May 2021

3rd YEAR OF EID-FONTE

PROGRESS BROCHURE

- Research & Dissemination
- IP and Awards
- Training
- Outreach
- Meetings

RESEARCH UPDATE
BY STENIO M. RANZINI

The desire for higher data rate systems to cope with the ever-demanding increase in capacity happens in all scales of the telecommunication system. The optical fiber communications, the backbone of the telecommunications systems, defines the systems where the light of a laser, trapped inside the optical fiber, is used to propagate the information. In this scenario, it is possible to divide the requirements of the optical communication system according to the fiber length. Considering fibers length up to ~100 km, we define the short-reach communication systems, whereas the opposite is called long-haul systems. New applications are stressing the current short-reach communication system which requires a scalably low-complexity solution to cope with this demand. One example is the upcoming 5G technology which is creating new data centers that will be located closer to the end-user, in the range of short-reach transmissions.

An attractive solution to this scenario is the use of Intensity-modulated and direct detected (IM/DD) systems which can provide low-complexity and low-latency links. However, chromatic dispersion (CD) is a major constraint to extending the transmission reach – especially for higher data-rate systems. As a solution to this impairment, we have been proposed the use of hybrid optoelectronic systems, which leverage sharing the complexity between optical and electrical domains. Specifically, the proposed solution uses an optical filter and a machine-learning algorithm to mitigate the CD. The machine-learning algorithm that we are using is called reservoir computing, which provides a strong advantage in the training process for nonlinear dynamic systems.

Alternatively to the proposed solution, the subcarrier multiplexing (SCM) system can also be used to tackle the same problem. In this case, instead of slicing the signal before detecting – as we have proposed – the signal is already transmitted with multiple subbands in a lower symbol rate, covering the same total bandwidth as the single carrier scenario. One key difference is that the SCM system is transmitting different information in each subband, while the proposed method applies a pre-processing filtering stage prior detection of a full band signal. In our latest results, we compare both systems numerically. We showed that an on-off keying modulation format at 32 GBd can reach up to 170 km with the optoelectronic system and 215 km with the SCM system.

DISSEMINATION
PEER-REVIEWED PAPERS (ALL)

Stenio M. Ranzini, ESR3, DTU and NBL

- F. Da Ros, S. M. Ranzini, R. Dischler, A. Cem, V. Aref, H. Bülow, and D. Ziba Machine-learning-based equalization for short-reach transmission: neural networks and reservoir computing. Proc. SPIE 11712, Metro and Data Center Optical Networks and Short-Reach. Links IV, 1171205;
  DOI: 10.1117/12.2583011

- S. M. Ranzini, R. Dischler, F. Da Ros, H. Bülow and D. Zibar. Experimental Investigation of Optoelectronic Receiver With Reservoir Computing in Short Reach Optical Fiber Communications. Journal of Lightwave Technology vol. 39, no. 8, pp. 2460-2467, 15 April, 2021; DOI: 10.1109/JLT.2021.3049473

- Stenio Magalhães Ranzini, Roman Dischler, Francesco Da Ros, Henning Bülow, Darko Zibar. Experimental Demonstration of Optoelectronic Equalization for Short-reach Transmission with Reservoir Computing. ACCEPTED for publication in: Proceedings of 46th European Conference on Optical Communication

- Stenio Magalhães Ranzini, Francesco Da Ros, Henning Bülow, Darko Zibar. Optoelectronic signal processing for chromatic dispersion mitigation in direct detection systems. Proceedings of 22nd International Conference on Transparent Optical Networks (ICTON) Published 2020 ISBN 978-1-7281-8423-4

- Francesco Da Ros, Stenio M. Ranzini, Henning Buelow and Darko Zibar. Reservoir-computing based equalization with optical pre-processing for short-reach optical transmission. IEEE Journal of Selected Topics in Quantum Electronics, vol. 26, no. 5, pp. 1-12, Sept.-Oct. 2020, Art no. 7701912; DOI:10.1109/JSTQE.2020.2975607

- Magalhaes Ranzini, S., Da Ros, F., and Zibar, D. Joint low-complexity opto-electronic chromatic dispersion compensation for short-reach transmission. Proceedings of 2019 IEEE Photonics Conference IEEE. San Antonio, United States, 29/09/2019. DOI:10.1109/IPCon.2019.8908278

- Tunable Optoelectronic Chromatic Dispersion Compensation Based on Machine Learning for Short-Reach transmission. Applied Sciences, vol. 9, no. 20.
  DOI: 10.3390/app9204332

Vladislav Neskorniuk, ESR1, AST and NBL

- Neskorniuk, Vladislav; Freire, Pedro J.; Napoli, Antonio; Spinnler, Bernhard; Schairer, Wolfgang; Prilepsky, Jaroslaw E.; Costa, Nelson; Turitsyn, Sergei. Simplifying the Supervised Learning of Kerr Nonlinearity Compensation Algorithms by Data Augmentation. Proceedings of 46th European Conference on Optical Communication. DOI: 10.1109/ECOC48923.2020.9333417

- Freire, Pedro J.; Neskorniuk, Vladislav; Napoli, Antonio; Spinnler, Bernhard; Costa, Nelson; Prilepsky, Jaroslaw E.; Riccardi, Emilio; Turitsyn, Sergei. Experimental Verification of Complex-Valued Artificial Neural Network for Nonlinear Equalization in Coherent Optical Communication Systems. Proceedings of 46th European Conference on Optical Communication Published: 2020. DOI: 10.1109/ECOC48923.2020.9333293

- Pedro J. Freire, Vladislav Neskorniuk, Antonio Napoli, Bernhard Spinnler, Nelson Costa, Ginni Khanna, Emilio Riccardi, Jaroslaw E. Prilepsky, Sergei K. Turitsyn. Complex-Valued Neural Network Design for Mitigation of Signal Distortions in Optical Links. Journal of Lightwave Technology. DOI: 10.1109/JLT.2020.3042414

Vinod Bajaj, ESR2, TUD and NBL

- Bajaj, Vinod; Buchali, Fred; Chagnon, Mathieu; Wahls, Sander; Aref, Vahid. Single-channel 1.61 Tb/s Optical Coherent Transmission Enabled by Neural Network-Based Digital Pre-Distortion. ACCEPTED for publication in: Proceedings of 46th European Conference on Optical Communication. DOI: 10.1109/ECOC48923.2020.9333267

- Vinod Bajaj, Shrinivas Chimmalgi, Vahid Aref and Sander Wahls. Exact NFDM Transmission in the Presence of Fiber-Loss. Journal of Lightwave Technology. DOI: 10.1109/JLT.2020.2984041

- V. Bajaj, S. Chimmalgi, V. Aref and S. Wahls. Exact nonlinear frequency division multiplexing in lossy fibers. Proc. 45th European Conference on Optical Communication (ECOC), Dublin, Ireland, Sep. 2019. DOI: 10.1049/cp.2019.0940

Abtin Shahkarami, ESR4, TPT and NBL

- None so far

CONFERENCES
5/2020 – 5/2021

Full details on website: https://fonte.astonphotonics.uk/conference-talks-and-posters/

Vladislav Neskorniuk, ESR1, AST and NBL

- **OFC 2021** – accepted presentation (Jun 2021)
- **ECOC2020** – TWO presentation (Dec 2020)
- **DigiCOSME workshop 2021** – presentation and co-chair (May 2021)

Vinod Bajaj, ESR2, TUD and NBL

- **OFC 2021** – TWO presentation accepted (Jun 2021)
- **ECOC2020** – oral presentation (Dec 2020)

Stenio M. Ranzini, ESR3, DTU and NBL

- **SBFoton 2021 -** Technical Programme Committee Member
- **OFC 2021** – accepted presentation (Jun 2021)
- **Photonic West 2021** – accepted presentation (Mar 2021)
- **ECOC2020** – oral presentation (Dec 2020)
- **ICTON2020** – INVITED oral presentation (Jul 2020)

Abtin Shahkarami, ESR4, TPT and NBL

- **DigiCOSME workshop 2021** – presentation (May 2021)

Additionally, **Francesco Da Ros** senior FONTE Consortium Members at DTU also presented FONTE research at

- **SBFoton** International Optics and Photonics Conference (IOPC) 2021

INTELLECTUAL PROPERTY
&
AWARDS/PRIZES

INTELLECTUAL PROPERTY

Stenio M Ranzini, ESR 3 at DTU currently on industrial secondment at Nokia Bell Labs (Germany), has one <u>patent application</u> in progress

AWARDS AND PRIZES

Vinod Bajaj has received the *Bell Labs Summer Intern Award for Outstanding Innovation* (Jul 2020). The research has now been published. **DOI:** <u>10.1109/ECOC48923.2020.9333267</u>

Vinod Bajaj also reached the final round and received an 'Honorable Mentions' in the *Corning Outstanding award competition* for his OFC2021 submission on '54.5 Tb/s WDM Transmission Over Field Deployed Fiber Enabled by Neural Network-Based Digital Pre-Distortion' (June 2021)

TRAINING EVENTS

In the past 12 months, FONTE organised the following training events

MACHINE LEARNING MINI-SYMPOSIUM

The aim of this mini-symposium, which included a practical course, was to facilitate high-level discussions between ESRs from ITNs FONTE, REAL-Net, WON and MOCCA on research challenges on machine learning in optical communications
2 days; 6 speakers ; 7-8 Sept 2020
https://fonte.astonphotonics.uk/symposium-machine-learning/

NUMERICAL IMPLEMENTATION OF BAYESIAN FILTERING FOR SIGNAL EQUALISATION AND DEMODULATION MINI SYMPOSIUM

The aim of this mini-symposium was to to facilitate high-level discussions on research challenges of Bayesian filtering implemented in telecoms applications between ESRs of ITNs FONTE, REAL-NET, MOCCA , WON, MEFISTA and POST-DIGITAL.
1 day; 6 speakers; 28 Oct 2020
https://fonte.astonphotonics.uk/bayesian-symposium/

ELECTRICAL ENGINEERING ARTIFICIAL INTELLIGENCE DAY @TPT

Organised by FONTE consortium partner Telecom Paris TPT, the seminar concentrated on the interplay between AI and the Electrical Engineering disciplines to show how this interdependency has the potential for decisive innovations.

1 day; 11 speakers ; 19 Nov 2020
https://fonte.astonphotonics.uk/tpt-ee-artificial-intelligence-day/

INTRODUCTION TO PHOTONIC RESERVOIR COMPUTING MINI SYMPOSIUM

Providing ESRs with an introduction to the powerful concept of Photonic Reservoir Computing and Neuromorphic Computing this event was jointly organised between ITNs POST-DIGITAL, FONTE and MOCCA .

1 day; 5 speakers; 24 Feb 2021
https://fonte.astonphotonics.uk/symposium-photonic-reservoir-computing/

MACHINE LEARNING PHOTONICS MLPH2021.

Co-organised by FONTE and bringing together experts in emerging photonic technologies, machine learning techniques, and fundamental physics, the Lake Como School of Advanced Studies aimed to educate ESRs in interdisciplinary approaches for understanding and designing complex photonic systems and their practical applications.

5 days; 5 speakers; 15-19 Mar 2021
https://fonte.astonphotonics.uk/machine-learning-photonics-mlph2021/

NANO AND INTEGRATED PHOTONICS WORKSHOP

4 day workshop co-organised by FONTE together the workshop covered novel materials, novel light sources, micro-resonators & frequency combs and finally advanced concepts

4 days; 25 speakers ; 19-22 Apr 2021
https://fonte.astonphotonics.uk/otaw-nano-and-integrated-photonics/

TRANSFERABLE SKILLS WORKSHOP 3

FONTE's third TSW The Workshop was focused on entrepreneurship skills, project management and science communication.

3 days; 3 facilitators; 22-24 Mar 2021
https://fonte.astonphotonics.uk/transferable-skills-workshop-tsw3/

3RD AND 4TH (FINAL) FONTE ANNUAL WORKSHOPS

These annual events are led by FONTE ESRs who report progress in their scientific research and discuss their results with the entire consortium. The workshops also provide a platform for Forward planning and are an important decision making forum.

25 Sept 2020 (3rd Annual worshop)
10 May 2021 (4th/Final Annual Workshop)

OUTREACH Activities 5/2020-5/2021

4 Mar 2021

ABTIN LIVE!
ESR Abtin Shahkarami (FONTE EID) & Elliot London (WON ETN) talk live on Instagram about life under COVID lockdown and their research in their two H2020 Project
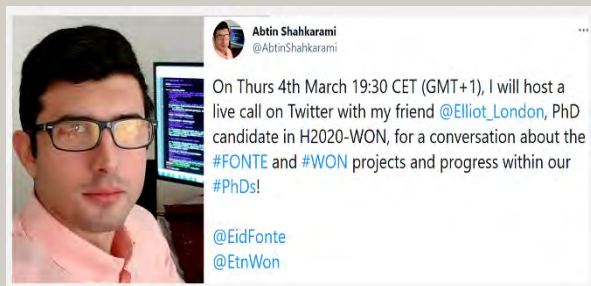
24 Mar 2021

ESRs Stenio M. Ranzini and Vladislav Neskorniuk join the FONTE Project Manager in an Outreach Event to 95 EMJMD students, talking about H2020, MSCA and the amazing opportunities offered by a PhD in ITNs.

21 May 2021

In celebration of the *International Day of Light* Aston Institute of Photonic Technologies at Aston University, OSA/SPIE Aston University Student Chapter, MSCA Projects MULTIPLY, REAL-NET, MOCCA, MEFISTA, POST-DIGITAL,WON, FONTE, MENTOR, MONPLAS, and EMJMD projects SMARTNET, PIXNET organised a one-day summit with light-themed lectures and fun activities.

Oct 2020

Foreign Language Bulletins
We have produced bulletins in Portuguese, Russian, Persian, Hindi and German about research progress and achievements in FONTE
Read them here
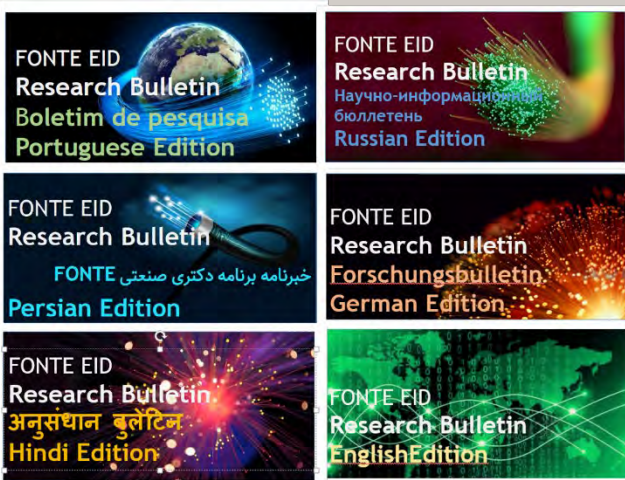
27 Oct 2020

Outreach in Brazil
ESR Stenio M. Ranzini was invited to his alma mater in Brazil to speak to current students about FONTE, MSCA and his current research
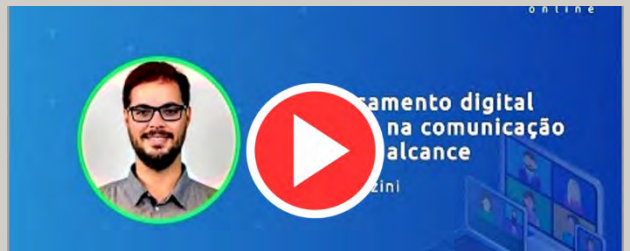
Sept 2020

Science Pitch Talks
Our ESRs Stenio, Vinod and Vlad prepared and recorded 5-minute pitch talks about their most recent research results
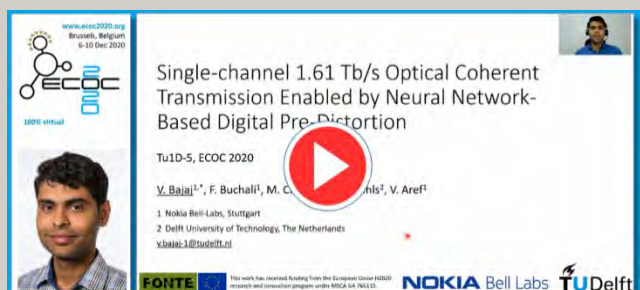
May 2021

Outreach Brochure celebrating IDL2021
To celebrate the *International Day of Light 2021 w*e have produced a brochure in which our ESRs describe how their research relates to the concept of' **light'**.
Read it here

OTHER NEWS

In Dec 2020 the research group of Darko Zibar (DTU), including our FONTE project and ESR3 Stenio M. Ranzini, featured in the **IEEE Photonics News letter**:

In May 2021 Francesco Da Ros, FONTE Consortium Member and Senior researcher at DTU Fotonik, was selected **Optical Society (OSA) Ambassador** to mentor and inspire the next generation of students and early career professionals in the global optics and photonics community.

Machine learning-researcher becomes OSA Ambassador

Hardware and components   Computer calculations   Telecommunication
Mathematical modeling

THURSDAY 06 MAY 21 | By Tobias Sydradal Lund

Francesco Da Ros, Senior researcher at DTU Fotonik, has been selected by the Optical Society (OSA) to mentor and inspire the next generation of students and early career professionals in the global optics and photonics community. In this article, he answers four questions about his research and what he is going to do as an OSA Ambassador.

What does it mean to you, to have been elected as OSA Ambassador?

I am thrilled to join the amazing team of the Optical Society (OSA) ambassadors. I have been volunteering within the OSA for nearly 10 years, starting with joining the local OSA student chapter (now DTU-LYS) during my master's studies, so being an OSA ambassador gives me the tools to continue my efforts on mentoring young researchers, providing invited lectures and organize outreach activities.

What is an OSA Ambassador?

OSA identifies an annual class of ambassadors as part of a program to elevate leaders in the years following their degree. The title of OSA Ambassador is more than a designation from the OSA. Ambassadors are empowered with resources from the OSA Foundation to support students and early-career professionals worldwide. As volunteers this year, the ambassadors will provide virtual programming, networking, and mentoring opportunities, mainly through the 400+ OSA Student Chapters worldwide.

Source: OSA

What research are you passionate about?

I have been working on applying advanced techniques from the machine learning toolbox to specific problems in photonics for a few years now. However, the powerful machine learning algorithms that are becoming so fundamental for advancing our society and improving our quality of life require an enormous amount of computing power resulting in unsustainable energy requirements. To address this challenge, I have shifted my focus to understand how photonics can help with this issue by providing an effective hardware platform for implementing the specific computing operation required by machine learning. This is the topic of my Villum Young Investigator project that gives me the freedom to explore such still blue-sky research.

How is photonics for machine learning going to benefit society?

In recent years, machine learning algorithms have become key enablers to advance the state-of-the-art in countless research disciplines and have profound applications within our daily life, e.g. from improving medical diagnosis to facilitating human interaction through speech recognition and language translation, up to more recent applications such as the advent of self-driving cars. All these amazing new technologies are based on having sufficient computing power for running machine learning algorithms. Unfortunately, current computing hardware is struggling to keep up with the demand in an energy-efficient way. New photonic-based hardware has the potential to push further developments in computing and thus yielding breakthroughs in countless research disciplines.

What are you going to do as an OSA ambassador?

As an OSA ambassador, I plan to focus on outreach and mentorship programs for researchers at different stages of their careers, i.e. not only young PhD students. Furthermore, I hope that my experience with outreach and teaching in Europe may provide some different perspectives to further increase diversity and inclusion within the photonics community.

"I hope that my experience with outreach and teaching in Europe may provide some different perspectives to further increase diversity and inclusion within the photonics community."

Francesco Da Ros

https://bit.ly/2RzEoPX

MANAGEMENT MEETINGS
5/2020-5/2021

- **25 Sept 2020**
Full Annual Network Meeting, including Supervisory Board and IP Board
- **12 Jan 2021**
Meeting between PO (EC/REA), Coordinator and Project Manager to discuss FONTE with new Project Officer
- **4 Feb 2021**
Supervisory Board Meeting
- **10 May 2021**
Full Annual Network Meeting, including Supervisory Board and IP Board

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