



MENTOR Machine Learning in Optical Networks A European Industrial Doctorate [EC GA 956713]

D6.2 (D29)

Interim report on publications and public engagement activities completed

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Beneficiaries

Aston Institute Of Photonic Technologies (Lead Beneficiary at Aston University)
Infinera Germany (Non-recruiting Beneficiary)
Infinera Portugal (Non-recruiting Beneficiary)
Sant'Anna School of Advanced Studies
Technical University of Denmark
Polytechnic University of Catalonia

Industrial Partners

Telecom Italia Mobile
Orange Telecom Company

List of Acronyms

AiPT	Aston Institute Of Photonic Technologies
AST	Aston University
CA	Consortium Agreement
DTU	Technical University of Denmark
EC	European Commission
EID	European Industrial Doctorate
ESR	Early Stage Researcher
GA	Grant Agreement
INF-G	INFINERA Germany (Non-recruiting Beneficiary)
INF-P	INFINERA Portugal (Non-recruiting Beneficiary)
MENTOR	Machine LEarning in optical NeTWORKs
ORANGE	Orange Telecom Company
SB	Supervisory Board
SSSA	Sant'Anna School of Advanced Studies
TIM	Telecom Italia Mobile
UPC	Polytechnic University of Catalonia

1. Context of MENTOR, European Industrial Doctorate (EID)

European Industrial Doctorate (EID) MENTOR, funded by the EC under Horizon2020 Marie Skłodowska-Curie ITN Action, is providing a world class, advanced, interdisciplinary training programme for six Early Stage Researchers (ESRs).

The goal is making MENTOR ESRs the next generation of engineering and research leaders in multi band optical communications. As MENTOR is an EID, our ESRs will spend 50% of their three years in academia and 50% in world-leading companies **Orange, Telecom Italia Mobile** and **Infinera**.

The aim of the project is to design the next generation of high-capacity optical networks, a key enabler of the global telecommunication infrastructure. Increasing demand (+ 20 % per year) requires a boost in capacity and calls for operators to reduce the cost per transmitted bit. Wide-band networks are more favourable to network operators, compared to more (or novel) fibres. However, wide-band optical systems present new major challenges:

- optical components must guarantee similar performance over a broad spectrum
- network optimization is carried out on a non-flat spectrum
- a much larger number of channels makes design, optimization and control a complex problem.

As a result, the application of machine-learning (ML) techniques is growing in importance for high-capacity multi-band (MB) optical systems. In fact, ML is the technique of choice to tackle this kind of complex technical problem.

This report details the scientific project output for the first 24 months of the project. It covers peerreviewed publications, conference talks and posters as well as the project's public deliverables and other scientific communication in other less formal settings such as local seminars.

Furthermore, this report summarises the public engagement activity, in particular outreach such as podcasts, videos and online and in person talks with students.

2. Scientific Project Output

MENTOR EID is a medium-sized project with 6 Early Stage Researchers (ESRs). The target is to have 18 journal papers and 14 conference papers attributed to its ESRs by the end of the project, along with 4 high impact journal papers and 16 seminar talks.

During MENTOR's first project year, (January 2021-December 2021), M1-M12, only ESRs 2-5 were recruited and started their research and training activities.

- ESR1: After Aston's initial recruit left for personal reasons in M12, Aston's second recruit ESR1 (Aston) started in M16.
- ESR6: After UPC's initial recruit left days before their planned start date in M11, UPC's second recruit started in M18.

Nevertheless, MENTOR's research activities were still promoted during the first year and also in the second year by those ESRs who were in place.

As research output is published, it is placed in repositories and archives such as <https://arxiv.org> and <https://github.com/> to make it discoverable. MENTOR aims to have its research output either gold or green Open Access by default.

2.1 Peer-reviewed Journal Publications and Conference Proceedings (newest on top)

1)

Journal of Optical Communications and Networking (ahead of print)

Lareb Zar Khan, Joao Pedro, Nelson Costa, Antonio Napoli, Lorenzo De Marinis, and Nicola Sambo

Data Augmentation to Improve Performance of Neural Networks for Failure Management in Optical Networks

<https://opg.optica.org/jocn/abstract.cfm?doi=10.1364/JOCN.472605>

Awaiting link (at SSSA Open Access repository)

2)

Published 2022 by IEEE in 27th OptoElectronics and Communications Conference (OECC) International Conference on Photonics in Switching and Computer (PSC)

Lareb Zar Khan, Ahmed Triki, Maxim Laye and Nicola Sambo

Optical Network Alarms Classification using Unsupervised Machine Learning

Published on IEEE Xplore 17 August 2022

DOI: [10.23919/OECC/PSC53152.2022.9849872](https://doi.org/10.23919/OECC/PSC53152.2022.9849872)

Awaiting link (at SSSA Open Access repository)

2.2 Peer-reviewed Conference Talks

1)

ECOC, Basel, Switzerland, 21 September 2022:

Lareb Zar Khan, Joao Pedro, Nelson Costa, Antonio Napoli, and Nicola Sambo

Oral Presentation: Data Augmentation to Improve Machine Learning for Optical Network Failure Management



Figure 1 ESR3 SSSA Lareb Zar Khan presenting at ECOC 2022, Basel, Switzerland.

2)

PSC 2022 - International Conference on Photonics in Switching and Computing, 3-6 July 2022

Lareb Zar Khan, Ahmed Triki, Maxim Laye and Nicola Sambo

Oral Presentation (remotely, Toyama, Japan): Optical Network Alarms Classification using Unsupervised Machine Learning

2.3 Scientific Posters at Events (peer-reviewed)

1)

ECOC, Basel, Switzerland, 20 September 2022:

Abdenmour Ben Terki, Joao Pedro, Antonio Eira, Antonio Napoli, and Nicola Sambo

Poster: Routing Spectrum Assignment Assisted by Reinforcement Learning in Multi-Band Optical Networks

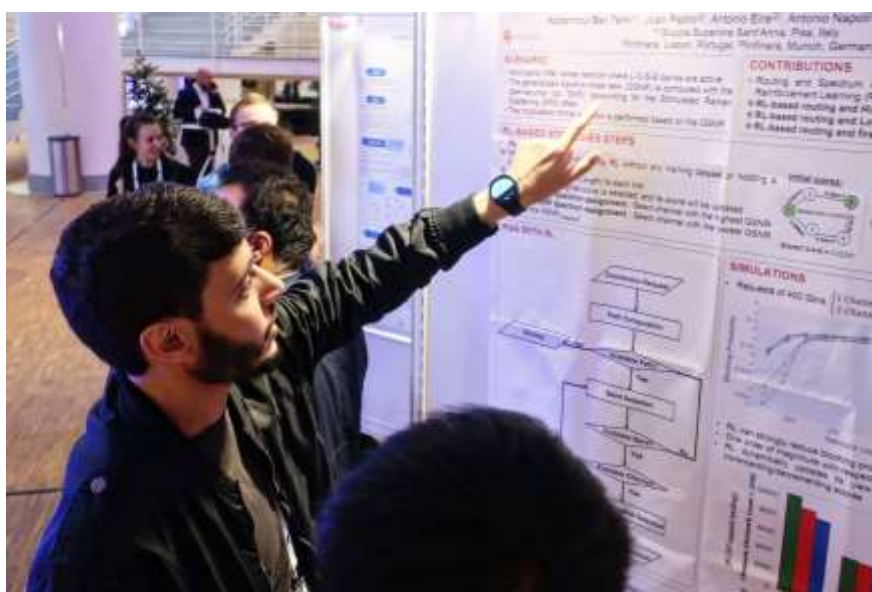


Figure 2 ESR4 SSSA Abdenmour Ben Terki discussing his poster at ECOC 2022, Basel, Switzerland.

2)

ECOC, Basel, Switzerland, 20 September 2022:

Mariano Devigili, Marc Ruiz, Nelson Costa, Antonio Napoli, João Pedro, Luis Velasco,

Poster: Dual Time and Frequency Domain Optical Layer Digital Twin

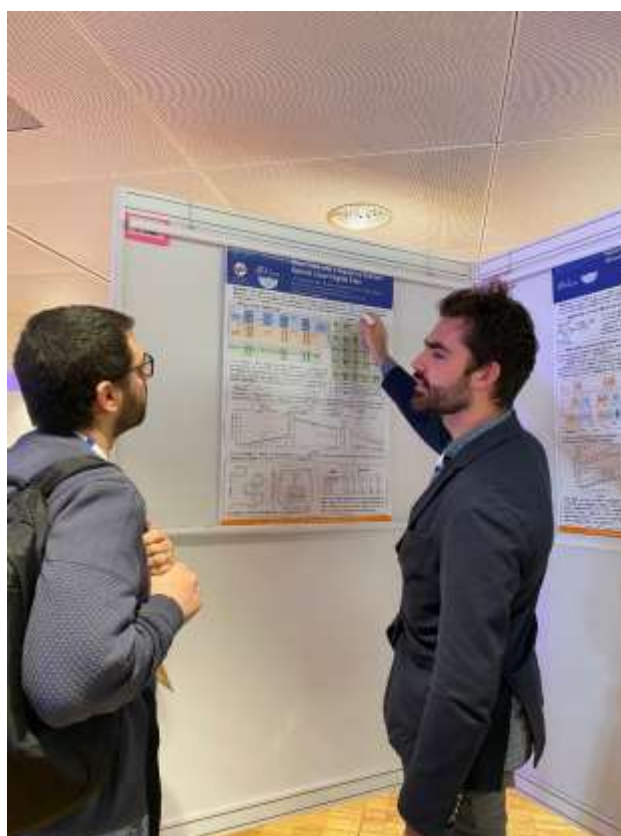


Figure 3 ESR5 UPC Mariano Devigili discussing his poster at ECOC 2022, Basel, Switzerland.

2.4 Scientific Papers (peer-reviewed)

MENTOR ESRs have submitted several papers which are currently available on pre-publication servers like Arxiv and are openly accessible.

- 2.4.1** Pedro J. Freire, **Sasipim Srivallapanondh**, Michael Anderson, Bernhard Spinnler, Thomas Bex, Tobias A. Eriksson, Antonio Napoli, Wolfgang Schairer, Nelson Costa, Michaela Blott, Sergei K. Turitsyn, Jaroslaw E. Prilepsky
Title: Implementing Neural Network-Based Equalizers in a Coherent Optical Transmission System Using Field-Programmable Gate Arrays
<https://arxiv.org/abs/2212.04703>
- 2.4.2** **Sasipim Srivallapanondh**, Pedro J. Freire, Bernhard Spinnler, Nelson Costa, Antonio Napoli, Sergei K. Turitsyn, Jaroslaw E. Prilepsky
Title: Knowledge Distillation Applied to Optical Channel Equalization: Solving the Parallelization Problem of Recurrent Connection
<https://arxiv.org/abs/2212.04569>
- 2.4.3** Pedro J. Freire, **Sasipim Srivallapanondh**, Antonio Napoli, Jaroslaw E. Prilepsky, Sergei K. Turitsyn
Title: Computational Complexity Evaluation of Neural Network Applications in Signal Processing
<https://arxiv.org/abs/2206.12191>

2.4.4 Marco Secondini, Stella Civella, Enrico Forestieri, **Lareb Zar Khan**

Title: New Lower Bounds on the Capacity of Optical Fiber Channels via Optimized Shaping and Detection

<https://arxiv.org/abs/2112.03796>

2.5 Accepted papers

1) Sasipim Srivallapanondh, Pedro J. Freire, Bernhard Spinnler, Nelson Costa, Antonio Napoli, Sergei K. Turitsyn, Jaroslav E. Prilepsky

Optical Fiber Communication Conference (OFC 2023)

Title: Knowledge Distillation Applied to Optical Channel Equalization: Solving the Parallelization Problem of Recurrent Connection

2) Lareb Zar Khan, Joao Pedro, Nelson Costa, Antonio Napoli, and Nicola Sambo

Journal of Optical Communications (JOCN)

Title: Data Augmentation to Improve Performance of Neural Networks for Failure Management in Optical Networks

DOI 10.1364/JOCN.472605 is registered for this article, publication pending.

Awaiting link (at SSSA - or other - Open Access repository)

3) Lareb Zar Khan, Joao Pedro, Nelson Costa, Antonio Napoli, and Nicola Sambo

Title: Data augmentation to Improve Machine Learning for optical network failure management.

Available on IEEE Xplore 2023 and link coming soon for SSSA - or other - Open Access repository.

4) Lareb Zar Khan, Joao Pedro, Nelson Costa, Antonio Napoli, and Nicola Sambo

Title: Data Augmentation to Reduce Computational Complexity of Neural-Network-Based Soft-Failure Cause Identifier.

Available on IEEE Xplore 2023 and link coming soon for SSSA - or other - Open Access repository.

5) Mariano Devigili, P. Nadimi Goki, N. Sambo, P. Castoldi, L. Potì, A. D'Amico, and V. Curri

IEEE Latin-American Conference on Communications (LATINCOM 30 November – 2 December 2022)

Title: Multi-band Optical Network Assisted by GNP: an Experimental Demonstration

6) Mariano Devigili, M. Ruiz, S. Barzegar, N. Costa, A. Napoli, J. Pedro, and L. Velasco

Optical Fiber Communication Conference (OFC 2023)

Title: Degradation Detection and Severity Estimation by Exploiting an Optical Time and Frequency Digital Twin

2.6 Submitted papers

1) Pedro J. Freire, **Sasipim Srivallapanondh**, Michael Anderson, Bernhard Spinnler, Thomas Bex, Tobias A. Eriksson, Antonio Napoli, Wolfgang Schairer, Nelson Costa, Michaela Blott, Sergei K. Turitsyn, Jaroslav E. Prilepsky

Journal of Lightwave Technology, 29 November 2022

Title: Implementing Neural Network-Based Equalizers in a Coherent Optical Transmission System Using Field-Programmable Gate Arrays

2) **Sasipim Srivallapanondh**, Pedro J. Freire, Antonio Napoli, Sergei K. Turitsyn, Jaroslav E. Prilepsky

Conference on Lasers and Electro-Optics 2023 (CLEO 2023), 22 November 2022

Title: Hardware Realization of Nonlinear Activation Functions for NN-based Optical Equalizers

3) **Mariano Devigili**, D. Sequeira, C. Santos, M. Ruiz, B. Shariati, N. Costa, A. Napoli, J. K. Fischer, J. Pedro, and L. Velasco

Conference on Lasers and Electro-Optics 2023 (CLEO 2023), 22 November 2022

Title: Experimental Validation of Deep Learning-based Models for Optical Time Domain Analysis

4) Pedro J. Freire, **Sasipim Srivallapanondh**, Antonio Napoli, Jaroslaw E. Prilepsky, Sergei K. Turitsyn
IEEE Transactions on Emerging Topics in Computational Intelligence, 18 July 2022

Title: Computational Complexity Evaluation of Neural Network Applications in Signal Processing

5) L. Velasco, **M. Devigili**, M. Ruiz

(Submitting soon) The 27th International Conference on Optical Network Design and Modelling (ONDM 2023)

Title: Applications of Digital Twin for Autonomous Zero-Touch Optical Networking

2.7 MENTOR Public Scientific Deliverables

The following deliverables (newest on top) have been submitted the European Commission via the Funding and Tender Portal. They have been made public and Open Access on the MENTOR Project website:

<https://mentor.astonphotonics.uk/deliverables/>

NB D1.1 and 2.2's publication are imminent, due 31 December 2022, and will be added to the site after being uploaded to the portal.

- [D4.1 UPC, Cases definition](#), 31 August 2022
- [D3.1 Infinera, Routing and spectrum assignment strategies for ultra-wideband optical networks](#), 31 July 2022
- [D2.1 DTU, Machine learning based laser noise characterisation](#), 30 April 2022.

Other Seminars, Talks and Memberships

1) **Lareb Zar Khan**, June 2022, SSSA

Internal Workshop of Networks and Services group

Presented work to other researchers within our research group.

2) **Abdenmour Ben Terki**, June 2022, SSSA

TeCIP Internal Workshop: RSA with Reinforcement Learning

3) **Mariano Devigili**

Member of [IEEE Communications Society](#)

4) **Abdenmour Ben Terki**

Member of [Quebec Engineers Order](#)

3. Public Engagement

Outreach and public engagement activities are meant to engage a large audience and to bring knowledge and expertise on a particular topic to the general public. The objective of outreach is to explain the benefits of research to a larger public, to promote research as a career choice, especially to the young audience. Engaging and communicating with the general public is also a way to better understand expectations, interests and concerns about science and technology.

3.1 Outreach Activities during the initial 24 months of the project

3.1.1 MENTOR YouTube Outreach Channel

In summer 2022, MENTOR launched a YouTube channel for the purpose of outreach.

https://www.youtube.com/channel/UCiHw_6iOe-hEhn-AosxeuYA

Views per clip range from 20-125+. There is currently a total of seven published clips, six of them Shorts. According to [Statista.com](https://www.statista.com), in June 2022 YouTube reported that the new Shorts feature now amasses over 30 billion daily views from global users, so there has been a focus on creating Shorts.

Each ESR has contributed to the channel.



Figure 4 MENTOR YouTube Channel, employing Shorts for outreach

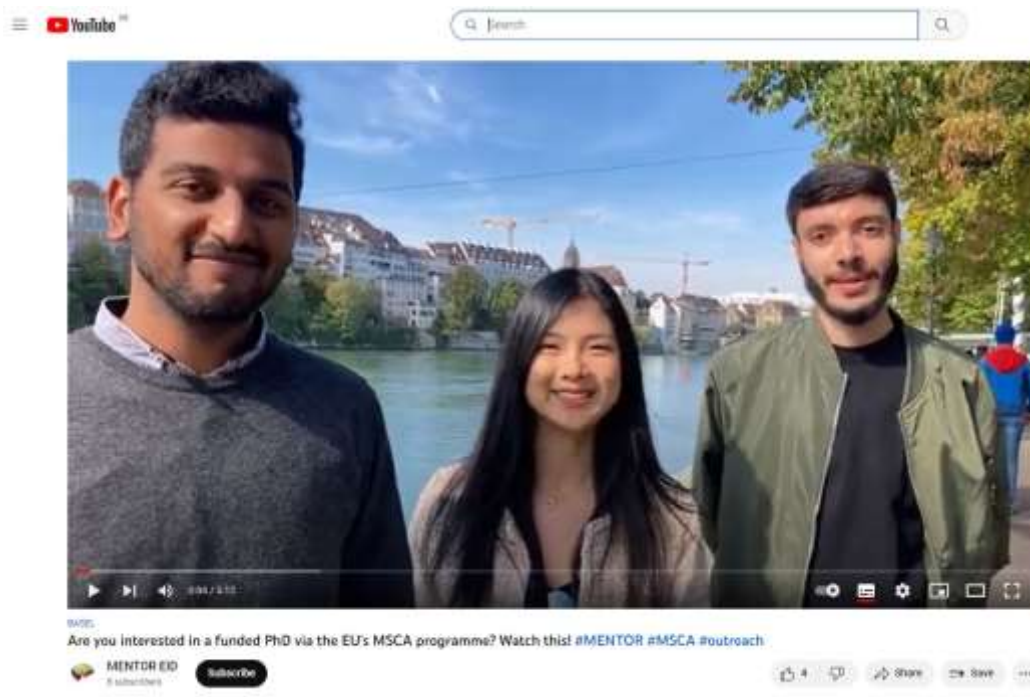


Figure 5 YouTube longer clip, group outreach, Basel, Switzerland.

3.1.2 MENTOR Outreach Podcast

In spring 2022, MENTOR launched a monthly, 5-part, outreach podcast via the platform [Anchor FM](#). The podcast features the ESRs talking about their research and is available on [Apple](#) and [Spotify](#). At the time of writing in December 2022, is averaging around 40 plays per episode. Three of five episodes have been published.



Figure 6 Anchor FM podcast platform which distributes to other platforms



Figure 7 The MENTOR Podcast on Apple

3.1.3 MENTOR Outreach, ESR Output

Outreach by ESR1, Sasipim Srivallapanondh

- [Cityfest](#), Aston Villa Football Club, one-day exposition of technologies that will contribute to future smart city life. Demonstrations on laser harp to secondary school students, October 2022.
- Outreach Podcast 'MENTOR Research Life', September 2022.
- YouTube, outreach group video, currently 129 views* and outreach solo short, currently 35 views* on MENTOR, choosing a PhD, benefits of MSCA programmes, the future of machine learning, September 2022.



Figure 8 ESR1 Aston Sasipim Srivallapanondh (centre) at Cityfest, Birmingham, UK, October 2022

Upcoming outreach for ESR1

- January 2023, Online outreach talk on MSCA opportunities to students Kasetsart University, Thailand.

Outreach by ESR2, DTU, Li Zhang

- YouTube, outreach solo short on the future of machine learning, currently 45 views*.



Figure 9 ES2 DTU Li Zhang YouTube Short

Upcoming outreach for ESR2

- February 2023, YouTube, outreach solo short in Chinese on MSCA programmes and MENTOR.

Outreach by ESR3, SSSA, Lareb Zar Khan

- Outreach Podcast 'MENTOR Research Life', November 2022.
- YouTube, outreach group video, currently 129 views*, and an outreach solo short, currently 127 views*, on MENTOR, choosing a PhD, benefits of MSCA programmes, uses of machine learning, November 2022.
- Outreach to ten Masters students on Photonic Integrated Circuits, Sensors and Networks (PIXNET), SSSA, March 2022.
- Outreach to nine PIXNET Master' Students, SSSA, November 2021.



Figure 10 ESR3 SSSA Lareb Zah Khan’s MENTOR Podcast episode, publicised on Twitter

Outreach by ESR4, SSSA, Abdennour Ben Terki

- Outreach Podcast ‘MENTOR Research Life’, December 2022.
- YouTube, outreach group video, currently 129 views* and an outreach solo short, currently 20 views* on MENTOR, choosing a PhD, benefits of MSCA programmes, uses of machine learning, September 2022.
- Outreach to ten Masters students on Photonic Integrated Circuits, Sensors and Networks (PIXNET), SSSA, March 2022.
- Outreach to nine PIXNET Masters Students, SSSA, November 2021.



Figure 11 ESR4 SSSA Abdennour Ben Terki doing online outreach with PIXNET Masters Students

Outreach by ESR5, UPC, Mariano Devigili

- YouTube outreach solo short, currently 28 views* on MSCA programmes, September 2022.
- In-person talk 'Optical networks: the infrastructure behind Internet' to around fifty Year 12 Students at Aston University Engineering Academy, UK, April 2022.



Figure 12 ESR5 UPC Mariano Devigili presenting to Year 12 students at the Aston University Engineering Academy, UK

Upcoming outreach for ESR5:

- January 2023, Outreach Podcast 'MENTOR Research Life'.

Outreach by ESR6, UPC, Prasunika Khare

- YouTube outreach solo short, currently 46 views*, on MSCA programmes, September 2022.



Figure 13 ESR6 UPC Prasunika Khare YouTube Short

Upcoming outreach for ESR6:

- February 2023, Outreach Podcast ‘MENTOR Research Life’.

* YouTube viewing figures at time of writing this report, December 2022.

3.2 Social Media

MENTOR engages with a global audience via [Twitter](#) and [LinkedIn](#). Here MENTOR communicates achievements, news of conferences, workshops and training sessions. ESRs are encouraged to have their own feeds too. Since joining Twitter in December 2022, MENTOR currently follows 229 people/organisations has 201 followers. Among influential followers we count: [@johnmdudley](#) with 6,673 followers (December 2022), [@ECOC_Exhibition](#) with 3,105 followers (December 2022) and [@EUDissemination](#) with 1,793 followers (December 2022).

MENTOR Partners, especially SSSA (6,337 followers) and Infinera (4,791 followers), retweet MENTOR news regularly. MENTOR members also tweeting individually about their science output (among other topics):

- Coordinator Sergei Turitsyn: [@im_sergei](#)
- WP2 Leader Darko Zibar: [@DarkoZibar14](#)
- ESR3 Lareb Zar Khan: [@larebzarkhan](#)

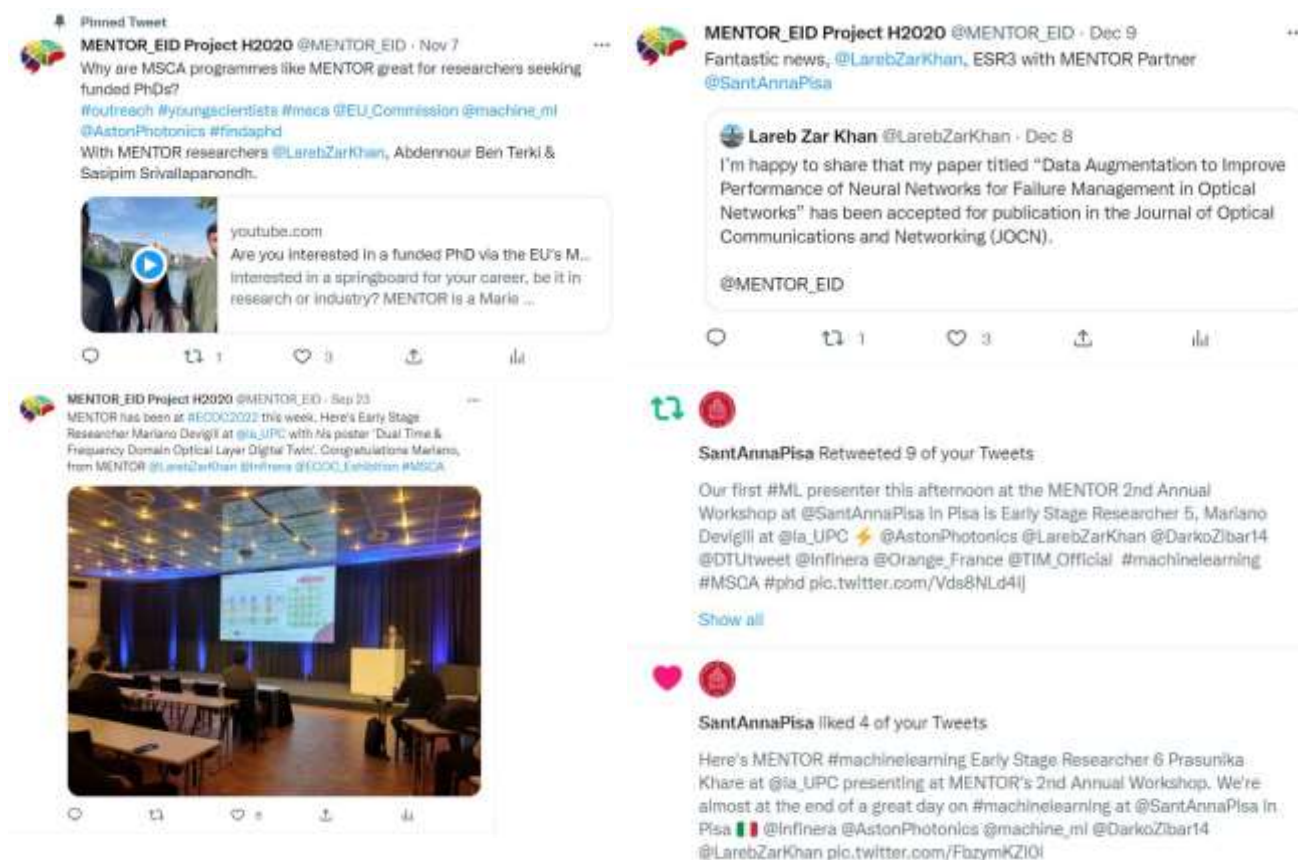


Figure 14 Example Tweets showing (clockwise) the 2nd Year MENTOR Workshop, news of the acceptance of an ESR's paper, an ESR presenting at ECOC and Partner retweets

On LinkedIn, MENTOR has 123 followers. Five of the six ESRs have their own profiles. Twitter and LinkedIn, along with the MENTOR website (mentor.astonphotonics.uk) are the main tools used to present MENTOR to the scientific community.

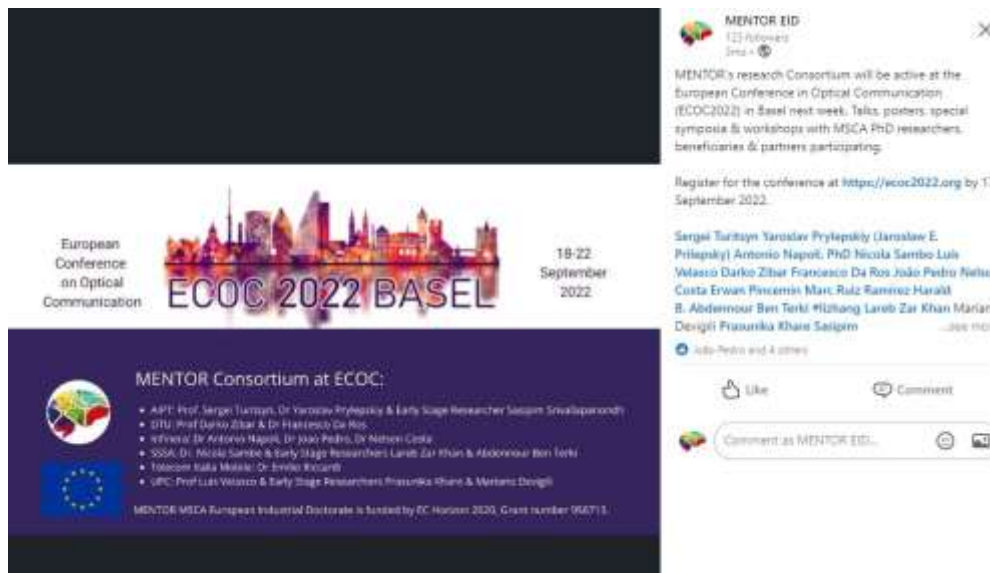


Figure 15 LinkedIn advertising MENTOR at ECOC 2022

3.3 Newsletters

MENTOR also publishes periodic [newsletters](#) using Mailchimp, drawing together the activities and news across the consortium from the previous 12-month period. The second newsletter is about to be published.



Figure 16 MENTOR Newsletter

EC Funding



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement number 956713