The Hi-Ring Architecture for Data Center Networks

Optical technologies have long been used for standard telecom applications ranging from long haul to metro and access networks. With the rapid expansion of traffic in data center networks, the deployment of optical technologies for computationally intensive short reach networking has attracted a lot of attention. The main interest in photonics comes from the fact that optical technologies are known for providing high bandwidth at low-cost and low power consumption. Unlike electrical switching, optical switching offers bit rate-independent operation; thus, the required processing capacity can greatly be reduced as there is no need to perform operations like electrical demultiplexing of high-speed data streams. Moreover, simultaneous switching of wavelength channels using an optical circuit switch yields energy-efficient operation, which is crucial to data centers.
125-GHz Microwave Signal Generation Employing an Integrated Pulse Shaper

We propose and experimentally demonstrate an on-chip pulse shaper for 125-GHz microwave waveform generation. The pulse shaper is implemented based on a silicon-on-insulator (SOI) platform that has a structure with eight-tap finite impulse response (FIR) and there is an amplitude modulator on each tap. By controlling the thermal heaters on the amplitude modulators, we obtain several signals centered at 125 GHz with typical envelopes, such as square envelope, triangular envelope, sawtooth envelope, Gaussian envelope, etc. Our scheme has some significant advantages, such as the central frequency of the generated microwave waveforms is larger than 100 GHz, and it has wide bandwidth when changing the time delay of the adjacent taps and compactness, capability for integration with electronics and small power consumption are also its merits.

General information
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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Huazhong University of Science and Technology
Authors: Liao, S. (Ekstern), Ding, Y. (Intern), Dong, J. (Ekstern), Wang, X. D. (Ekstern), Zhang, X. (Ekstern)
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Scopus rating (2010): SJR 1.802 SNIP 2.411
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25-Gb/s Transmission Over 2.5-km SSMF by Silicon MRR Enhanced 1.55-μm 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 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.

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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)
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Bandwidth-adaptable silicon photonic differentiator employing a slow light effect

A photonic differentiator (DIFF) plays a crucial role in photonic circuits. Despite the fact that a DIFF having a tera-hertz bandwidth has been reported, the practical bandwidth is limited to being a bandpass response. In this Letter, we propose...
the concept of a bandwidth-adaptable DIFF, which exploits the slow light effect in a photonic crystal waveguide (PhCW) to overcome the inherent bandwidth limitation of current photonic DIFFs. We fabricated a PhCW Mach-Zehnder interferometer (PhCW-MZI) on the silicon-on-insulator material platform to validate our concept. Input Gaussian pulses with full width to half-maximums (FWHMs) ranging from 2.7 to 81.4 ps are accurately differentiated using our PhCW-MZI. Our all-passive scheme circumvents the bandwidth bottlenecks of previously reported photonic DIFFs and can greatly broaden the application area of photonic DIFFs. (C) 2017 Optical Society of America

**General information**

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, Centre of Excellence for Silicon Photonics for Optical Communications, High-Speed Optical Communication, Huazhong University of Science and Technology
Authors: Yan, S. (Ekstern), Cheng, Z. (Ekstern), Frandsen, L. H. (Intern), Ding, Y. (Intern), Zhou, F. (Ekstern), Dong, J. (Ekstern), Zhang, X. (Ekstern)
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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.

High coincidence-to-accidental ratio continuous-wave photon-pair generation in a grating-coupled silicon strip waveguide: Letters
We demonstrate a very high coincidence-to-accidental ratio of 673 using continuous-wave photon-pair generation in a silicon strip waveguide through spontaneous four-wave mixing. This result is obtained by employing on-chip photonic-crystal-based grating couplers for both low-loss fiber-to-chip coupling and on-chip suppression of generated spontaneous Raman scattering noise. We measure a minimum heralded second-order correlation of g\(\text{H}(2)\) (0) = 0.12, demonstrating that our source operates in the single-photon regime with low noise. (C) 2017 The Japan Society of Applied Physics
**High-dimensional quantum key distribution based on multicore fiber using silicon photonic integrated circuits**

Quantum key distribution provides an efficient means to exchange information in an unconditionally secure way. Historically, quantum key distribution protocols have been based on binary signal formats, such as two polarization states, and the transmitted information efficiency of the quantum key is intrinsically limited to 1 bit/photon. Here we propose and experimentally demonstrate, for the first time, a high-dimensional quantum key distribution protocol based on space division multiplexing in multicore fiber using silicon photonic integrated lightwave circuits. We successfully realized three mutually unbiased bases in a four-dimensional Hilbert space, and achieved low and stable quantum bit error rate well below both the coherent attack and individual attack limits. Compared to previous demonstrations, the use of a multicore fiber in our protocol provides a much more efficient way to create high-dimensional quantum states, and enables breaking the information efficiency limit of traditional quantum key distribution protocols. In addition, the silicon photonic circuits used in our work integrate variable optical attenuators, highly efficient multicore fiber couplers, and Mach-Zehnder interferometers, enabling manipulating high-dimensional quantum states in a compact and stable manner. Our demonstration paves the way to utilize state-of-the-art multicore fibers for noise tolerance high-dimensional quantum key distribution, and boost silicon photonics for high information efficiency quantum communications.

**Integrated graphene plasmonic waveguide modulators**

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- State: Published
- Organisations: Center for Nanostructured Graphene, Department of Photonics Engineering, Structured Electromagnetic Materials, Nanophotonic Devices, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications
- Authors: Xiao, S. (Intern), Ding, Y. (Intern), Guan, X. (Intern), Mortensen, N. A. (Intern)
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On-Chip SDM Switching for Unicast, Multicast and Traffic Grooming in Data Center Networks

This paper reports on the use of a novel photonic integrated circuit that facilitates multicast and grooming in an optical data center architecture. The circuit allows for on-chip spatial multiplexing and demultiplexing as well as fiber core switching. Using this device, we experimentally verify that multicast and/or grooming can be successfully performed along the full range of output ports, for different group size and different power ratio. Moreover, we experimentally demonstrate SDM transmission and 5 Tbit/s switching using the on-chip fiber switch with integrated fan-in/fan-out devices and achieve errorfree performance (BER≤10−9) for a network scenario including simultaneous unicast/multicast switching and traffic grooming.

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Web of Science (2008): Indexed yes
We present our work on photonic crystal membrane devices exploiting Fano resonance between a line-defect waveguide and a side coupled nanocavity. Experimental demonstration of fast and compact all-optical switches for wavelength-conversion is reported. It is shown how the use of an asymmetric structure in combination with cavity-enhanced nonlinearity can be used to realize non-reciprocal transmission at ultra-low power and with large bandwidth. A novel type of laser structure, denoted a Fano laser, is discussed in which one of the mirrors is based on a Fano resonance. Finally, the design, fabrication and characterization of grating couplers for efficient light coupling in and out of the indium phosphide photonic crystal platform is discussed.

Photonic crystal Fano resonances for realizing optical switches, lasers and non-reciprocal elements

We present our work on photonic crystal membrane devices exploiting Fano resonance between a line-defect waveguide and a side coupled nanocavity. Experimental demonstration of fast and compact all-optical switches for wavelength-conversion is reported. It is shown how the use of an asymmetric structure in combination with cavity-enhanced nonlinearity can be used to realize non-reciprocal transmission at ultra-low power and with large bandwidth. A novel type of laser structure, denoted a Fano laser, is discussed in which one of the mirrors is based on a Fano resonance. Finally, the design, fabrication and characterization of grating couplers for efficient light coupling in and out of the indium phosphide photonic crystal platform is discussed.
Robust photonic differentiator employing slow light effect in photonic crystal waveguide

A robust photonic DIFF exploiting the slow light effect in a photonic crystal waveguide is proposed and experimentally demonstrated. Input Gaussian pulses with full-width half-maximums ranging from 2.7 ps to 81.4 ps can be accurately differentiated.

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, Centre of Excellence for Silicon Photonics for Optical Communications, High-Speed Optical Communication, Huazhong University of Science and Technology
Authors: Yan, S. (Ekstern), Cheng, Z. (Ekstern), Frandsen, L. H. (Intern), Ding, Y. (Intern), Zhou, F. (Ekstern), Dong, J. (Ekstern), Zhang, X. (Ekstern)
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Slow-light-enhanced energy efficiency for graphene microheaters on silicon photonic crystal waveguides

Slow light has been widely utilized to obtain enhanced nonlinearities, enhanced spontaneous emissions and increased phase shifts owing to its ability to promote light-matter interactions. By incorporating a graphene on a slow-light silicon photonic crystal waveguide, here we experimentally demonstrate an energy-efficient graphene microheater with a tuning efficiency of 1.07 nm/W and power consumption per free spectral range of 3.99 mW. The rise and decay times (10-90%) are only 750 and 525 ns, which, to the best of our knowledge, are the fastest reported response times for microheaters in silicon photonics. The corresponding figure of merit of the device is 2.543 nW, one order of magnitude better than results reported in previous studies. The influence of the length and shape of the graphene heater to the tuning efficiency is further investigated, providing valuable guidelines for enhancing the tuning efficiency of the graphene microheater.

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Authors: Yan, S. (Ekstern), Zhu, X. (Intern), Frandsen, L. H. (Intern), Xiao, S. (Intern), Mortensen, N. A. (Intern), Dong, J. (Ekstern), Ding, Y. (Intern)
Number of pages: 8
Publication date: 2017
Main Research Area: Technical/natural sciences

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Journal: Nature Communications
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Ultra-high efficiency, fast graphene micro-heater on silicon

We demonstrate an ultra-high efficiency and fast graphene microheater on silicon photonic crystal waveguide. By taking advantage of slow-light effect, a tuning efficiency of 1.07 nm/mW and power consumption per free spectral range of 3.99 mW. A fast rise and decay times (10% to 90%) of only 750 ns and 525 ns are achieved. The corresponding figure of merit of the device is 2.543 nW·s, one order of magnitude better than results reported in previous studies.

General information
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Organisations: Center for Nanostructured Graphene, Department of Photonics Engineering, Nanophotonic Devices, Centre of Excellence for Silicon Photonics for Optical Communications, Structured Electromagnetic Materials, High-Speed Optical Communication, Huazhong University of Science and Technology
Authors: Yan, S. (Ekstern), Zhu, X. (Intern), Frandsen, L. H. (Intern), Xiao, S. (Intern), Mortensen, N. A. (Intern), Dong, J. (Ekstern), Ding, Y. (Intern)
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Electronic versions: Graphene_Heater_META2017_FINAL.pdf
Comparison of wavelength conversion efficiency between silicon waveguide and microring resonator

Wavelength conversion based on degenerate four-wave mixing (FWM) was demonstrated and compared between silicon nanowire and microring resonator (MRR). 15 dB enhancement of conversion efficiency (CE) with relatively low input pump power (5 mW) was achieved experimentally in an MRR. The impacts of bus waveguide length and propagation loss were theoretically analyzed under the effect of nonlinear loss.

Demonstration of orbital angular momentum (OAM) modes emission from a silicon photonic integrated device for 20 Gbit/s QPSK carrying data transmission in few-mode fiber

We experimentally demonstrate orbital angular momentum (OAM) mode emission from a high emission efficiency OAM emitter for 20 Gbit/s QPSK carrying data transmission in few-mode fiber (FMF). Two modes propagate through a 3.6km three-mode FMF with measured OSNR penalties less than 4 dB at a BER of 2e-3.
Differential phase-time shifting protocol for QKD (DPTS)

We explore the implementation of a novel protocol for fiber-based high-dimensional quantum key distribution (QKD) which improves over the traditional DPS-QKD and COW protocols.

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Organisations: Department of Photonics Engineering, Fiber Optics, Devices and Non-linear Effects, Centre of Excellence for Silicon Photonics for Optical Communications, High-Speed Optical Communication, Nanophotonic Devices
Authors: Usuga Castaneda, M. A. (Intern), Bacco, D. (Intern), Christensen, J. B. (Intern), Ding, Y. (Intern), Rottwitt, K. (Intern), Oxenløwe, L. K. (Intern)
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"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.

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Authors: Cristofori, V. (Intern), Da Ros, F. (Intern), Ding, Y. (Intern), Shen, A. (Ekstern), Gallet, A. (Ekstern), Make, D. (Ekstern), Duan, G. (Ekstern), Oxenløwe, L. K. (Intern), Peucheret, C. (Ekstern)
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Error-free Dispersion-uncompensated Transmission at 20 Gb/s over SSMF using a Hybrid III-V/SOI DML with MRR Filtering

Error-free 20-Gb/s directly-modulated transmission is achieved by enhancing the dispersion tolerance of a III-V/SOI DFB laser with a silicon micro-ring resonator. Low (~0.4 dB) penalty compared to back-to-back without ring is demonstrated after 5-km SSMF.

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Authors: Cristofori, V. (Intern), Kamchevska, V. (Intern), Ding, Y. (Intern), Shen, A. (Ekstern), Duan, G. (Ekstern), Peucheret, C. (Ekstern), Oxenløwe, L. K. (Intern)
Number of pages: 2
Publication date: 2016

Experimental Demonstration of 7 Tb/s Switching Using Novel Silicon Photonic Integrated Circuit
We demonstrate BER performance <10^-9 for a 1 Tb/s/core transmission over 7-core fiber and SDM switching using a novel silicon photonic integrated circuit composed of a 7x7 fiber switch and low loss SDM couplers.

General information
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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Macquarie University
Authors: Ding, Y. (Intern), Kamchevska, V. (Intern), Dalgaard, K. (Intern), Ye, F. (Intern), Asif, R. (Intern), Gross, S. (Ekstern), Withford, M. J. (Ekstern), Galili, M. (Intern), Moroika, T. (Intern), Oxenløwe, L. K. (Intern)
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Linear all-optical signal processing using silicon micro-ring resonators
Silicon micro-ring resonators (MRRs) are compact and versatile devices whose periodic frequency response can be exploited for a wide range of applications. In this paper, we review our recent work on linear all-optical signal processing applications using silicon MRRs as passive filters. We focus on applications such as modulation format conversion, differential phase-shift keying (DPSK) demodulation, modulation speed enhancement of directly modulated lasers (DMLs), and monocycle pulse generation. The possibility to implement polarization diversity circuits, which reduce the polarization...
dependence of standard silicon MRRs, is illustrated on the particular example of DPSK demodulation.

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**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).

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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), Oxeniøwe, L. K. (Intern), Yvind, K. (Intern)
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Publication date: 2016
Photonics arbitrary waveform generator based on Taylor synthesis method

Arbitrary waveform generation has been widely used in optical communication, radar system and many other applications. We propose and experimentally demonstrate a silicon-on-insulator (SOI) on chip optical arbitrary waveform generator, which is based on Taylor synthesis method. In our scheme, a Gaussian pulse is launched to some cascaded microrings to obtain first-, second- and third-order differentiations. By controlling amplitude and phase of the initial pulse and successive differentiations, we can realize an arbitrary waveform generator according to Taylor expansion. We obtain several typical waveforms such as square waveform, triangular waveform, flat-top waveform, sawtooth waveform, Gaussian waveform and so on. Unlike other schemes based on Fourier synthesis or frequency-to-time mapping, our scheme is based on Taylor synthesis method. Our scheme does not require any spectral disperser or large dispersion, which are difficult to fabricate on chip. Our scheme is compact and capable for integration with electronics. (C) 2016 Optical Society of America
OPTICS, FREQUENCY COMB GENERATION, APODIZED GRATING COUPLER, FBG ARRAYS, CHIP, EFFICIENCY
Polarization diversity silicon microring resonator for WDM ADD-DROP filtering
We have demonstrated a polarization-diversity silicon microring resonator with a low PDL of

General information
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Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Nanophotonic Devices, Centre of Excellence for Silicon Photonics for Optical Communications, Department of Micro- and Nanotechnology
Authors: Hu, H. (Intern), Ding, Y. (Intern), Oxenløwe, L. K. (Intern)
Number of pages: 3
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Main Research Area: Technical/natural sciences
Conference: 2016 Optical Fiber Communication Conference and Exhibition, Anaheim, California, United States, 20/03/2016 - 20/03/2016
Micro-optical devices and technology, Micromechanical and nanomechanical devices and systems, Integrated optics, Design and modelling of MEMS and NEMS devices, Multiplexing and switching in optical communication, elemental semiconductors, integrated optics, light polarisation, micromechanical resonators, micro-optics, silicon, wavelength division multiplexing, polarization diversity silicon microring resonator, WDM add-drop filtering, polarization independent ADD/DROP, WDM signal, bit rate 10 Gbit/s, Si
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Reconfigurable SDM Switching Using Novel Silicon Photonic Integrated Circuit
Space division multiplexing using multicore fibers is becoming a more and more promising technology. In space-division multiplexing fiber network, the reconfigurable switch is one of the most critical components in network nodes. In this paper we for the first time demonstrate reconfigurable space-division multiplexing switching using silicon photonic integrated circuit, which is fabricated on a novel silicon-on-insulator platform with buried Al mirror. The silicon photonic integrated circuit is composed of a 7x7 switch and low loss grating coupler array based multicore fiber couplers. Thanks to the Al mirror, grating couplers with ultra-low coupling loss with optical multicore fibers is achieved. The lowest total insertion loss of the silicon integrated circuit is as low as 4.5 dB, with low crosstalk lower than -30 dB. Excellent performances in terms of low insertion loss and low crosstalk are obtained for the whole C-band. 1 Tbit/s/core transmission over a 2-km 7-core fiber and space-division multiplexing switching is demonstrated successfully. Bit error rate performance below 10-9 is obtained for all spatial channels with low power penalty. The proposed design can be easily upgraded to reconfigurable optical add/drop multiplexer capable of switching several multicore fibers.

General information
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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications
Authors: Ding, Y. (Intern), Kamchevska, V. (Intern), Dalgaard, K. (Intern), Ye, F. (Intern), Asif, R. (Intern), Gross, S. (Ekstern), Withford, M. J. (Ekstern), Galli, M. (Intern), Morioka, T. (Intern), Oxenløwe, L. K. (Intern)
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Publication date: 2016
Main Research Area: Technical/natural sciences
Route-asymmetrical light transmission of a fiber-chip-fiber optomechanical system

In this paper, we proposed and experimentally demonstrated a route-asymmetrical light transmission scheme based on the thermal radiative effect, which means that forward and backward propagations of an optical device have different transmittances provided they are not present simultaneously. Employing a fiber-chip-fiber optomechanical system, our scheme has successfully achieved a broad operation bandwidth of at least 24 nm and an ultra-high route-asymmetrical transmission ratio (RATR) up to 63 dB. The route-asymmetrical device has been demonstrated effectively with not only the continuous-wave (CW) light but also 10 Gbit/s on-off-keying (OOK) digital signals. Above mentioned unique features can be mostly attributed to the significant characteristics of the thermal radiative effect, which could cause a fiber displacement up to tens of microns. The powerful and significant thermal radiative effect opens up a new opportunity and method for route-asymmetrical light transmission. Moreover, this research may have important applications in all-optical systems, such as the optical limiters and ultra-low loss switches.

General information
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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Huazhong University of Science and Technology, National Sun Yat-sen University
Authors: Liu, L. (Ekstern), Ding, Y. (Intern), Cai, X. (Ekstern), Dong, J. (Ekstern), Zhang, X. (Ekstern)
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Silicon photonics for multicore fiber communication
We review our recent work on silicon photonics for multicore fiber communication, including multicore fiber fan-in/fan-out, multicore fiber switches towards reconfigurable optical add/drop multiplexers. We also present multicore fiber based quantum communication using silicon devices.

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The Hi-Ring architecture for datacentre networks
This paper summarizes recent work on a hierarchical ring-based network architecture (Hi-Ring) for datacentre and short-range applications. The architecture allows leveraging benefits of optical switching technologies while maintaining a high level of connection granularity. We discuss results of optical switching in the various physical dimensions incorporated in the hierarchical nodes and we discuss recent results on global synchronisation of nodes in a ring topology.

General information
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Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Nanophotonic Devices
Authors: Galili, M. (Intern), Kamchevska, V. (Intern), Ding, Y. (Intern), Oxenløwe, L. K. (Intern)
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Topography Optimized Components for Mode- and Wavelength Division Multiplexing

This thesis deals with the topic of passive integrated nanophotonic devices realized in silicon on insulator material. The project has been concerned with all the steps of the process: Design, fabrication and characterization. The focus has been on using the inverse design method topology optimization. The method has been employed extensively to obtain various nanophotonic components. One of the outcomes of the project has been the development of a solid understanding of the benefits and limitations of topology optimization. This thesis presents numerous designs that have been characterized both through simulations and experiments. Among these are converters and (de-)multiplexers for mode division multiplexing, both realized with a record small footprint. Wavelength multiplexing devices were used as a basis for investigating the correlation between structure sizes and performance. Fortunately a larger footprint does not always give rise to better performance, however allowing for smaller feature sizes will. The design of compact tapers was commenced. Difficulties were met when working with very wide waveguides but methods for overcoming these were suggested. A novel form of cladding modulated Bragg gratings, utilizing continuous rails to modify the refractive index and cause the reflections, has also been proposed and experimentally verified as part of this project. This work has contributed additional components to the toolbox of devices necessary for integrated photonics. It has been shown that topology optimization is a strong method for creating extremely compact devices, the small features do however mean that they are not yet possible to fabricate on a large scale. Complex device functionalities can be obtained. Building on previous work of simpler structures it is comparatively easy to remake the new designs and then increase complexity without much impact on the footprint. The benefit of inverse design tools, like topology optimization, is that they lead to structures without geometrical constraints and which are independent of the designer. This project has however shown, that the best results are obtained when iterating on the optimized structures and providing the tool with well-chosen starting point structures.

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Organisations: Department of Photonics Engineering, Department of Physics, Quantum Physics and Information Technology, Centre of Excellence for Silicon Photonics for Optical Communications, Nanophotonic Devices, High-Speed Optical Communication
Authors: Frelsen, L. F. (Intern), Frandsen, L. H. (Intern), Ding, Y. (Intern)
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Publication: Research › Ph.D. thesis – Annual report year: 2017

Topology optimized design of a transverse electric higher order mode converter
The investigation of methods to support the ever increasing demand for data transfer has continued for years; one such method suggested within the field of optical communication, is space division multiplexing (SDM) [1]. Simultaneously the field of photonic integrated circuits (PICs) is being investigated due to attractive features such as high device density and low operating power [2]. For PICs it is necessary with a toolbox of devices and one such of importance to the processing of on chip SDM is the mode converter. Several schemes have been used to realize such devices [3] [4]. In this paper we present the possibility of employing topology optimization (TO) to design a device that allows for reversible conversion between the transverse electric fundamental even (TE0) mode and the second higher order odd mode (TE2). Topology optimization is an iterative inverse design process, where repeated finite-difference time-domain (FDTD) calculations are made in accordance with a sensitivity analysis. This is done using a software package which has been developed in house, and which has shown to deliver low loss designs with a controllable bandwidth in addition to small device footprints [5]. The design is made for fabrication in silicon-on-insulator (SOI) and previous work has shown excellent concordance between simulations and experimental results when employing 3D TO [6].
Topology-optimized mode converter in a silicon-on-insulator photonic wire waveguide
A 1.4 μm × 3.4 μm fundamental to first order mode converter for the transverse electric polarization was designed using topology optimization. Insertion loss <2 dB (100 nm bandwidth) and extinction ratio >9.5 dB.

Topology optimized mode multiplexing in silicon-on-insulator photonic wire waveguides
We design and experimentally verify a topology optimized low-loss and broadband two-mode (de-)multiplexer, which is (de-)multiplexing the fundamental and the first-order transverse-electric modes in a silicon photonic wire. The device has a footprint of 2.6 μm x 4.22 μm and exhibits a loss 14 dB in the C-band. Furthermore, we demonstrate that the design method can be expanded to include more modes, in this case including also the second order transverse-electric mode, while maintaining functionality.
Two-dimensional distributed-phase-reference protocol for quantum key distribution

Quantum key distribution (QKD) and quantum communication enable the secure exchange of information between remote parties. Currently, the distributed-phase-reference (DPR) protocols, which are based on weak coherent pulses, are among the most practical solutions for long-range QKD. During the last 10 years, long-distance fiber-based DPR systems have been successfully demonstrated, although fundamental obstacles such as intrinsic channel losses limit their performance. Here, we introduce the first two-dimensional DPR-QKD protocol in which information is encoded in the time and phase of weak coherent pulses. The ability of extracting two bits of information per detection event, enables a higher secret key rate in specific realistic network scenarios. Moreover, despite the use of more dimensions, the proposed protocol remains simple, practical, and fully integrable.
Arbitrary waveform generator and differentiator employing an integrated optical pulse shaper

We propose and demonstrate an optical arbitrary waveform generator and high-order photonic differentiator based on a four-tap finite impulse response (FIR) silicon-on-insulator (SOI) on-chip circuit. Based on amplitude and phase modulation of each tap controlled by thermal heaters, we obtain several typical waveforms such as triangular waveform, sawtooth waveform, square waveform and Gaussian waveform, etc., assisted by an optical frequency comb injection. Unlike other proposed schemes, our scheme does not require a spectral disperser which is difficult to fabricate on chip with high resolution. In addition, we demonstrate first-, second- and third-order differentiators based on the optical pulse shaper. Our scheme can switch the differentiator patterns from first- to third-order freely. In addition, our scheme has distinct advantages of compactness, capability for integration with electronics.

General information

State: Published
Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Huazhong University of Science and Technology, Jilin University
Authors: Liao, S. (Ekstern), Ding, Y. (Intern), Dong, J. (Ekstern), Yang, T. (Ekstern), Chen, X. (Ekstern), Gao, D. (Ekstern), Zhang, X. (Ekstern)
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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
Effective carrier sweepout in a silicon waveguide by a metal-semiconductor-metal structure

We demonstrate effective carrier depletion by metal-semiconductor-metal junctions for a silicon waveguide. Photo-generated carriers are efficiently swept out by applying bias voltages, and a shortest carrier lifetime of only 55 ps is demonstrated.

General information
State: Published
Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Diode Lasers and LED Systems
Authors: Ding, Y. (Intern), Hu, H. (Intern), Ou, H. (Intern), Oxenløwe, L. K. (Intern), Yvind, K. (Intern)
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Conference: 2015 Conference on Lasers and Electro-Optics 2015 (CLEO), San Jose, CA, United States, 10/05/2015 - 10/05/2015
DOIs:
10.1364/CLEO_SI.2015.SM1I.5
Effective electro-optical modulation with high extinction ratio by a graphene-silicon microring resonator

Graphene opens up for novel optoelectronic applications thanks to its high carrier mobility, ultra-large absorption bandwidth, and extremely fast material response. In particular, the opportunity to control optoelectronic properties through tuning of the Fermi level enables electro-optical modulation, optical-optical switching, and other optoelectronics applications. However, achieving a high modulation depth remains a challenge because of the modest graphene-light interaction in the graphene-silicon devices, typically, utilizing only a monolayer or few layers of graphene. Here, we comprehensively study the interaction between graphene and a microring resonator, and its influence on the optical modulation depth. We demonstrate graphene-silicon microring devices showing a high modulation depth of 12.5 dB with a relatively low bias voltage of 8.8 V. On-off electro-optical switching with an extinction ratio of 3.8 dB is successfully demonstrated by applying a square-waveform with a 4 V peak-to-peak voltage.
Efficient silicon PIC mode multiplexer using grating coupler array with aluminum mirror for few-mode fiber

We demonstrate a silicon PIC mode multiplexer using grating couplers. An aluminum mirror is introduced for coupling efficiency improvement. A highest coupling efficiency of $-10.6$ dB with $3.7$ dB mode dependent coupling loss is achieved.

Increase in data capacity utilising dimensions of wavelength, space, time, polarisation and multilevel modulation using a single laser

Increasing the capacity of optical networks while have the objective of lowering the total consumed energy per bit is challenging. By exploiting several dimensions, i.e. wavelength, space, time, polarisation and multilevel modulation simultaneously, a single laser can offer formidable capacity performance with potentially reduced energy consumption per bit. Up to 43 Tbit/s has been demonstrated.
Nonreciprocal light transmission based on the thermal radiative effect

Nonreciprocal light transmission is critical in building optical isolations and circulations in optical communication systems. Achieving high optical isolation and broad bandwidth with CMOS-compatibility are still difficult in silicon nano-photonics. Here we first experimentally demonstrate that the fiber-chip-fiber optomechanical structure, which is based on the thermal radiative effect, is effective at achieving a broad operation bandwidth of 24 nm and an ultra-high nonreciprocal transmission ratio up to 63 dB. These satisfactory nonreciprocal performances can mostly be attributed to the significant characteristics of the thermal radiative effect, which could cause a fiber displacement up to tens of microns. This powerful thermal radiative effect opens up a new opportunity for nonreciprocal light transmission which is promising to be used in complete on-chip nonreciprocal devices in the future.

On-chip grating coupler array on the SOI platform for fan-in/fan-out of MCFs with low insertion loss and crosstalk

We report the design and fabrication of a compact multi-core fiber fan-in/fan-out using a grating coupler array on the SOI platform. The grating couplers are fully-etched, enabling the whole circuit to be fabricated in a single lithography and etching step. Thanks to the apodized design for the grating couplers and the introduction of an aluminum reflective mirror, a highest coupling efficiency of -3.8 dB with 3 dB coupling bandwidth of 48 nm and 1.5 dB bandwidth covering the whole C band, together with crosstalk lower than -32 dB are demonstrated. (C)2015 Optical Society of America
Photonic compressive sensing with a micro-ring-resonator-based microwave photonic filter

A novel approach to realize photonic compressive sensing (CS) with a multi-tap microwave photonic filter is proposed and demonstrated. The system takes both advantages of CS and photonics to capture wideband sparse signals with sub-Nyquist sampling rate. The low-pass filtering function required in the CS is realized in a photonic way by using a frequency comb and a dispersive element. The frequency comb is realized by shaping an amplified spontaneous emission (ASE) source with an on-chip micro-ring resonator, which is beneficial to the integration of photonic CS. A proof-of-concept experiment for a two-tone signal acquisition with frequencies of 350 MHz and 1.25 GHz is experimentally demonstrated with a compression factor up to 16.
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.

General information
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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Diode Lasers and LED Systems, University of Rennes, Huazhong University of Science and Technology, Université de Rennes
Authors: Peucheret, C. (Ekstern), Ding, Y. (Intern), Xu, J. (Ekstern), Da Ros, F. (Intern), Ou, H. (Intern), Parini, A. (Ekstern)
Silicon nanowires for ultra-fast and ultrabroadband optical signal processing

In this paper, we present recent research on silicon nanowires for ultra-fast and ultra-broadband optical signal processing at DTU Fotonik. The advantages and limitations of using silicon nanowires for optical signal processing are revealed through experimental demonstrations of various optical signal processing.

Thermal-tuned optical pulse shaper for arbitrary waveform generation with integrated waveguides

We demonstrate an on-chip thermal-tuned optical pulse shaper based on the four-path finite impulse response (FIR). Four typical waveform are demonstrated by tuning the phase and amplitude of each path.
Topology optimized design for silicon-on-insulator mode converter
The field of photonic integrated circuits (PICs) has attracted interest in recent years as they allow high device density while requiring only low operating power. The possibility of exploiting mode division multiplexing (MDM) in future optical communication networks is being investigated as a potential method for supporting the constantly increasing internet traffic demand [1]. Mode converters are important components necessary to support on-chip processing of MDM signals and multiple approaches has been followed in realizing such devices [2], [3]. Topology optimization (TO) [4] is a powerful inverse design tool which has experimentally proven to deliver robust designs with controllable bandwidth and low loss [5], [6]. Here it is shown how TO has been used to obtain a small footprint, low-loss, broad-band design for mode conversion between the transverse electric fundamental even (TE$_0$) mode and the first higher order odd mode (TE$_1$) in a photonic wire. The design is to be fabricated in silicon-on-insulator (SOI) material, and previous work has shown excellent correspondence between simulations and experimental results for 3D TO [7].

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Ultra-compact broadband higher order-mode pass filter fabricated in a silicon waveguide for multimode photonics

An ultra-compact and broadband higher order-mode pass filter in a 1D photonic crystal silicon waveguide is proposed and experimentally demonstrated. The photonic crystal is designed for the lower order mode to work in the photonic band gap, while the higher order mode is located in the air band. Consequently, light on the lower order mode is prohibited to pass through the filter, while light on a higher order mode can be converted to a Bloch mode in the photonic crystal and pass through the filter with low insertion loss. As an example, we fabricate a similar to 15-μm-long first-order-mode pass filter that filters out the fundamental mode and provides a measured insertion loss of similar to 1.8 dB for the first-order-mode pass signals. The extinction ratio is measured to be around 50 dB (with a variation of +/- 10 dB due to the detection limitation of the measurement setup) in the measured wavelength range from 1480 to 1580 nm. Additionally, calculations predict the extinction ratio to be larger than 50 dB in a 170 nm broad bandwidth. (C) 2015 Optical Society of America
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Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.497 SNIP 2.056 CiteScore 3.86
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.458 SNIP 2.095 CiteScore 3.52
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.596 SNIP 1.95 CiteScore 3.52
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Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.518 SNIP 2.475 CiteScore 3.69
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Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.669 SNIP 2.293
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 3.167 SNIP 2.665
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 3.408 SNIP 2.378
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 3.489 SNIP 2.102
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 3.143 SNIP 2.334
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 3.251 SNIP 2.483
Web of Science (2005): Indexed yes
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Scopus rating (2003): SJR 3.708 SNIP 2.573
Web of Science (2003): Indexed yes
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Scopus rating (2001): SJR 3.62 SNIP 2.244
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Scopus rating (2000): SJR 3.416 SNIP 1.705
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Ultra-compact Higher-Order-Mode Pass Filter in a Silicon Waveguide
An 3.7 μm long higher-order-mode pass filter with an extinction ratio larger than 20 dB is demonstrated in a 1D corrugated silicon multimode waveguide

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication
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Multimode, Filter, Silicon waveguide, Photonic Crystals
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Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

Wavelength Conversion of a 640 Gbit/s DPSK Nyquist Channel Using a Low-Loss Silicon Nanowire
640 Gbit/s N-OTDM DPSK wavelength conversion is demonstrated in a Si-nanowire. All 64 tributaries are converted within an average power penalty of 1 dB at the FEC BER-limit3E-3. Only 22-fJ/bit switching energy is required

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Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

Wavelength Conversion of DP-QPSK Signals in a Silicon Polarization Diversity Circuit
Multichannel wavelength conversion is experimentally demonstrated for high-speed 128 Gb/s dual-polarization quadrature phase-shift keying signals using four-wave mixing in a polarization diversity circuit with silicon nanowires as nonlinear elements. The wavelength conversion performance is investigated for both single- and three-channel input signals, showing quality factors well >9.8 dB (corresponding to bit-error-ratios better than 10(-3)) and with a negligible power penalty compared with the back-to-back case.

General information
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Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Nanophotonic Devices, Diode Lasers and LED Systems, University of Sydney, Monash University, University of Rennes
Authors: Vukovic, D. (Intern), Schroeder, J. (Ekstern), Ding, Y. (Intern), Pelusi, M. D. (Ekstern), Du, L. B. (Ekstern), Ou, H. (Intern), Peucheret, C. (Intern)
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1.28 Tbaud Nyquist-OTDM Transmission over a 7-Core Fiber Using an On-Chip SDM Coupler

We have demonstrated the first 1.28-Tbaud Nyquist-OTDM-SDM transmission over a 67.4 - km seven-core fiber with an aggregated data rate of 7.2 Tbit/s using a silicon SDM coupler. 10 - GHz control pulses were transmitted through the center core.

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, polarisation-insensitive and phase-sensitive applications including processing of spectrally-efficient data formats and optical phase regeneration.
Fully-etched apodized fiber-to-chip grating coupler on the SOI platform with -0.78 dB coupling efficiency using photonic crystals and bonded Al mirror

We design and fabricate an ultra-high coupling efficiency fully-etched apodized grating coupler on the SOI platform using photonic crystals and bonded aluminum mirror. Ultra-high coupling efficiency of -0.78 dB with a 3 dB bandwidth of 74 nm are demonstrated.

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Diode Lasers and LED Systems, University of Rennes
Authors: Ding, Y. (Intern), Ou, H. (Intern), Peucheret, C. (Ekstern), Yvind, K. (Intern)
Number of pages: 3
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Communication, Networking and Broadcast Technologies, Components, Circuits, Devices and Systems, Fields, Waves and Electromagnetics, Photonics and Electrooptics, Couplers, Couplings, Fiber gratings, Gratings, Mirrors, Optical waveguides, Silicon
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Publication: Research - peer-review › Article in proceedings – Annual report year: 2014

Fully etched apodized grating coupler on the SOI platform with −058 dB coupling efficiency

We design and fabricate an ultrahigh coupling efficiency (CE) fully etched apodized grating coupler on the silicon-on-insulator (SOI) platform using subwavelength photonic crystals and bonded aluminum mirror. Fabrication error sensitivity and coupling angle dependence are experimentally investigated. A record ultrahigh CE of −0.58 dB with a 3 dB bandwidth of 71 nm and low back reflection are demonstrated.

General information
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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Diode Lasers and LED Systems, University of Rennes
Authors: Ding, Y. (Intern), Peucheret, C. (Intern), Ou, H. (Intern), Yvind, K. (Intern)
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Integrated programmable photonic filter on the silicon -on- insulator platform.
We propose and demonstrate a silicon - on - insulator (SOI) on - chip programmable filter based on a four - tap finite impulse response structure. The photonic filter is programmable thanks to amplitude and phase modulation of each tap controlled by thermal heater s. We further demonstrate the tunability of the filter central wavelength, bandwidth and variable passband shape. The tuning range of the central wavelength is at least 42% of the free spectral range. The bandwidth tuning range is at least half of the free spectral range. Our scheme has distinct advantages of compactness, capability for integrating with electronics.

General information
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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Huazhong University of Science and Technology, University of Rennes
Authors: Liao, S. (Ekstern), Ding, Y. (Intern), Peucheret, C. (Ekstern), Yang, T. (Ekstern), Dong, J. (Ekstern), Zhang, X. (Ekstern)
Pages: 31993–31998
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Scopus rating (2016): CiteScore 3.48 SJR 1.487 SNIP 1.589
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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
Mode-selective wavelength conversion based on four-wave mixing in a multimode silicon waveguide

We propose and demonstrate all-optical mode-selective wavelength conversion in a silicon waveguide. The mode-selective wavelength conversion relies on strong four-wave mixing when pump and signal light are on the same spatial mode, while weak four-wave mixing is obtained between different modes due to phase mismatch. A two-mode division multiplexing circuit with tapered directional coupler based (de)multiplexers and a multimode waveguide is designed and fabricated for this application. Experimental results show clear eye-diagrams and moderate power penalties for the wavelength conversion of both modes.

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Diode Lasers and LED Systems
Authors: Ding, Y. (Intern), Xu, J. (Intern), Ou, H. (Intern), Peucheret, C. (Intern)
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Main Research Area: Technical/natural sciences

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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
On-chip grating coupler array on the SOI platform for fan-in/fan-out of multi-core fibers with low insertion loss and crosstalk

We design and fabricate a compact multi-core fiber fan-in/fan-out using a fully-etched grating coupler array on the SOI platform. Lowest coupling loss of 6.8 dB with 3 dB bandwidth of 48 nm and crosstalk lower than ×32 dB are demonstrated.
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 efficient 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].
Polarization-insensitive wavelength conversion of 40 Gb/s NRZ-DPSK signals in a silicon polarization diversity circuit

Polarization insensitive wavelength conversion of a 40 Gb/s non-return-to-zero (NRZ) differential phase-shift keying (DPSK) data signal is demonstrated using four-wave mixing (FWM) in a silicon nanowire circuit. Polarization independence is achieved using a diversity circuit based on polarization rotators and splitters, which is fabricated by a simple process on the silicon-on-insulator (SOI) platform. Error-free performance is achieved with only 0.5 dB of power penalty compared to the wavelength conversion of a signal with well optimized input polarization. Additionally, data transmission over 161 km standard single-mode fiber (SSMF) is demonstrated at 40 Gb/s using optical phase conjugation (OPC) in the proposed circuit.
Topology optimized mode conversion in a photonic crystal waveguide fabricated in silicon-on-insulator material

We have designed and for the first time experimentally verified a topology optimized mode converter with a footprint of ∼6.3 μm × ∼3.6 μm which converts the fundamental even mode to the higher order odd mode of a dispersion engineered photonic crystal waveguide. 2D and 3D topology optimization is utilized and both schemes result in designs theoretically showing an extinction ratio larger than 21 dB. The 3D optimized design has an experimentally estimated insertion loss lower than ∼2 dB in an ∼43 nm bandwidth. The mode conversion is experimentally confirmed in this wavelength range by recording mode profiles using vertical grating couplers and an infrared camera. The experimentally determined extinction ratio is > 12 dB and is believed to be limited by the spatial resolution of our setup. © 2014 Optical Society of America.

General information
State: Published
Organisations: Department of Photonics Engineering, Nanophotonic Devices, Department of Mechanical Engineering, Solid Mechanics, High-Speed Optical Communication
Authors: Frandsen, L. H. (Intern), Elesin, Y. (Intern), Frellsen, L. F. (Intern), Mitrovic, M. (Intern), Ding, Y. (Intern), Sigmund, O. (Intern), Yvind, K. (Intern)
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Light extinction, Optimization, Three dimensional, Topology, Extinction ratios, Infra-red cameras, Optimized designs, Photonic crystal waveguide, Silicon-on-insulator materials, Spatial resolution, Vertical gratings, Wavelength ranges, Optical waveguides
Ultra-low coupling loss fully-etched apodized grating coupler with bonded metal mirror

A fully etched apodized grating coupler with bonded metal mirror is designed and demonstrated on the silicon-on-insulator platform, showing an ultra-low coupling loss of only 1.25 dB with 3 dB bandwidth of 69 nm.

General information
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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Diode Lasers and LED Systems, University of Rennes
Authors: Ding, Y. (Intern), Peucheret, C. (Intern), Ou, H. (Intern)
Pages: 139-140
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Main Research Area: Technical/natural sciences
Electronic versions:
ThD2.pdf
DOIs:
10.1109/Group4.2014.6961965
Source: PublicationPreSubmission
Source-ID: 100044254
Publication: Research - peer-review › Article in proceedings – Annual report year: 2014

Ultra-wide band signal generation using a coupling-tunable silicon microring resonator

Ultra-wide band signal generation using a silicon microring resonator tuned to an NRZ-DPSK modulated optical carrier is proposed and demonstrated. The scheme is shown to enable the generation of UWB signals with switchable polarity and tunable bandwidth by simply tuning the coupling regions of the microring resonator. Monocycle pulses with both negative and positive polarities are successfully synthesized experimentally.

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Diode Lasers and LED Systems, Huazhong University of Science and Technology
Authors: Ding, Y. (Intern), Huang, B. (Intern), Peucheret, C. (Intern), Xu, J. (Intern), Ou, H. (Intern), Zhang, X. (Ekstern), Huang, D. (Ekstern)
Pages: 6078-6085
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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
Wavelength conversion of a 128 Gbit/s DP-QPSK signal is demonstrated using FWM in a polarization diversity circuit with silicon nanowires as nonlinear elements. Error-free performances are achieved with a negligible power penalty.
All-optical 10 Gb/s AND logic gate in a silicon microring resonator

An all-optical AND logic gate in a single silicon microring resonator is experimentally demonstrated at 10 Gb/s with 50% RZ-OOK signals. By setting the wavelengths of two intensity-modulated input pumps on the resonances of the microring resonator, field-enhanced four-wave mixing with a total input power of only 8.5 dBm takes place in the ring, resulting in the generation of an idler whose intensity follows the logic operation between the pumps. Clear and open eye diagrams with a bit-error ratio below 10−9 are achieved.

General information
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Organisations: Nanophotonic Devices, High-Speed Optical Communication, Department of Photonics Engineering, Diode Lasers and LED Systems, Huazhong University of Science and Technology
Authors: Xiong, M. (Intern), Lei, L. (Intern), Ding, Y. (Intern), Huang, B. (Intern), Ou, H. (Intern), Peucheret, C. (Intern), Zhang, X. (Ekstern)
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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
Mode-Selective Wavelength Conversion Based on Four-Wave Mixing in a Multimode Silicon Waveguide

We report all-optical mode-selective wavelength conversion based on four-wave mixing in a multimode Si waveguide. A two-mode division multiplexing circuit using tapered directional coupler based (de)multiplexers is used for the application. Experimental results show clear eye-diagrams and moderate power penalties for the conversion of both modes.
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.
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 × 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.
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.

Silicon Photonic Integrated Circuit Mode Multiplexer

We propose and demonstrate a novel silicon photonic integrated circuit enabling multiplexing of orthogonal modes in a few-mode fiber (FMF). By selectively launching light to four vertical grating couplers, all six orthogonal spatial and polarization modes supported by the FMF are successfully excited independently.
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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

Scopus rating (2005): SJR 2.97 SNIP 2.454
Web of Science (2005): Indexed yes

Scopus rating (2004): SJR 3.286 SNIP 2.716
Web of Science (2004): Indexed yes

Scopus rating (2003): SJR 3.44 SNIP 2.467
Web of Science (2003): Indexed yes

Scopus rating (2002): SJR 3.566 SNIP 2.117
Web of Science (2002): Indexed yes

Scopus rating (2001): SJR 3.519 SNIP 1.678
Web of Science (2001): Indexed yes

Scopus rating (2000): SJR 2.345 SNIP 1.202
Web of Science (2000): Indexed yes

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Original language: English

Grating coupler, Mode multiplexer, Photonic integrated circuit (PIC), Silicon-on-insulator, Space-division multiplexing (SDM)
Simultaneous Polarization Demultiplexing and Demodulation of PolMux-DPSK Signals in a Silicon Chip

Simultaneous polarization demultiplexing and demodulation of PolMux-DPSK signals is demonstrated using a polarization splitter and rotator together with a single microring resonator on a silicon chip. System experimental results validate the concept.

General information
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Organisations: Nanophotonic Devices, High-Speed Optical Communication, Department of Photonics Engineering, Diode Lasers and LED Systems
Authors: Huang, B. (Intern), Ding, Y. (Intern), Ou, H. (Intern), Peucheret, C. (Intern)
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Systematic comparison of FWM conversion efficiency in silicon waveguides and MRRs

Wavelength conversion based on four-wave mixing is theoretically compared in silicon micro-ring resonators and nanowires under the effect of nonlinear loss. The impact of the bus waveguide length and MRR position are also quantified.

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Organisations: Nanophotonic Devices, High-Speed Optical Communication, Department of Photonics Engineering, Diode Lasers and LED Systems, Huazhong University of Science and Technology
Authors: Xiong, M. (Intern), Ding, Y. (Intern), Ou, H. (Intern), Peucheret, C. (Intern), Zhang, X. (Ekstern)
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Conference: 18th OptoElectronics and Communications Conference (OECC 2013), Kyoto, Japan, 30/06/2013 - 30/06/2013
Source: dtu
Source-ID: n::oai:DTIC-ART:iel/392313469::32072
Publication: Research - peer-review » Article in proceedings – Annual report year: 2013

Topology Optimized Mode Conversion In a Photonic Crystal Waveguide

We experimentally demonstrate an ultra-compact TE0-TE1 mode converter obtained in a photonic crystal waveguide by utilizing topology optimization and show a ~39 nm bandwidth around 1550 nm with an insertion loss lower than ~3 dB.
Ultra-High-Efficiency Apodized Grating Coupler Using a Fully Etched Photonic Crystal
We demonstrate an apodized fiber-to-chip grating coupler using fully etched photonic crystal holes on the silicon-on-insulator platform. An ultra-high coupling efficiency of 1.65 dB (68%) with 3 dB bandwidth of 60 nm is experimentally demonstrated.

Ultra-high-efficiency apodized grating coupler using fully etched photonic crystals
We present an efficient method to design apodized fiber-to-chip grating couplers with Gaussian output profiles for efficient coupling between standard single mode fibers and silicon chips. An apodized grating coupler using fully etched photonic crystal holes on the silicon-on-insulator platform is designed, and fabricated in a single step of lithography and etching. An ultralow coupling loss of $-1.74 \pm 0.09$ dB (67% coupling efficiency) with a 3 dB bandwidth of 60 nm is experimentally measured.
Wideband polarization splitter and rotator with large fabrication tolerance and simple fabrication process

We propose and demonstrate a polarization splitter and rotator (PSR) built on a silicon-on-insulator platform. The PSR is constructed with a tapered waveguide followed by a 2×2 multimode interferometer and can be simply fabricated in a single lithography and etching step. A low insertion loss (<2.5 dB with minimum insertion loss of 0.6 dB) and a low polarization crosstalk (<−12 dB) over a wide operation bandwidth (∼100 nm) with a large fabrication tolerance (>50 nm) are experimentally demonstrated.
Wide-band Polarization Splitter and Rotator with Large Fabrication Tolerance and Simple Fabrication Process

We demonstrate a polarization splitter and rotator built on the silicon-on-insulator platform. The device shows low insertion loss (0.6 dB), low polarization crosstalk (<-12 dB), wide bandwidth (~100 nm), and large fabrication tolerance (60 nm).

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Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication, Diode Lasers and LED Systems
Authors: Ding, Y. (Intern), Ou, H. (Intern), Peucheret, C. (Intern)
Pages: OTh4I.2
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)
41.6 Gb/s RZ-DPSK to NRZ-DPSK Format Conversion in a Microring Resonator

RZ-DPSK to NRZ-DPSK format conversion in a silicon microring resonator is demonstrated experimentally for the first time at 41.6 Gb/s. The converted signal eye diagrams and bit-error-rate measurements show the good performance of the scheme.

General information
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Organisations: High-Speed Optical Communication, Department of Photonics Engineering, Nanophotonic Devices, Huazhong University of Science and Technology
Authors: Xiong, M. (Intern), Ozolins, O. (Intern), Ding, Y. (Intern), Huang, B. (Intern), An, Y. (Intern), Ou, H. (Intern), Peucheret, C. (Intern), Zhang, X. (Ekstern)
Number of pages: 2
Pages: 891-892
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Publisher: IEEE
ISBN (Print): 978-1-4673-0976-9
ISBN (Electronic): 978-1-4673-0977-6
Main Research Area: Technical/natural sciences
Conference: The 17th OptoElectronics and Communications Conference, OECC 2012, Busan, Korea, Republic of, 02/07/2012 - 02/07/2012
Electronic versions:
SC2_1085_FormatConversion_MRR.pdf
DOIs:
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Oral presentation.
Publication: Research - peer-review › Article in proceedings – Annual report year: 2012

Cascadability of Silicon Microring Resonators for 40-Gbit/s OOK and DPSK Optical Signals

The cascadability of a single silicon micro-ring resonator for CSRZ-OOK and CSRZ-DPSK signals is experimentally demonstrated at 40 Gbit/s for the first time. Error-free performance is obtained for both modulation formats after 5 cascaded resonators.

General information
State: Published
Organisations: High-Speed Optical Communication, Department of Photonics Engineering, Nanophotonic Devices, Riga Technical University
Authors: Ozolins, O. (Intern), An, Y. (Intern), Lali-Dastjerdi, Z. (Intern), Ding, Y. (Intern), Bobrovs, V. (Ekstern), Ivanovs, G. (Ekstern), Peucheret, C. (Intern)
Number of pages: 3
Pages: AS1G.1
Publication date: 2012

Host publication information
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Main Research Area: Technical/natural sciences
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Electronic versions:
53E16d01.pdf
Fabrication tolerant polarization splitter and rotator based on a tapered directional coupler

A polarization splitter and rotator (PSR) based on a tapered directional coupler with relaxed fabrication tolerance is proposed and demonstrated on the silicon-on-insulator platform. The device is simply constructed by parallel-coupling a narrow silicon waveguide with a linearly tapered wider waveguide. Compared to previously reported PSRs based on a normal directional coupler, which suffer from stringent requirements on the accuracy of the narrow waveguide width, the introduced tapered structure of the wide waveguide can be used to compensate the fabrication errors of the narrow waveguide. In addition, only a single step of exposure and etching is needed for the fabrication of the device. Similar high conversion efficiencies are experimentally demonstrated for a narrow waveguide width deviation of 14 nm with large tolerance to the coupler length.
Linear signal processing using silicon micro-ring resonators

We review our recent achievements on the use of silicon micro-ring resonators for linear optical signal processing applications, including modulation format conversion, phase-to-intensity modulation conversion and waveform shaping.

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Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Nanophotonic Devices, Diode Lasers and LED Systems, South China Normal University, Wuhan National Laboratory for Optoelectronics
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Pages: ITh5B.1
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Publisher: Optical Society of America
Main Research Area: Technical/natural sciences
Conference: 5th International Photonics and OptoElectronics Meetings (POEM 2012), Wuhan, China, 01/11/2012 - 01/11/2012
Electronic versions:
Modulation Speed Enhancement of Directly Modulated Lasers Using a Micro-ring Resonator

A silicon micro-ring resonator is used to enhance the modulation speed of a 10-Gbit/s directly modulated laser to 40 Gbit/s, demonstrating a potentially integratable transmitter design for high-speed optical interconnects.

On-chip Mode Multiplexer Based on a Single Grating Coupler

A two-mode multiplexer based on a single grating coupler is proposed and demonstrated on a silicon chip. The LP01 and LP11 modes of a few-mode fiber are excited from TE0 and TE1 silicon waveguide modes.
Simultaneous RZ-OOK to NRZ-OOK and RZ-DPSK to NRZ-DPSK format conversion in a silicon microring resonator

Simultaneous RZ-OOK to NRZ-OOK and RZ-DPSK to NRZ-DPSK modulation format conversion in a single silicon microring resonator with free spectral range equal to twice the signal bit rate is experimentally demonstrated for the first time at 41.6 Gb/s. By utilizing an optimized custom-made microring resonator with high coupling coefficient followed by an optical bandpass filter with appropriate bandwidth, good conversion performances for both modulation formats are achieved according to the converted signals eye diagrams and bit-error-rate measurements.

General information
State: Published
Organisations: Nanophotonic Devices, High-Speed Optical Communication, Department of Photonics Engineering, Diode Lasers and LED Systems, Huazhong University of Science and Technology
Authors: Xiong, M. (Intern), Ozolins, O. (Intern), Ding, Y. (Intern), Huang, B. (Intern), An, Y. (Intern), Ou, H. (Intern), Peucheret, C. (Intern), Zhang, X. (Ekstern)
Pages: 27263-27272
Publication date: 2012
Main Research Area: Technical/natural sciences

Publication information
Journal: Optics Express
Volume: 20
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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
Transmission Property of Directly Modulated Signals Enhanced by a Micro-ring Resonator

A silicon micro-ring resonator is used to enhance the modulation speed of a 10-Gbit/s directly modulated laser to 40 Gbit/s. The generated signal is transmitted error free over 4.5 km SSMF. Dispersion tolerance is also studied.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Nanophotonic Devices
Authors: An, Y. (Intern), Lorences Riesgo, A. (Intern), Seoane, J. (Intern), Ding, Y. (Intern), Ou, H. (Intern), Peucheret, C. (Intern)
Number of pages: 2
Pages: 915-916
Publication date: 2012

Host publication information
Title of host publication: Proceedings of the 17th OptoElectronics and Communications Conference
Publisher: IEEE
ISBN (Print): 978-1-4673-0976-9
ISBN (Electronic): 978-1-4673-0977-6
Main Research Area: Technical/natural sciences
Conference: The 17th OptoElectronics and Communications Conference, OECC 2012, Busan, Korea, Republic of, 02/07/2012 - 02/07/2012
Electronic versions:
SC2_1086.pdf
DOI:
10.1109/OECC.2012.6276694
A novel and simple bandwidth and wavelength-tunable optical bandpass filter based on silicon microrings in a Mach-Zehnder interferometer (MZI) structure is proposed and demonstrated. In this filter design, the drop transmissions of two microring resonators are combined to provide the desired tunability. A detailed analysis and the design of the device are presented. The shape factor and extinction ratio of the filter are optimized by thermally controlling the phase difference between the two arms of the MZI. Simultaneous bandwidth and wavelength tunability with in-band ripple control is demonstrated by thermally tuning the resonance offset between the two microring resonators.
Demultiplexing of OTDM-DPSK signals based on a single semiconductor optical amplifier and optical filtering

We propose and demonstrate the use of a single semiconductor optical amplifier (SOA) and optical filtering to time demultiplex tributaries from an optical time division multiplexing-differential phase shift keying (OTDM-DPSK) signal. The scheme takes advantage of the fact that phase variations added to the target channel by cross-phase modulation from the control signal are effectively subtracted in the differential demodulation scheme employed for DPSK signals. Demultiplexing from 80 to 40 Gbit/s is demonstrated with moderate power penalty using an SOA with recovery time twice as long as the bit period at 80 Gbit/s. Large dynamic ranges for the input power and SOA current are experimentally demonstrated. The scheme is expected to be scalable toward higher bit rates. © 2011 Optical Society of America.
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**Original language:** English

**Electronic versions:**
Efficient and compact TE-TM polarization converter built on silicon-on-insulator platform with a simple fabrication process

An efficient TE-TM polarization converter built on a silicon-on-insulator nanophotonic platform is demonstrated. The strong cross-polarization coupling effect in air-cladded photonic-wire waveguides is employed to realize the conversion. A peak TE-TM coupling efficiency of 87% (-0.6 dB insertion loss) is measured experimentally. A polarization conversion efficiency of >92% with an overall insertion loss of < 1.6 dB is obtained in a wavelength range of 40nm. The proposed device is compact, with a total length of 44 μm and can be fabricated with one lithography and etching step. © 2011 Optical Society of America.
A 640 Gbit/s NRZ OTDM signal has been successfully generated for the first time by format conversion of a 640 Gbit/s OTDM signal from RZ to NRZ. First, a coherent 640 Gbit/s OTDM RZ signal is generated by wavelength conversion of the original incoherent OTDM signal utilizing Kerr switching in a highly nonlinear fiber. Second, RZ-to-NRZ format conversion is achieved in a specially designed silicon microring resonator with FSR of 1280 GHz, Q value of 638, high extinction ratio and low coupling loss to optical fiber. A 640 Gbit/s NRZ OTDM signal with very clear eye-diagram and narrower bandwidth than both the original incoherent 640 Gbit/s and the wavelength converted coherent 640 Gbit/s RZ OTDM signals has been obtained. Bit error ratio measurements show error free.
Multi-Channel 40 Gbit/s NRZ-DPSK Demodulation Using a Single Silicon Microring Resonator

We comprehensively analyze the demodulation of wavelength division multiplexed (WDM) non return-to-zero differential phase-shift keying (NRZ-DPSK) signals by a single microring resonator. Simultaneous demodulation of multiple 40 Gbit/s WDM NRZ-DPSK channels is demonstrated using a single silicon microring resonator with free spectral range (FSR) of 100 GHz. Bit error measurements show very good performance for both through and drop port demodulations for all channels, and the drop port demodulation exhibits better wavelength detuning tolerance than for demodulation using a Mach-Zehnder delay interferometer (MZDI).

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Nanophotonic Devices, Huazhong University of Science and Technology
Authors: Ding, Y. (Intern), Xu, J. (Intern), Peucheret, C. (Intern), Pu, M. (Intern), Liu, L. (Intern), Seoane, J. (Intern), Ou, H. (Intern), Zhang, X. (Ekstern), Huang, D. (Ekstern)
Pages: 677-684
Publication date: 2011
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Lightwave Technology
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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
Silicon-on-insulator polarization splitting and rotating device for polarization diversity circuits

A compact and efficient polarization splitting and rotating device built on the silicon-on-insulator platform is introduced, which can be readily used for the interface section of a polarization diversity circuit. The device is compact, with a total length of a few tens of microns. It is also simple, consisting of only two parallel silicon-on-insulator wire waveguides with different widths, and thus requiring no additional and nonstandard fabrication steps. A total insertion loss of -0.6dB and an extinction ratio of 12dB have been obtained experimentally in the whole C-band.
Simple and efficient methods for the accurate evaluation of patterning effects in ultrafast photonic switches

Although patterning effects (PEs) are known to be a limiting factor of ultrafast photonic switches based on semiconductor optical amplifiers (SOAs), a simple approach for their evaluation in numerical simulations and experiments is missing. In this work, we experimentally investigate and verify a theoretical prediction of the pseudo random binary sequence (PRBS) length needed to capture the full impact of PEs. A wide range of SOAs and operation conditions are investigated. The very simple form of the PRBS length condition highlights the role of two parameters, i.e. the recovery time of the SOAs as well as the operation bit rate. Furthermore, a simple and effective method for probing the maximum PEs is demonstrated, which may relieve the computational effort or the experimental difficulties associated with the use of long PRBSs for the simulation or characterization of SOA-based switches. Good agreement with conventional PRBS characterization is obtained. The method is suitable for quick and systematic estimation and optimization of the switching performance.

General information
State: Published
Organisations: High-Speed Optical Communication, Department of Photonics Engineering, Nanophotonics Theory and Signal Processing
Authors: Xu, J. (Intern), Ding, Y. (Intern), Peucheret, C. (Intern), Xue, W. (Intern), Seoane, J. (Intern), Zsigri, B. (Intern), Jeppesen, P. (Intern), Mørk, J. (Intern)
Pages: 155-161
Publication date: 2011
Main Research Area: Technical/natural sciences

Publication information
Journal: Optics Express
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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
SOA-based OTDM-DPSK Demultiplexing Assisted by Offset-Filtering

We demonstrated for the first time 80 to 40 Gb/s OTDM-DPSK demultiplexing using a single SOA assisted by offset-filtering. Error free performance is achieved with an average power penalty of 5.5 dB.
Towards Polarization Diversity on the SOI Platform With Simple Fabrication Process

We present a polarization diversity circuit built on the silicon-on-insulator (SOI) platform, which can be fabricated by a simple process. The polarization diversity is based on two identical air-clad asymmetrical directional couplers, which simultaneously play the roles of polarization splitter and rotator. A silicon polarization diversity circuit with a single microring resonator is fabricated on the SOI platform. Only $1$-dB polarization-dependent loss is demonstrated. A significant improvement of the polarization dependence is obtained for 20-Gb/s nonreturn-to-zero differential phase-shift keying (NRZ-DPSK) demodulation using the polarization diversity circuit, compared to a single microring resonator without polarization diversity.
Ultra-wide Band Signal Generation Using a Silicon Micro-ring Resonator

Ultra-wide band signal generation using a silicon micro-ring resonator tuned to a NRZ-DPSK modulated optical carrier is proposed and demonstrated. Tuning of the coupling regions of the micro-ring enables the synthesis of monocycle pulses.

General information
State: Published
Organisations: High-Speed Optical Communication, Department of Photonics Engineering, Technical University of Denmark, Huazhong University of Science and Technology
Authors: Ding, Y. (Intern), Peucheret, C. (Intern), Xu, J. (Intern), Hou, H. (Ekstern), Zhang, X. (Ekstern), Huang, D. (Ekstern)
Pages: 258-259
Publication date: 2011

Bibliographical note
Color versions of one or more of the figures in this letter are available online at http://ieeexplore.ieee.org.
Source: orbit
Source-ID: 312250
Publication: Research - peer-review › Journal article – Annual report year: 2011

DOIs:
10.1109/LPT.2011.2169776
Bandwidth tunable filter based on silicon microring-MZI structure

A novel bandwidth tunable bandpass filter based on a silicon microring-MZI structure is proposed and demonstrated. By thermally tuning the resonance offset between the two microring resonators, and adding the two drop transmissions together, the bandwidth of the microring-MZI filter can be easily linearly tuned with low in-band ripples.

General information
State: Published
Organisations: Department of Photonics Engineering, Nanophotonic Devices, High-Speed Optical Communication
Authors: Ding, Y. (Intern), Zhang, X. (Ekstern), Huang, D. (Ekstern), Pu, M. (Intern), Liu, L. (Intern), Xu, J. (Intern), Ou, H. (Intern), Peucheret, C. (Intern)
Pages: ThP20
Publication date: 2010

Experimental validation of efficient methods for the prediction of patterning effects in SOA-based optical switches

We demonstrate simultaneous demodulation of multiple 40 Gbit/s WDM NRZ-DPSK channels using a single silicon microring resonator with FSR of 100 GHz. Bit error measurements show very good performances for both through and drop demodulations for all channels

General information
State: Published
Organisations: High-Speed Optical Communication, Department of Photonics Engineering, Nanophotonics Theory and Signal Processing
Authors: Xu, J. (Intern), Ding, Y. (Intern), Xue, W. (Intern), Peucheret, C. (Intern), Seoane, J. (Intern), Zsigri, B. (Intern), Jeppesen, P. (Intern), Mark, J. (Intern)
Pages: P2.22
Publication date: 2010

Multi-Channel 40 Gbit/s NRZ-DPSK demodulation using a single silicon microring resonator

We demonstrate simultaneous demodulation of multiple 40 Gbit/s WDM NRZ-DPSK channels using a single silicon microring resonator with FSR of 100 GHz. Bit error measurements show very good performances for both through and drop demodulations for all channels

General information
Multi-channel WDM RZ-to-NRZ format conversion at 50 Gbit/s based on single silicon microring resonator
We comprehensively analyze multiple WDM channels RZ-to-NRZ format conversion using a single microring resonator. The scheme relies on simultaneous suppression of the first order harmonic components in the spectra of all the RZ channels. An optimized silicon microring resonator with free spectral range of 100 GHz and Q value of 7900 is designed and fabricated for this purpose. Multi-channel RZ-to-NRZ format conversion is demonstrated experimentally at 50 Gbit/s for WDM channels with 200 GHz channel spacing using the fabricated device. Bit error rate (BER) measurements show very good conversion performances for the scheme
RZ-to-NRZ format conversion at 50 Gbit/s based on a silicon microring resonator

We demonstrate RZ-to-NRZ format conversion at 50 Gbit/s based on silicon microring resonator with FSR of 100 GHz. Bit error rate measurements show a low power penalty compared to electrical NRZ signal for error free operation.
Tunable microwave phase shifter based on silicon-on-insulator microring resonator

We demonstrate microwave phase shifters based on electrically tunable silicon-on-insulator microring resonators (MRRs). MRRs with different quality factors are fabricated and tested. A continuously tunable phase shift of up to 336 at a microwave frequency of 40 GHz is obtained using a high-quality-factor (28 000) MRR with only 1.6-mW power consumption. A quasi-linear phase shift in the range of 0 – 204 at 40 GHz with a radio-frequency power variation less than 1.3 dB is also achieved by using a lower-quality-factor MRR.
We propose and demonstrate tunable microwave phase shifters based on electrically tunable silicon-on-insulator microring resonators. The phase-shifting range and the RF-power variation are analyzed. A maximum phase-shifting range of 0°–600° is achieved by utilizing a dual-microring resonator. A quasi-linear phase shift of 360° with RF-power variation lower than 2dB and a continuous 270° phase shift without RF-power variation at a microwave frequency of 40GHz are also demonstrated.
Projects:

**Long distance quantum communication**

Department of Photonics Engineering  
Period: 15/08/2017 → 14/08/2020  
Number of participants: 4  
Phd Student: Da Lio, Beatrice (Ekstern)  
Supervisor: Bacco, Davide (Intern)  
Ding, Yunhong (Intern)  
Main Supervisor: Rottwitt, Karsten (Intern)

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Grundforskningsfonden  
Project: PhD

**mid-IR Si Photonic Chips for Optical Interconnects**  
Department of Photonics Engineering  
Period: 15/12/2016 → 14/12/2019  
Number of participants: 4  
Phd Student: Hui, Tak Lok (Intern)  
Supervisor: Ding, Yunhong (Intern)  
Hu, Hao (Intern)  
Main Supervisor: Galili, Michael (Intern)

**Financing sources**  
Source: Internal funding (public)  
Name of research programme: Eksternt finsieret virksomhed  
Project: PhD

**Silicon Photonic Integrated Devices for Space Division Multiplexing**  
Department of Photonics Engineering  
Period: 01/02/2016 → 31/01/2019  
Number of participants: 4  
Phd Student: Baumann, Jan Markus (Intern)  
Supervisor: Ding, Yunhong (Intern)  
Morioka, Toshio (Intern)  
Main Supervisor: Frandsen, Lars Hagedorn (Intern)

**Financing sources**
**Silicon PIC for ROADM in MCF Communication — Wavelength band switching**

In future optical networks, MCF communication should be combined with WDM technology in order to achieve a maximum communication capacity. However, in network nodes, when channels from different cores of the input MCF are carried at the same wavelength and need to be switched to the same core of the output MCF, a wavelength conflict occurs. Fortunately, such conflict could be avoided by wavelength-converting the waveband from one input core to another band.

Traditional transponders based on optical to electrical to optical (O/E/O) conversions not only have higher energy consumption, but are unable to perform wavelength band conversion. Silicon (Si), amorphous silicon (a-Si), or silicon nitride (Si$_3$N$_4$) not only enable wide-band wavelength conversion with modulation format transparency, but also share the same platform as silicon PIC-based ROADMs. The goal of this Sapere Aude project is to explore wavelength band switching in silicon PIC-based ROADMs using ultra-low loss Si, a-Si or Si$_3$N$_4$ nano-waveguides, which will be fabricated at DTU Danchip. Depending on the input core for which FWM needs to be performed, pump light will be selectively coupled to the corresponding nano-waveguide. The converted signals will be coupled to the required core of the output MCF by the switching matrix in the ROADM.

Department of Photonics Engineering

Nanophotonic Devices

High-Speed Optical Communication

Period: 01/11/2013 → 31/10/2016

Number of participants: 1

Project ID: DFF – 1335-00771

Project participant:

Ding, Yunhong (Intern)

Project

**Silicon Photonic Integrated Circuits for Reconfigurable Optical Add/Drop Multiplexer in Multicore Fibre Communication**

The information revolution has modified our life style in terms of work, services, medical treatment, entertainment, etc. Nowadays, optical fibre networks are capable of transmitting a large amount of information by means of short pulses of light. It has been thought that the transmission capacity of optical fibres would be inexhaustible. However, the fast increasing demands from HDTV, IPTV, rich media services, as well as business services are pushing the amount of information transmitted over traditional optical fibre networks close to their ultimate capacity limitation. Multicore fibre communication, where multiple cores are introduced in a single fibre, exploits space as a new dimension, allowing a many-fold increase of capacity. However, achieving a higher transmission capacity is only one requirement for future networks. In order to achieve a real commercial success, this new technology must also support photonic routing in future multicore fibre network nodes, where many functionalities still remain to be demonstrated. This project will explore integrated solutions for the required functionalities in multicore fibre communication, targeting low loss and low energy consumption of network nodes. The project will develop a compact silicon chip integrating all the networking functionalities together, aiming to demonstrate a powerful module and pushing multicore fibre communications one step closer to reality.

Department of Photonics Engineering

Nanophotonic Devices

High-Speed Optical Communication

Period: 01/11/2013 → 31/10/2016

Number of participants: 1

Acronym: SimcROADM

Project ID: DFF – 1337-00152

Project participant:

Ding, Yunhong (Intern)

Project

**Topology Optimized Components for Mode- and Wavelength Division Multiplexing**

Department of Photonics Engineering

Period: 01/10/2013 → 11/01/2017

Number of participants: 6

PhD Student:

Frellsen, Louise Floor (Intern)
Supervisor:
Ding, Yunhong (Intern)
Main Supervisor:
Frandsen, Lars Hagedorn (Intern)
Examiner:
Galili, Michael (Intern)
Liu, Liu (Intern)
Madsen, Søren Peder (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Eksternt finansieret virksomhed

**Relations**
Publications:
Topology Optimized Components for Mode- and Wavelength Division Multiplexing
Project: PhD