Photonic Delay-based Reservoir Computing Integrated on InP Chip

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Integrated Photonics Reservoir computing

Delay-based reservoir computing (RC) offers a simple technological route to implement photonic neuromorphic computation. Its operation boils down to a time-multiplexing with the delay limiting the processing speed. As most optical setups end up to be bulky employing long fiber loops or free-space optics, the processing speeds are limited in the range of kSa/s to tens of MSa/s [1]. In this work, we focus on external cavities which are far shorter than what has been realized before in experiment. We present the results of an experimental validation of reservoir computing based on a semiconductor laser with a 10.8 cm delay line, both integrated on an active/passive InP photonic chip built on the Jeppix platform [3]. The single mode laser operates around 1550nm with a side mode suppression of larger than 20dB.

Results

The performance is tested by one-step-ahead prediction of a laser generated timeseries from the Santa-Fe timeseries competition. A three level mask with 23 nodes separated by 50ps is employed, which corresponds to a speed of 0.87 GSa/s. The performances are indicated by the Normalized Mean Square Error(NMSE) in Fig. 1. The NMSE is calculated by a 80-20% split of the data set for training and testing, and the best performance out of 5-fold cross validation is chosen as the performance of a particular set.

The left plot in figure 1, illustrates how the performance relates to the pump current of the reservoir laser (Threshold current I_{th}=15mA). At higher pump strength the performance improves significantly. In the middle plot we put the injection wavelength along the abscissa. The lowest NMSE or the best performance is observed at 1549.96nm, which is also the lasing wavelength, hence at the point where injection locking is achieved. The last plot has the total current applied to the two feedback SOA’s placed along the abscissa, i.e. the feedback strength increases along the y-axis. We see that the performance generally improves as feedback increases, with some outliers that can be attributed to changes of feedback phase.

The best experimental NMSEs reached here, is an NMSE of 0.13. Which is in the same range as the value of 0.12 reached by Larger et. al. [5] with an optoelectronic setup with 400 virtual nodes at a processing speed of 48 kSa/s. Brunner et al. [3] achieved a prediction error as low as 10.6%, at a speed of 13 MSa/s with a fiberloop. We have achieved a significant speed up, with computation speed of 0.87 GSa/s, while also drastically decreasing the footprint of the setup.

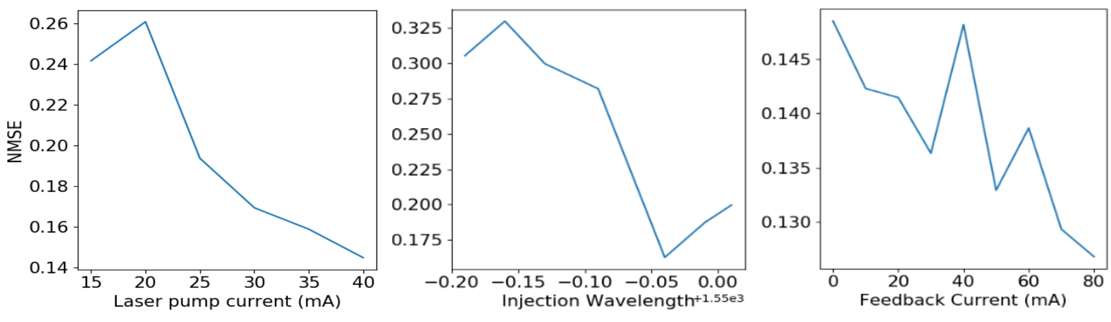

Fig. 1 The performance indicated by the NMSE as a function of the pump current (left), Injection wavelength (middle) and combined current applied to the two SOA's in the delay line (right)

References

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35 words abstract:

We present an experimental validation of delay-based reservoir computing using a semiconductor laser integrated on an InP chip, reaching computation speeds of up to 0.87 GSa/s. The scheme is benchmarked using timeseries prediction tasks.

ROOM 14c ICM

EE-2.3 SUN 14:45

Visible/Multi-THz 2D Spectroscopy for Phase Sensitive Investigation of Ultrafast Carrier Dynamics

•*J. Allerbeck[1], L. Spitzner[1], T. Kurihara[1,3], A. Leitenstorfer[1], and D. Brida[1,2]; [1]University of Konstanz, Konstanz, Germany; [2]Université du Luxembourg, Luxembourg, Luxembourg; [3]Japan Society for the Promotion of Science, Tokyo, Japan*

Asymmetric two-dimensional spectroscopy with visible excitation and multi-THz readout enables phase sensitive investigation of correlations between high- and low-energy excitations as demonstrated in preliminary studies that track ultrafast carrier dynamics in graphite.

EE-2.4 SUN 15:00

Observing Nonlinear Plasmon-Exciton Coupling for Enhanced Harmonic Generation

•*J. Zhong[1], J. Yi[1], D. Wang[2], A. Korte[1], A. Chimeh[1], P. Schaaf[2], E. Runge[3], and C. Lienau[1]; [1]Institut für Physik, Carl von Ossietzky Universität, Oldenburg, Germany; [2]Institut für Werkstofftechnik, Technische Universität Ilmenau, Ilmenau, Germany; [3]Institut für Physik, Technische Universität Ilmenau, Ilmenau, Germany*

The microscopic origin of plasmon-enhanced

ROOM 21 ICM

[2]ARC Centre of Excellence for Engineered Quantum Systems, Macquarie University, NSW 2109, Australia; [3]Chemical and Quantum Physics, School of Sciences, RMIT University, Melbourne 3001, Australia; [4]Fraunhofer Institut für Angewandte Festkörperphysik (IAF), Freiburg, Germany; [5]Institute for Quantum Optics / IQST, Universität Ulm, Ulm, Germany; [6]ARC Centre of Excellence for Nanoscale BioPhotonics, School of Sciences, RMIT University, Melbourne, VIC 3001, Australia

We report the progress of our experimental study towards NV laser magnetometry in open fibre cavities and the theoretical study of NV absorbed diamond Raman laser in such a micro-cavity for magnetic sensing applications.

JSV-2.4 SUN 15:00

Use of optical quantum sensors to study chemical processes

•*V. Cimini, I. Gianani, L. Ruggiero, T. Gasperi, M. Sbroscia, E. Roccia, D. Tofani, F. Bruni, M.A. Ricci, and M. Barbieri; Università degli studi di Roma Tre, Roma, Italy*

Optimal sensors should have two basic features: use quantum effects and follow noisy dynamic processes. Here we implement a quantum multiparameter protocol, robust against time-varying noise to study the dynamic of a chemical process.

ROOM 1 Hall A1

CH-2.4 SUN 14:45

Extending the Exposure Time in High-Resolution Mobile Tunnel LIDAR

•*T. Murakami, N. Saito, T. Michikawa, Y. Komachi, M. Sakashita, S. Kogure, K. Kase, S. Wada, and K. Midorikawa; RIKEN Center for Advanced Photonics, 2-1 Hirosawa, Wako, Saitama, Japan*

We showed that enough exposure time is essential to satisfy the SN ratio and safety standards in a high-resolution vehicle-mounted laser measurement, and introduced time delay integration method as a solution

CH-2.5 SUN 15:00

Atmospheric CO_2-detection via Scheimpflug DIAL Employing a Simple Fiber Amplifier

X. Yang[1,2], J. Larsson[3], •R. Lindberg[1], C. Xu[4], J. Bood[3], M. Brydegaard[3,5], and F. Laurell[1]; [1]Department of Applied Physics, Royal Institute of Technology (KTH), Stockholm, Sweden; [2]Centre for Optical and Electromagnetic Research (COER), State Key Laboratory of Modern Optical Instrumentation, Hangzhou, China; [3]Department of Physics, Div. of Com-

ROOM 2 Hall A1

CF-2.4 SUN 14:45

76 fs SWCNT-SA mode-locked Tm:MgWO4 laser at 2 μm

L. Wang[1], Y. Zhao[1], Y. Wang[1], L. Zhang[2], H. Lin[2], J.E. Bae[3], S.Y. Choi[3], F. Rotermund[3], P. Loiko[4], X. Mateos[5], U. Griebner[1], V. Petrov[1], and •W. Chen[1,2]; [1]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Berlin, Germany; [2]Key Laboratory of Optoelectronic Materials Chemistry and Physics, Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences, Fuzhou, China; [3]Department of Physics, KAIST, Daejeon, South Korea; [4]ITMO University, Petersburg, Russia; [5]Física i Cristal·lografia de Materials i Nanomaterials (FiCMA-FiCNA), Universitat Rovira i Virgili (URV), Tarragona, Spain

We report on a SWCNT-SA mode-locked Tm:MgW laser with chirped mirrors for dispersion management, delivering pulses as short as 76 fs at 2037 nm with a repetition rate of 86.5 MHz.

CF-2.5 SUN 15:00

Chirped-pulse optical parametric oscillators

•*P. Liu and Z. Zhang; Huazhong University of Science & Technology, Wuhan, China*

We demonstrated that by introducing self-phase-modulation effects into a conventional optical-parametric-oscillator (OPO) cavity and dis-

ROOM 6 Hall A1

CI-2.4 SUN 15:00

Experimental observation of propagation direction dependent performance of single-mode multi-core and few-mode fiber links

•*R. S. Luis[1], G. Rademacher[1], B.J. Puttnam[1], H. Furukawa[1], Y. Awaji[1], R. Maruyama[2], K. Aikawa[2], and N. Wada[1]; [1]NICT, Koganei, Japan; [2]Fujikura Ltd., Chiba, Japan*

We report the observation of direction dependent performance on links using multi-core and few-mode fibers. We show increased crosstalk sensitivity by 0.9 dB for

ROOM 7 Hall A1

CE-2.4 SUN 15:00

Super-Quadratic Up-conversion Luminescence among Lanthanide Ions

•*I. Carrasco[1], L. Laversenne[2], S. Bigotta[3], A. Toncelli[3], M. Tonelli[3], A.I. Zagumennyi[4], and M. Pollnau[1]; [1]Advanced Technology Institute, Department of Electrical and Electronic Engineering, University of Surrey, Guildford, United Kingdom; [2]Department of Materials and Functions, Institut NEEL, CNRS/UGA UPR2940, Grenoble, France; [3]NEST-Istituto Nanoscienze-CNR and Dipartimento di Fisica, Universita di Pisa, Pisa, Italy; [4]Prokhorov Institute of General Physics, Russian Academy of Sciences, Moscow, Russia*

We measured the dependence between upconversion (visible)

ROOM 8 Hall A1

JSI-1.3 SUN 14:45

Non-volatile photonic weights and their impact on photonic reservoir computing systems

•*P. Stark[1], J. Geler Kremer[2,1], F. Eltes[1], D. Caimi[1], J. Fompeyrine[1], B.J. Offrein[1], and S. Abel[1]; [1]IBM Research – Zurich, Rüschlikon, Switzerland; [2]The University of Texas at Austin, Austin, USA*

We demonstrate non-volatile synaptic weights based on ferroelectric barium titanate films integrated on Si waveguides for a photonic reservoir computing system. We discuss the impact of imperfections in such hardware weights on the reservoir performance.

JSI-1.4 SUN 15:00

Photonic Delay-based Reservoir Computing Integrated on InP Chip

•*K. Harkhoe[1], G. Verschaffelt[1], A. Katumba[2], P. Bienstman[2], and G. Van der Sande[1]; [1]Applied Physics Research Group, Vrije Universiteit Brussel, Brussel, Belgium; [2]Photonics Research Group, Ghent University – IMEC, Gent, Belgium*

We present an experimental validation of delay-based reservoir computing using a semiconductor laser integrated on an InP chip, reaching computation speeds of up to 0.87

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