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Status and recent results from the POF-ALL EU project: large-core plastic fibers for low cost, high-speed short reach applications (invited talk)

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IST-FP6 – STREP project n. 027549 – POF-ALL

Paving the Optical Future with Affordable Lightning-fast Links

Summary

- The POF-ALL project: framework and goals
- The POF-ALL consortium
- Update on the latest technical achievements
- Expected impact

The POF-ALL project: framework and goals

What is POF-ALL ?

- It's a research project financed by the European Community within the Sixth Framework Program (FP6)
  - POF-ALL means "Paving the Optical Future with Affordable Lightning-fast Links"
  - IST-FP6 STREP project n. 027549
  - Duration: 01/2006 – 06/2008 (30 months)
  - Total Cost: €2.6 m
  - EC Contribution: €1.6 m
- The official "motto":

"POF-ALL shall develop a technology based on Plastic Optical Fiber (POF) to allow delivery of 100+ Mbit/s symmetrically to residential users at costs far lower than existing alternatives."

POF-ALL: The goal

- The technical goal is to design and build low-cost "optical modems" based on large-core POF, operating:
  - symmetrically (upload speed = download speed)
  - At either 100 Mbit/s or 1 Gbit/s
  - over distances ranging up tp 200 meters
  - and being simple enough to be installed by anyone with no special tools

- The potential applications are:
  - last part of Telcos' access networks (edge networks);
  - in-building networks of multi-dwelling units, condominiums and high rise buildings.

POF-ALL: The goal

- The use of large core POF (1mm diameter) greatly eases installation with respect to standard glass optical fiber (GOF)
  - Large core POF is mechanically resilient, easy to connectorise and tolerant to dusty environment
  - Installation can be done by unskilled personnel

BUT

- The use of POF introduces significant challenges, due to physical transmission impairments
  - POF has much higher attenuation and dispersion than GOF

POF-ALL: The goal

- The POF-ALL project focuses on:
  - large-area POF (Ø 1mm)
  - PMMA based
  - High Numerical aperture (NA=0.5)
  - Step-Index or Graded-Index
- I will simply indicate this class of fibers as "POF" in the rest of this presentation

- The ultimate technical target of the project is to optimize components, devices, transmission and protocol to make "POF optical modems" possible (both technically and economically)

POF-ALL: The goal

- POF-ALL will also gauge market's potential and assess customers' requirement, to ensure that the project outcome will be an economically viable and cost-effective solution matching real user's requirements.

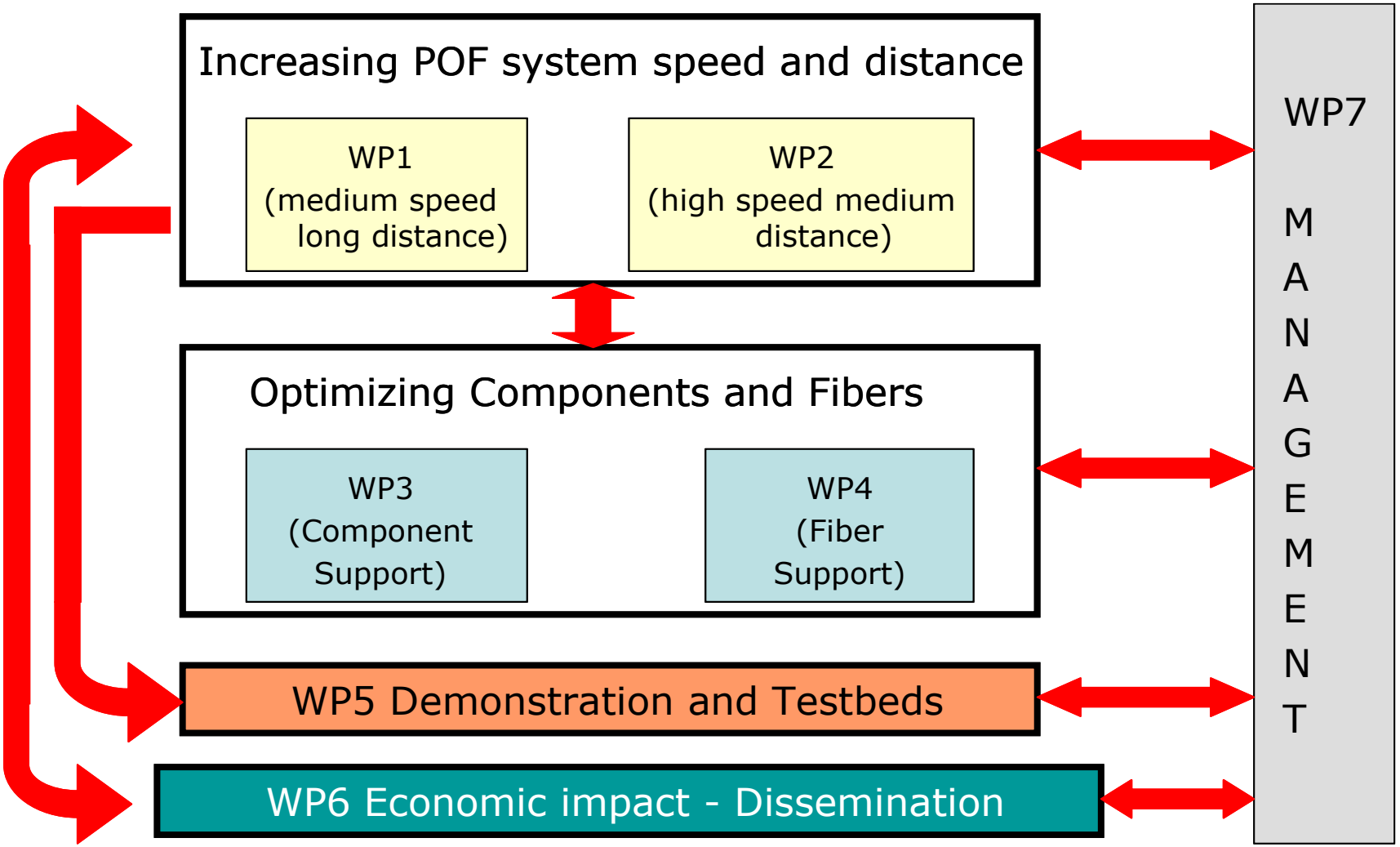
- An appraisal of the project's economic impact in Europe will be carried out, in order to evaluate how can a low-cost POF-based solution for edge access networks accelerate the accomplishment of EU's broadband-for-all policy.

- A constant work of information and dissemination will be carried out in order to attract interest, share results within EU and increase knowledge and accelerate adoption of POF-ALL's technical achievements.

POF-ALL: Activities

- The project is organized in seven work-packages:
  - WP1 – Advanced transmission techniques for 100 Mbit/s over long distances (200+ m)
  - WP2 – Module conception and transmission experiments of high speed data (1 Gbit/s and more) over intermediate distances (50-100 m)
  - WP3 – Component support
  - WP4 – Fiber support
  - WP5 – Demonstration and Test-beds
  - WP6 – Economic impact, Dissemination
  - WP7 – Management

POF-ALL: Activities



The POF-ALL Consortium

POF-ALL: Partners

1. *Istituto Superiore "Mario Boella" (Italy)*
2. *Luceat SpA (Italy)*
3. *DieMount GmbH (Germany)*
4. *Plastic Optical Fiber Application Center (Germany)*
5. *Fraunhofer Institute (Germany)*
6. *Università Duisburg-Essen (Germany)*
7. *Technische Universiteit Eindhoven (The Netherlands)*
8. *Fastweb SpA (Italy)*
9. *STMicroelectronics (Italy) (withdrawn in 2006)*
10. *Siemens (Germany)*
11. *Teleconnect (Germany)*

POF-ALL: Partners

- The consortium includes:
  - two ICT research institutes (ISMB and Fraunhofer)
  - two SMEs specifically devoted to POF (Luceat and Diemount)
  - One SME specialized in xDSL (Teleconnect)
  - large optoelectronic companies (Siemens, STMicroelectronics)
  - one FTTH national telecom operator (Fastweb)
  - three universities (POFAC, UDE and TUE)

- The consortium was created in order to put together:
  - Basic research capabilities (through research centers and universities)
  - Small companies working in the POF market
  - Two big optoelectronic vendors (Siemens and STMicroelectronics)
  - A perspective final user (Fastweb)

Update on the latest technical achievements

Where did we start from?

- The "perceived" performance for POF (Step-Index, PMMA, 1mm) is usually very low
  - Typically, most people think this medium works only over small distances (50-60 meters) at low bitrate (100 Mbit/s max)
  - Actually, most commercial transceivers hardly perform better than this.

- In January 2006, the POF-ALL consortium started its work to demonstrate that POF can actually provide much higher performances that what was usually perceived.

The "myths"

- POF doesn't have enough bandwidth
  - FALSE: using digital signal processing (DSP), we demonstrated very high bit rates on Step-Index POF
  - We also obtained excellent performance on Graded-Index POF without DSP.
- Large area, 1mm photodiodes don't have sufficient bandwidth:
  - FALSE: we demonstrated large-area photodiode setups that are suitable for Gigabit/s transmission
- Optical transmitters are too expensive for home networking applications
  - FALSE: we demonstrated that LEDs can be easily used up to 100 Mbit/s
  - For Gigabit/s transmission, we showed that red laser dies used in commercial DVDs can be efficiently used

The technical work

- POF-ALL developed several technical solutions in parallel
  - At the end of the project, we will compare the results and determine the most commercially viable
- 100 Mbit/s over 200+ meters on SI-POF
  - 8-PAM and adaptive equalization
  - OFDM and VDLS2 chipset
  - Alternative optical QAM schemes
- 1 Gbit/s over up to 100 meters
  - Standard modulation with GI-POF, optimizing large area components
  - OFDM with SI-POF

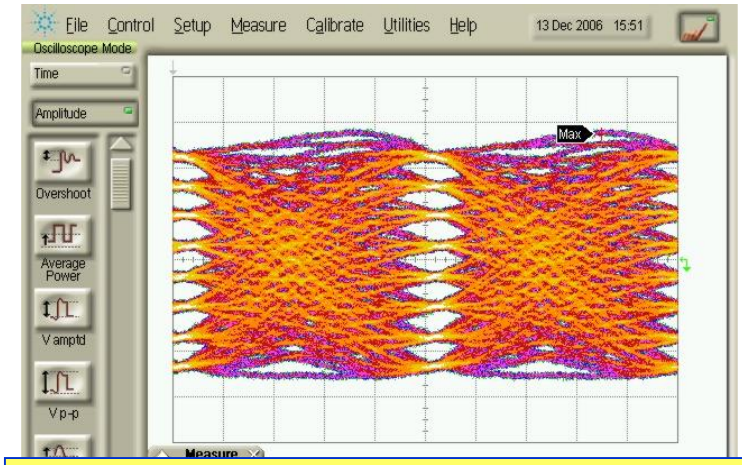
100 Mbit/s over 200+ meters on SI-POF

Approach #1 (ISMB group)

- Multi-level 8-PAM transmission
- Pre- and post- equalization
- Forward error correction (FEC)

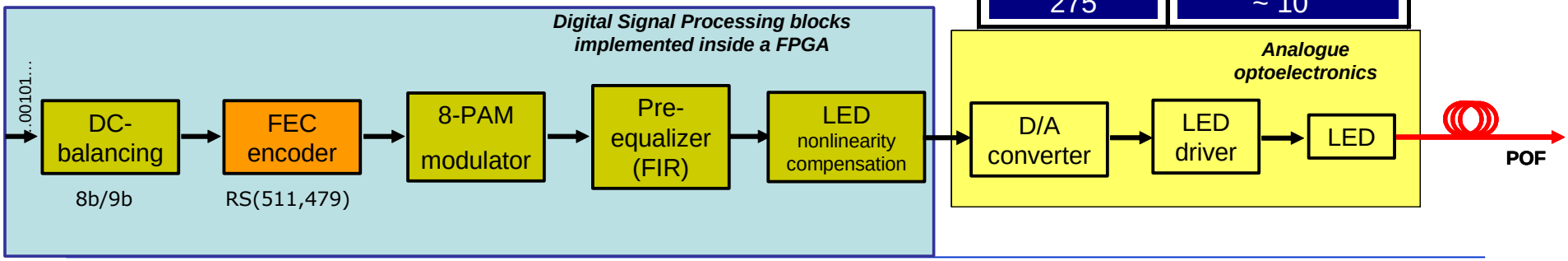
Current status:

- FPGA demonstrator available
- 200 meters error-free before FEC
- 275 meters error-free after FEC



8-PAM eye-diagram after 200 meter, 120 Mbit/s line rate

POF Link (m)	BER
200	Error free
225	<< 10^{-8}
250	~ 10^{-6}
275	~ 10^{-3}

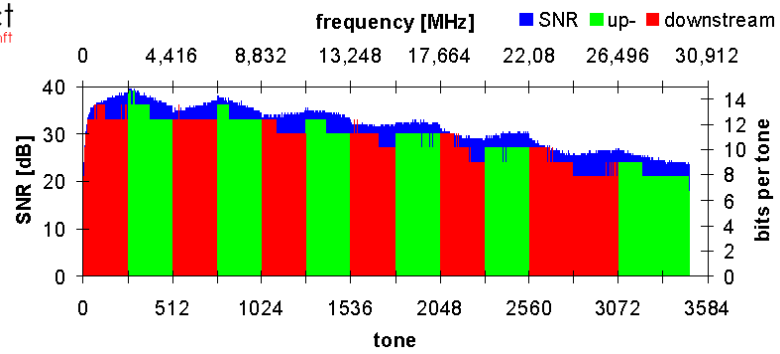


100 Mbit/s over 200+ meters on SI-POF

Teleconnect
Verbindungen in die Zukunft

Approach #2 (Teleconnect group)

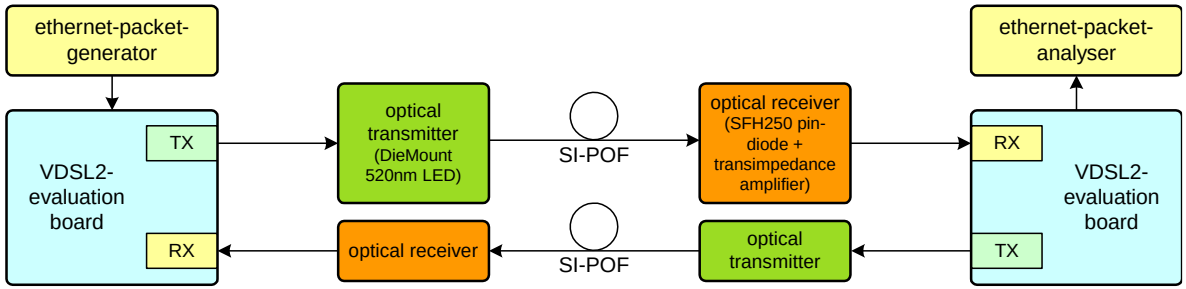
- Orthogonal Frequency Division Multiplexing (OFDM)
  - This is a modulation technique that is having huge success in other fields, such as xDSL



Bit-per-tone allocation in the 200 meter demonstrator using VDSL chips

Current status:

- fully engineered prototype using standard VDSL2 chips
- symmetrical data rate of more than 100 Mbps over 200 meters
- excellent noise margin for shorter distances or lower data rates

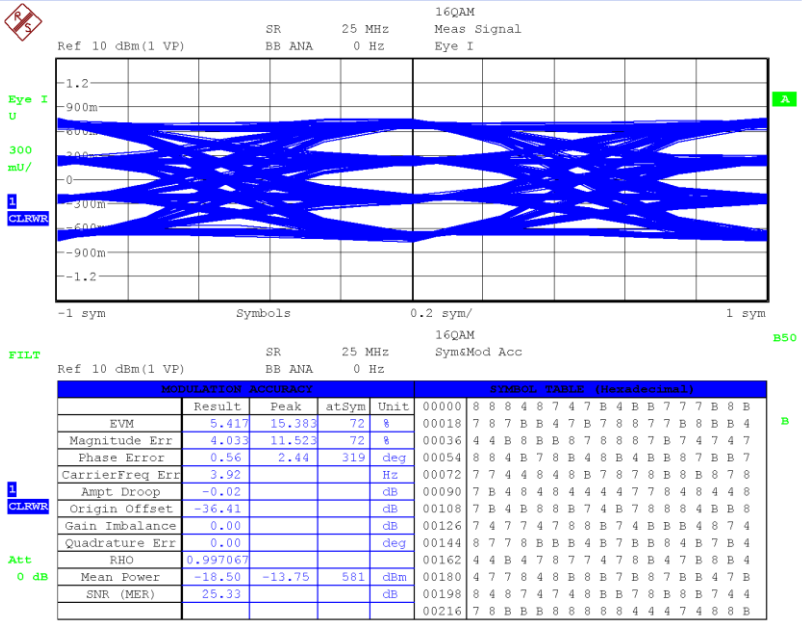


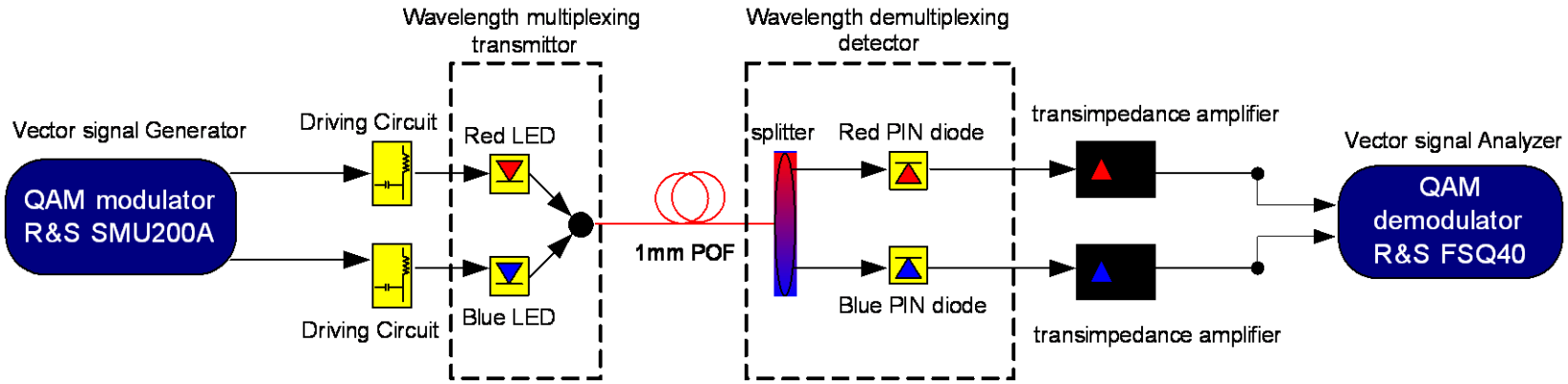
100 Mbit/s over 200+ meters on SI-POF

TU/e technische universiteit eindhoven

Approach #3 (TUE group)

- QAM modulation over two different wavelengths (red and blue, “Wavelength Sliced QAM”)





1 Gbit/s over up to 100 meters

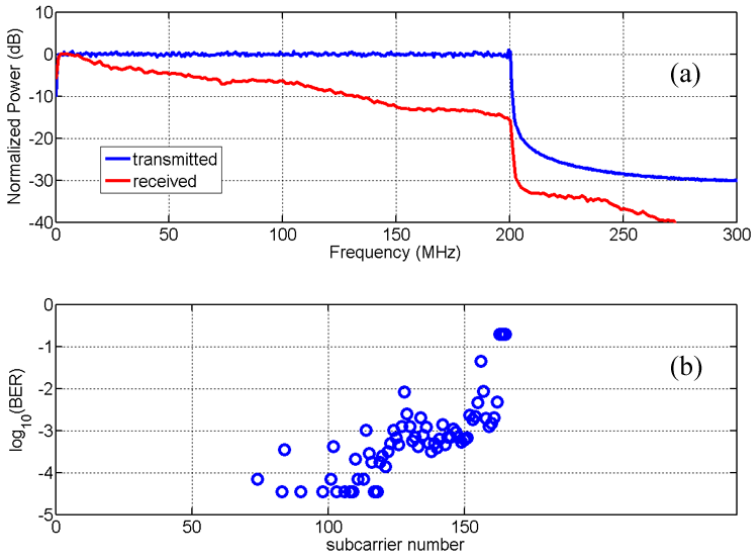
SIEMENS TU/e technische universiteit eindhoven

Approach #4 (Siemens/TUE group)

- Orthogonal Frequency Division Multiplexing (OFDM) up to 1 Gbit/s

Current status:

- Proof-of-concept experiments
- 1 Gbit/s over 100 meters using red DVD laser
- 1 Gbit/s over 25 meters using red LED



(a) Transmitted and received OFDM spectrum over 25 m of SI-POF. (b) Bit-error ratio per subcarrier, of 165 sub-carriers in total. No errors detected for subcarriers w/o marker.

- Preliminary results up to 10 Gbit/s (under development)

Comments

- All these approaches strongly rely on advanced digital signal processing
  - It's a well-established trend in all other telecommunication fields for the last 40 years
  - Even the optical transmission community recently "discovered" DSP
  - The rationale is the astonishing evolution of digital electronic capabilities and performances
- When applied to SI-POF, our approach means increasing the system complexity in order to achieve the maximum ease of installation (do-it-yourself).

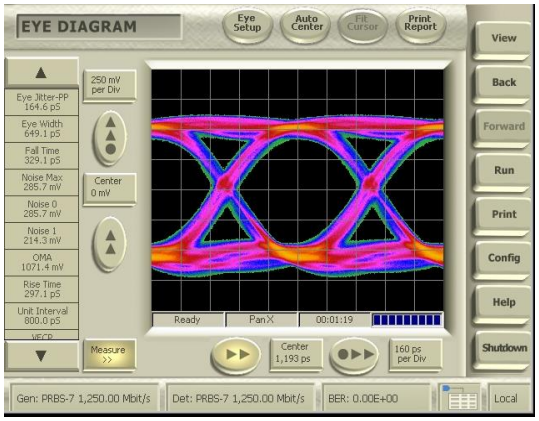
1 Gbit/s over up to 100 meters

Approach #5 (Fraunhofer/POFAC/Diemount group)

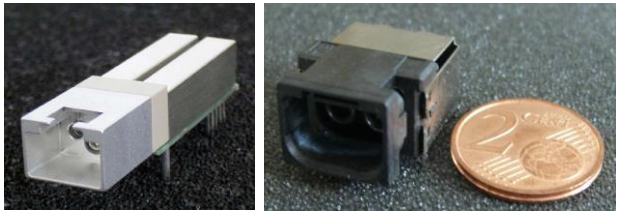
- A more traditional approach is also followed in the POF-ALL project, towards 1 Gbit/s transmission over 100 meter of 1mm GI-POF
  - Modulation is traditional binary NRZ
  - The effort is on component optimization
    - ➔ Optimization of red DVD laser driver
    - ➔ Optimization of receiver configuration for large area photodiodes

Current status:

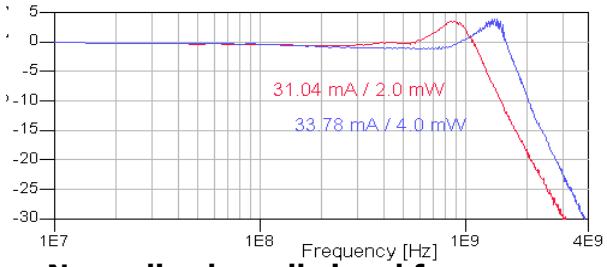
- Small form factor transceivers for 1.25 GBit/s over 30+ m available
- Laboratory demonstration over 100 meters



Eye-diagram for a 50 m GI-PMMA-POF link



Small form factor transceiver devices currently manufactured within POF-ALL



Normalized small signal frequency response of red edge emitting laser diode

POF-ALL related articles at ECOC 2007

- Besides this symposium:
- Session "Multimode fibre in access networks", Thursday 20.09.07, 8.30-10.00
  - D. Cárdenas, A. Nespola, S. Camatel, S. Abrate, R. Gaudino, "100Mb/s Transmissions over Short Reach SI-POF Links: Experimental Demonstration of Extended Reach Systems"
  - J. Lee, F. Breyer, S.Randel, J. Zeng, H. van den Boom, T. Koonen, "Discrete Multi-Tone Modulation for Low-Cost and Robust 10-Gb/s Transmission over Polymer Optical Fibre"
  - F. Breyer, J. Lee, S. Randel, N. Hanik, "1.25 Gbit/s Transmission over up to 100 m Standard 1 mm Step-Index Polymer Optical Fibre using FFE or DFE Equalisation schemes"

Expected Impact

POF-ALL: Impact

- We have demonstrated that impressive performances can be achieved with large core POF - even SI-POF!

- The POF community now knows that:
  - 100m and even 200m are feasible at 100Mbps (first commercial application expected in 2009)
  - 1 Gbit/s over 50-100 meters will soon be available

- Some of the POF-ALL approaches are very close to a fully-engineered setup, namely:
  - The OFDM approach (with VDSL2+ ICs)
  - The NRZ approach over GI-POF

POF-ALL: Impact

- New applications become possible with large-core POF:
  - Edge networks
  - Home networking
  - Industrial automation (Industrial Ethernet, SERCOS III …)
  - Video surveillance
- Each one of these markets is potentially very large
- For sure, **we lack standards** that take these results into account

Home networking

- Ongoing discussions with European Telcos show that the most promising scenario for POF is “home networking” i.e., cabling inside the apartment

- The rationale for this is:
  - FTTH brings (or will bring) extremely good performance links up to the “apartment door”
  - This high performance should be preserved also inside the apartment (particularly for IPTV/ HDTV)
    - ➔ Wireless or Powerline may not be the “one-solves-all” solution

Home networking

- For application inside the apartment links are typically below 50 meters
  - Due to its ease of installation (do-it-yourself), POF is a good candidate here
  - Commercial devices covering this distance at 100 Mbit/s starts to be available
- But Telcos typically want any technology to be future-proof over a 20-25 year time frame
  - POF-ALL results shows that POF can give bitrate-distance products much higher than 100Mbit/·50 meter
- …Could this be a unique opportunity for POF?

- WEB site:
www.ist-pof-all.org

- For any info regarding the project:
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- To contact the coordinator
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