BroadBand Europe, Antwerp

3-6 December 2007

Latest results from the POF-ALL EU Project: Toward Improved Capacity over Large-Core Plastic Optical Fibers

Authors: **Roberto Gaudino, A. Nocivelli, H. Kragl, O. Ziemann, N. Weber, D. Jaeger, T. Koonen, C. Lezzi, A. Bluschke, S. Randel**

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

Paving the Optical Future with Affordable Lightning-fast Links

Summary

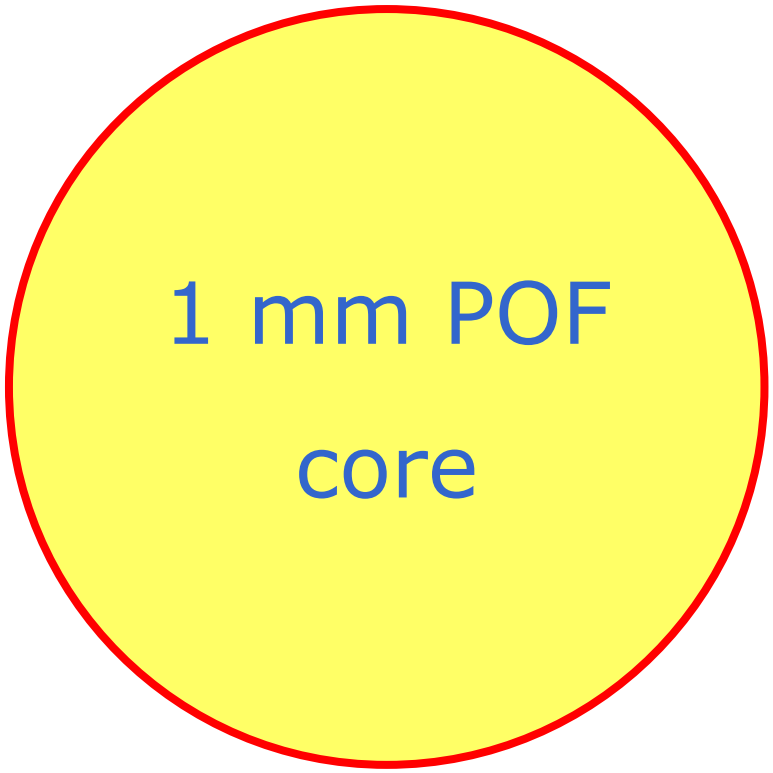
- The POF-ALL project: framework and goals
- The POF-ALL consortium
- Update on the latest technical achievements
- Expected impact

The POF-ALL project: framework and goals

What is POF-ALL ?

- It's a STREP 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

POF-ALL: The goal



(the three pictures show the actual proportions)

- The POF-ALL project focuses on:
  - large-area POF (Ø 1mm)
  - PMMA-based
  - Step-Index or Graded-Index

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 100 Mbit/s or more
  - over distances ranging from 100 to 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
  - in-apartment networks

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
  - Even "Do-it-yourself" installation is possible

BUT

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

POF-ALL: Activities

- The project is organized in seven work-packages:
  - WP1 – Advanced transmission techniques for 100 Mbit/s over long distances (300+ m)
  - WP2 – Module conception and transmission experiments of high speed data (1 Gbit/s and more) over intermediate distances (100+ m)
  - WP3 – Component support
  - WP4 – Fiber support
  - WP5 – Demonstration and Test-beds
  - WP6 – Economic impact, Dissemination
  - WP7 – Management

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. *Universität 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)
  - A large optoelectronic company (Siemens)
  - 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 Step-Index, PMMA, 1mm POF, is usually very low
  - Typically, most people think this medium works only over small distances (50-60 meters) at low bit-rate (100 Mbit/s max)
  - Actually, most commercial transceivers hardly perform better than this, and are today used in:
    - Industrial automation
    - Automotive (i.e., inside 6-7 million cars, as of today)

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

The "myths"

- 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
- Most typical: 1mm POF don't have enough bandwidth
  - FALSE: using digital signal processing (DSP), we demonstrated very high bit rates on 1mm Step-Index POF
  - We also obtained excellent performance on 1mm Graded-Index POF without DSP.

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

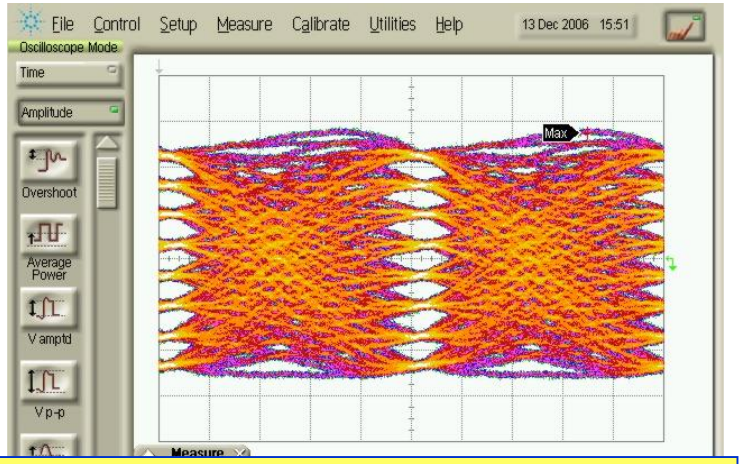
100 Mbit/s over 200+ meters on SI-POF

Approach #1 (ISMB group)

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

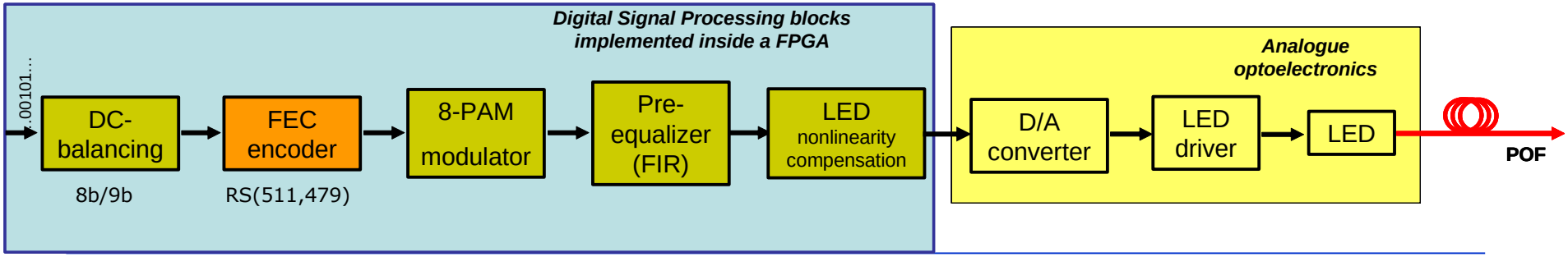
Current status:

- 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)	Post-Equalization alone	Pre- and Post-Equalization
200	Error free	Error free
225	<< 10^{-8}	< 10^{-8}
250	~ 10^{-6}	~ 10^{-5}
275	~ 10^{-3}	~ 10^{-2}



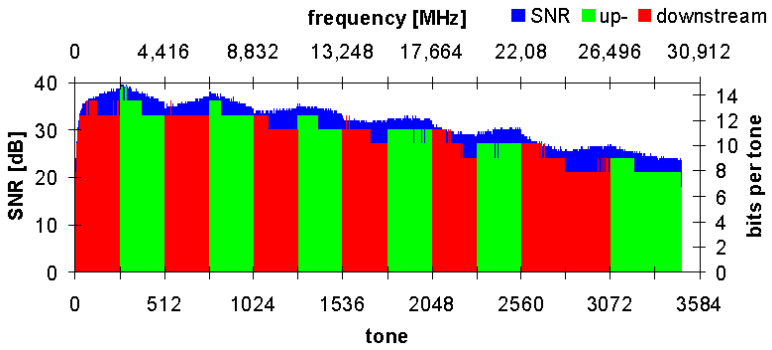
100 Mbit/s over 200+ meters on SI-POF

Approach #2 (Teleconnect group)

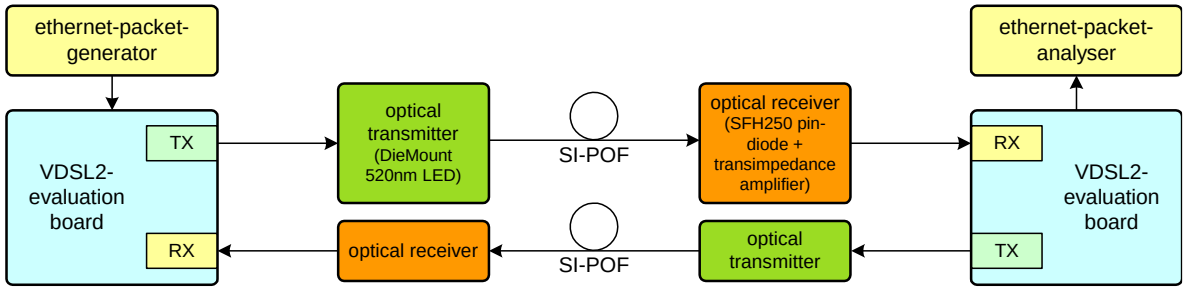
- Orthogonal Frequency Division Multiplexing (OFDM)
  - This is a modulation technique that is having huge success in other fields, such as xDSL

Current status:

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



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

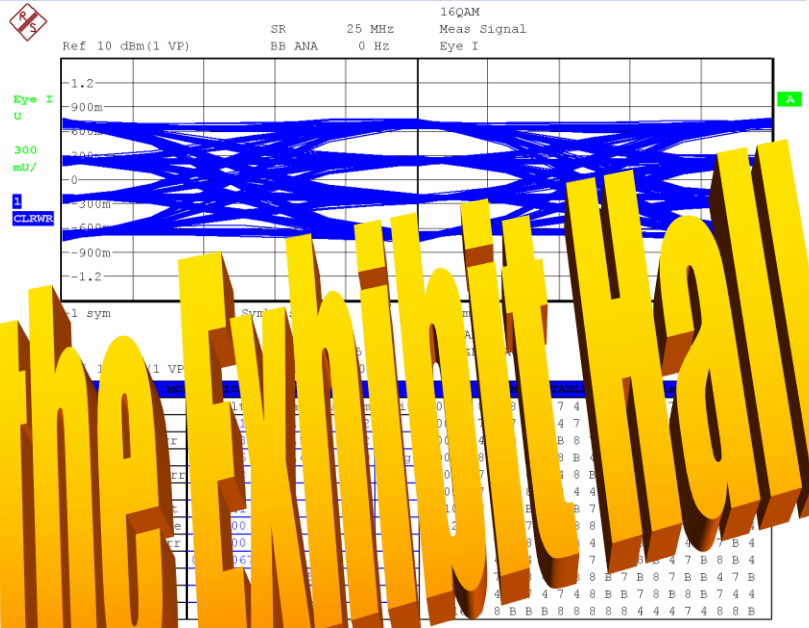


100 Mbit/s over 200+ meters on SI-POF

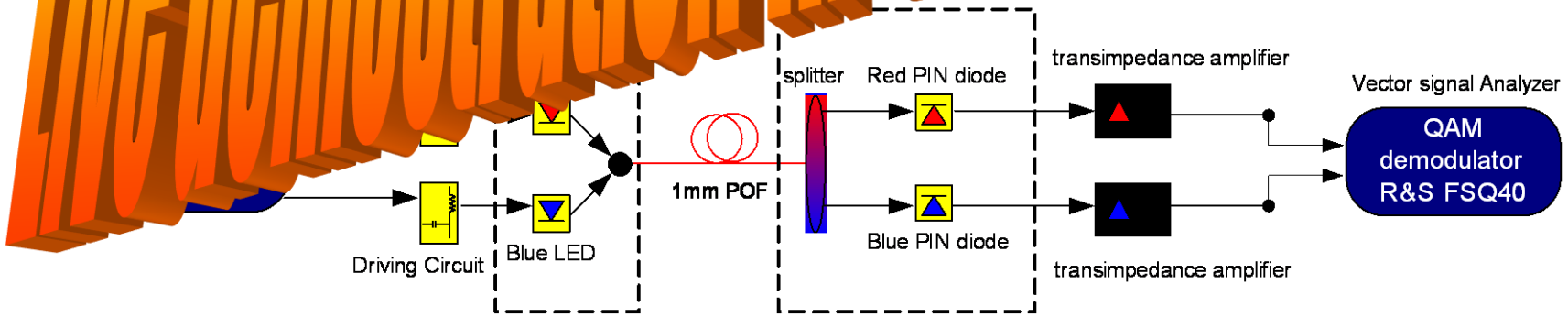
TU/e technische universiteit eindhoven

Approach #3 (TUE group)

- QAM modulation over two different wavelengths (red and blue, "Wave...
  Sli...



Live demonstration in the Exhibit Hall!



1 Gbit/s over up to 100 meters

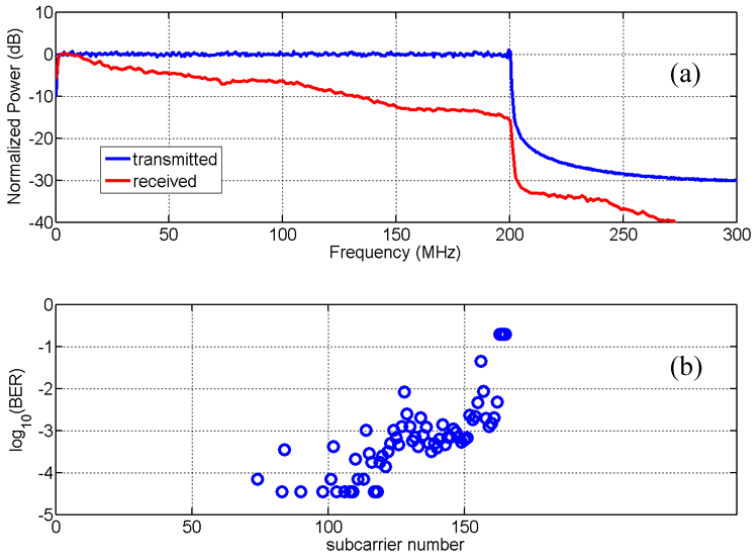
SIEMENS TU/e technische universiteit eindhoven

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)

Press Release #1

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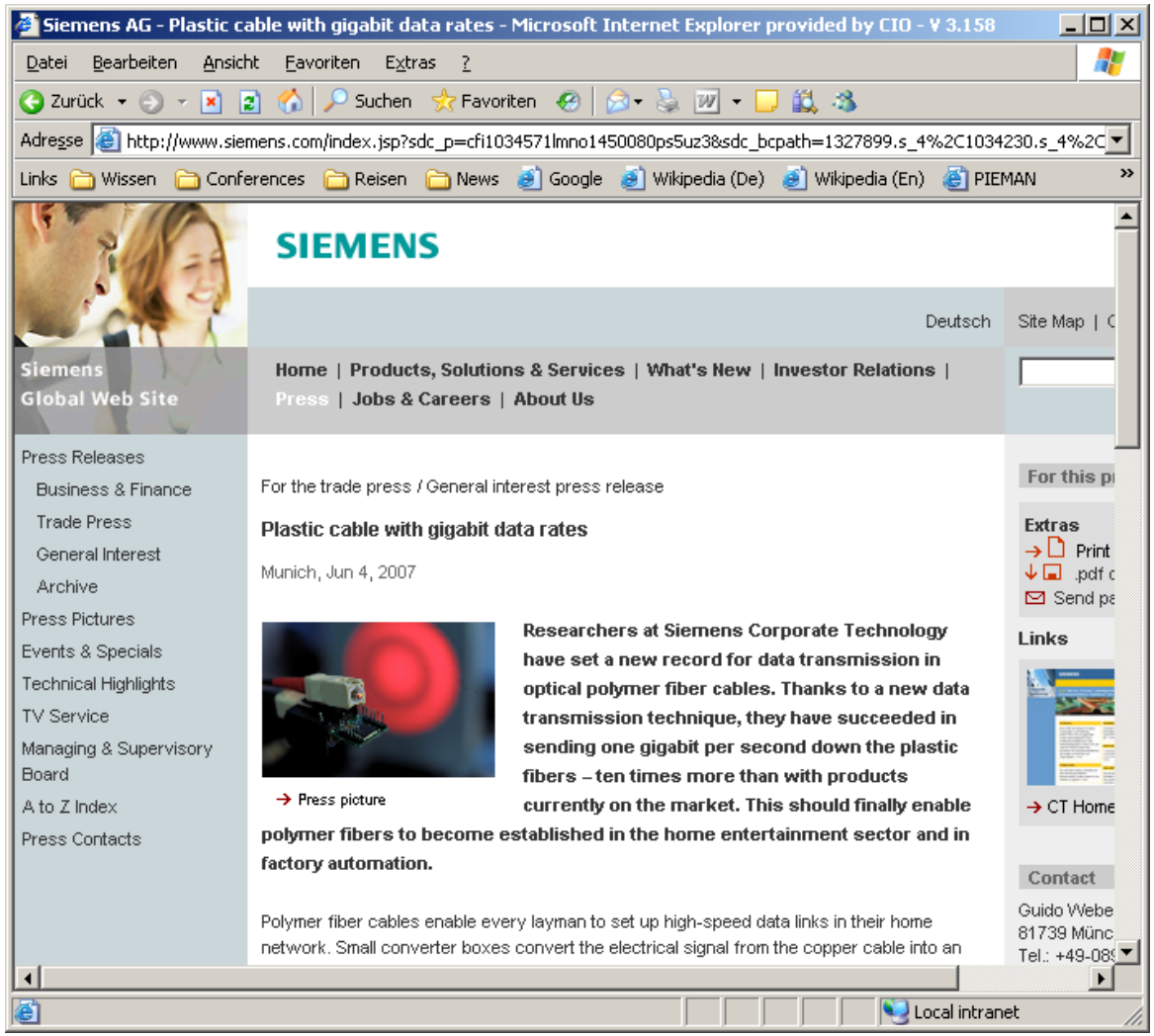

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Brazil:

18 de junho de 2007

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TELECOM E REDES

BANDA LARGA

Siemens testa fibra ótica de polímero com velocidade de 1Gbps

Por John Blau, para o IDG Now!*
Publicada em 05 de junho de 2007 às 15h53
Atualizada em 05 de junho de 2007 às 16h06

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Dusseldorf - Flexibilidade e menor custo de instalação são as principais vantagens do cabo de polímero, segundo a empresa.

Pesquisadores da Siemens AG transmitiram informação por uma fibra ótica à base de polímeros a

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hiệm sợi quang polymer 1Gbps - Microsoft Internet Explorer

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TIN TỨC — Thứ Hai ngày 25/06/2007

Siemens thử nghiệm sợi quang polymer 1Gbps

Ngày đăng: 11/6/2007 10h9

Công nghệ mới mở ra khả năng dễ dàng xây dựng các mạng gia đình liên kết nhiều PC và TV độ nét cao.

Các nhà nghiên cứu tại Siemens đã truyền dữ liệu qua cáp sợi quang polymer đạt tốc độ khoảng 1Gbps, mở ra những khả năng mới cho công nghệ như dễ dàng xây dựng các mạng gia đình liên kết nhiều PC và TV độ nét cao.

Ngày 5/6/2007, giám đốc dự án Sebastian Randel cho biết, cáp polymer cho phép người dùng tự mình cài đặt. Không giống cáp sợi quang làm bằng thủy tinh, cáp sợi quang polymer chỉ dày độ 1mm, rất mềm dẻo, dễ cắt (chỉ cần một chiếc dao lam), dễ lắp vào bộ nối.

Dù cáp sợi quang làm bằng thủy tinh (hiện đang được sử dụng rất rộng rãi) có thể truyền dữ liệu với tốc độ cao hơn cáp sợi quang làm bằng polymer rất nhiều, nhưng nó dày hơn khá nhiều trong lớp vỏ bảo vệ, bị gẫy nếu bị cuộn chặt, ông Randel cho biết. Muốn cắt gọn ghế loại cáp này để lắp vào bộ nối cần dao cắt bằng kim cương.

ĐƯỢC NHIỀU NGƯỜI ĐỌC
- VDC và Motorola thỏa thuận triển khai WiMAX
- CMC và FPT trở thành đối tác bán hàng cao cấp nhất của Microsoft
- Đăng ký ADSL và điện thoại cố định của Viettel không cần hộ khẩu
- Điểm báo ngày 23/6/2007
- Tomb Raider: Anniversary - Kiều nữ tái xuất "giang hồ"
- Trung tâm Thông Tin Bưu Điện khai trương dịch vụ giá trị gia tăng SMS

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西门子创造1G聚合光纤数据传输速度纪录

http://tech.QQ.com 2007年06月07日08:57 enet硅谷动力 评论0条

【eNet硅谷动力消息】周二西门子的研究人员在聚合光纤上实现了1Gbps（1千兆字节/秒）的传输速度，为连接PC和高清晰电视的家庭网络等技术提供了可能。

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SEK07现场 iriver真机曝光

西门子的项目经理塞巴斯蒂安·兰德尔（Sebastian Randel）称，聚合光纤可自己安装（DIY），与玻璃光纤不同的是，这种网线更为灵活也更易裁减和插接。他表示，聚合光纤直径约1毫米，不容易折断但可用剃须刀割断。

虽然应用广泛的玻璃光纤比聚合光纤速度更快，但保护层使其显得厚很多，而且用力弯曲也会折断。同时要切割或连接时需要钻石刀片。当新的高速服务如IPTV出现后，对易安装和低成本的家庭网络系统的需求日益增长。

Press Release #6

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1Gbit/s transmitted on plastic fiber

11 June 2007

Siemens Corporate Technology has achieved gigabit data rates on "plastic" cable.

Researchers at Siemens Corporate Technology say they have set a new record for data transmission in optical polymer fiber cables. A new data transmission technique allows the transmission of 1 Gbit/s down a plastic fiber - 10 times more than with other such products, currently available. "This achievement should finally enable polymer fibers to become established in the home entertainment sector and in factory automation," said Sebastian Randel, project manager at Siemens Corporate Technology.

Polymer fiber cables enable the establishment of high-speed data links even on a home network. Small converter boxes

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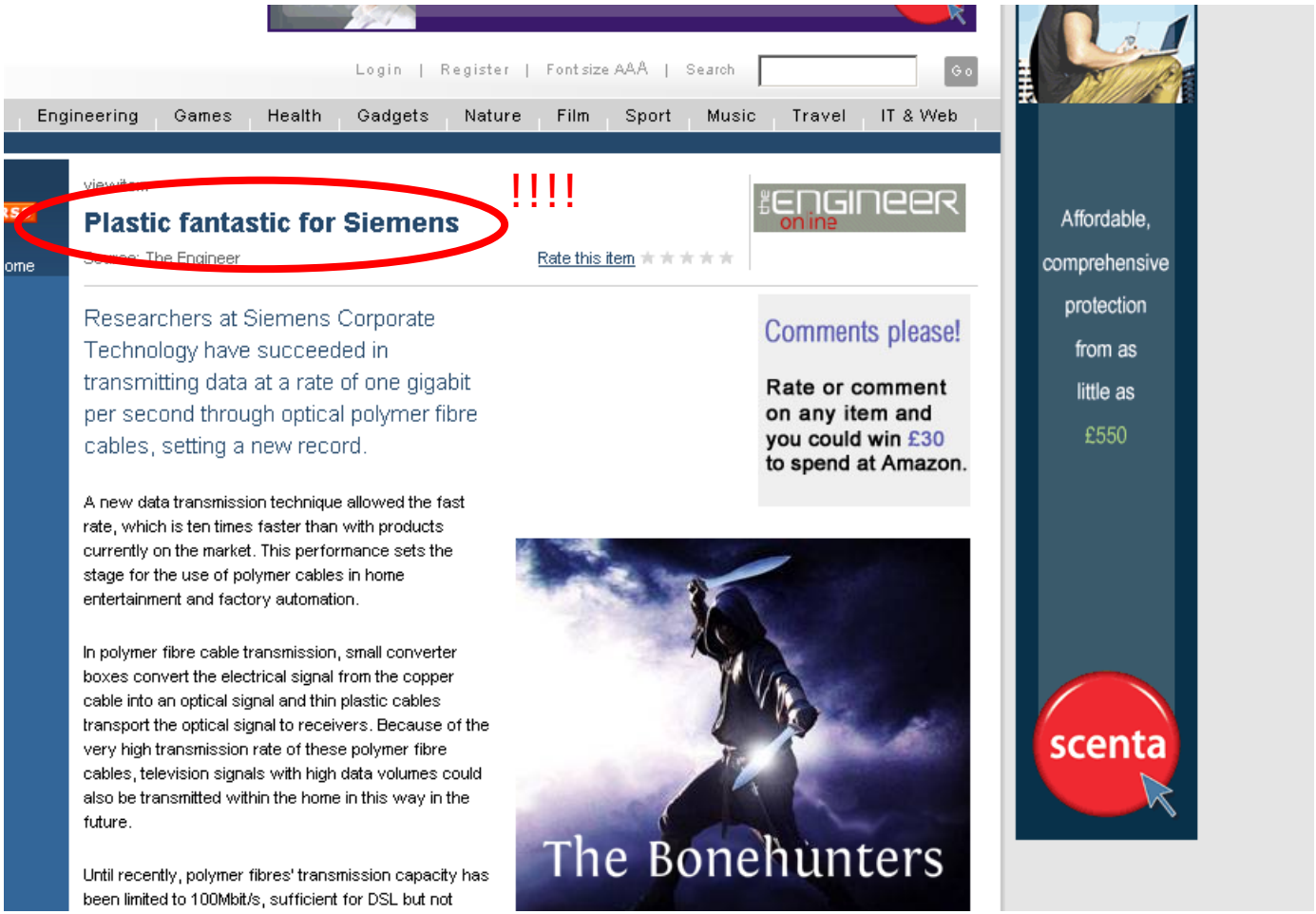


Comments

- 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).

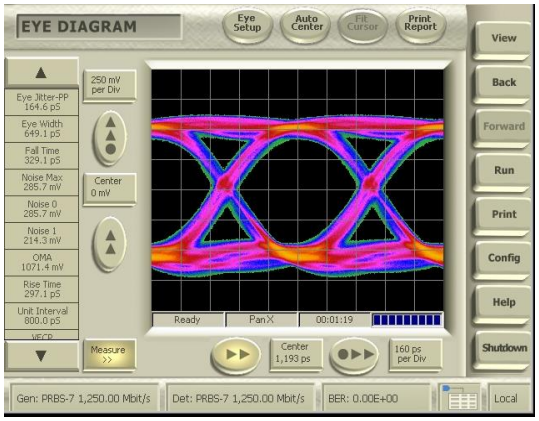
1 Gbit/s over up to 100 meters

Approach #5 (Fraunhofer/POFAC/Diemount group)

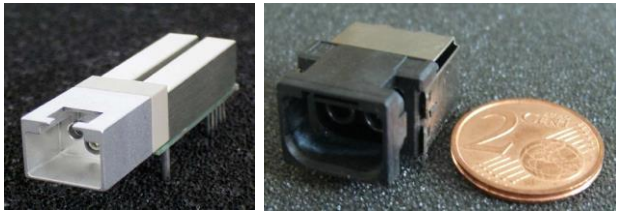
- A more traditional approach is also followed in the POF-ALL project, towards 1 Gbit/s transmission over 100 meter of 1mm GI-POF
  - Modulation is traditional binary NRZ
  - The effort is on component optimization
    - ➔ Optimization of red DVD laser driver
    - ➔ Optimization of receiver configuration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

Current status:

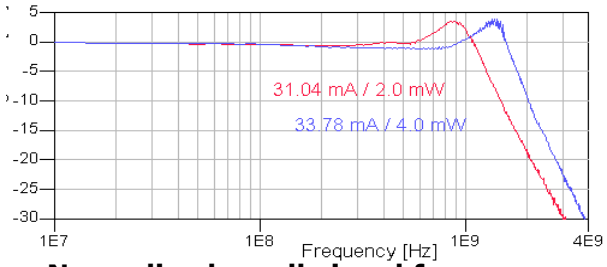
- Small form factor transceivers for 1.25 GBit/s over 30+ m available
- Laboratory demonstration over 100 meters



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 recent POF Conference 2007

13 papers

- **COMPONENTS**
  - Sklarek, Danielzik, Vinogradov, Ziemann, Lednicky, Offenbeck, Kragl , (Schott AG Mainz, POF-AC, Fraunhofer Institute for Integrated Circuits Erlangen, DieMount GmbH), "The influence of photo diode diameter on maximum data rate and sensitivity of POF systems"
  - Offenbeck, Weber, (Fraunhofer Institute for Integrated Circuits IIS), "Versatile alterable gigabit transceiver for large core fibers ready for mass production"
  - Moellers, Gindera, Bulters, Hung, Jager (Universitat Duisburg-Essen), "High-speed transceiver for Radio-Over-POF applications"
  - Camatel, Nespola, Càrdenas, Abrate, Gaudino (Istituto Superiore Mario Boella, Politecnico di Torino), "LED non-linearity characterization and compensation"
- **DATACOM - I**
  - Lee, Randel, Vinogradov, Ziemann, Offenbeck, Koonen (Eindhoven University of Technology, Siemens AG, POF-AC, Fraunhofer Institute for Integrated Circuits), "10Gbit/s over large diameter polymer optical fibers using discrete multitone modulation"
  - Gaudino, Nocivelli, Kragl, Ziemann, Weber, Jager, Koonen, Lezzi, Bluschke, Randel (Istituto Superiore Mario Boella, Politecnico di Torino, Luceat S.p.A., DieMount GmbH, POF-AC, Fraunhofer Institute, Universitat Duisburg-Essen, Technische Universiteit Eindhoven, Fastweb S.p.A., Teleconnect GmbH, Siemens AG), Invited paper: "Status and recent results from the POF-ALL EU project: toward improved capacity and new application of large-core POF"
  - Offenbeck, Weber, Vinogradov (Fraunhofer Institute for Integrated Circuits IIS, POF-AC), "Analog GHz transmission over large core fibres for DVB satellite links of sophisticated coding schemes"
  - Breyer, Lee, Randel, Hanik (Technische Universitat Munchen, Eindhoven University of Technology, Siemens AG), "10Gbit/s transmission over 220 m perfluorinated graded-index polymer optical fiber using PAM-4 modulation and simple equalization schemes"
- **DATACOM-II**
  - Yang, Van den Boom, Koonen (Eindhoven University of Technology), "Wavelength multiplexed quadrature amplitude modulation for low cost high capacity data transmission over plastic optical fibre"
  - Randel, Lee, Breyer (Siemens AG, Eindhoven University of Technology, Technische Universitat Munchen), "1Gbit/s transmission over POF using light-emitting diodes"
  - Nespola, Camatel, Abrate, Càrdenas, Gaudino (Istituto Superiore Mario Boella, Politecnico di Torino), "Fast-Ethernet transmission over extended reach SI-POF links"
- **DATACOM-III**
  - Kragl, Bluschke, Ziemann (DieMount GmbH, Teleconnect GmbH, POF-AC), "POF data link applications in the field of local access networks"
  - Gaudino, Bosco, Bluschke, Hofmann, Kiss, Rietzsch, Randel, Lee, Breyer (Istituto Superiore Mario Boella, Politecnico di Torino, Teleconnect GmbH, Siemens AG, Eindhoven University of Technology, Teshnische Universitat Munchen), "On the ultimate capacity of SI-POF links and the use of OFDM: recent results from the POF-ALL project"

Expected Impact

POF-ALL: Impact

- We have demonstrated that impressive performances can be achieved with large core POF
  - 200m are feasible at 100Mbps
  - Several tens of meters at 1 Gbps
- Some of the approaches are very close to a fully-engineered setup, namely:
  - The OFDM approach (with VDSL2+ ICs)
  - The NRZ 1 Gbps approach over 30 m GI-POF

POF-ALL: Impact

- New applications become possible with large core POF:
  - Industrial automation (Industrial Ethernet, SERCOS III …)
  - Video surveillance
  - Edge networks
  - Home networking

- The last point seems the most promising
  - Several national incumbent operators are currently considering POF for “optics inside the apartment”

POF inside the apartment?

- "TRUE" FTTH will (sooner or later) bring an extremely good digital connection up to the "apartment main door"
  - 100 Mbps per residential user is offered today in some FTTH commercial offers (Japan, Korea)
  - Higher bit rates will surely be offered in the future (up to Gbps) and people will use them!

- Some operators are being concerned on how to "distribute" this inside the apartment
  - By the way: who will install the in-apartment network?
    - ➔ The Telecom operator themselves?
      - Very expensive
      - The in-apartment network is very often reconfigured
    - ➔ The final user himself?
      - A good solution if a do-it-yourself approach is possible

POF inside the apartment?

- What are the options (for a mass-rollout) inside the apartment?
- Wireless
  - + Installation is trivial and unexpensive
  - - Still, it is a shared media!!
  - - Can it ever (reliably) reach the Gbps range?
- Glass fibers
  - + Very future proof!!
  - - Anyway, installation cost appears too high
- UTP Cat.5 or higher
  - - Installation is less simple than one usually think
  - - Cable is quite thick
- POF
  - + Better performance than UTP Cat.5 (similar to higher Cat)
  - + Extreme ease of installation

POF-ALL: Contacts

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