



SYSTEM DEMONSTRATIONS

Employing a Single DPLL for Joint Carrier Phase Estimation in Few-Mode Fiber Transmission

R.G.H. van Uden, C.M. Okonkwo, V.A.J.M. Sleiffer, H.-S. Chen, M. Kushnerov, H. de Waardt, and A.M.J. Koonen

OFC 2013 paper OM2C.1.

Single DPLL Joint Carrier Phase Compensation for Few-Mode Fiber Transmission

R.G. H. van Uden, C.M. Okonkwo, V.A. J. M. Sleiffer, M. Kushnerov, H. de Waardt, and A. M. J. Koonen

Photonics Technology Letters, 25(14), 1381-1384, 2013.

Performance Comparison of CSI Estimation Techniques for FMF Transmission Systems

R.G.H. van Uden, C.M. Okonkwo, V.A.J.M. Sleiffer, H. de Waardt, A.M.J. Koonen

IEEE Summer Topicals 2013, paper WC4.2.

Adaptive Step Size MIMO Equalization for Few-Mode Fiber Transmission Systems

R.G.H. van Uden, C.M. Okonkwo, V.A.J.M. Sleiffer, H. De Waardt, A.M.J. Koonen

ECOC 2013, paper Th.2.C.2.

2.576Tb/s (23×2×56Gb/s) Mode Division Multiplexed 4PAM over 11.8 km Differential Mode Delay Uncompensated Few-Mode Fiber using Direct Detection

R.J.H. van Uden, C.M. Okonkwo, H.S. Chen, F.M. Huijskens, B. Corbett, R. Winfield, H. De Waardt, A.M.J. Koonen

ECOC 2013, paper We.3.D.2.

WDM Transmission at 2 μ m over Low-Loss Hollow Core Photonic Bandgap Fiber

N. Mac Suibhne, Z. Li, B. Baeuerle, J. Zhao, J.P. Wooler, S.U. Alam, F. Poletti, M.N. Petrovich, A.M. Heidt, N.V. Wheeler, N.K. Baddela, E. Numkam, I.P. Giles, D.J. Giles, R. Phelan, J. O'Carroll, B. Kelly, D. Murphy, Brian Corbett, A.D. Ellis, D.J. Richardson, F.C. Garcia Gunning

OFC2013, paper OW1I.6



20 x 960-Gb/s MDM-DP-32QAM transmission over 60km FMF with inline MM-EDFA

V.A.J.M. Sleiffer, P. Leoni, Y. Jung, J. Surof, M. Kushnerov, V. Veljanovski, D.J. Richardson, S.U. Alam, L. Grüner-Nielsen, Y. Sun, B. Corbett, R. Winfield, S. Calabrò, B. Sommerkorn-Krombholz, H. Von Kirchbauer, and H. De Waardt

ECOC 2013, paper We.2.D.2

High Capacity Mode-Division Multiplexed Optical Transmission in a Novel 37-cell Hollow-Core Photonic Bandgap Fiber

V.A.J.M. Sleiffer, Y. Jung, N.K. Baddela, J. Surof, M. Kushnerov, V. Veljanovski, J.R. Hayes, N.V. Wheeler, E.R. Numkam Fokoua, J.P. Wooler, D.R. Gray, N. H.-L. Wong, F.R. Parmigiani, S. Alam, M.N. Petrovich, F. Poletti, D.J. Richardson, H de Waardt

JLT 2013, (online ieeexplore, issue number not assigned yet)

A First Glance at Coherent Optical Transmission using Photonic Bandgap Fiber as a Transmission Medium

V.A.J.M. Sleiffer, Y. Jung, P. Leoni, M. Kushnerov, V. Veljanovski, N. V. Wheeler, N. Baddela, J. R. Hayes, J. Whooler, E. Numkam, R. Slavik, F. Poletti, M. N. Petrovich, S. Alam, D. J. Richardson, H. de Waardt

IEEE summer topical, 2013, (Invited) paper WC2.4

High Capacity Multi-Mode Transmission Systems Using Higher-Order Modulation Formats

V.A.J.M. Sleiffer, Y. Jung, P. Leoni, M. Kushnerov, R.G.H. van Uden, V. Veljanovski, L. Grüner-Nielsen, Y. Sun, D.J. Richardson, S. U. Alam, F. Poletti, B. Corbett, R. Winfield, H. de Waardt

OECC 2013, (Invited) paper MR1-1

30.7 Tb/s (96x320 Gb/s) DP-32QAM transmission over 19-cell Photonic Band Gap Fiber

V.A.J.M. Sleiffer, Y. Jung, P. Leoni, M. Kushnerov, N. Wheeler, N. Baddela, R. van Uden, C. Okonkwo, J. R. Hayes, J. Wooler, E. R. Numkam Fokoua, R. Slavik, F. Poletti, M. Petrovich, V. Veljanovski, S. Alam, D. J. Richardson, H. de Waardt

OFC 2013, paper OW11.5

Low Computational Complexity Mode Division Multiplexed OFDM Transmission over 130 km of Few Mode Fiber



B. Inan, Y. Jung, V. Sleiffer, M. Kushnerov, L. Gruner-Nielsen, S. Adhikari, S.L. Jansen, D.J. Richardson, S. Alam, B. Spinnler, N. Hanik

OFC 2013, paper OW4F.4

73.7 Tb/s (96X3x256-Gb/s) mode-division-multiplexed DP-16QAM transmission with inline MM-EDFA

V.A.J.M. Sleiffer, Y. Jung, V. Veljanovski, R.G.H. van Uden, M. Kushnerov, Q. Kang, L. Grüner-Nielsen, Y. Sun, D.J. Richardson, S. Alam, F. Poletti, J.K. Sahu, A. Dhar, H. Chen, B. Inan, A.M.J. Koonen, B. Corbet, R. Winfield, A.D. Ellis, and H. de Waardt

Optics Express, 20 (26), B428-B438, 2012

Demonstration of a Photonic Integrated Mode Coupler With MDM and WDM Transmission

H. Chen, V. Sleiffer, B. Snyder, M. Kushnerov, R. van Uden, Y. Jung, C.M. Okonkwo, O. Raz, P. O'Brien, H. de Waardt, and T. Koonen

IEEE Photonics Technology Letters, 25, (21), 2013

3 MDM x 8 WDM x 320-Gb/s DP-32QAM Transmission over a 120km Few-Mode Fiber Span Employing 3-Spot Mode Couplers

H. Chen, V. Sleiffer, R. van Uden, C. Okonkwo, M. Kushnerov, F. Huijskens, L. Grüner-Nielsen, Y. Sun, H. de Waardt and T. Koonen

OECC/PS 2013, (Post deadline) paper PD3-6

Demonstration of a Photonic Integrated Mode Coupler with 3.072Tb/s MDM and WDM transmission over Few-Mode Fiber

H. Chen, V. Sleiffer, B. Snyder, Maxim Kushnerov, R. van Uden, Y. Jung, C. Okonkwo, O. Raz, P. O'Brien, H. de Waardt and T. Koonen

OECC/PS 2013, (Post deadline) paper PD2-5

Employing Prism-based 3-Spot Mode Couplers for High Capacity MDM/WDM Transmission

H. Chen, V. Sleiffer, F. Huijskens, R. van Uden, C. Okonkwo, P. Leoni, M. Kushnerov, L. Grüner-Nielsen, Y. Sun, H. de Waardt and T. Koonen

IEEE Photonics Technology Letters, 2013 (online ieeexplore, issue number not assigned yet)

480 km Transmission of MDM 576-Gb/s 8QAM using a Few-Mode Re-circulating Loop



V.A.J.M. Sleiffer, H. Chen, Y. Jung, M. Kuschnerov, D.J. Richardson, S.U. Alam, Y. Sun, L. Grüner-Nielsen, N. Pavarelli, B. Snyder, P. O'Brien, A.D. Ellis, A.M.J. Koonen & H. de Waardt

IPC 2013, (Post deadline) paper PD6

73.7 Tb/s (96X3x256-Gb/s) mode-division-multiplexed DP-16QAM transmission with inline MM-EDFA

V.A.J.M. Sleiffer, Y. Jung, V. Veljanovski, R.G.H. van Uden, M. Kuschnerov, Q. Kang, L. Grüner-Nielsen, Y. Sun, D.J. Richardson, S. Alam, F. Poletti, J.K. Sahu, A. Dhar, H. Chen, B. Inan, A.M.J. Koonen, B. Corbett, R. Winfield, A.D. Ellis, and H. de Waardt

ECOC 2012, postdeadline paper Th.3.C.4

We show transmission of a 73.7 Tb/s (96x3x256-Gb/s) DP-16QAM mode-division-multiplexed signal over 119km of few-mode fiber with inline multi-mode EDFA, using 6x6MIMO digital signal processing. The total demonstrated net capacity is 57.6 Tb/s (SE 12 bits/s/Hz).

Wavelength Division Multiplexing at 2 μ m

N. MacSuibhne, Z. Li, B. Baeuerle, J. Zhao, J.P. Wooler, S.U. Alam, F. Poletti, M.N. Petrovich, A.M. Heidt, I.P. Giles, D.J. Giles, B. Pálsdóttir, L. Grüner-Nielsen, R. Phelan, J. O'Carroll, B. Kelly, D. Murphy, A.D. Ellis, D.J. Richardson, F.C. Garcia Gunning

ECOC 2012, postdeadline paper Th.3.A.3

This paper shows, for the first time, the implementation of a WDM subsystem at the 2 μ m wavelength window with mixed formats. Three wavelength channels were directly modulated with BPSK Fast-OFDM at 5Gbit/s per channel, with a fourth channel NRZ-OOK externally modulated at 8.5Gbit/s giving a total capacity in excess of 20 Gbit/s.

Mode division multiplexed 3x112-Gb/s DP-QPSK transmission over 80-km few-mode fiber with inline MM-EDFA and blind DSP

V.A.J.M. Sleiffer, Y. Jung, B. Inan, H. Chen, R.G.H. van Uden, M. Kuschnerov, D. van den Borne, S.L. Jansen, V. Veljanovski, A.M.J. Koonen, D.J. Richardson, S. Alam, F. Poletti, J. Sahu, A. Dhar, B. Corbett, R. Winfield, A. Ellis, H. De Waardt

ECOC 2012, paper TU1C2.

We show transmission of a 3x112 Gb/s DP QPSK mode-division-multiplexed signal up to 80km, with and without multi-mode EDFA, using blind 6x6 MIMO digital signal processing. We show that the OSNR penalty induced by mode-mixing in the multi-mode EDFA is negligible.



1.45 Tbit/s low latency data transmission through 19-cell hollow core photonic band gap fibre

R.Slavik, M.N.Petrovich, N.V.Wheeler, J.R.Hayes, N.K.Baddela, D.Gray, F.Poletti, D.J.Richardson

European Conference on Optical Communication (ECOC) Amsterdam 16-20 Sept 2012 paper Mo.2.F.2

We report transmission of 37 x 40 Gbit/s C-band channels over 250-m of hollow core band gap fibre, at 99.7% the speed of light in vacuum. BER penalty below 1 dB as compared to back-to-back was measured across the C-band.

20Gbit/s Two LP11 Modes Transmission over 10km Two-moded Fiber without Crosstalk Compensation

H.-S. Chen, A.M.J. Koonen, B. Corbett, R. Winfield, and H.P.A. van den Boom

OECC 2012, paper 6B2-1

High separation ratio between degenerate LP11 modes is demonstrated through a Fourier Optics simulation model using the binary phase plates. 20Gbit/s transmission of two LP11 modes without crosstalk compensation is realized over 10km Two-moded Fiber.

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6276611>

20Gbit/s Two LP11 Modes Transmission over 10km Two-moded Fiber without Crosstalk Compensation

H. -S. Chen, A. M. J. Koonen¹, B. Corbett, R. Winfield, and H. P. A. van den Boom

OECC'12, paper 6B2-1.

High separation ratio between degenerate LP11 modes is demonstrated through a Fourier Optics simulation model using the binary phase plates. 20Gbit/s transmission of two LP11 modes without crosstalk compensation is realized over 10km Two-moded Fiber.

<http://dx.doi.org/10.1109/OECC.2012.6276611>

Phase Plate Tolerances in a Tri-Mode Demultiplexer

R. v. Uden, C. Okonkwo, H. d. Waardt and A. M. J. Koonen

SUM 2012 IEEE Photonics Society Summer Topical Meeting on Space Division Multiplexing for Optical Systems and Networks, paper WC1.3



The tolerance in a mode-demultiplexer to rotational, longitudinal offset and phase mismatch is demonstrated to be 25 degrees, 15% of the $1/e^2$ radius of the LP₀₁ mode, and 45 degrees respectively for <1dB SNR penalty.

<http://dx.doi.org/10.1109/PHOSST.2012.6280804>

30-Gb/s Bidirectional Transparent Optical Transmission With an MMF Access and an Indoor Optical Wireless Link

Haoshuo Chen, Henrie P. A. van den Boom, Eduward Tangdionga, Ton Koonen

IEEE Photonics Technology Letters, Vol. 24, No. 7, April 1, 2012 pp 572-574.

This letter describes a 30-Gb/s bidirectional transparent optical transmission, over a 4.4-km multimode fiber (MMF) in combination with an indoor optical wireless (OW) link, which could provide limited mobility. Due to MMF's advantages, such as lower installation costs and easy maintenance, it is used as the access link. To enhance the MMFs bandwidth and provide the feasibility to use standard single-mode devices in the OW terminal (OWT), center launching and center detection techniques are both utilized. The stability of the indoor OW channel and the modal noise in MMF are investigated. Discrete multitone modulation with power and bit loading algorithms are applied to improve system's frequency utilization efficiency and robustness.

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6125217>

Experimental and Theoretical Investigations of Intensity-Modulation and Direct-Detection Optical Fast-OFDM over MMF-links

E. Giacomidis, S. K. Ibrahim, J. Zhao, J. M. Tang, A. D. Ellis, I. Tomkos

IEEE Photonics Technology Letters, Vol. 24, No. 1, pp.52-54, (2012).

Abstract—We demonstrate the first experimental implementation of a 3.9-Gb/s differential binary phase-shift keying (DBPSK)-based double sideband (DSB) optical fast orthogonal frequency-division-multiplexing (FOFDM) system with a reduced subcarrier spacing equal to half the symbol rate over 300m of multimode fiber (MMF) using intensity-modulation and direct-detection (IM/DD). The required received optical power at a bit-error rate (BER) of $10E-3$ was measured to be ~ -14.2 dBm with a receiver sensitivity penalty of only 0.2 dB when compared to the back-to-back case. Experimental results agree very well with the theoretical predictions.

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6054002>



Experimental Demonstration of Cost-Effective Intensity-Modulation and Direct-Detection Optical Fast-OFDM over 40km SMF Transmission

E. Giacoumidis, S.K. Ibrahim, J. Zhao, J.M. Tang, I. Tomkos, and A.D. Ellis

OFC 2012, paper JW2A.65, (2012).

We demonstrate the first experimental implementation of intensity-modulation and direct-detection 7.6Gb/s DBPSK-based DSB optical Fast-OFDM with a reduced subcarrier spacing equal to half of the symbol rate per subcarrier over 40km SMF.

<http://www.opticsinfobase.org/abstract.cfm?uri=NFOEC-2012-JW2A.65>