



**SEVENTH FRAMEWORK PROGRAMME
THEME 3
Information and Communication Technologies**

Project acronym: *PHOCUS*

Project full title: Towards a PHOtonic liquid state machine based on delay-CoUpdled Systems

Contract no.: 240763

Organisation name of the lead contractor for this deliverable: IFISC, Universitat de les Illes Balears (UIB)

Deliverable due date: Month 36

Start date of project: 01.01.2010

Duration: 3 years

Deliverable D16: Year 3 Management Report

Dissemination level: CONFIDENTIAL

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SUMMARY

The aim of the PHOCUS project is to design and implement a photonics realization of a liquid state machine (LSM), with the potential for versatile and fast signal handling. We target to achieve high computational performance with only a small number of photonics components, using dynamical systems with time delay to realize the required high dimensionality for the LSM.

In this third year we have submitted the following deliverables:

D9	Influence of input method, topology and diversity	3, 6	R	PU	30
D12	Optimizing the configuration for a feature recognition task	3, 5	R	PU	30
D13	Final Plan for the use and dissemination of Foreground	2	R	PU	33
D14	Report on the awareness and wider social implications	2	R	PU	35
D15	Implementation of computational task and performance comparison with other systems	3, 4, 5, 6	R/D	PU	36
D16	Year 3 Management report	1	R	CO	36
D17	Year 3 Scientific report	1	R	PU	36
D18	Final report	1	R	CO	36

We have also achieved the following Milestones:

6	Motifs of delay-coupled neuron populations: diversity effects in the elements and the delay	3, 4	30	Deliverable D9
7	Topology and motifs implementation	5, 6	30	Deliverable D9
8	Optimizing the configuration and plasticity effects	3, 4, 5	30	Deliverable D12
9	Implementation of the final system for the proof of principles	6	36	Deliverable D15

BRIEF ACCOUNT OF THE PROGRESS OF THE PROJECT

The third year of the project started on January 1st 2012.

The fifth general meeting took place in Brussels, organized by the partner VUB, on July 2nd and 3rd with the participation of all group leaders as well as other members of the project. The first day was used to present the scientific achievements during the previous six months and the second one to discuss administrative issues and coordinate the tasks for the following six months. A successful progress of the project was observed and no correction actions were required.

To organize the final deliverables and start to prepare the material for the final review, a one-day meeting took place in Mallorca on September 24th with the participation of all the WPs leaders and some other members.

The group continued its activity by disseminating results in international journals, conferences as well as demonstration. At the end of the year a manuscript, with the first experimental implementation of an all-optical reservoir computing working at GHz rates, was accepted for publication in Nature Communications. The manuscript is the result of the close collaboration between the groups CSIC and UIB, although other members of the PHOCUS consortium participated in discussions. The manuscript entitled “Parallel photonic information processing at GByte/s data rates using transient states” by D. Brunner, M.C. Soriano, C.R. Mirasso & I. Fischer, appeared in January 2013. It showed experimentally, and for the first time, that a single semiconductor laser subject to delay optical feedback is capable of processing information at GByte/s as efficiently as the most advanced traditional reservoir computing approaches but at a much higher speed.

During 2012 and according to the suggestions of the reviewers the Web page was reorganized and continuously updated. The web page (<http://ifisc.uib-csic.es/phocus>) still contains the most relevant information about the project but now with a more appealing format. Concerning the EC funding, the money was received on May 16th 2012 and was transferred without any delay to the rest of the partners.

During the last year we continued with the effort to promote the project and its results in the media. Just to highlight few examples, a press release about the article **Photonic Nonlinear Transient Computing with Multiple-Delay Wavelength Dynamics**, Romain Martinenghi, Sergei Rybalko, Maxime Jacquot, Yanne K. Chembo

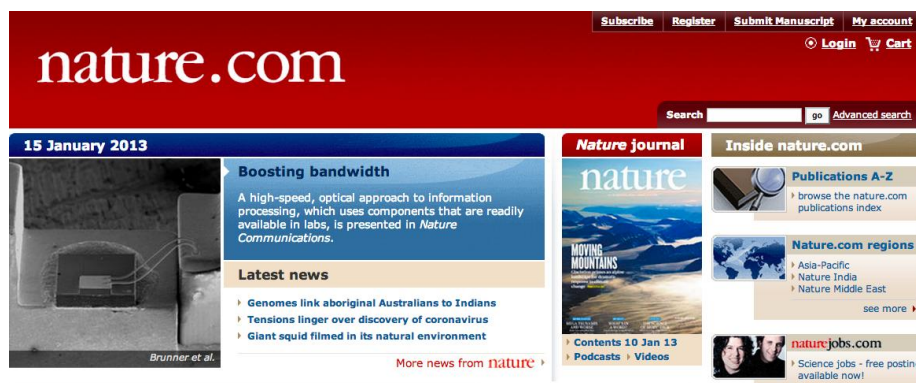
& Laurent Larger, Physical Review Letters **108**, 244101 (2012), from UFC partner was written by Giovanni Volpe in Optics and Photonics Phocus of September 2012.



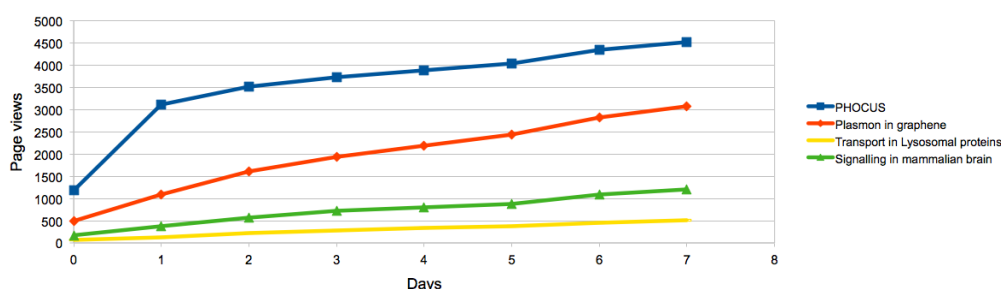
Photonic Brains

Thinking at the speed of light may soon acquire new meaning — inspired by how the brain processes information, researchers present an optical system capable of recognizing spoken words.

A press release, covering the paper **Parallel photonic information processing at gigabyte per second data rates using transient states**, D. Brunner, M.C. Soriano, C.R. Mirasso and I. Fischer, Nature Communications, **4**DOI:10.1038/ncomms2368, (2013) was submitted and reported by different press agencies (see for details http://ifisc.uib-csic.es/phocus/index.php?option=com_content&view=article&id=53&Itemid=59). The general impact was excellent, having interviews from Spain, USA and Russia. Moreover, the paper appeared in the cover page of Nature webpage during the week that the paper was published, as shown the image.



Interestingly, the number of visits to the article via the web page was the largest, compared with the other articles of the same days, as shown in the graphic. It is remarkable that the web page was visited about 4500 times in one week.



PUBLICATIONS

1. M. C. Soriano, J. Garcia-Ojalvo, C. R. Mirasso, and I. Fischer, *Complex Photonics: Dynamics and applications of delay-coupled semiconductor lasers*, accepted for publication in Review of Modern Physics (2013).
2. D. Brunner, M.C. Soriano, C.R. Mirasso and I. Fischer “*Parallel photonic information processing at gigabyte per second data rates using transient states*”, Nature Communications, DOI: 10.1038/ncomms2368, (2013).
3. M. C. Soriano, S. Ortín, D. Brunner, L. Larger, C. R. Mirasso, I. Fischer, and L. Pesquera “*Optoelectronic reservoir computing: tackling noise-induced performance degradation*”, Opt. Exp. **21**, 12 (2013).
4. L. Larger, M. C. Soriano, D. Brunner, L. Appeltant, J. M. Gutierrez, L. Pesquera, C. R. Mirasso, I. Fischer, *Photonic information processing beyond Turing: an optoelectronic implementation of reservoir computing*, Opt. Exp. 20, 3241 (2012).
5. K. Hicke, M. A. Escalona, M. C. Soriano, D. Brunner, I. Fischer and C. R. Mirasso, “*Information processing using transient dynamics of semiconductor lasers subject to delayed feedback*”, Invited Paper, J. of Sel. Topics in Quantum Electron., accepted for publication.
6. R. Martinenghi, S. Rybalko, M. Jacquot, Y. Chembo, L. Larger, “*Photonic Nonlinear Transient Computing with Multiple-Delay Wavelength Dynamics*”, Physical Review Letters, Vol.108, 244101 (2012).
7. L. Larger, “*Delay dynamics in optoelectronics: fundamental and applications from chaos to fixed point, through limit cycles*”, accepted for publication in Phil. Trans. Roy. Soc. A, (2013).
8. J. M. Gutiérrez, D. San-Martin, S. Ortin, and L. Pesquera, Simple Reservoirs with Chain Topology Based on a Single Time-Delay Nonlinear Node, ESANN 2012 proceedings, European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, pp. 13-18, i6doc.com publ., ISBN 978-2-87419-049-0.
7. S. Ortin, D. San-Martin, L. Pesquera, and J. M. Gutiérrez, *Photonic Single Nonlinear-delay Dynamical Node for Information Processing*, SPIE Proceedings, “*Semiconductor lasers and laser dynamics V*”, Eds. K. Panajotov,

- M. Sciamanna, A. Valle, R. Michalzik, vol. 8432, art. 8432 14 (SPIE, Washington, DC), ISBN: 9780819491244. DOI: 10.1117/12.922463 (2012).
8. M. C. Soriano, D. Brunner, S. Ortín, C. R. Mirasso, L. Larger, I. Fischer, and L. Pesquera, *A Novel Photonics Approach to Unconventional Information Processing*, European Conference and Exhibition on Optical Communication (ECEO 2012), OSA Technical Digest (online) (Optical Society of America, 2012), paper We.2.F.2.
<http://www.opticsinfobase.org/abstract.cfm?URI=ECEO-2012-We.2.F.2>
 9. D. Brunner, X. Porte, M. C. Soriano, and I. Fischer, *Real-time frequency dynamics and high-resolution spectra of a semiconductor laser with delayed feedback*, Sci. Rep. **2**, 732 (2012).
 10. O. D’Huys, I. Fischer, J. Danckaert, and R. Vicente, *Spectral and correlation properties of rings of delay-coupled elements: Comparing linear and nonlinear systems*, Phys. Rev. E **85**, 056209 (2012).
 11. Otti D’Huys, Raul Vicente, Jan Danckaert and Ingo Fischer, *Dynamical properties of two delay-coupled lasers: on spectra, correlations and synchronisation*, Proceedings of SPIE Volume: 8432 Semiconductor Lasers and Laser Dynamics V, Editor(s): Panajotov, K; Sciamanna, M; Valle, A; et al., Article Number: 843215 DOI: 10.1117/12.922307 (2012).
 12. L. Appeltant, M.C. Soriano, G. Van der Sande, J. Danckaert, S. Massar, J. Dambre, B. Schrauwen, C. R. Mirasso, and I. Fischer, *Computing using delayed feedback systems: towards photonics*, Proceedings of SPIE Volume: Nonlinear Optics and Applications VI, vol. 8434, Article Number: 84341W DOI: 10.1117/12.922805 (2012).
 13. 1. H. Toutounji, J. Schumacher, G. Pipa. “*Optimized Temporal Multiplexing for Reservoir Computing with a Single Delay-Coupled Node*”, Proceedings of the 2012 International Symposium on Nonlinear Theory and its Applications, Palma, Majorca, Spain
 14. 2. J. Schumacher, R. Haslinger, and G. Pipa, “*Statistical modeling approach for detecting generalized synchronization*”, Phys. Rev. E **85**, 056215 (2012).
 15. E. J. Ngamga, D. V. Senthilkumar, A. Prasad, P. Parmananda, N. Marwan, and J. Kurths, “*Distinguishing dynamics using recurrence-time statistics*”, Phys. Rev. E **85** 026217(1-10) (2012).

16. D. V. Senthilkumar, M. Manju Shrii and J. Kurths, “*Noise-enhanced phase synchronization in time-delayed Systems*”, Phys. Rev. E 85 026218(1-6) (2012).
17. M. Manju Shrii, D. V. Senthilkumar and J. Kurths, “*Delay coupling enhances synchronization in complex networks*”, Eurphys. Lett. 98 10003(1-6) (2012).
18. K. Srinivasan, D. V. Senthilkumar, I. Raja Mohamed, K. Murali, M. Lakshmanan and J. Kurths, “*Anticipating, complete and lag synchronizations in RC phase-shift network based coupled Chua's circuits without delay*”, Chaos 22 023124(1-9) (2012).
19. M. Manju Shrii, D. V. Senthilkumar and J. Kurths, “*Delay-induced synchrony in complex networks with conjugate coupling*”, Phys. Rev. E 85 057203(1-5) (2012).
20. R. Suresh, D. V. Senthilkumar, M. Lakshmanan and J. Kurths, “*Transition to complete synchronization and global intermittent synchronization in an array of time-delay Systems*”, Phys. Rev. E 86 016212(1-7) (2012).
21. R. Suresh, D. V. Senthilkumar, M. Lakshmanan and J. Kurths, “*Global and partial phase synchronizations in arrays of piecewise linear time-delay systems*”, Int. J. Bifurcation Chaos 22 1250178(1-25) (2012).
22. Wei Zou, D. V. Senthilkumar, Yang Tang and J. Kurths, “*Stabilizing oscillation death by multicomponent coupling with mismatched delays*”, Phys. Rev. E 86 036210(1-9) (2012).
23. X. L. Yang, D. V. Senthilkumar and J. Kurths, “*Nontrivial influences of information transmission delays on noise-induced spatiotemporal patterns in complex neuronal networks*”, Chaos 22 043159(1-7) (2012).
24. L. Weicker, T. Erneux, M. Jacquot, Y. Chembo, L. Larger, “*Crenelated fast oscillatory outputs of a two delay electro-optic oscillator*”, Physical Review E, Vol.85, 026206 (2012).
25. L. Weicker, T. Erneux, O. D'Huys, J. Danckaert, M. Jacquot, Y. Chembo, L. Larger, “*Strongly asymmetric square-waves in a time delayed system*”, Physical Review E, Vol.86, 055201(R)(2012).

EDITORIAL WORK

1. Ingo Fischer, Guest Editor for a theme issue on “*Dynamics, control and information in delay-coupled systems*” in the Philosophical Transactions of the Royal Society A, accepted (2013).

BOOK CHAPTERS

1. Cristina M. Gonzalez, Miguel C. Soriano, M. Carme Torrent, Jordi Garcia-Ojalvo, and Ingo Fischer, *Dynamical and Synchronization Properties of Delay-Coupled Lasers*, in ‘Nonlinear Laser Dynamics: From Quantum Dots to Cryptography’, Kathy Lüdge (Editor), Heinz Georg Schuster (Series Editor), ISBN: 978-3-527-41100-9, Wiley-VCH, Weinheim (2012).
2. D. V. Senthilkumar, M. Manju Shree and J. Kurths, Chapter 31 on “*Phase and complete synchronizations in time-delay Systems*” in the book on the 75th birthday of Prof. Leon Chua entitled “*Chaos, CNN, Memristors and Beyond*” World Scientific (2013).

SUPERVISION OF THESIS

1. Lennert Appeltant: "Liquid state computing based on delay-coupled systems", PhD Thesis, Advisors: J. Danckaert, I. Fischer and G. Van der Sande (finished 06/2012), Brussels (Belgium) and Palma de Mallorca (Spain).
2. André Kovac and Maximilian Koall, "Overcoming the limited fading memory capacity of a single node reservoir computer", BsC thesis, Department of Neuroinformatics, University Osnabrück, 2012.
3. Alexander Meier, 'Multi scale Reservoir computing Using SORN and Mackey-Glass System', BsC thesis, Department of Neuroinformatics, University Osnabrück, 2012.
4. Henning Lange, 'Time Series Prediction with Reservoir Computers using a Delay Coupled Non-Linear System', BsC thesis, Department of Neuroinformatics, University Osnabrück, 2012.
5. Marcel Nonnenmacher, 'Optimization of reservoir for RC systems based on a single nonlinear node on the nParity task', BsC thesis, Department of Neuroinformatics, University Osnabrück, 2012.
6. Rafael Reisenhofer, 'A Volterra Series Approach to Liquid State Machines by Application of the Lambert W Function', BsC thesis, Department of Neuroinformatics, University Osnabrück, 2012.

PARTICIPATION TO CONFERENCES

- C. Mirasso, “Information processing with transients states generated by delay-coupled dynamical systems”, (Plenary Talk) Dynamics Days South America 2012, Cartagena, Colombia, November 2012.
- C. Mirasso, “Mimicking the brain: information processing with delay-coupled systems”, (Invited Talk) Mecánica Estadística del Desequilibrio y Física No Lineal, MEDYFINOL 2012 XVII edition, Santiago de Chile, Chile, December 2012.
- D. Brunner, “Photonic information processing based on Reservoir computing”, (Invited Talk) Lindau Nobel Laureate Meetings, Lindau & Mainau Island, Germany July 2012.
- D. Brunner, “Information processing utilizing delay systems”, (Invited Talk) International Conference on Delayed Complex Systems, Palma de Mallorca, Spain, June 2012.
- D. Brunner, “All optical Reservoir Computing with GByte/s rate”(Invited Talk) European conference on Complex Systems (ECCS), Brussels, Belgium, September 2012.
- D. Brunner, “Information processing utilizing delay systems”,(Talk) NOLTA 2012, Palma de Mallorca, Spain, October 2012.
- M. C. Soriano, R. Modeste Nguimdo, P. Colet, "Delay identification in semiconductor lasers with optical feedback", XVIII Congreso de Física Estadística FISES"12, Palma de Mallorca, Spain, October 2012. (Poster)
- M. C. Soriano, G. Van der Sande, I. Fischer , C. R. Mirasso, "Synchronization Without Correlation", (Talk) 2012 International Symposium on Nonlinear Theory and its Applications (NOLTA 2012), Palma de Mallorca, Spain, October 2012. (Talk)

- I. Fischer, “Delay-Coupled Laser Networks: Complex Behavior, Synchronization and Applications”, (Invited Talk) DPG Conference, 25.-30. March 2012, Berlin, Germany.
- I. Fischer “Generalized synchronization of nonlinear oscillators: How to understand and how to detect?”, (Invited Talk) NeFF-Workshop on Non-linear and model-free Interdependence Measures in Neuroscience, 26.-27. April 2012, Frankfurt, Germany.
- I. Fischer, “Dynamics and Synchronization Phenomena in Delay-Coupled Laser Systems”, (Invited Talk) NOLTA2012, International Symposium on Nonlinear Theory and its Applications, 22.-26. October 2012, Palma de Mallorca, Spain.
- I. Fischer, “Chaotic delayed maps and their natural measure” (Invited Talk), NOLTA2012, International Symposium on Nonlinear Theory and its Applications, 22.-26. October 2012, Palma de Mallorca, Spain.
- G.Pipa, key note lecture, ‘Self-organized Reservoir computing’, International conference on Artificial Neuronal Networks, Lausanne, Switzerland, September 2012
- H. Toutounji, ‘Neuronal plasticity leads to noise robust population code’, Osnabrück Computational Cognition Alliance Meeting 2010, Osnabrück, Germany, June 2012
- H. Toutounji, ‘Optimized Temporal Multiplexing for Reservoir Computing with a Single Delay-Coupled Node’, 2012 International Symposium on Nonlinear Theory and its Applications, Palma, Majorca, Spain, October 2012
- D. V. Senthilkumar, “Noise-enhanced Phase synchronization in time-delay systems”, 2nd International Symposium On Complex Dynamical Systems and Applications, Presidency University, Kolkata, India, January 9 - 11, 2012.

- D. V. Senthilkumar, “Delay-enhanced synchronization in complex networks”, International Conference on Delayed Complex Systems (DCS12), Palma de Mallorca, Spain, 4 - 8 June, 2012.
- D. V. Senthilkumar participated in international conference on Data analysis and modelling in Earth sciences (DAMES 2012), Potsdam, Germany, 8 - 10 October 2012.
- L. Larger, L. Weicker, M. Jacquot, Y.K. Chembo, T. Erneux, “Temporally nonlocal dual delay electro-optic phase dynamics, and its bifurcation scenario”, CLEO US, San Jose, California, USA (May 6-11, 2012).
- M. Jacquot, L. Weicker, Y.K. Chembo, T. Erneux, L. Larger, “Crenelated slow-fast oscillations in a dual delay nonlinear photonic dynamics”, ECC 12, Univ. of Michigan, Michigan, USA (May 16-19, 2012).
- L. Weicker, T. Erneux, M. Jacquot, Y. Chembo, L. Larger, “Analytical and experimental study of two delay optoelectronic oscillator”, DCS12, p.31, Univ. Illes Balears, IFISC, Palma de Mallorca, Spain, 4-8 June 2012.
- L. Larger, M. Soriano, L. Appeltent, D. Brunner, C. Mirasso, I. Fischer, J.M. Gutierrez, L. Pesquera, R. Martinenghi, M. Jacquot, Y. K. Chembo, “Emulating a complex dynamical network through a nonlinear delay dynamics: application to photonic Reservoir Computing”, 7th Crimean School and Workshop, Mellas, Crimea, Ukraine (May 20-27, 2012).
- S. Ortín, L. Pesquera, and J. M. Gutiérrez, *Reservoir Computing with Two Decoupled Nonlinear Delay Nodes*, Proceedings of the 2012 International Symposium on Nonlinear Theory and its Applications (NOLTA, IEICE Japan 2012), paper B4L-D4, pp. 515-518, Palma de Mallorca, Spain.

- S. Ortin, D. San-Martin, L. Pesquera, and J. M. Gutiérrez, “Photonic Single Nonlinear-delay Dynamical Node for Information Processing” (talk), SPIE Photonics Europe. Brussels (Belgium), 16-19 April 2012.
- J. M. Gutiérrez, D. San-Martin, S. Ortin, and L. Pesquera, “Simple Reservoirs with Chain Topology Based on a Single Time-Delay Nonlinear Node” (talk), European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning. Bruges (Belgium), 25-27 April 2012.
- L. Appeltant, S. Ortin, G. V. D. Sande, L. Pesquera, and J. Danckaert, “Computational performance of a single bandpass electro-optic delay oscillator” (talk), Dynamics Days Europe, Gothenburg (Sweden), 2-7 September 2012.
- S. Ortin, L. Pesquera, and J. M. Gutiérrez, “Memory and nonlinear mapping in Reservoir Computing with two uncoupled nonlinear delay nodes” (talk), European Conference on Complex Systems (Information processing with recurrent dynamical systems: theory and experiment). Brussels (Belgium), 3-7 September 2012.
- M. C. Soriano, D. Brunner, S. Ortín, C. R. Mirasso, L. Larger, I. Fischer, and L. Pesquera, “A Novel Photonics Approach to Unconventional Information Processing” (talk), European Conference on Optical Communication (CLEO Focus Meeting). Amsterdam (The Netherlands), 16-20 September 2012.
- S. Ortin, L. Pesquera, and J. M. Gutiérrez, “Reservoir Computing with Two Decoupled Nonlinear Delay Nodes” (talk), International Symposium on Nonlinear Theory and its Applications (NOLTA) (Unconventional Approaches to Computation Session). Palma de Mallorca (Spain), 22-26 October 2012.

CONFERENCES ORGANIZATION

- CDCS 2012, “International Conference on Delayed Complex Systems”, Palma de Mallorca, Spain, June 2012. I. Fischer General Co-Chair, C. Mirasso and M. C. Soriano, Scientific Organizing Committee.
- NOLTA 2012, “International Symposium on Nonlinear Theory and its Applications, Palma de Mallorca, Spain, October 2012. C. Mirasso General Co-Chair; I. Fischer Scientific Co-Chair.
- ECCS'12 Satellite Meeting: Information processing with recurrent dynamical systems: theory and experiment, Brussels (Belgium), 6. September 2012, I. Fischer Organizer.
- Cleo Focus meeting, Amsterdam (Netherlands), 16.-20. September 2012, I. Fischer Member of the programme committee.

MEETINGS, EXCHANGES AND VISITS AMONG PARTNERS

04/02/2012 - 05/02/2012: Fifth PHOCUS Meeting, organized by UFC-P5 (Besançon, France) with the participation of all the Group Leaders and participants of the Project.

12/03/2012-16/03/2012: S. Ortín (UC) visited UIB and CSIC, to work on WP3 and WP6 with I. Fischer, M.C. Soriano and C. Mirasso.

16/04/2012 – 13/07/2012 J. M. Gutierrez (UC) visited IFISC (UIB and CSIC).

16/04/2012-20/04/2012: S. Ortín (UC) visited VUB to work on WP 3 with L. Appeltatnt, G. Van de Sande and J. Danckaert.

01/05/2012 - 04/05/2012 I. Fischer and P. Colet (CSIC) visited VUB.

21/05/2012 - 23/05/2012 I. Fischer and P. Colet (CSIC) visited VUB.

2/7/2012 – 3/7/2011: Sixth PHOCUS meeting organized by VUB (Brussels, Belgium) with the participation of all the Group Leaders and participants of the Project.

03/09/2012-07/09/2012 Meeting of project participants D. Brunner, L. Pesquera, L. Larger, J. Danckaert, G. Van der Sande and I. Fischer.

24/09/2012: Meeting in Palma de Mallorca to discuss the progress of the different workpackages. All partners assisted.

14/11/2012-16/11/2012 Laurent Larger visited the UOS team to discuss the use and implementation of adaptive delay coupled RC.

BRIEF DESCRIPTION OF SCIENTIFIC INTERACTIONS

WORKPACKAGE 3 (PARTICIPATING GROUPS: VUB, UIB, UC, PIK).

In 2010 and 2011, in a collaborative effort, the partners have proven the information processing capabilities of delay-dynamical systems, and of a single nonlinear node with delay in particular. In 2012, the consortium continued its modelling efforts, extending previous results to the all-optical system, as well as the case of multiple nodes. Modelling efforts were oriented towards realistic experimental situations, implying quite strong interactions with WP6. In particular, UIB strongly collaborated with CSIC to develop and optimize structures, including multiple nodes. Also, UIB and UC collaborated in the study of different possibilities for the feedback loops, including closed and open feedback as well as the case in which nodes are well separated (extreme learning) as reservoir. A senior researcher of UC spent several weeks at UIB/CSIC to discuss these issues.

The strong collaboration between UIB, CSIC and VUB gave rise to the defence of the thesis by Lennert Appeltant in spring 2012 supervised by J. Danckaert, I. Fischer and G. Van der Sande.

WORKPACKAGE 4 (PARTICIPATING GROUPS: UOS, UIB, UC, PIK).

Research activities WP4 in the third year involved work by the UOS group, the UFC and the UC group. Research was focused on neuro-inspired adaptation of delay-coupled systems to improve computation and the noise robustness of RC. The research included first adaptation of the mask and node position, second, the use of approximations to improve digital systems based implementation with the UFC group, and third the inclusion of feedback to allow for practically infinite memory for a limited set of RC states. Research on neuro-inspired adaptation was developed by the UOS group. UC group supported this research by running part of numerical simulations of such neuro-inspired adaptation rules. UFC participated with by guiding research questions and highlighting needs for digital implementation and fully optical implementations of neuro-inspired adaptation rules.

WORKPACKAGE 5 (PARTICIPATING GROUPS: UC, UIB, CSIC, UFC-P5, PIK).

Research activity within WP5 in the third year focused on the influence of different input methods and topologies on the performance of an electronic circuit with Mackey-Glass nonlinearity. Multi-valued input pre-processing masks, as opposed to two-valued masks, were identified as better option for time series prediction tasks. Concerning topology, we have found that the memory capacity of a single node does not increase in experiments with electronic circuits by using two mutually coupled nodes with delay. We have also implemented an electronic FPGA based platform with an analog nonlinearity that fits a Mackey-Glass like function with exponent around 6. It has been shown that this FPGA based platform can be used as a real time demonstrator to predict the output of an electronic chaotic generator. The collaborations between all the groups were essential for the completion of the objectives. Several research visits supported these activities, including an exchange between UIB and CSIC with UC.

WORKPACKAGE 6 (PARTICIPATING GROUPS: CSIC, UFC-P5, UC AND VUB).

Research activity within WP6 in the third year focused on the experimental realization of the electro-optical and all-optical reservoir computing by using single and multiple devices as well as single and multiple feedback lines. In the first part of the period we progressed on the design of a controllable electro-optic setup with a multiple delay line generated by a field-programmable gate array (FPGA). This approach is very promising for an on-line photonic Reservoir Computing (RC) processing. In the following we proceeded with the implementation and demonstration of an all-optical RC based on the nonlinearity of a delay-coupled semiconductor laser diode. We considered both single device with all-optical feedback and different injection schemes (electrical and optical) as well as multiple node architectures with independent and coupled nonlinear systems. Results are extensively reported in deliverables D15 and D17. The work was carried out in a strong collaboration between groups CSIC, UFC and VUB.

PROBLEMS AND POSSIBLE REMEDIAL ACTIONS

No important problems were found during the third year.

USE OF RESOURCES

Use of Resources

Period 3 (25 - 36)
(01-01-2012 - 31-12-2012)

Project Number	240763	Project Acronym	PHOCUS
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Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 1 for the period. UNIVERSITAT DE LES ILLES BALEARS				
Work Package	Item description	Amount in €	Explanation	Free Text
WP 1 WP 2 WP 3 WP 4 WP 5	Other direct cost	1,725 €	PHOCUS project meeting, Besançon, 4-7/02-2012. C. Mirasso and M. Cornelles.	Travel and Subsistence
WP 1 WP 2 WP 3 WP 4 WP 5	Other direct cost	1,042 €	PHOCUS project review meeting, Brussels, 1-3/07/2012. C. Mirasso and M. Cornelles.	Travel and Subsistence
WP 2 WP 3 WP 4 WP 5	Other direct cost	550 €	Scientific cooperation of Dr. Silvia Ortin (UC) in PHOCUS, Palma, 12-16/03/2012.	Travel and accomodation expenses
WP 3 WP 4 WP 5	Other direct cost	213 €	Working coffebreak of PHOCUS meeting in Palma on 25/09/2012	Other direct costs
WP 2 WP 3 WP 4 WP 5	Personnel costs	58,046 €	1,00 personmonths in WP2, 7,51 personmonths in WP3, 2,55 personmonths in WP4 and 5,41 personmonths in WP5.	
WP 3 WP 4 WP 5 WP 2	Other direct cost	1,324 €	Publication cost for "Optoelectronic reservoir computing: tackling noise-induced performance degradation (M. Cornelles)	Other direct costs
WP 2	Other direct cost	3,138 €	Participation of C. Mirasso (key note speaker) in "Dynamics Days South America 2012 Conference", Cartagena de Indias, Colombia, 20-26/11/2012.	Travel and subsistence
WP 2	Other direct cost	2,497 €	Participation of C. Mirasso (invited	Travel and subsistence

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 1 for the period.				
UNIVERSITAT DE LES ILLES BALEARS				
Work Package	Item description	Amount in €	Explanation	Free Text
			talk) in "Conference on Nonequilibrium Statistical Mechanics and Nonlinear Physics", Santiago de Chile (3-8/12/2012), and scientific cooperation and invited talks at the Instituto de Física Teórica, Universidade Estadual Paulista, Sao Paulo and Instituto Nacional de Pesquisas Espaciais, Sao Paulo, Brazil (8-12/12/2012)	
WP 1	Personnel costs	7,501 €	1,77 personmonths	PHOCUS management effort
	Indirect costs	53,151 €		
TOTAL COSTS		129,187 €		

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 2 for the period.				
AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS				
Work Package	Item description	Amount in €	Explanation	Free Text
WP 1 WP 2 WP 5 WP 6	Personnel costs	66,863 €	Personnel costs for Ingo Fischer (10 personmonths)	Personnel costs
WP 6 WP 5	Personnel costs	58,813 €	Personnel costs for Pere Colet (10 personmonths)	
WP 2 WP 5 WP 6	Other direct cost	397 €		Other direct costs

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 2 for the period. AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS				
Work Package	Item description	Amount in €	Explanation	Free Text
			Fiber Beam Splitter 3x3 for coupling and detection of multiple optical sources in all-optical reservoir computing setup	
WP 2 WP 5 WP 6	Other direct cost	786 €	Trip (Fischer) to Phocus review meeting in Besancon, France, 5.-7. February 2012	Travel and subsistence
WP 2 WP 5 WP 6	Other direct cost	463 €	Trip (Daniel Brunner) to Phocus review meeting in Besancon, France, 5.-7. February 2012	Travel and subsistence
WP 2 WP 5 WP 6	Other direct cost	512 €	Trip (Fischer) to visit Phocus project partner, scientific coordination, work on publications and discussions May 2012	Travel and subsistence
WP 2 WP 5 WP 6	Other direct cost	500 €	Trip (Fischer) to visit Phocus project partner, scientific coordination, work on publications and discussions, PhD defense of L. Appeltant, 1.-2. May 2012	Travel and subsistence
WP 2 WP 5 WP 6	Other direct cost	128 €	Trip (Colet) to visit Phocus project partner, scientific coordination, work on publications and discussions, PhD defense of L. Appeltant, 1.-2. May 2012	Travel and subsistence
WP 2 WP 5 WP 6	Other direct cost	508 €	Trip (Fischer) to Phocus project meeting, 1.July 2012	Travel and subsistence
WP 2 WP 5 WP 6	Other direct cost	310 €	Trip (Konstantin Hicke) to Phocus project meeting, 1.July 2012	Travel and subsistence
WP 2 WP 5 WP 6	Other direct cost	338 €	Trip (Jade Martinez) to summer school in Peyresque (France), covering Reservoir Computing, August 2012	Travel and subsistence

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 2 for the period. AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS				
Work Package	Item description	Amount in €	Explanation	Free Text
WP 2 WP 5 WP 6	Other direct cost	474 €	Trip (Jade Martinez) to school on Fiber Optics in Valencia, July 2012	Travel and subsistence
WP 2 WP 5 WP 6	Other direct cost	322 €	Trip (Fischer) to Spring meeting of German Physical Society, 25.-30. March 2012, Berlin, invited talk (covering RC)	Travel and subsistence
WP 2 WP 5 WP 6	Other direct cost	400 €	Inscriptions (Pere Colet, Tomas Jüngling, Xavier Porte and Neus Oliver) for 2012 International Symposium on Nonlinear Theory and its Applications in Palma de Mallorca, Spain, 22.-26. October 2012, Special sessions on RC	Other direct costs
WP 2 WP 5 WP 6	Other direct cost	550 €	Inscription (Miguel Cornelles) for 2012 International Symposium on Nonlinear Theory and its Applications in Palma de Mallorca, Spain, 22.-26. October 2012, Special sessions on RC	Other direct costs
WP 2 WP 5 WP 6	Other direct cost	550 €	Inscription (Daniel Brunner) for 2012 International Symposium on Nonlinear Theory and its Applications in Palma de Mallorca, Spain, 22.-26. October 2012, Special sessions on RC	Other direct costs
WP 6 WP 5 WP 2	Other direct cost	400 €	Inscription (Daniel Brunner) for International Conference on Delayed Complex Systems, Palma de Mallorca, 4.-8. June 2012	Other direct costs

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 2 for the period. AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS				
Work Package	Item description	Amount in €	Explanation	Free Text
WP 2 WP 5 WP 6	Other direct cost	200 €	Inscription (Daniel Brunner) for 62nd Lindau Nobel Laureate Meeting 1.-6.July 2012, Lindau, Germany	Other direct costs
WP 2 WP 5 WP 6	Other direct cost	159 €	Further Consumables (Cable for Arbitrary Wave From Generator, Opto-Couplers, Electronic cables for lab)	Consumables
	Indirect costs	49,013 €		
TOTAL COSTS		181,686 €		

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 3 for the period. STIFTUNG FRANKFURT INSTITUTE FOR ADVANCED STUDIES				
Work Package	Item description	Amount in €	Explanation	Free Text
	Indirect costs	0 €		
TOTAL COSTS		0 €		

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 4 for the period. UNIVERSITE DE FRANCHE-COMTE				
Work Package	Item description	Amount in €	Explanation	Free Text
WP 5	Other direct cost	773 €	Electronic components	Consumables
WP 5	Other direct cost	109 €	Electronic devices	Consumables
WP 2	Other direct cost	5,545 €	dissemination for internal project at FEMTO-ST, with Fuel Cell diagnosis application of RC; invited conference on RC; organisation of a summer school on non linear dynamics and photonic delay-based RC; conference on photonic delay systems, theory and application to RC; Collaboration and working visit for a seminaire by Dr. Lukosevicius.	Travel and subsistence
WP 6	Other direct cost	566 €		

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 4 for the period.				
UNIVERSITE DE FRANCHE-COMTE				
Work Package	Item description	Amount in €	Explanation	Free Text
			Travel to Palma: collaboration with partners UIB and CSIC	Travel and subsistence
WP 1	Other direct cost	1,021 €	PHOCUS meeting in Besancon	Travel and subsistence
WP 5	Other direct cost	21 €	TVA for sending by DHL of electronic devices	Other direct costs
WP 6	Other direct cost	2,635 €	additional for instruments dedicated to photonic RC (digital scope); future student for next project on photonic RC and Chimera states; additional for instruments dedicated to photonic RC (optical spectrum analyzer)	Consumables
WP 1	Personnel costs	3,557 €	0.33 PM for L. Larger principle investigator	Personnel direct costs
WP 2	Personnel costs	3,557 €	0.33 PM for L. Larger principle investigator	Personnel direct costs
WP 5	Personnel costs	17,206 €	0.44 PM for L. Larger principle investigator and 2.4 PM for Romain Martinenghi PhD Student	Personnel direct costs
WP 6	Personnel costs	38,733 €	1 PM for L. Larger principle investigator, 1.16 PM for Maxime Jacquot scientific collaborator and 7.4 PM for Romain Martinenghi PhD Student	Personnel direct costs
	Indirect costs	44,233 €		
TOTAL COSTS		117,956 €		

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 5 for the period. UNIVERSIDAD DE CANTABRIA				
Work Package	Item description	Amount in €	Explanation	Free Text
WP 1 WP 2 WP 3 WP 4 WP 5 WP 6	Personnel costs	55,016 €	Personnel costs	Salaries of 1 senior researcher
				(PESQUERA: 3,5 pm), 1 postdoc student (ORTIN: 12 pm).Pesquera: WP1 (0.4); WP2 (0.3); WP3 (0.2); WP4 (0.2); WP5 (1.4); WP6 (1). Ortin: WP3 (1.7); WP4 (1.3); WP5 (6); WP6 (3)
WP 1 WP 2 WP 3 WP 4 WP 5 WP 6	Other direct cost	758 €	Travel Cost	PHOCUS Meeting in Besançon (05-06/02/2012: Ortin),
WP 3	Other direct cost	232 €	Travel Cost	Visit to IFSIC, P. Mallorca (10-16/03/2012: Ortín)
WP 2 WP 3	Other direct cost	1,718 €	Travel Cost	SPIE PHOTONICS EUROPE in Brussels (14-22/04/2012: Ortín),
WP 2 WP 3	Other direct cost	1,160 €	Travel Cost	ESSAN 2012 CONFERENCE in Bruges, Belgium (24-26/04/2012: Gutiérrez Llorente)
WP 2 WP 3	Other direct cost	310 €	Other direct cost	Congress fees for ECCS 12 (Brussels 03-07/09/2012: Pesquera)
WP 1 WP 2 WP 3 WP 4 WP 5 WP 6	Other direct cost	1,221 €	Travel Cost	PHOCUS meeting in Brussels (01-03/07/2012: Pesquera, Ortín)
	Indirect costs	36,249 €		
TOTAL COSTS		96,664 €		

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 6 for the period.				
POTSDAM INSTITUT FUER KLIMAFOLGENFORSCHUNG				
Work Package	Item description	Amount in €	Explanation	Free Text
WP 3	Personnel costs	25,957 €	personnel costs	personnel costs Dharmapuri Vijayan, Senthilkumar (5.7 PM)
WP 3	Other direct cost	2,834 €	other direct costs	travel costs Jürgen Kurths -Besancon, PHOCUS meeting Feb. 2012 and Palma de Mallorca Konferenz NOLTA 2012 Oct. 2012
WP 4	Personnel costs	28,689 €	personnel costs	personnel costs Dharmapuri Vijayan, Senthilkumar (6.3 PM)
WP 4	Other direct cost	2,256 €	other direct costs	travel costs D.V. Senthilkumar, - Palma de Mallorca Int. Conference DCS 2012 June 2012 and Review meeting PHOCUS Sep. 2012,- Brüssel PHOCUS Review meeting July 2012
	Other direct cost	38 €	other direct costs	post charges FORM C
	Indirect costs	37,881 €		
Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 6 for the period.				
POTSDAM INSTITUT FUER KLIMAFOLGENFORSCHUNG				
Work Package	Item description	Amount in €	Explanation	Free Text
TOTAL COSTS		97,655 €		

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 7 for the period.				
VRIJE UNIVERSITEIT BRUSSEL				
Work Package	Item description	Amount in €	Explanation	Free Text
WP 3 WP 6	Personnel costs	39,975 €	Van Der Sande Guy & Appeltant Lennert	Van Der Sande Guy & Appeltant Lennert
WP 3 WP 6	Personnel costs	49,367 €	KEUNINCKX Lars & Jan Danckaert	KEUNINCKX Lars & Jan Danckaert
WP 6 WP 3	Other direct cost	995 €	Travel and other costs related to consortium meetings: Osnbruck meeting, 2nd Review Meeting Bescancon Jan Dankcaert, Guy Vandersanden en L.Appeltant, Palma de Mallorca - stay L.Appeltant	
	Indirect costs	54,202 €		
TOTAL COSTS		144,539 €		

Table 3.1 Personnel, subcontracting and other Major cost items for beneficiary 8 for the period.				
UNIVERSITAET OSNABRUECK				
Work Package	Item description	Amount in €	Explanation	Free Text
	Personnel costs	95,704 €	Salaries for senior researcher, 2 research assistants, and 7 graduate/ and non-graduate student assistants	WP1,WP 2,WP 3, WP4
	Other direct cost	7,439 €	Travel to Palma, Besancon, Basel, Frankfurt, Brussels, Osnabrück, Pegresa	WP 1,WP 2,WP 3,WP 4
	Other direct cost	926 €	Durabele equipment depreciation (Laptop)	WP 1
	Other direct cost	659 €	Honorarium for talk by Jean Pascal Pfister and Publication fee	WP 2
	Indirect costs	62,836 €		
TOTAL COSTS		167,564 €		