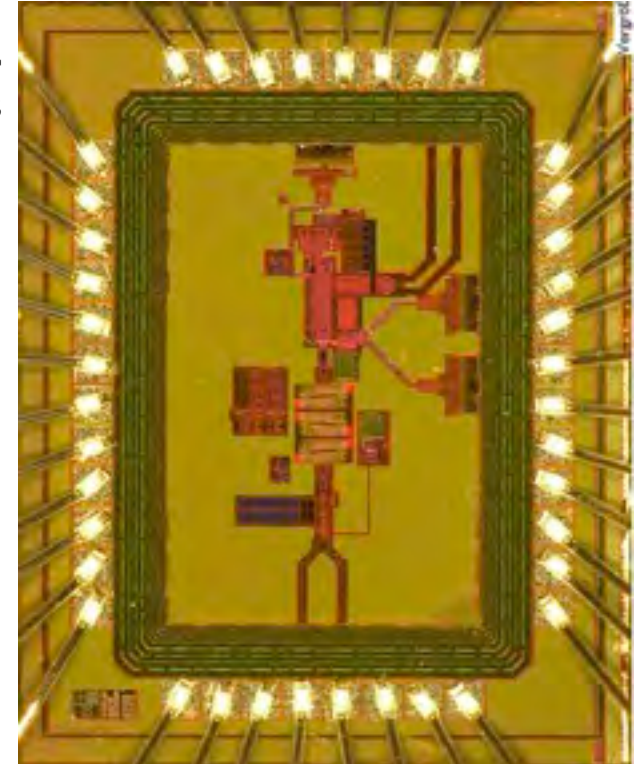
- ▶ sampling rate full 1 Gbit/s
- ▶ only two levels, no nonlinearity issues
- ▶ sophisticated equalisation (dynamic range)
- ▶ but possible (e.g. NRZ w/ DFE, POF-AC 2010):



Real-time measurement results at 1.25 Gbit/s

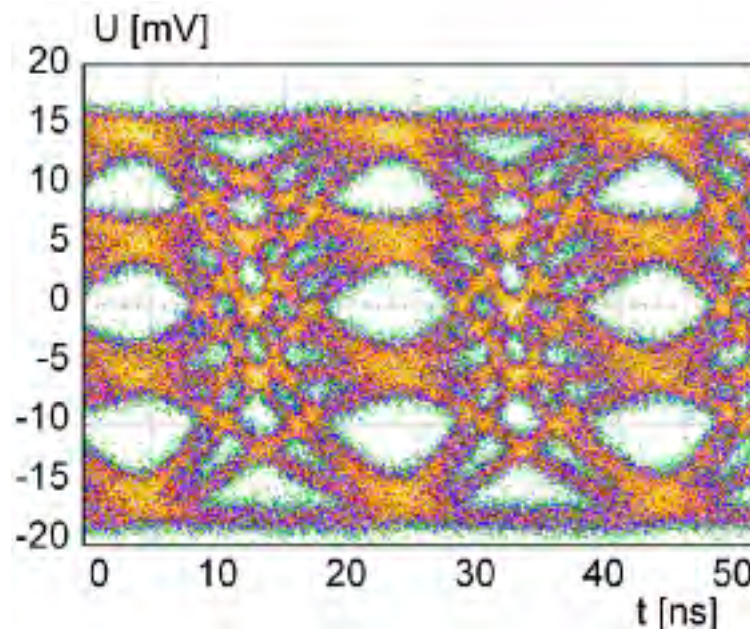


- ▶ channel setup:
POF length: 50 m
4QW RCLED+ driver;
receiver: ARX31125
- ▶ results:
BER < 10^{-3} without FEC
-> error free with FEC
- ▶ estimated receiver chip size in 90 nm CMOS (including FEC): Total: $\approx 1 \text{ mm}^2$
- ▶ transmitter chip size in 90 nm CMOS: FEC encoder, driver & control circuitry: $< 5 \text{ mm}^2$ for an integrated solution



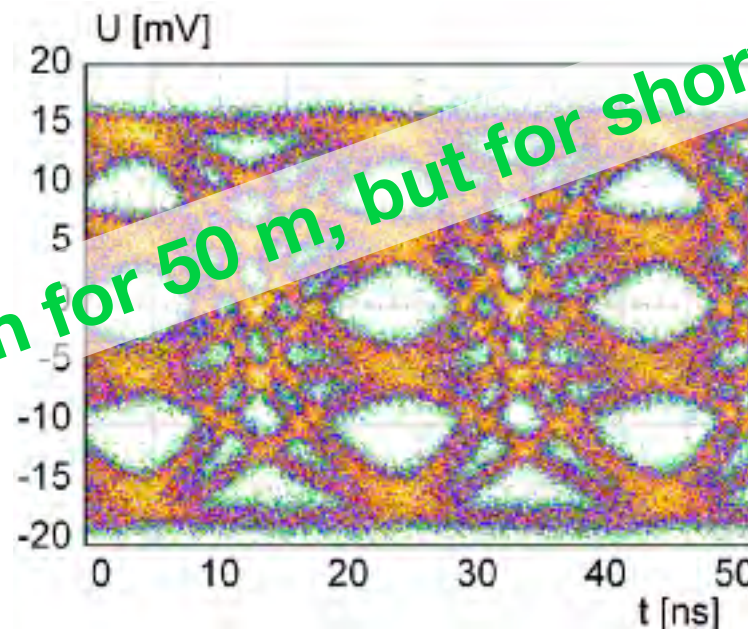
Pulse-Amplitude Modulation (m-PAM)

- ▶ lower sampling rate: $\log_2(m)$ lower symbol rate
- ▶ nonlinear characteristics of components
- ▶ crest factor of the signal increases



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Agreed upon for 50 m, but for shorter links???

Current status

Actual activities

Actual activities

- ▶ **transmission scheme**

- ▶ m-PAM w/ equalisation (FFE/DFE vs THP)

Actual activities

- ▶ **transmission scheme**

- ▶ m-PAM w/ equalisation (FFE/DFE vs THP)

- ▶ **light source**

- ▶ (RC)-LED vs VCSELs

Actual activities

▶ **transmission scheme**

- ▶ m-PAM w/ equalisation (FFE/DFE vs THP)

▶ **light source**

- ▶ (RC)-LED vs VCSELs

▶ **passive interface**

- ▶ characterisation methods (losses, coupling conditions...)
- ▶ connectors etc.

Interested?

- ▶ next meeting will be on May 5th in Frankfurt (**this town!**)
- ▶ further information on the website
<http://www.vde.com/en/dke/std/projects/POF/Pages/default.aspx>
- ▶ contact:
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 - ▶ C.-A. Bunge: bunge@hft-leipzig.de
 - ▶ O. Ziemann: olaf.ziemann@pofac.ohm-hochschule.de