Experimental Comparison of Probabilistic Shaping Methods for Unrepeated Fiber Transmission

This paper studies the impact of probabilistic shaping on effective signal-to-noise ratios (SNRs) and achievable information rates (AIRs) in a back-to-back configuration and in unrepeated nonlinear fiber transmissions. For back-to-back, various shaped quadrature amplitude modulation (QAM) distributions are found to have the same implementation penalty as uniform input. By demonstrating in transmission experiments that shaped QAM input leads to lower effective SNR than uniform input at a fixed average launch power, we experimentally confirm that shaping enhances the fiber nonlinearities. However, shaping is ultimately found to increase the AIR, which is the most relevant figure of merit as it is directly related to spectral efficiency. In a detailed study of these shaping gains for the nonlinear fiber channel, four strategies for optimizing QAM input distributions are evaluated and experimentally compared in wavelength division multiplexing (WDM) systems. The first shaping scheme generates a Maxwell-Boltzmann (MB) distribution based on a linear additive white Gaussian noise channel. The second strategy uses the Blahut-Arimoto algorithm to optimize an unconstrained QAM distribution for a split-step Fourier method based channel model. In the third and fourth approach, MB-shaped QAM and unconstrained QAM are optimized via the enhanced Gaussian noise (EGN) model. Although the absolute shaping gains are found to be relatively small, the relative improvements by EGN-optimized unconstrained distributions over linear AWGN optimized MB distributions are up to 59%. This general behavior is observed in 9-channel and fully loaded WDM experiments.
Simultaneous MIMO-free transmission of a record number (12) of orbital angular momentum modes over 1.2 km is demonstrated. WDM compatibility of the system is shown by using 60 WDM channels with 25 GHz spacing and 10 Gbaud QPSK.
1.5-μm Directly modulated transmission over 66 km of SSMF with an integrated hybrid III-V/SOI DFB laser

A hybrid III-V/SOI directly modulated DFB laser operating at 1.5 μm is fabricated, showing a side mode suppression ratio above 50 dB and a 3-dB bandwidth of 12 GHz. Error-free transmission (BER <10−9) at 10 Gb/s over 66-km SSMF is demonstrated without dispersion compensation and FEC.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Nanophotonic Devices, University of Rennes, III-V Lab, Commissariat a l’Energie Atomique, CEA-Leti, 17 rue des Martyrs, F-38054, Grenoble, France
Authors: Cristofori, V. (Intern), Da Ros, F. (Intern), Chaibi, M. E. (Ekstern), Ding, Y. (Intern), Bramerie, L. (Ekstern), Shen, A. (Ekstern), Gallet, A. (Ekstern), Duan, G. (Ekstern), Hassan, K. (Ekstern), Olivier, S. (Ekstern), Oxenløwe, L. K. (Intern), Peucheret, C. (Ekstern)
Pages: 103-104
Publication date: 2017

25-Gb/s Transmission Over 2.5-km SSMF by Silicon MRR Enhanced 1.55-mu m III-V/SOI DML

The use of a micro-ring resonator (MRR) to enhance the modulation extinction ratio and dispersion tolerance of a directly modulated laser is experimentally investigated with a bit rate of 25 Gb/s as proposed for the next generation data center communications. The investigated system combines a 11-GHz 1.55-μm m directly modulated hybrid III-V/SOI DFB laser realized by bonding III-V materials (InGaAlAs) on a silicon-on-insulator (SOI) wafer and a silicon MRR also fabricated on SOI. Such a transmitter enables error-free transmission (BER <10(-9)) at 25 Gb/s data rate over 2.5-km standard single mode fiber without dispersion compensation nor forward error correction. As both laser and MRR are fabricated on the
SOI platform, they could be combined into a single device with enhanced performance, thus providing a cost-effective transmitter for short reach applications.

**General information**

**State:** Published  
**Organisations:** Department of Photonics Engineering, High-Speed Optical Communication, Nanophotonic Devices, Thales, Thales, Lab 3 5, F-91767 Palaiseau, France, Acreo Swedish ICT AB, FOTON Laboratory, III-V Lab, KTH - Royal Institute of Technology  
**Authors:** Cristofori, V. (Intern), Da Ros, F. (Intern), Ozolins, O. (Ekstern), Chaibi, M. E. (Ekstern), Bramerie, L. (Ekstern), Ding, Y. (Intern), Pang, X. (Ekstern), Shen, A. (Ekstern), Gallet, A. (Ekstern), Duan, G. (Ekstern), Hassan, K. (Ekstern), Olivier, S. (Ekstern), Popov, S. (Ekstern), Jacobsen, G. (Ekstern), Oxenløwe, L. K. (Intern), Peucheret, C. (Ekstern)  
**Pages:** 960-963  
**Publication date:** 2017  
**Main Research Area:** Technical/natural sciences

**Publication information**

**Journal:** IEEE Photonics Technology Letters  
**Volume:** 29  
**Issue number:** 12  
**ISSN (Print):** 1041-1135  
**Ratings:**  
BFI (2017): BFI-level 2  
Web of Science (2017): Indexed yes  
BFI (2016): BFI-level 2  
Scopus rating (2016): CiteScore 2.52 SJR 1.018 SNIP 1.279  
Web of Science (2016): Indexed yes  
BFI (2015): BFI-level 2  
Scopus rating (2015): SJR 1.263 SNIP 1.327 CiteScore 2.62  
Web of Science (2015): Indexed yes  
BFI (2014): BFI-level 2  
Scopus rating (2014): SJR 1.461 SNIP 1.614 CiteScore 2.78  
Web of Science (2014): Indexed yes  
BFI (2013): BFI-level 2  
Scopus rating (2013): SJR 1.487 SNIP 1.547 CiteScore 2.95  
ISI indexed (2013): ISI indexed yes  
Web of Science (2013): Indexed yes  
BFI (2012): BFI-level 2  
Scopus rating (2012): SJR 1.623 SNIP 1.706 CiteScore 2.46  
ISI indexed (2012): ISI indexed yes  
Web of Science (2012): Indexed yes  
BFI (2011): BFI-level 2  
Scopus rating (2011): SJR 1.51 SNIP 2.012 CiteScore 2.48  
ISI indexed (2011): ISI indexed yes  
Web of Science (2011): Indexed yes  
BFI (2010): BFI-level 2  
Scopus rating (2010): SJR 1.474 SNIP 1.623  
Web of Science (2010): Indexed yes  
BFI (2009): BFI-level 2  
Scopus rating (2009): SJR 1.775 SNIP 1.804  
Web of Science (2009): Indexed yes  
BFI (2008): BFI-level 1  
Scopus rating (2008): SJR 2.081 SNIP 1.818  
Web of Science (2008): Indexed yes  
Scopus rating (2007): SJR 2.345 SNIP 1.566  
Web of Science (2007): Indexed yes  
Scopus rating (2006): SJR 2.112 SNIP 1.884  
Web of Science (2006): Indexed yes
4-PAM Dispersion-Uncompensated Transmission with Micro-Ring Resonator Enhanced 1.55-μm DML
Real-time transmission of 14-GBd 4-PAM signal is demonstrated by combining a commercial 1.55-μm DML with a silicon MRR. BER below the HD-FEC threshold is measured after 26-km SSMF transmission without offline digital signal processing.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Acreo Swedish ICT AB, FOTON Laboratory, KTH - Royal Institute of Technology
Authors: Da Ros, F. (Intern), Cristofori, V. (Intern), Ozolins, O. (Ekstern), Chaibi, M. E. (Ekstern), Pang, X. (Ekstern), Jacobsen, G. (Ekstern), Popov, S. (Ekstern), Galili, M. (Intern), Oxenløwe, L. K. (Intern), Peucheret, C. (Ekstern)
Publication date: 2017

Host publication information
Title of host publication: CLEO: Science and Innovations 2017
Publisher: Optical Society of America OSA
Article number: STu1M.5
Main Research Area: Technical/natural sciences
Conference: CLEO: Science and Innovations 2017, San Jose, United States, 14/05/2017 - 14/05/2017
DOIs:
10.1364/CLEO_SI.2017.STu1M.5

Bibliographical note
From the session: Optical Interconnect Systems (STu1M)
Source: PublicationPreSubmission
Source-ID: 133890349
Publication: Research - peer-review › Article in proceedings – Annual report year: 2017

4-PAM dispersion-uncompensated transmission with micro-ring resonator enhanced 1.55-μm DML
Real-time transmission of 14-GBd 4-PAM signal is demonstrated by combining a commercial 1.55-μm DML with a silicon MRR. BER below the HD-FEC threshold is measured after 26-km SSMF transmission without offline digital signal processing.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Acreo Swedish ICT AB, University of Rennes, KTH - Royal Institute of Technology
A configurable FPGA FEC unit for Tb/s optical communication

Decoding of FEC (forward error correction) for optical communication beyond 1 Tb/s is investigated. A configurable single FPGA solution is presented having configurations supporting bit-rates in the range from 40 Gb/s to 1.6 Tb/s. The design allows for trade-offs of bit-rate, footprint, and latency within the resources of the FPGA. A proof-of-concept lab experiment at 40 Gb/s was conducted and pre-FEC — post-FEC performance validated with simulated results.

Bit-rate-transparent optical RZ-to-NRZ format conversion based on linear spectral phase filtering

We propose a novel and strikingly simple design for all-optical bit-rate-transparent RZ-to-NRZ conversion based on optical phase filtering. The proposed concept is experimentally validated through format conversion of a 640 Gbit/s coherent RZ signal to NRZ signal.
Characterization and optimization of a high-efficiency AlGaAs-On-Insulator-based wavelength converter for 64- and 256-QAM signals

In this paper, we demonstrate wavelength conversion of advanced modulation formats such as 10-GBd 64-QAM and 256-QAM with high conversion efficiency over a 29-nm spectral window by using four-wave mixing in an AlGaAs-On-Insulator (AlGaAsOI) nano-waveguide. A thorough characterization of the wavelength converter is reported, including the optimization of the AlGaAsOI nano-waveguide in terms of conversion efficiency and associated bandwidth and the analysis of the impact of the converter pump quality and power as well as the signal input power. The optimized converter enables generating idlers with optical signal-to-noise ratio (OSNR) above 30 dB over a 29-nm bandwidth leading to error-free conversion of 64-QAM and 256-QAM with OSNR penalty below 1.0 dB and 2.0 dB respectively. The generated idlers exhibit an OSNR margin to the chosen forward error correction thresholds of >3 dB and >7 dB for 64-QAM and 256-QAM, respectively, that can be used for transmission after conversion.

General information
State: Accepted/In press
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Coding and Visual Communication, Nanophotonic Devices
Number of pages: 8
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication Information
Journal: Journal of Lightwave Technology
ISSN (Print): 0733-8724
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.87 SJR 1.233 SNIP 1.881
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.689 SNIP 1.955 CiteScore 4.15
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.801 SNIP 2.423 CiteScore 4.23
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.533 SNIP 2.341 CiteScore 4.03
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.711 SNIP 2.335 CiteScore 3.21
ISI indexed (2012): ISI indexed yes
We demonstrate error-free performance of an MRR filtered DML on the SOI platform over 40- and 81-km of SSW. The device operates up to 17.5 Gb/s over 81 km and 20 Gb/s over 40 km.

**Bibliographical note**
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Source: PublicationPreSubmission

Source-ID: 133665129

Publication: Research - peer-review › Journal article – Annual report year: 2017

**Directly Modulated and ER Enhanced Hybrid III-V/SOI DFB Laser Operating up to 20 Gb/s for Extended Reach Applications in PONs**

We demonstrate error-free performance of an MRR filtered DML on the SOI platform over 40- and 81-km of SSW. The device operates up to 17.5 Gb/s over 81 km and 20 Gb/s over 40 km.

**General information**

State: Published

Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Nanophotonic Devices, Centre of Excellence for Silicon Photonics for Optical Communications, Technical University of Denmark, III V Lab, III V Lab, 1 Ave A Fresnel, F-91767 Palaiseau, France, Univ Rennes 1, Univ Rennes 1, CNRS UMR 6082, ENSSAT, FOTON Lab, F-22305 Lannion, France, FOTON Laboratory, III-V Lab
Experimental analysis of pilot-based equalization for probabilistically shaped WDM systems with 256QAM/1024QAM

Pilot based equalization is studied in a 5x10 Gbaud WDM transmission experiment. The equalization is independent of the modulation format and is demonstrated for 256/1024QAM with uniform and probabilistically optimized distribution using an optimized pilot insertion rate of 2-5%.

Nonlinear Phase Noise Compensation in Experimental WDM Systems with 256QAM

Nonlinear phase noise (NLPN) is studied in an experimental wavelength division multiplexed (WDM) system operating at 256QAM. Extremely narrow linewidth lasers (<1 kHz) at the transmitter and the receiver allow for extracting the phase part of the nonlinear noise in a Raman amplified link. Based on the experimental data, the autocorrelation function of the NLPN is estimated and it matches the theoretical predictions. Several algorithms are examined as candidates for tracking and compensating the NLPN. It is shown that algorithms which exploit the distribution of the NLPN achieve higher gains than standard methods, which only exploit the correlation properties. Up to 300 km reach increase is achieved for a 5x10 GBAud WDM system with base distance of up to 1600 km. The gains are comparable to the gains of single channel digital back-propagation, with even further improvements from the combination of both techniques.
Optical spectral reshaping for directly modulated 4-pulse amplitude modulation signals

The tremendous traffic growth in intra/inter-datacenters requires low-cost high-speed integrated solutions [1]. To enable a significantly reduced footprint directly modulated lasers (DMLs) have been proposed instead of large external modulators. However, it is challenging to use DMLs due to their low dispersion tolerance and limited achievable extinction ratio (ER). A promising solution to this problem is optical spectral reshaping (OSR) since it is possible to increase the dispersion tolerance as well as to enhance the achievable ER for both on-off-keying [2] and 4-pulse amplitude modulation (PAM) [3] signals. However, moving to 4-PAM, many of the impressive demonstrations reported so far rely heavily on off-line digital signal processing (DSP), which increases latency, power consumption and cost. In this talk, we report on (i) a detailed numerical analysis on the complex transfer function of the optical filter for optical spectral reshaping in case of pulse amplitude modulation and (ii) an experimental demonstration of real-time dispersion-compensated transmission of 10-Gb/s and 14-Gb/s PAM signals up to 10- and 26-km SSMF. This is achieved by combining a commercial 10-Gb/s DML with optical spectral shaping, thus removing the need for any complex off-line DSP and improving dispersion tolerance. These achievements are enabled by OSR based on a passive microring resonator fabricated on the SOI platform [4]. Significant improvement in receiver sensitivities was observed for both a 10-Gb/s signal after 10-km SSMF transmission and 14-Gb/s with no penalty after 26-km SSMF transmission.
Regeneration of phase unlocked serial multiplexed DPSK signals in a single phase sensitive amplifier

We demonstrate phase-regeneration of phase unlocked OTDM-DPSK serial signals in a single phase sensitive amplifier through optical cross-phase modulation. The BER of an 8×10 Gbit/s OTDM-DPSK signal is improved by 2 orders of magnitude.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Department of Micro- and Nanotechnology
Authors: Guan, P. (Intern), Da Ros, F. (Intern), Kjøller, N. (Intern), Hu, H. (Intern), Røge, K. M. (Intern), Galili, M. (Intern), Morioka, T. (Intern), Oxenløwe, L. K. (Intern)
Number of pages: 3
Pages: 1-3
Publication date: 2017

Host publication information
Title of host publication: Optical Fiber Communication Conference 2017
Publisher: Optical Society of America OSA
ISBN (Print): 978-1-943580-23-1
Series: 2017 Optical Fiber Communications Conference and Exhibition (ofc)
Main Research Area: Technical/natural sciences
Conference: Optical Fiber Communication Conference 2017, Los Angeles, United States, 19/03/2017 - 19/03/2017
Differential phase shift keying, Phase noise, Repeaters, Multiplexing, Receivers, Nonlinear optics
Electronic versions:
OFC2017.pdf
DOIs:
10.1364/OFC.2017.Th4I.5

Bibliographical note
From the session: Coherent Optical Signal Processing (Th4I)
Source: FindIt
Source-ID: 2371002306
Publication: Research - peer-review › Article in proceedings – Annual report year: 2017

Single Channel 106 Gbit/s 16QAM Wireless Transmission in the 0.4 THz Band

We experimentally demonstrate a single channel 32-GBd 16QAM THz wireless link operating in the 0.4 THz band. Post-FEC net data rate of 106 Gbit/s is successfully achieved without any spatial/frequency multiplexing.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Acreo Swedish ICT AB, Tianjin University, Zhejiang University, KTH - Royal Institute of Technology
Number of pages: 3
Publication date: 2017

Host publication information
Title of host publication: Optical Fiber Communication Conference 2017
Publisher: Optical Society of America (OSA)
Article number: Tu3B.5
ISBN (Print): 978-1-943580-23-1
Series: 2017 Optical Fiber Communications Conference and Exhibition (ofc)
Main Research Area: Technical/natural sciences
Conference: Optical Fiber Communication Conference 2017, Los Angeles, United States, 19/03/2017 - 19/03/2017
DOIs:
10.1364/OFC.2017.Tu3B.5

Bibliographical note
Supercontinuum comb sources for broadband communications based on AlGaAs-on-insulator
We experimentally demonstrated 10 GHz frequency comb spectral broadening in an AlGaAsOI nano-waveguide with the peak power of only several watts. The spectral broadened 10 GHz frequency comb has high optical signal to noise ratio (OSNR) at the output of the nano-waveguide. As far as we know, it is the first photonic chip based frequency comb, relying on spectral broadening of a 10 GHz mode-locked laser comb in an AlGaAsOI nano-waveguide, with a sufficient comb output power to support several hundred Tbit/s optical data.

Ultra-broadband optical signal processing using AlGaAs-OI devices
Aluminum Gallium Arsenide on insulator (AlGaAs-OI) has recently been developed into a very attractive platform for optical signal processing. This paper reviews key results of broadband optical signal processing using this platform.

Ultra-broadband optical signal processing using AlGaAs-OI devices
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Ultra-broadband optical signal processing using AlGaAs-OI devices
Aluminum Gallium Arsenide on insulator (AlGaAs-OI) has recently been developed into a very attractive platform for optical signal processing. This paper reviews key results of broadband optical signal processing using this platform.
Wavelength conversion of QAM signals in a low loss CMOS compatible spiral waveguide

We demonstrate wavelength conversion of quadrature amplitude modulation (QAM) signals, including 32-GBd quadrature phase-shift keying and 10-GBd 16-QAM, in a 50-cm long high index doped glass spiral waveguide. The quality of the generated idlers for up to 20 nm of wavelength shift is sufficient to achieve a BER performance below the hard decision forward error correction threshold BER performance.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, City University of Hong Kong, Chinese Academy of Sciences, National Research University of Information Technologies, Swinburne University of Technology
Authors: Da Ros, F. (Intern), Porto da Silva, E. (Intern), Zibar, D. (Intern), Chu, S. T. (Ekstern), Little, B. E. (Ekstern), Morandotti, R. (Ekstern), Galili, M. (Intern), Moss, D. J. (Ekstern), Oxenløwe, L. K. (Intern)
Number of pages: 8
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: APL Photonics
Volume: 2
Issue number: 4
Article number: 046105
ISSN (Print): 2378-0967
Ratings:
Web of Science (2017): Indexed yes
Web of Science (2016): Indexed yes
Original language: English
Electronic versions:
1_2E4978945.pdf
DOIs:
10.1063/1.4978945
Source: FindIt
Source-ID: 2356015446
Publication: Research - peer-review › Journal article – Annual report year: 2017

16 channel WDM regeneration in a single phase-sensitive amplifier through optical Fourier transformation: ECOC 2016 – Post Deadline

We demonstrate simultaneous phase regeneration of 16-WDM DPSK channels using optical Fourier transformation and a single phase-sensitive amplifier. The BERs of 16-WDM×10-Gbit/s phase noise degraded DPSK signals are improved by 0.4-1.3 orders of magnitude.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications
Authors: Guan, P. (Intern), Da Ros, F. (Intern), Lilieholm, M. (Intern), Hu, H. (Intern), Røge, K. M. (Intern), Galili, M. (Intern), Morioka, T. (Intern), Oxenløwe, L. K. (Intern)
Number of pages: 22
Publication date: 2016
16-QAM Field-Quadrature Decomposition using Polarization-Assisted Phase Sensitive Amplification

Simultaneous I and Q extraction for 16-QAM is experimentally demonstrated through field-quadrature decomposition using a polarization-assisted phase sensitive amplifier. The quadrature components are successfully received and performance is evaluated through bit-error-ratio testing.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications
Authors: Kjøller, N. (Intern), Piels, M. (Intern), Da Ros, F. (Intern), Dalgaard, K. (Intern), Gallili, M. (Intern), Oxenløwe, L. K. (Intern)
Number of pages: 2
Publication date: 2016

260 Gbit/s photonic-wireless link in the THz band: Postdeadline Paper

A single-transmitter/single-receiver THz link (0.3-0.5 THz) with a record net data rate of 260 Gbit/s is experimentally demonstrated. Spectrally efficient multi-channel signal transmission is enabled by a novel frequency-band-allocation scheme with pre-and post-digital equalization.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, RISE ICT, Tianjin University, Zhejiang University, KTH - Royal Institute of Technology
Number of pages: 2
Publication date: 2016
Broadband and Efficient Dual-Pump Four-Wave Mixing in AlGaAs-On-Insulator Nano-Waveguide

We characterize dual-pump four-wave-mixing in AlGaAs-on-insulator nano-waveguides and demonstrate an output conversion efficiency as high as -8.5 dB at 155-mW pump power. The idler optical signal-to-noise ratio is above 25 dB over a 26-nm bandwidth.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Nanophotonic Devices
Authors: Da Ros, F. (Intern), Pu, M. (Intern), Ottaviano, L. (Intern), Hu, H. (Intern), Semenova, E. (Intern), Galili, M. (Intern), Yvind, K. (Intern), Oxenløwe, L. K. (Intern)
Number of pages: 2
Publication date: 2016

Characterization of a Wavelength Converter for 256-QAM Signals Based on an AlGaAs-On-Insulator Nano-waveguide

High efficiency and broadband wavelength conversion in a 9-mm AlGaAs-On-Insulator waveguide is shown to provide high-quality (OSNR > 30 dB) idler generation over a 28-nm bandwidth enabling error-free conversion of 10-GBd 256-QAM with OSNR penalty below 2.5 dB.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Coding and Visual Communication, Nanophotonic Devices
Constellation Shaping for WDM systems using 256QAM/1024QAM with Probabilistic Optimization

In this paper, probabilistic shaping is numerically and experimentally investigated for increasing the transmission reach of wavelength division multiplexed (WDM) optical communication system employing quadrature amplitude modulation (QAM). An optimized probability mass function (PMF) of the QAM symbols is first found from a modified Blahut-Arimoto algorithm for the optical channel. A turbo coded bit interleaved coded modulation system is then applied, which relies on many-to-one labeling to achieve the desired PMF, thereby achieving shaping gain. Pilot symbols at rate at most 2% are used for synchronization and equalization, making it possible to receive input constellations as large as 1024QAM. The system is evaluated experimentally on a 10 Gbaud, 5 channels WDM setup. The maximum system reach is increased w.r.t. standard 1024QAM by 20% at input data rate of 4.65 bits/symbol and up to 75% at 5.46 bits/symbol. It is shown that rate adaptation does not require changing of the modulation format. The performance of the proposed 1024QAM shaped system is validated on all 5 channels of the WDM signal for selected distances and rates. Finally, it was shown via EXIT charts and BER analysis that iterative demapping, while generally beneficial to the system, is not a requirement for achieving the shaping gain.

General information

State: Published
Organisations: Department of Photonics Engineering, Coding and Visual Communication, Centre of Excellence for Silicon Photonics for Optical Communications, High-Speed Optical Communication, Department of Telecommunication, Department of Micro- and Nanotechnology
Authors: Yankov, M. P. (Intern), Da Ros, F. (Intern), Porto da Silva, E. (Intern), Forchhammer, S. (Intern), Larsen, K. J. (Intern), Oxenløwe, L. K. (Intern), Galili, M. (Intern), Zibar, D. (Intern)
Pages: 5146 - 5156
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information

Journal: Journal of Lightwave Technology
Volume: 34
Issue number: 22
ISSN (Print): 0733-8724
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.87 SJR 1.233 SNIP 1.881
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.689 SNIP 1.955 CiteScore 4.15
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.801 SNIP 2.423 CiteScore 4.23
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.533 SNIP 2.341 CiteScore 4.03
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Direct modulation of a hybrid III-V/Si DFB laser with MRR filtering for 22.5-Gb/s error-free dispersion-uncompensated transmission over 2.5-km SSMF

Error-free and penalty-free transmission over 2.5 km SSMF of a 22.5 Gb/s data signal from a directly modulated hybrid III-V/Si DFB laser is achieved by enhancing the dispersion tolerance using a silicon micro-ring resonator.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Nanophotonic Devices, III-V Lab, FOTON Laboratory
Experimental Comparison of Gains in Achievable Information Rates from Probabilistic Shaping and Digital Backpropagation for DP-256QAM/1024QAM WDM Systems

Gains in achievable information rates from probabilistic shaping and digital backpropagation are compared for WDM transmission of $5 \times 10$ Gb/s DP-256QAM/1024QAM up to 1700 km of reach. The combination of both techniques is shown to provide gains of up to $\sim 0.5$ bits/QAM symbol.

Experimental Demonstration of Multidimensional Switching Nodes for All-Optical Data Center Networks

This paper reports on a novel ring-based data center architecture composed of multidimensional switching nodes. The nodes are interconnected with multicore fibers and can provide switching in three different physical, hierarchically overlaid dimensions (space, wavelength, and time). The proposed architecture allows for scaling in different dimensions while at the same time providing support for connections with different granularity. The ring topology reduces the number of different physical links required, leading to simplified cabling and easier link management, while optical bypass holds the prospect of low latency and low-power consumption. The performance of the multidimensional switching nodes has been investigated in an experimental demonstration comprising three network nodes connected with multicore fibers. Both high capacity wavelength connections and time-shared subwavelength connections have been established for connecting different nodes by switching in different physical dimensions. Error-free performance (BER $< 10^{-9}$) has been achieved for all the connections with various granularity in all the investigated switching scenarios. The scalability of the system has been studied by increasing the transmission capacity to 1 Tbit/s/core equivalent to 7 Tbit/s total throughput in a single seven-core multicore fiber. The error-free performance (BER $< 10^{-9}$) for all the connections confirms that the proposed architecture can meet the existing demands in data centers and accommodate the future traffic growth.
Experimental Study of Nonlinear Phase Noise and its Impact on WDM Systems with DP-256QAM

A probabilistic method for mitigating the phase noise component of the non-linear interference in WDM systems with Raman amplification is experimentally demonstrated. The achieved gains increase with distance and are comparable to the gains of single-channel digital back-propagation.

Low-penalty up to 16-QAM wavelength conversion in a low loss CMOS compatible spiral waveguide

Wavelength conversion of 32-Gbaud QPSK and 10-Gbaud 16-QAM is demonstrated using a 50-cm long low loss spiral Hydex-glass waveguide. BER < HD-FEC threshold is achieved over 10 nm bandwidth with OSNR penalty < 0.5 dB.
On-chip mode division multiplexing technologies

Space division multiplexing (SDM) is currently widely investigated in order to provide enhanced capacity thanks to the utilization of space as a new degree of multiplexing freedom in both optical fiber communication and on-chip interconnects. Basic components allowing the processing of spatial modes are critical for SDM applications. Here we present such building blocks implemented on the silicon-on-insulator (SOI) platform. These include fabrication tolerant wideband (de) multiplexers, ultra-compact mode converters and (de) multiplexers designed by topology optimization, and mode filters using one-dimensional (1D) photonic crystal silicon waveguides. We furthermore use the fabricated devices to demonstrate on-chip point-to-point mode division multiplexing transmission, and all-optical signal processing by mode-selective wavelength conversion. Finally, we report an efficient silicon photonic integrated circuit mode (de) multiplexer for few-mode fibers (FMFs).

General information

State: Published
Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Others, Diode Lasers and LED Systems, Huazhong University of Science and Technology, FOTON Laboratory
Authors: Ding, Y. (Intern), Frellsen, L. F. (Intern), Guan, X. (Intern), Xu, J. (Ekstern), Da Ros, F. (Intern), Ou, H. (Intern), Peucheret, C. (Ekstern), Frandsen, L. H. (Intern), Oxenløwe, L. K. (Intern), Yvind, K. (Intern)
Number of pages: 1
Pages: 977407
Publication date: 2016

Host publication information
Title of host publication: Proceedings of Spie
Volume: 9774
Publisher: SPIE - International Society for Optical Engineering
ISBN (Print): 9781510600096

Series: Proceedings of SPIE - International Society for Optical Engineering
ISSN: 0277-786X
Main Research Area: Technical/natural sciences
ENGINEERING, OPTICS, TELECOMMUNICATIONS, TAPERED DIRECTIONAL COUPLER, APODIZED GRATING COUPLER, SILICON WAVE-GUIDE, TOPOLOGY OPTIMIZATION, DESIGN, FIBER, DEMULTIPLEXER, FABRICATION, EFFICIENCY, CONVERSION, Mode division multiplexing, mode (de)multiplexer, mode converter, mode filter, topology optimization, photonic integrated circuit, Electronic, Optical and Magnetic Materials, Condensed Matter Physics, Computer Science Applications, Electrical and Electronic Engineering, Applied Mathematics, Integrated circuits, Light transmission, Multiplexing equipment, Optical communication, Optical fiber communication, Optical fiber fabrication, Optical fibers, Optical signal processing, Photonic devices, Photonics technology, Pulse analyzing circuits, Reconfigurable hardware, Shape optimization, Signal processing, Silicon, silicon on insulator technology, Space division multiple access, Topology, Waveguide filters, Mode converter, Mode filters, Mode-division multiplexing, Photonic integrated circuits, Multiplexing, Optical communication devices, equipment and systems, Optical system design, Optical information, image formation and analysis, Optical harmonic generation, frequency conversion, parametric oscillation and amplification, Photonic bandgap materials, Spatial filters, zone plates, and polarizers, Optical fibre fabrication, cladding, splicing, joining, Integrated optics, Multiplexing and switching in optical communication, Metal-insulator-semiconductor structures, Optical materials, Optical coatings and filters, Optical, image and video signal processing, demultiplexing, integrated optics, optical design techniques, optical fibre communication, optical fibre fabrication, optical filters, optical information processing, optical wavelength conversion, optimisation, photonic crystals, silicon, silicon-on-insulator, few-mode fibers, silicon photonic integrated circuit mode demultiplexer, mode-selective wavelength conversion, all-optical signal processing, on-chip point-to-point mode division multiplexing transmission, 1D photonic crystal silicon waveguides, mode filters, ultracompact mode converters, fabrication tolerant wideband, silicon-on-insulator platform, spatial mode
Phase-sensitive Four-wave Mixing in AlGaAs-on-Insulator Nano-waveguides

Phase-sensitive four-wave mixing is experimentally demonstrated in a 5-mm long AlGaAsOI nano-waveguide. More than 7 dB of phase-sensitive extinction ratio are reported without neither using active biasing nor polarization-assisted schemes. Measurements show a good match with numerical predictions.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications
Authors: Da Ros, F. (Intern), Pu, M. (Intern), Ottaviano, L. (Intern), Hu, H. (Intern), Semenova, E. (Intern), Gallili, M. (Intern), Yvind, K. (Intern), Oxenløwe, L. K. (Intern)
Number of pages: 2
Publication date: 2016

Host publication information
Title of host publication: Proceedings of 2016 IEEE Photonics Conference
Publisher: IEEE
Main Research Area: Technical/natural sciences
Conference: 2016 IEEE Photonics Conference, Waikoloa Beach, HI, United States, 02/10/2016 - 02/10/2016
Four-wave mixing, Phase sensitive amplification, Integrated waveguides
Electronic versions: DaRos_IPC16_submitted.pdf
Source: PublicationPreSubmission
Source-ID: 127459883
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

Performance of Multi-Channel DBP with Long-haul Frequency-Referenced Transmission

The impact of frequency referenced WDM source on the performance of dual polarization multi-channel digital backpropagation (MC-DBP) is experimentally investigated up to 4000 km of transmission. For a system with $4 \times 8$ Gbd DP-QPSK, such approach allows 0.6 dB more MC-DBP Q2-factor gain in the nonlinear regime, compared with an unreferenced scheme.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications
Authors: Porto da Silva, E. (Intern), Da Ros, F. (Intern), Zibar, D. (Intern)
Number of pages: 3
Publication date: 2016

Host publication information
Title of host publication: Proceedings of Optical Fiber Communications Conference and Exposition
Publisher: Optical Society of America (OSA)
Main Research Area: Technical/natural sciences
Conference: 2016 Optical Fiber Communication Conference and Exhibition, Anaheim, California, United States, 20/03/2016 - 20/03/2016
DOI: 10.1364/OFC.2016.Th2A.32

Bibliographical note
From the session: Poster Session II (Th2A)
Source: PublicationPreSubmission
Source-ID: 122900573
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

Phase-sensitive Four-wave Mixing in AlGaAs-on-Insulator Nano-waveguides

Phase-sensitive four-wave mixing is experimentally demonstrated in a 5-mm long AlGaAsOI nano-waveguide. More than 7 dB of phase-sensitive extinction ratio are reported without neither using active biasing nor polarization-assisted schemes. Measurements show a good match with numerical predictions.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Nanophotonic Devices
Authors: Da Ros, F. (Intern), Pu, M. (Intern), Ottaviano, L. (Intern), Hu, H. (Intern), Semenova, E. (Intern), Gallili, M. (Intern), Yvind, K. (Intern), Oxenløwe, L. K. (Intern)
Number of pages: 2
Publication date: 2016

Host publication information
Title of host publication: Proceedings of 2016 IEEE Photonics Conference
Publisher: IEEE
Main Research Area: Technical/natural sciences
Conference: 2016 IEEE Photonics Conference, Waikoloa Beach, HI, United States, 02/10/2016 - 02/10/2016
Four-wave mixing, Phase sensitive amplification, Integrated waveguides
Electronic versions: DaRos_IPC16_submitted.pdf
Source: PublicationPreSubmission
Source-ID: 127459883
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016
QPSK regeneration without active phase-locking
QPSK regeneration without active phase stabilization is investigated in numerical simulations. We propose an improved scheme for phase-locking free QPSK regeneration showing significant improvements in the error vector magnitude of the signal.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications
Authors: Kjøller, N. (Intern), Da Ros, F. (Intern), Røge, K. M. (Intern), Galili, M. (Intern), Oxenløwe, L. K. (Intern)
Number of pages: 2
Publication date: 2016

Host publication information
Title of host publication: 2016 Conference on Lasers and Electro-Optics
Publisher: Optical Society of America (OSA)
ISBN (Print): 9781943580118
Series: 2016 Conference on Lasers and Electro-optics (cleo)
Main Research Area: Technical/natural sciences
Conference: Conference on Lasers and Electro-Optics 2016, San Jose, California, United States, 05/06/2016 - 05/06/2016
Phase noise, Repeaters, Optical fiber amplifiers, Binary phase shift keying, Adaptive optics
Source: Findit
Source-ID: 2349999097
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

Single-Source AlGaAs Frequency Comb Transmitter for 661 Tbit/s Data Transmission in a 30-core Fiber
We demonstrate an AlGaAs-on-insulator nano-waveguide-based frequency comb with high OSNR enabling a single-source to fully load a 9.6-km heterogeneous 30-core fibre with 661 Tbit/s data achieved by 30xcores, 80xWDM, 40 Gbaud, and PDM-16QAM

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Nanophotonic Devices, Fujikura Ltd., NTT Corporation
Number of pages: 2
Publication date: 2016

Host publication information
Title of host publication: CLEO: Applications and Technology 2016
Publisher: Optical Society of America (OSA)
ISBN (Print): 978-1-943580-11-8
Main Research Area: Technical/natural sciences
Conference: Conference on Lasers and Electro-Optics 2016, San Jose, California, United States, 05/06/2016 - 05/06/2016
DOIs: 10.1364/CLEO_AT.2016.JTh4C.1

Bibliographical note
From the session: Postdeadline Session III (JTh4C)
Source: PublicationPreSubmission
Source-ID: 124260832
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

Synchronization Algorithm for SDN-controlled All-Optical TDM Switching in a Random Length Ring Network
We propose and demonstrate an algorithm that allows for automatic synchronization of SDN-controlled all-optical TDM switching nodes connected in a ring network. We experimentally show successful WDM-SDM transmission of data bursts between all ring nodes.

General information
Synchronization in a Random Length Ring Network for SDN-Controlled Optical TDM Switching

In this paper we focus on optical time division multiplexed (TDM) switching and its main distinguishing characteristics compared with other optical subwavelength switching technologies. We review and discuss in detail the synchronization requirements that allow for proper switching operation. In addition, we propose a novel synchronization algorithm that enables automatic synchronization of software defined networking controlled all-optical TDM switching nodes connected in a ring network. Besides providing synchronization, the algorithm also can facilitate dynamic slot size change and failure detection. We experimentally validate the algorithm behavior and achieve correct operation for three different ring lengths. Moreover, we experimentally demonstrate data plane connectivity in a ring network composed of three nodes and show successful wavelength division multiplexing space division multiplexing transmission and switching of data bursts when using the proposed algorithm to provide synchronization.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Networks Technology and Service Platforms, Copenhagen Center for Health Technology, University of Bristol
Authors: Kamchevska, V. (Intern), Cristofori, V. (Intern), Da Ros, F. (Intern), Guo, B. (Ekstern), Jackson, C. (Ekstern), Fagertun, A. M. (Intern), Ruepp, S. R. (Intern), Nejabati, R. (Ekstern), Simeonidou, D. (Ekstern), Dittmann, L. (Intern), Berger, M. S. (Intern), Oxenløwe, L. K. (Intern), Galili, M. (Intern)
Number of pages: 3
Publication date: 2016

Publication information
Journal: Journal of Optical Communications and Networking
Volume: 9
Issue number: 1
ISSN (Print): 1943-0620
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.621 SNIP 1.325 CiteScore 3.06
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.883 SNIP 1.736 CiteScore 3.39
Web of Science (2015): Indexed yes
THz photonic wireless links with 16-QAM modulation in the 375-450 GHz band

We propose and experimentally demonstrate THz photonic wireless communication systems with 16-QAM modulation in the 375-450 GHz band. The overall throughput reaches as high as 80 Gbit/s by exploiting four THz channels with 5 Gbaud 16-QAM baseband modulation per channel. We create a coherent optical frequency comb (OFC) for photonic generation of multiple THz carriers based on photo-mixing in a uni-travelling carrier photodiode (UTC-PD). The OFC configuration also allows us to generate reconfigurable THz carriers with low phase noise. The multiple-channel THz radiation is received by using a Schottky mixer based electrical receiver after 0.5 m free-space wireless propagation. 2-channel (40 Gbit/s) and 4-channel (80 Gbit/s) THz photonic wireless links with 16-QAM modulation are reported in this paper, and the bit error rate (BER) performance for all channels in both cases is below the hard decision forward error correction (HD-FEC) threshold of 3.8e-3 with 7% overhead. In addition, we also successfully demonstrate hybrid photonic wireless transmission of 40 Gbit/s 16-QAM signal at carrier frequencies of 400 GHz and 425 GHz over 30 km standard single mode fiber (SSMF) between the optical baseband signal transmitter and the THz wireless transmitter with negligible induced power penalty.
Tolerance of continuous NFT spectrum to the optical fiber channel impairments
The impact of launch power, additive white Gaussian noise and fiber loss on the nonlinear Fourier transform (NFT) continuous spectrum is investigated. NFT is shown to undergo lower spectral distortion than the discrete Fourier transform.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Gaiarin, S. (Intern), Da Ros, F. (Intern), Sørensen, M. P. (Intern), Zibar, D. (Intern)
Number of pages: 3
Publication date: 2016
computational complexity of the proposed CPR scheme is studied, and reduction factors of 24.5 | 30.1 and 59.1 | 63.3 are achieved for C-16QAM and C-64QAM, respectively, compared to single-stage BPS in the form of multipliers | adders.

**General information**
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, RISE ICT, KTH - Royal Institute of Technology
Authors: Rodrigo Navarro, J. (Ekstern), Kakkar, A. (Ekstern), Pang, X. (Ekstern), Iglesias Olmedo, M. (Ekstern), Ozolins, O. (Ekstern), Da Ros, F. (Intern), Piels, M. (Intern), Schatz, R. (Ekstern), Zibar, D. (Intern), Jacobsen, G. (Ekstern), Popov, S. (Ekstern)
Number of pages: 11
Publication date: 2016
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Photonics
Volume: 3
Issue number: 2
ISSN (Print): 2304-6732

**Wavelength Conversion of QPSK and 16-QAM Coherent Signals in a CMOS Compatible Spiral Waveguide**
We characterize a wavelength converter based on a 50-cm long low-loss spiral Hydex waveguide. A 10-nm FWM bandwidth is shown over which low OSNR penalty (< 0.5dB) wavelength conversion of QPSK and 16-QAM is reported.

**General information**
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Swinburne University of Technology, City University of Hong Kong, Chinese Academy of Sciences, Institut National de la Recherche Scientifique
Authors: Da Ros, F. (Intern), Porto da Silva, E. (Intern), Zibar, D. (Intern), Chu, S. T. (Ekstern), Little, B. E. (Ekstern), Morandotti, R. (Ekstern), Gallii, M. (Intern), Moss, D. J. (Ekstern), Oxenløwe, L. K. (Intern)
Publication date: 2016

**Host publication information**
Title of host publication: Integrated Photonics Research, Silicon and Nanophotonics 2016
Publisher: SPIE - International Society for Optical Engineering
ISBN (Print): 978-1-943580-14-9
Main Research Area: Technical/natural sciences

**Bibliographical note**
From the session: Highly Nonlinear Optical Fibres and Nanowires (IM3A)
Source: PublicationPreSubmission
Source-ID: 125287201
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

**A Novel Phase Sensitive Amplifier Based QPSK Regenerator Without Active Phase-Locking**
We propose a novel QPSK regenerator scheme based on phase sensitive amplification of a pre-conditioned signal avoiding active phase-locking. Signal pre-conditioning is demonstrated experimentally with error-free (BER < 10-9)
performance for a 10-Gbaud QPSK signal.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications
Authors: Kjøller, N. (Intern), Da Ros, F. (Intern), Røge, K. M. (Intern), Guan, P. (Intern), Galili, M. (Intern), Oxenløwe, L. K. (Intern)
Number of pages: 2
Publication date: 2015

Host publication information
Title of host publication: Proceedings of IEEE Photonics Conference
Publisher: IEEE
ISBN (Print): 9781479974658
Main Research Area: Technical/natural sciences
Conference: 2015 IEEE Photonics Conference, Reston, Virginia, United States, 04/10/2015 - 04/10/2015
Optical signal processing, Cross phase modulation, Phase sensitive amplification
DOIs: 10.1109/IPCon.2015.7323558
Source: PublicationPreSubmission
Source-ID: 118221737
Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

Experimental Demonstration of 6-Mode Division Multiplexed NG-PON2: Cost Effective 40 Gbit/s/Spatial-Mode Access Based on 3D Laser Inscribed Photonic Lanterns
We report the first space-division-multiplexed based symmetric NG-PON2 network by efficiently transmitting 40 Gbit/s/spatial-mode. Error free transmission (BER of 10−9) is obtained for all the downstream and upstream data tributaries over 1-km 6-spatial-mode FMF without using MIMO DSP

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Optoscribe Ltd
Authors: Asif, R. (Intern), Hu, H. (Intern), Mitchell, P. (Ekstern), Macdonald, J. (Ekstern), Da Ros, F. (Intern), Psaila, N. (Ekstern), Ye, F. (Intern), Oxenløwe, L. K. (Intern), Morioka, T. (Intern)
Number of pages: 3
Publication date: 2015
Main Research Area: Technical/natural sciences
Electronic versions: ecoc_2015_manuscript_final.pdf
DOIs: 10.1109/ECOC.2015.7341921
Source: PublicationPreSubmission
Source-ID: 116743924
Publication: Research - peer-review › Paper – Annual report year: 2015

Experimental Demonstration of Multidimensional Switching Nodes for All-Optical Data Centre Networks
We experimentally demonstrate network nodes that enable SDM/WDM/TDM switching. 1 Tbit/s/core error-free performance is achieved for connections with different granularities being switched between three network nodes interconnected with 7-core multicore fibres.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Networks Technology and Service Platforms
Number of pages: 2
Publication date: 2015
Main Research Area: Technical/natural sciences
Source: PublicationPreSubmission
Kerr Nonlinearity Mitigation: Mid-Link Spectral Inversion Versus Digital Backpropagation in 5x28-GBd PDM 16-QAM Signal Transmission

We experimentally investigate Kerr nonlinearity mitigation of a 28-GBd polarization-multiplexed 16-QAM signal in a five-channel 50-GHz spaced wavelength-division multiplexing (WDM) system. Optical phase conjugation (OPC) employing the mid-link spectral inversion technique is implemented by using a dual-pump polarization-independent fiber-optic parametric amplifier and compared to digital backpropagation (DBP) compensation over up to 800-km in a dispersion-managed link. In the single-channel case, the use of the DBP algorithm outperformed the OPC with a Q-factor improvement of 0.9 dB after 800-km transmission. However, signal transmission was not possible with DBP in the WDM scenario over the same link length while it was enabled by the OPC with a maximum Q-factor of 8.6 dB.
Multichannel nonlinear distortion compensation using optical phase conjugation in a silicon nanowire

We experimentally demonstrate compensation of nonlinear distortion caused by the Kerr effect in a 3 x 32-Gbaud quadrature phase-shift keying (QPSK) wavelength-division multiplexing (WDM) transmission system. We use optical phase conjugation (OPC) produced by four-wave mixing (FWM) in a 7-mm long silicon nanowire. A clear improvement in Q-factor is shown after 800-km transmission with high span input power when comparing the system with and without the optical phase conjugation module. The influence of OSNR degradation introduced by the silicon nanowire is analysed by comparing transmission systems of three different lengths. This is the first demonstration of nonlinear compensation using a silicon nanowire. (C)2015 Optical Society of America
ISSN (Print): 1094-4087

Ratings:

BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes

BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.48 SJR 1.487 SNIP 1.589
Web of Science (2016): Indexed yes

BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.976 SNIP 1.755 CiteScore 3.78
Web of Science (2015): Indexed yes

BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.349 SNIP 2.166 CiteScore 4.18
Web of Science (2014): Indexed yes

BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.358 SNIP 2.226 CiteScore 4.38
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes

BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.587 SNIP 2.145 CiteScore 3.85
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes

BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.579 SNIP 2.606 CiteScore 4.04
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes

BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.943 SNIP 2.466
Web of Science (2010): Indexed yes

BFI (2009): BFI-level 2
Scopus rating (2009): SJR 3.092 SNIP 2.669
Web of Science (2009): Indexed yes

BFI (2008): BFI-level 2
Scopus rating (2008): SJR 3.195 SNIP 2.393
Web of Science (2008): Indexed yes

Scopus rating (2007): SJR 3.27 SNIP 2.032
Web of Science (2007): Indexed yes

Scopus rating (2006): SJR 3.233 SNIP 2.326
Web of Science (2006): Indexed yes

Scopus rating (2005): SJR 3.334 SNIP 2.379
Web of Science (2005): Indexed yes

Scopus rating (2004): SJR 2.833 SNIP 2.499
Web of Science (2004): Indexed yes

Scopus rating (2003): SJR 2.688 SNIP 2.193
Web of Science (2003): Indexed yes

Scopus rating (2002): SJR 1.547 SNIP 1.673
Web of Science (2002): Indexed yes

Scopus rating (2001): SJR 1.442 SNIP 1.39
Web of Science (2001): Indexed yes

Scopus rating (2000): SJR 1.246 SNIP 0.714
Web of Science (2000): Indexed yes

Scopus rating (1999): SJR 1.381 SNIP 0.838

Original language: English

OPTICS, WAVELENGTH CONVERSION, SPECTRAL INVERSION, WAVE-GUIDE, DISPERSION, SYSTEMS, SIGNALS, LINK, OFDM
Optical phase conjugation for nonlinearity compensation in WDM PDM 16-QAM transmission over dispersion-compensated and dispersion-uncompensated links

Kerr nonlinearity compensation by optical phase conjugation is demonstrated in a WDM PDM 16-QAM system. Improved received signal quality is reported for both dispersion-compensated and dispersion-uncompensated transmission and a comparison with digital backpropagation is provided.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, FRAUNHOFER Gesellschaft, FOTON, Technical University of Berlin
Authors: Da Ros, F. (Intern), Sackey, I. (Extern), Jazayerifar, M. (Extern), Richter, T. (Extern), Elschner, R. (Extern), Meuer, C. (Extern), Noelle, M. (Extern), Molle, L. (Extern), Petermann, K. (Extern), Fischer, J. (Extern), Schubert, C. (Extern), Peucheret, C. (Extern)
Pages: 72-73
Publication date: 2015

Host publication information
Title of host publication: Proceedings of 2015 IEEE Photonics Society Summer Topicals Meeting Series
Publisher: IEEE
ISBN (Print): 978-1-4799-7468-9
Main Research Area: Technical/natural sciences
Electronic versions:
DaRos_SummerTopicals2015_NOL_PID3621375_submitted.pdf

Perspectives of Long-Haul WDM Transmission Systems Based on Phase-insensitive Fiber-Optic Parametric Amplifiers

The deployment of phase-insensitive fiber-opticparametric amplifiers (PI-FOPAs) as inline amplifiers in longhaul WDM transmission systems is discussed, and it is outlined how to design PI-FOPAs to be a valuable upgrade option for this application.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Technische Universität Berlin, FOTON, Technical University of Berlin, Fraunhofer Gesellschaft
Authors: Jazayerifar, M. (Extern), Sackey, I. (Extern), Elschner, R. (Extern), Da Ros, F. (Intern), Richter, T. (Extern), Meuer, C. (Extern), Peucheret, C. (Extern), Schubert, C. (Extern), Petermann, K. (Extern)
Pages: 211-212
Publication date: 2015

Host publication information
Title of host publication: Proceedings of 2015 IEEE Photonics Society Summer Topicals Meeting Series
Publisher: IEEE
ISBN (Print): 978-1-4799-7468-9
Main Research Area: Technical/natural sciences
Electronic versions:
Jazayerifar_SumTop2015_v5_submitted.pdf

DOIs:
Phase Regeneration of a BPSK Data Signal Using a Lithium Niobate Phase Modulator

We propose a scheme for phase regeneration of an optical binary phase shift keying (BPSK) data signal using a Lithium Niobate (LiNbO₃) phase modulator. The scheme is based on heterodyne detection of the BPSK data signal with a continuous wave local oscillator (CW-LO). Carrier recovery is then achieved in the electrical domain using a ×2 frequency-multiplier and a narrow-band filtering scheme. Subsequently, a superposition of the recovered carrier and the heterodyne detected data signal is used to modulate the CW-LO in a LiNbO₃ phase modulator. The result is a parametric mixing process in the optical domain, leading to a phase-regenerated BPSK data signal by the coherent superposition with a phase-inverted copy. The proposed scheme constitutes a compact and stable setup, where active phase-stabilization of the electrical data- and carrier-paths can potentially be avoided. An analytical derivation of the working principle is provided, using Jacobi–Anger expansions to describe the phase-modulation. A proof-of-principle experiment is carried out, demonstrating regeneration of a 10 Gb/s NRZ-BPSK data signal degraded by a 5-GHz sinusoidal phase-noise tone. In the proof-of-principle demonstration, the decorrelated data- and LO-carriers are derived from the same CW source. A preliminary test with separate CW sources for data and LO, but without the required electrical narrow-band carrier filtering, is also included. Finally, numerical simulations of the regenerator performance in the presence of wideband phase- and amplitude-noise are performed.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication
Authors: Mulvad, H. C. H. (Intern), Da Ros, F. (Intern), Galili, M. (Intern), Dalgaard, K. (Intern), Oxenløwe, L. K. (Intern)
Pages: 2189-2198
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Lightwave Technology
Volume: 33
Issue number: 11
ISSN (Print): 0733-8724
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.87 SJR 1.233 SNIP 1.881
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.689 SNIP 1.955 CiteScore 4.15
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.801 SNIP 2.423 CiteScore 4.23
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.533 SNIP 2.341 CiteScore 4.03
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.711 SNIP 2.335 CiteScore 3.21
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.605 SNIP 2.758 CiteScore 3.2
ISI indexed (2011): ISI indexed yes
Phase-sensitive optical processing in silicon waveguides

Parametric optical signal processing is reviewed for silicon nano-rib-waveguides with a reverse-biased pin-junction. Phase-sensitive parametric amplification with a phase-sensitive extinction of more than 20 dB has been utilized for the regeneration of DPSK signals.

General information

State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Technische Universität Berlin, University of Rennes, Technical University of Berlin, Innovations for High Performance Microelectronics GmbH
Number of pages: 3
Publication date: 2015

Host publication information

Title of host publication: Proceedings of the Optical Fiber Communication Conference and Exhibition 2015
Publisher: IEEE
Article number: Tu2F.4
ISBN (Print): 978-1-55752-937-4
Main Research Area: Technical/natural sciences
Conference: Optical Fiber Communications Conference and Exposition 2015, Los Angeles, CA, United States, 22/03/2015 - 22/03/2015
Signal processing for on-chip space division multiplexing

Our recent results on the demonstration of on-chip mode-division multiplexing are reviewed, with special emphasis on nonlinear all-optical signal processing. Mode-selective parametric processes are demonstrated in a silicon-on-insulator waveguide.

Host publication information
Title of host publication: Signal Processing in Photonic Communications 2015
Publisher: Optical Society of America OSA
Article number: SpT2E.3
ISBN (Print): 978-1-55752-000-5
Main Research Area: Technical/natural sciences
Conference: Signal Processing in Photonic Communications 2015, Boston, Massachusetts, United States, 27/06/2015 - 27/06/2015
DOIs: 10.1364/SPPCOM.2015.SpT2E.3

All-Optical Regeneration System for Optical Wavelength Division Multiplexed Communication Systems
The invention relates to an all-optical regeneration system for regeneration of optical wavelength division multiplexed WDM data signals in an optical WDM communication system. The system comprises a WDM-to-Optical time domain multiplexing OTDM, WDM-to-OTDM, converter, capable of converting an input WDM data signal comprising multiple wavelength channels into an input OTDM data signal comprising multiple time multiplexed time channels. The system further comprises an all-optical regenerator unit being configured for regenerating the input OTDM data signal into an output OTDM data signal. The system additionally comprises an OTDM-to-WDM converter for converting the output OTDM data signal to an output WDM data signal. An input of the all-optical regenerator unit is in optical communication with an output of the WDM-to-OTDM converter, and an output of the all-optical regenerator unit is in optical communication with an input of the OTDM-to-WDM converter. The invention further relates to a method for all-optical regeneration of WDM data signals.

Publication information
IPC: H04B10/291
All-Optical Signal Processing using Silicon Devices

This paper presents an overview of recent work on the use of silicon waveguides for processing optical data signals. We will describe ultra-fast, ultra-broadband, polarization-insensitive and phase-sensitive applications including processing of spectrally-efficient data formats and optical phase regeneration.

Design and Performance Evaluation of an OPC Device Using a Dual-Pump Polarization-Independent FOPA

The performance of a polarization-independent fiber-based optical parametric amplifier is experimentally investigated in terms of amplification and wavelength conversion for optical phase conjugation applications using 5×28-GBd PDM 16-QAM signals. Good conjugated signal quality up to 13-dB gain is obtained.
Experimental demonstration of an OFDM receiver based on a silicon-nanophotonic discrete Fourier transform filter.

We experimentally demonstrate the demultiplexing of 8×13.4 Gbaud OFDM-QPSK subcarriers using a silicon nanophotonic-based discrete Fourier transform (DFT) filter. All eight subcarriers showed less than 1.5 dB OSNR penalty compared to the theoretical limit.

Kerr nonlinearity compensation in a 5×28-Gbd PDM 16-QAM WDM system using fiber-based optical phase conjugation

Effective Kerr nonlinearity mitigation is experimentally demonstrated using optical phase conjugation in the middle of an 800-km dispersion-compensated link for a 5-channel WDM 28-Gbd PDM 16-QAM signal. A Q-factor improvement of 0.9 dB over no mitigation allows a BER.

Kerr nonlinearity mitigation in 5 × 28-Gbd PDM16-QAM signal transmission over a dispersion-uncompensated link with backward-pumped distributed Raman amplification.

We present experimental and numerical investigations of Kerr nonlinearity compensation in a 400-km standard single-mode fiber link with distributed Raman amplification with backward pumping. A dual-pump polarization-independent fiber-based optical parametric amplifier is used for mid-link spectral inversion of 5 × 28-Gbd polarization-multiplexed 16-Q AM signals. Signal quality factor (Q-factor) improvements of 1.1 dB and 0.8 dB were obtained in the cases of a single-channel and a five-channel wavelength-division multiplexing (WDM) system, respectively. The experimental results are compared to numerical simulations with good agreement. It is also shown with simulations that a maximum transmission reach of 2400 km enabled by the optical phase conjugator is possible for the WDM signal.
Optical Processing of High Dimensionality Signals

Optical parametric amplifiers (OPAs) combine high-gain broadband amplification at nearly arbitrary wavelengths with the prospect for achieving an ideally 0-dB noise figure when used in phase-sensitive configuration. Furthermore, several recent demonstrations confirm their potential for all-optical signal processing, including wavelength conversion, optical phase conjugation (OPC), and signal regeneration.

This project focuses precisely on the applications of OPAs for all-optical signal processing with a two-fold focus: on the one hand, processing the advanced modulation formats required to increase the capacity of future communication systems; on the other hand, the different nonlinear material suitable for providing parametric amplification. Therefore, three different materials, namely silica highly nonlinear fibers (HNLFs), silicon waveguides, and periodically poled lithium niobate (PPLN) waveguides, are investigated. The limits of parametric amplification for 16-quadrature amplitude modulation (QAM) signals are first characterized. The acquired knowledge is then applied to the design of a black-box OPC-device used to provide Kerr nonlinearity compensation for a 5-channel polarization-division multiplexing (PDM) 16-QAM signal at 1.12 Tbps with significant improvements in received signal quality.

Furthermore, the first demonstration of phase regeneration for binary phase-shift keying (BPSK) signals using the silicon platform is presented. The silicon-based OPA relies on a novel design where a reverse-biased p-i-n junction fabricated along the waveguide allows decreasing the nonlinear absorption, thus achieving phase-sensitive extinction ratios in excess of 20 dB. Finally, a recently proposed quadrature phase-shift keying (QPSK)-to-2×BPSK wavelength and format converter is characterized experimentally by implementing it using fiber-, silicon, and PPLN-based platforms. Similar results have been measured for all three media under continuous-wave operation and for fiber- and PPLN-based implementations under modulated signal operations with little penalty introduced by the conversion.

Altogether this work demonstrates the potential of phase-insensitive and phase-sensitive parametric processing applied to high-dimensionality modulation formats.
Parametric Optical Signal Processing in Silicon Waveguides with Reverse-biased p-i-n Junctions

The use of silicon-on-insulator waveguides with free carriers removal using a reverse-biased p-i-n junction for parametric optical signal processing is reviewed. High-efficiency wavelength conversion and phase-sensitive regeneration are reported.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, University of Rennes, Technische Universität Berlin, Innovations for High Performance Microelectronics GmbH
Authors: Peucheret, C. (Ekstern), Da Ros, F. (Intern), Vukovic, D. (Intern), Dalgaard, K. (Intern), Galili, M. (Intern), Gajda, A. (Ekstern), Zimmermann, L. (Ekstern), Tillack, B. (Ekstern), Petermann, K. (Ekstern)
Pages: 116-117
Publication date: 2014

Host publication information
Title of host publication: Proceedings of 2014 IEEE Summer Topicals Meeting Series
Publisher: IEEE
ISBN (Print): 978-1-4799-2767-8
Main Research Area: Technical/natural sciences
Conference: 2014 Summer Topicals Meeting Series, Montreal, Canada, 14/06/2014 - 14/06/2014
Nonlinear optical signal processing, Silicon nano-waveguides, Four-wave mixing, Phase-sensitive processes
DOIs:
10.1109/SUM.2014.67

Bibliographical note
TuD4 » Nonlinear processing in emerging material platforms II (15:30 - Tuesday, 15th July, Tchalkovsky)
Publication: Research - peer-review › Article in proceedings – Annual report year: 2014

Parametric Phase-sensitive and Phase-insensitive All-optical Signal Processing on Multiple Nonlinear Platforms - Invited talk.

Parametric processes in materials presenting a second- or third-order nonlinearity have been widely used to demonstrate a wide range of all-optical signal processing functionalities, including amplification, wavelength conversion, regeneration, sampling, switching, modulation format conversion, optical phase conjugation, etc. The recent evolution of optical communication systems towards advanced modulation formats making use of the phase dimension, as well as polarization and, more recently, space-multiplexing, has created new requirements, as well as new opportunities, for parametric all-optical signal processing. In this presentation, we will review our recent results on the demonstration of all-optical parametric signal processing using different nonlinear platforms, including highly nonlinear optical fibers (HNLFs), silicon nanowires, and periodically-poled lithium niobate (PPLN) waveguides. In particular, we will show how phase-sensitive processes can be engineered to demonstrate phase-quadrature separation, which we have recently demonstrated in HNLFs [1] and PPLN waveguides [2]. Silicon nanowires are particularly attractive for signal processing thanks to their compact size, CMOS-compatible fabrication process, degrees of freedom in dispersion engineering, and high nonlinear coefficient. However, the detrimental effect of free-carrier absorption induced by two-photon absorption has so far prevented them from being used for the demonstration of phase-sensitive processing. Thanks to the introduction of p-i-n junctions across silicon waveguides, we have recently been able to demonstrate phase-sensitive extinction ratios as high as 20 dB, allowing the phase regeneration of phase-modulated signals under continuous wave pumping operation [3]. One of the well-known limitations of planar waveguide devices for all-optical signal processing is their inherent polarization sensitivity. We will show how the introduction of polarization-diversity circuits relying on electric and wideband polarization splitters and rotators [4] can overcome this limitation. Finally, we will also discuss the introduction of signal processing functionalities that are compatible with the novel dimension of space multiplexing. More speciﬁcally, we will show how mode-selective wavelength conversion based on four-wave mixing can be realized in a multimode silicon waveguide [5].

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Nanophotonic Devices, Diode Lasers and LED Systems, University of Rennes, Huazhong University of Science and Technology, Tokyo University of Science, Innovations for High Performance Microelectronics GmbH, Technische Universität Berlin, Technical University of Berlin
Publication date: 2014
Event: Abstract from 35th Progress In Electromagnetics Research Symposium, Guangzhou (Canton), China.
Phase regeneration of DPSK signals in a silicon waveguide with reverse-biased p-i-n junction

Phase regeneration of differential phase-shift keying (DPSK) signals is demonstrated using a silicon waveguide as nonlinear medium for the first time. A p-i-n junction across the waveguide enables decreasing the nonlinear losses introduced by free-carrier absorption (FCA), thus allowing phase-sensitive extinction ratios as high as 20 dB to be reached under continuous-wave (CW) pumping operation. Furthermore, the regeneration properties are investigated under dynamic operation for a 10-Gb/s DPSK signal degraded by phase noise, showing receiver sensitivity improvements above 14 dB. Different phase noise frequencies and amplitudes are examined, resulting in an improvement of the performance of the regenerated signal in all the considered cases.

General information

State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Innovations for High Performance Microelectronics GmbH, Technical University of Berlin
Pages: 5029-5036
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information

Journal: Optics Express
Volume: 22
Issue number: 5
ISSN (Print): 1094-4087
Ratings:

- BFI (2017): BFI-level 2
- Web of Science (2017): Indexed yes
- BFI (2016): BFI-level 2
- Scopus rating (2016): CiteScore 3.48 SJR 1.487 SNIP 1.589
- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 2
- Scopus rating (2015): SJR 1.976 SNIP 1.755 CiteScore 3.78
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 2
- Scopus rating (2014): SJR 2.349 SNIP 2.166 CiteScore 4.18
- Web of Science (2014): Indexed yes
- BFI (2013): BFI-level 2
- Scopus rating (2013): SJR 2.358 SNIP 2.226 CiteScore 4.38
- ISI indexed (2013): ISI indexed yes
- Web of Science (2013): Indexed yes
- BFI (2012): BFI-level 2
- Scopus rating (2012): SJR 2.587 SNIP 2.145 CiteScore 3.85
- ISI indexed (2012): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 2
- Scopus rating (2011): SJR 2.579 SNIP 2.606 CiteScore 4.04
- ISI indexed (2011): ISI indexed yes
- Web of Science (2011): Indexed yes
- BFI (2010): BFI-level 2
Simultaneous QPSK-to-2 × BPSK wavelength and Modulation Format Conversion in PPLN
Phase-sensitive cascaded second-harmonic generation and difference-frequency generation in a periodically poled lithium niobate waveguide allow converting two orthogonal quadratures of an optical field to different wavelengths, thus enabling simultaneous quadrature phase-shift keying-to-2×binary phase-shift keying modulation format and wavelength conversions. Static phase-sensitive extinction ratios above 20 dB are obtained for both quadratures, resulting in error-free dynamic operation with low penalty (BER (10⁻⁹)) at 10 Gbaud.
A comparison of nonlinear media for parametric all-optical signal processing
We systematically compare nonlinear media for parametric signal processing by determining the minimum pump power that is required for a given conversion efficiency in a degenerate four-wave mixing process, including the effect of nonlinear loss.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication
Authors: Martinez Diaz, J. (Ekstern), Bohigas Nadal, J. (Ekstern), Vukovic, D. (Intern), Da Ros, F. (Intern), Palushani, E. (Intern), Peucheret, C. (Intern)
Number of pages: 2
Pages: 679-680
Publication date: 2013

Host publication information
Title of host publication: Proceedings of IEEE Photonics Conference (IPC) 2013
Publisher: IEEE
ISBN (Print): 978-1-4577-1506-8
Main Research Area: Technical/natural sciences
DOIs:
10.1109/IPCon.2013.6656477

Bibliographical note
ThG1.5
Publication: Research - peer-review › Article in proceedings – Annual report year: 2013

All-optical network coding for DPSK signals
All-optical network coding for path protection is experimentally demonstrated using four-wave mixing in SOAs for 10 Gbit/s NRZ-DPSK signals with error free performance. The total power penalty after two cascaded XOR stage is only 2 dB.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication
Authors: An, Y. (Intern), Da Ros, F. (Intern), Peucheret, C. (Intern)
Pages: JW2A.60
Publication date: 2013

Host publication information
Title of host publication: 2013 Optical Fiber Communication Conference and Exposition and the National Fiber Optic Engineers Conference (OFC/NFOEC)
Publisher: IEEE
ISBN (Print): 978-1-4799-0457-0
Main Research Area: Technical/natural sciences
Conference: 2013 Optical Fiber Communication Conference and Exposition and the National Fiber Optic Engineers Conference, Anaheim, CA, United States, 17/03/2013 - 17/03/2013
DOIs:
10.1364/NFOEC.2013.JW2A.60
Publication: Research - peer-review › Article in proceedings – Annual report year: 2014

All-optical three-input logic minterms generation using semiconductor optical amplifier-based Sagnac interferometer
All-optical three-input logic minterms are generated at 42 Gbit/s with a Sagnac interferometer by using cross-phase modulation in a semiconductor optical amplifier. To the best of the author's knowledge, this is the first time that high-speed logic operations with more than two inputs have been experimentally demonstrated in a Sagnac interferometer. Correct and clear temporal waveforms are successfully observed. Bit error ratios and optical signal-to-noise ratios are measured to demonstrate the effectiveness of the method. As the basic units of combinational logic operations, logic minterms are promising candidates to construct reconfigurable and programmable logic functions.
Continuous Wave Phase-Sensitive Four-Wave Mixing in Silicon Waveguides With Reverse-Biased p-i-n Junctions

Phase-sensitive four-wave mixing is experimentally demonstrated using continuous wave pumps in silicon waveguides with p-i-n junctions. The reverse biasing allows decreasing the free carrier lifetime, enabling a phase-sensitive extinction ratio in excess of 15 dB.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Technische Universität Berlin, Innovations for High Performance Microelectronics GmbH
Authors: Da Ros, F. (Intern), Vukovic, D. (Intern), Gajda, A. (Ekstern), Zimmermann, L. (Ekstern), Petermann, K. (Ekstern), Peucheret, C. (Intern)
Number of pages: 3
Publication date: 2013

Fiber Optical Parametric Chirped Pulse Amplification of Sub-Picosecond Pulses
We demonstrate experimentally, for the first time to our knowledge, fiber optical parametric chirped pulse amplification of 400-fs pulses. The 400-fs signal is stretched, amplified by 26 dB and compressed back to 500 fs.

General information
State: Published
Organisations: Department of Photonics Engineering, Fiber Optics, Devices and Non-linear Effects, High-Speed Optical Communication
Authors: Cristofori, V. (Intern), Lali-Dastjerdi, Z. (Intern), Da Ros, F. (Intern), Rishej, L. S. (Intern), Galili, M. (Intern), Peucheret, C. (Intern), Rottwitt, K. (Intern)
Number of pages: 2
Pages: TuS2-3
Publication date: 2013
High Efficiency Wavelength Conversion of 40 Gbps Signals at 1550 nm in SOI Nano-Rib Waveguides Using p-i-n Diodes

We demonstrate enhancement of FWM wavelength conversion of a 40 Gbps signal in a reverse-biased p-i-n junction silicon waveguide. A conversion efficiency of −4.6 dB enables a conversion power penalty as low as 0.2 dB.

On-chip two-mode division multiplexing using tapered directional coupler-based mode multiplexer and demultiplexer

Abstract: We demonstrate a novel on-chip two-mode division multiplexing circuit using a tapered directional coupler-based TE0&TE1 mode multiplexer and demultiplexer on the silicon-on-insulator platform. A low insertion loss (0.3 dB), low mode crosstalk (< −16 dB), wide bandwidth (~100 nm), and large fabrication tolerance (20 nm) are measured. An on-chip mode multiplexing experiment is carried out on the fabricated circuit with non return-to-zero (NRZ) on-off keying (OOK) signals at 40 Gbit/s. The experimental results show clear eye diagrams and moderate power penalty for both TE0 and TE1 modes.
Orthogonal Phase Quadratures Conversion to Different Wavelengths Through Phase-Sensitive Four Wave Mixing in an Highly Nonlinear Fiber

Phase-sensitive processes exploiting FWM in an HNLF allow simultaneously converting two orthogonal quadratures of an optical signal to different wavelengths. Conversion efficiencies to two 90°-phase-shifted idlers exceeding 10 dB of phase-sensitive extinction ratio are obtained experimentally.

Phase Noise Tolerant QPSK Receiver Using Phase Sensitive Wavelength Conversion

A novel QPSK receiver based on a phase noise reduction pre-stage exploiting PSA in a HNLF and balanced detection is presented. Receiver sensitivity improvement over a conventional balanced receiver is demonstrated.

Polarization diversity DPSK demodulator on the silicon-on-insulator platform with simple fabrication

We demonstrate a novel polarization diversity differential phase-shift keying (DPSK) demodulator on the SOI platform, which is fabricated in a single lithography and etching step. The polarization diversity DPSK demodulator is based on a novel polarization splitter and rotator, which consists of a tapered waveguide followed by a 2 x 2 multimode interferometer. A lowest insertion loss of 0.5 dB with low polarization dependent loss of 1.6 dB and low polarization dependent extinction ratio smaller than 3 dB are measured for the polarization diversity circuit. Clear eye-diagrams and a finite power penalty of only 3 dB when the input state of polarization is scrambled are obtained for 40 Gbit/s non return-to-zero DPSK (NRZ-DPSK) demodulation.
Publication information
Journal: Optics Express
Volume: 21
Issue number: 6
ISSN (Print): 1094-4087

Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.48 SJR 1.487 SNIP 1.589
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.976 SNIP 1.755 CiteScore 3.78
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.349 SNIP 2.166 CiteScore 4.18
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.358 SNIP 2.226 CiteScore 4.38
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.587 SNIP 2.145 CiteScore 3.85
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.579 SNIP 2.606 CiteScore 4.04
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.943 SNIP 2.466
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 3.092 SNIP 2.669
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 3.195 SNIP 2.393
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 3.27 SNIP 2.032
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 3.233 SNIP 2.326
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 3.334 SNIP 2.379
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.833 SNIP 2.499
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 2.688 SNIP 2.193
Web of Science (2003): Indexed yes
Polarization Diversity DPSK Demodulator on the Silicon-on-Insulator Platform with Simple Fabrication

We demonstrate a novel polarization diversity DPSK demodulator on the SOI platform with low polarization dependent loss (1.6 dB) and low polarization dependent extinction ratio (<3 dB). System experiments verify the low polarization dependency.

QPSK-to-2xBPSK wavelength and modulation format conversion through phase-sensitive four-wave mixing in a highly nonlinear optical fiber

A phase-sensitive four-wave mixing (FWM) scheme enabling the simultaneous conversion of the two orthogonal quadratures of an optical signal to different wavelengths is demonstrated for the first time under dynamic operation using a highly nonlinear optical fiber (HNLF) as the nonlinear medium. The scheme is first optimized with respect to the power levels and phases of the four phase-coherent pumps. The successful modulation and wavelength conversion of the two complex quadratures of a quadrature phase-shift keying (QPSK) signal to two binary phase-shift keying (BPSK) signals is then demonstrated experimentally with no power penalty at a bit-error-ratio (BER) of 10−9 compared to direct interferometric demodulation of the QPSK signal.
Signal Quality Enhancement of Directly-Modulated VCSELs Using a Micro-Ring Resonator Transfer Function

A micro-ring resonator transfer function is used to enhance the quality of signals generated using directly modulated VCSELs. The scheme is demonstrated up to 25 Gbit/s with a 17.6-GHz VCSEL, with up to 10 dB sensitivity improvement.

Spectral compression of a DWDM grid using optical time-lenses

We experimentally demonstrate the compression of a dense wavelength-division multiplexing (DWDM) grid via a spectral imaging system based on two time-lenses. A 100-GHz DWDM-grid is compressed to 50-GHz with error-free performance for all channels.
Demonstration of Cascaded In-Line Single-Pump Fiber Optical Parametric Amplifiers in Recirculating Loop Transmission
The performance of cascaded single-pump fiber optical parametric amplifiers (FOPAs) is experimentally studied for the first time using recirculating loop transmission with 80-km dispersion managed spans. Error-free performance has been achieved over 320 km for 40-Gbit/s CSRZ-OOK and CSRZ-DPSK modulated signals.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Fiber Optics, Devices and Non-linear Effects
Number of pages: 3
Pages: Mo.2.C.5
Publication date: 2012

Host publication information
Title of host publication: ECOC Technical Digest
Publisher: Optical Society of America
Main Research Area: Technical/natural sciences
Conference: 38th European Conference and Exhibition on Optical Communication, Amsterdam, Netherlands, 16/09/2012 - 16/09/2012
Electronic versions:
Mo.2.C.5.pdf
DOIs:
10.1364/ECEOC.2012.Mo.2.C.5

Bibliographical note
This paper was published in ECOC Technical Digest and is made available as an electronic reprint with the permission of OSA. The paper can be found at the following URL on the OSA website: http://www.opticsinfobase.org/abstract.cfm?URI=ECEOC-2012-Mo.2.C.5. Systematic or multiple reproduction or distribution to multiple locations via electronic or other means is prohibited and is subject to penalties under law.

Gain optimization in fiber optical parametric amplifiers by combining standard and high-SBS threshold highly nonlinear fibers
Combining Al-doped and Ge-doped HNLFs as gain media in FOPAs is proposed and optimized, resulting in efficient SBS mitigation while circumventing the additional loss of the high SBS threshold Al-doped fiber.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Fiber Optics, Devices and Non-linear Effects
Authors: Da Ros, F. (Intern), Rottwitt, K. (Intern), Peucheret, C. (Intern)
Number of pages: 2
Pages: CM4N.5
Publication date: 2012

Host publication information
Title of host publication: CLEO Technical Digest
Publisher: Optical Society of America
Main Research Area: Technical/natural sciences
Conference: Conference on Lasers and Electro-Optics (CLEO 2012), San Jose, CA, United States, 06/05/2012 - 06/05/2012
Electronic versions:
DaRos_CLEO_12_CM4N.5.pdf

Bibliographical note
This paper was published in CLEO Technical Digest and is made available as an electronic reprint with the permission of OSA. The paper can be found at the following URL on the OSA website. Systematic or multiple reproduction or distribution...
Pulse Distortion in Saturated Fiber Optical Parametric Chirped Pulse Amplification

Fiber optical parametric chirped pulse amplification is experimentally compared for different chirped pulses in the picosecond regime. The amplified chirped pulses show distortion appearing as pedestals after recompression when the amplifier is operated in saturation.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Fiber Optics, Devices and Non-linear Effects
Authors: Lali-Dastjerdi, Z. (Intern), Da Ros, F. (Intern), Rottwitt, K. (Intern), Galili, M. (Intern), Peucheret, C. (Intern)
Number of pages: 2
Pages: JW2A.82
Publication date: 2012

Host publication information
Title of host publication: CLEO Technical Digest
Publisher: Optical Society of America
Main Research Area: Technical/natural sciences
Conference: Conference on Lasers and Electro-Optics (CLEO 2012), San Jose, CA, United States, 06/05/2012 - 06/05/2012
Electronic versions:
JW2A.82.pdf
DOI: 10.1364/CLEO.2012.JW2A.82

Bibliographical note
This paper was published in CLEO Technical Digest and is made available as an electronic reprint with the permission of OSA. The paper can be found at the following URL on the OSA website: http://www.opticsinfobase.org/abstract.cfm?URI=CLEO-2012-JW2A.82. Systematic or multiple reproduction or distribution to multiple locations via electronic or other means is prohibited and is subject to penalties under law.
QPSK Phase Regeneration in Saturated Degenerate Dual-pump Phase Sensitive Amplifiers
A novel scheme exploiting saturation effects in fiber optical parametric amplifiers using a degenerate dual-pump phase sensitive configuration is proposed and analyzed. QPSK phase regeneration is numerically demonstrated in a nonlinear interferometer structure.

General information
State: Published
Organisations: High-Speed Optical Communication, Department of Photonics Engineering
Authors: Da Ros, F. (Intern), Peucheret, C. (Intern)
Pages: 105-106
Publication date: 2011

Host publication information
Title of host publication: 2011 IEEE Photonics Conference
Publisher: IEEE
ISBN (Print): 978-1-4244-8940-4
Main Research Area: Technical/natural sciences
DOIs: 10.1109/PHO.2011.6110447
Links: http://www.photonicsconferences.org/PHOTONICS2011/

Bibliographical note
Oral presentation.
Source: orbit
Source-ID: 286672
Publication: Research - peer-review › Article in proceedings – Annual report year: 2011

Projects:

Optical phase conjugation for high-spectrally efficient transmission
Department of Photonics Engineering
Period: 01/10/2017 → 30/09/2020
Number of participants: 4
Phd Student:
Kaminski, Pawel Marcin (Intern)
Supervisor:
Da Ros, Francesco (Intern)
Forchhammer, Søren (Intern)
Main Supervisor:
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Financing sources
Source: Internal funding (public)
Name of research programme: Grundforskningsfonden
Project: PhD

Optical Processing of High Dimensionality Signals
Department of Photonics Engineering
Period: 15/09/2011 → 26/01/2015
Number of participants: 7
Phd Student:
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Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.

Relations
Publications:
Optical Processing of High Dimensionality Signals
Project: PhD