



Deliverable 5.1

Scientific school conference 1

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1. Background

The first scientific school and network conference titled *Microresonator frequency combs. Fundamentals and applications* was organised by the University of Bath, UK on Monday 6 – Wednesday 8 April 2020.¹

This event aimed to expose Early Stage Researchers (ESRs) who have joined the MICROCOMB Marie Skłodowska-Curie Innovative Training Network, and external participants at any stage of their careers, to the field of microresonator frequency combs. A series of lectures by the consortium members and external experts from industry and academia were expected to cover both background knowledge and state of the art in this growing research and innovation area.

The topics and key words for the event include - frequency combs, optical metrology, nonlinear photonics, microresonators, solitons, precision spectroscopy, astrophotonics, optical information processing, RF photonics, materials, fabrication.

Lectures and oral presentations organised in 45-, 30- and 15-minute slots, included 3 to 8 minutes for questions and discussions. Poster sessions, coffee breaks and organised meal events intended to provide further opportunities to consolidate and develop links within the consortium and with external community.

The invited speakers are highly regarded specialists in the area of microresonator frequency combs both from academia and industry, including renowned names such as Prof Alex Gaeta from Columbia University, Prof Luigi Lugiato from the University of Insubria or Dr Ronald Holzwarth, Managing Director of Menlo Systems. All consortium members were also invited to present their talks, including Early Stage Researchers and the beneficiary research group members.

Apart from the formal side of the conference, the organisers planned team bonding activities in a form of a sightseeing and hiking trip to Cheddar Gorge in Somerset, UK <https://www.nationaltrust.org.uk/cheddar-gorge> for ESRs and evening informal dinners for all delegates.

However, the conference fell onto the unfortunate timing of the Covid-19 pandemic outbreak, which led to the international lockdown and the national and international travel restrictions. For that reason the organisers (University of Bath) decided to cancel the conference and deliver the content in an alternative format of online webinars via Microsoft Teams, and spread across two academic years 2019/20 and 2020/21 in the period of 6 April – 13 July 2020 and 7 September – 30 November 2020²

¹ <https://www.microcomb-eu.org/network-conference>

² <https://www.microcomb-eu.org/webinars>



2. Invited speakers

2.1 External Speakers

Professor Luigi Lugiato is an Italian physicist and professor emeritus at the University of Insubria, Italy. He is best known for his work in theoretical nonlinear and quantum optics, and especially for the Lugiato–Lefever equation. He has authored more than 340 scientific articles, and the textbook *Nonlinear Dynamical Systems*. His work has been theoretical but has stimulated a large number of important experiments in the world. It is also characterized by the fact of combining the classical and quantum aspects of optical systems.

Prof Lugiato prepared a talk titled: *Spontaneous Kerr Solitons in Photonic-Crystal Resonators*

Professor Alexander Gaeta and his team at Columbia University, USA is particularly focused on how light of one colour interacts with a material to create new colours. For example, they can create these new frequencies of light using silicon rings created by Professor Michal Lipson's group, which results in the generation of optical frequency "combs". Such a comb source consists of many colours that are discretely spaced with extraordinary precision and have a wide range of applications in extremely accurate clocks, optical communications, astronomical measurements, spectroscopy, and sensing of chemical and biological agents. Overall, his research covers a wide range of topics within quantum and nonlinear optics and includes nonlinear optics with femtosecond laser pulses, nanophotonics, nonlinear propagation in optical waveguides, and the generation and processing of light fields for quantum computing and communications.

Prof Gaeta prepared a talk titled: *Microresonator-Based Optical Frequency Combs*

Professor Scott Papp is a Physicist in the NIST Time and Frequency Division and Lecturer at the University of Colorado, Boulder, USA. He received a Ph.D in 2008 from JILA at University of Colorado for experiments on long-sought beyond mean-field physics in Bose-Einstein condensates. From 2008-2010 he worked at Caltech as a Postdoctoral Fellow at the Center for the Physics of Information on atomic ensemble quantum memories, multipartite entanglement, and cavity opto-mechanics. Since 2010 he has worked at NIST, leading investigations of Kerr frequency combs and other optical devices.

Prof Papp prepared a talk titled: *Spontaneous Kerr Solitons in Photonic-Crystal Resonators*

Dr Francois Leo received his diploma in engineering (physics department) from the university of Brussels in 2005. His master thesis was entitled: "Microscopic study of $14O + p$ elastic scattering". He then worked towards a PhD degree at the OPERA-photonique Department of the Applied Science Faculty of ULB thanks to a Doctoral fellowship of the Belgian Fund for Scientific Research (FRRIA). He got the PhD degree in Applied Physical Sciences in November 2010 by defending his thesis entitled "Study of the dissipative structures of passive optical cavities: theory and experiment". He then stayed one year as a Postdoc in Brussels before joining the photonics research group in Ghent. Currently, since 2016, Francois is a Postdoctoral researcher, Chargé de recherche FNRS at Université libre de Bruxelles.



Dr Leo prepared a talk titled: Dissipative structures and frequency comb generation in fibre resonators

Dr Alessia Pasquazi received her PhD in Engineering from the University of Roma Tre in 2009. She has been MELS fellow (Quebec, Canada) from 2010-2011 and EU Marie-Curie Fellow from 2013-2015. She works in the field of nonlinear photonics and she is currently Reader in experimental physics at the University of Sussex. Alessia is leading the research in ultrafast integrated optics at the EPic Lab (<http://www.sussex.ac.uk/physics/epic/>) Her scientific production includes 44 publications in top journals such as Nature Photonics, Nature Communications, Physical Review Letters and about 150 conferences and 3 patents. Her work in optics received more than 1400 citations (h-index=20). She serve as editor of the Scientific Reports journal (Nature Publishing Group) and member and chair of panels for several conferences, organised by SPIE, OSA and IEEE societies. She has been program chair of the OSA 'Nonlinear Photonics conference' (2018).

Dr Pasquazi prepared a talk titled: *Microcombs Based on Laser Cavity Solitons*

Dr Patrick Gill MBE, FRS is a Senior NPL Fellow in Time & Frequency at the National Physical Laboratory (NPL), United Kingdom

Gill was educated at the University of Sussex and the University of Oxford where he was awarded a Doctor of Philosophy degree in 1975 for research on Charge Transfer as a Laser Excitation Mechanism. Gill is a Fellow of the Institute of Physics (FInstP) and was awarded their Young Medal and Prize in 2008 for world-leading contributions to optical frequency metrology. He also received the I. I. Rabi Award in 2007 from the IEEE International Frequency Control Symposium for contributions to time and frequency metrology and the realisation of single ion optical frequency standards. More recently, his group received the Royal Institute of Navigation's Duke of Edinburgh Award in 2014 for long term atomic clock development. Patrick is a visiting professor at Imperial College London and the University of Oxford. He was awarded an MBE for services to Science in The Queen's 2015 New Year Honours. Gill was elected a Fellow of the Royal Society (FRS) in 2016.

Dr Gill prepared a talk titled: *High accuracy frequency metrology with optical clocks and frequency combs*

Dr Jonathan Silver, Royal Academy of Engineering Fellow at City, University of London, and Higher Research Scientist at the National Physical Laboratory, United Kingdom. Dr Silver prepared a talk titled: *Applications of Kerr interaction between counterpropagating light in a microresonator.*



2.2 Speakers from the Consortium

Dr Ronald Holzwarth, Managing Director, CTO and co-founder of Menlo Systems GmbH, Germany. Dr Holzwarth prepared two talks titled: *Two decades of frequency combs* and *Combs for Astronomy*.

Professor Tobias J. Kippenberg, Professor of Physics at EPFL and leads the Laboratory of Photonics and Quantum Measurement. Prof Kippenberg prepared a talk titled: *Photonic-chip based soliton microcombs*.

Dr Rudolf Neuhaus, Product Manager Scientific Diode Lasers at TOPTICA Photonics AG., Germany. Dr Neuhaus prepared a talk titled: *Laser technology for the Microcomb community*.

Dr Ingo Breunig, Group Leader in the Department of Microsystems Engineering (IMTEK) of the University of Freiburg, Germany. Dr Breunig prepared a talk titled: *Frequency conversion in microcavities made of non-centrosymmetric crystals*.

Dr Pascal Del'Haye, Group Leader at the Microphotonics Research Laboratory at Max Planck Institute for the Science of Light, Germany. Dr Del'Haye prepared a talk titled: *Stabilized THz Wave Generation with Soliton Microcombs*

Michael Geiselmann, Co-founder, managing director of Ligentec, Switzerland

Professor Christian Koos, Professor at Karlsruhe Institute of Technology, Institute of Photonics and Quantum Electronics (IPQ). Prof Koos prepared a talk titled: *Germany, Chip-scale frequency comb sources: Device concepts and applications in communications and distance metrology*

Professor Pascual Muñoz, Professor at the Departamento de Comunicaciones, Universitat Politècnica de València, Spain. Prof Muñoz prepared a talk titled: *Silicon nitride photonics ecosystem: technologies, challenges and opportunities*

Dr Nathalie Piqué, Leader of a research group at the Max Planck Institut für Quantenoptik, Garching, and the Ludwig Maximilian University of Munich, Germany in the Laser Spectroscopy Division of Professor T.W. Hänsch. Dr Piqué prepared a talk titled: *Laser frequency combs and microcombs for molecular sensing*

Dr Rémi Rivière Optical Performance & Calibration Engineer Airbus Defence and Space (Space Systems, Inc.), Germany. Dr Rivière prepared a talk titled: *Microcombs for spaceborne optical spectroscopy*

Dr Paul Seidler Research Staff Member in the Quantum Technology group at IBM Research – Zurich in Rüschlikon, Switzerland. Dr Seidler prepared a talk titled: *Integrated nanophotonics with gallium phosphide*

Professor Dmitry Skryabin, Professor at the University of Bath in the Department of Physics, United Kingdom. Prof Skryabin prepared a talk titled *Recent results from Bath on theory and modelling of $\chi(3)$ and $\chi(2)$ microresonators*

Professor Victor Torres-Company, Associate Professor at Microtechnology and Nanoscience, Photonics Laboratory at Chalmers University of Technology, Sweden. Prof Torres-Company prepared a talk titled: *Dark solitons in optical microresonators*

3. Webinars

As mentioned earlier The First Scientific School and Network Conference fell onto the unfortunate timing of the Covid-19 pandemic outbreak, due to which had to be cancelled. This situation was adjusted to the new circumstances by offering the Early Stage Researchers a vibrant series of webinars planned from 6 April until 30 November 2020, with a summer break in between. Speakers originally invited for the conference

3.1 Introductory webinar for ESRs, event 1

Monday 6 April 2020

First webinar took place via Microsoft Teams on Monday, 6 April 2020 with an introductory webinar for ESRs.³

The webinar was divided into three sessions, each chaired by the project PIs: Dmitry Skryabin - Session 1, Ingo Breunig – Session 2 and Pascual Munoz – Session 3. Each ESR was given an opportunity to present their background, education, and current research projects in a 15-minute talk supported with a PowerPoint presentation, that included a question and answers session.

Participants

14 MICROCOMB ESRs – also speakers

9 Consortium members

1 non-ESR researchers from a beneficiary group

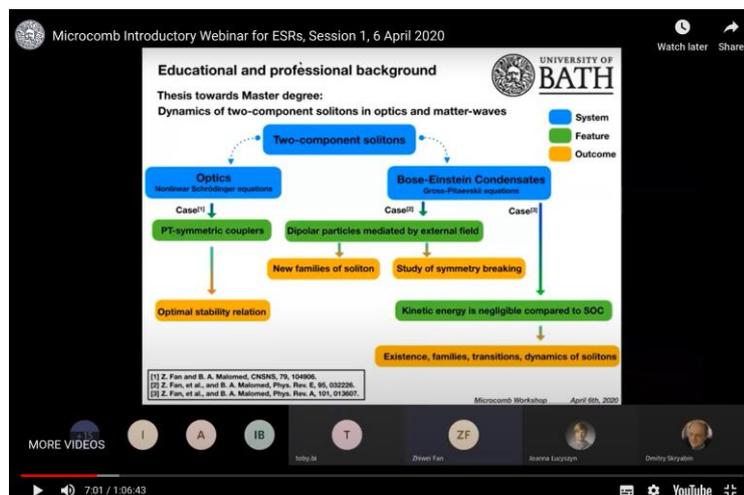
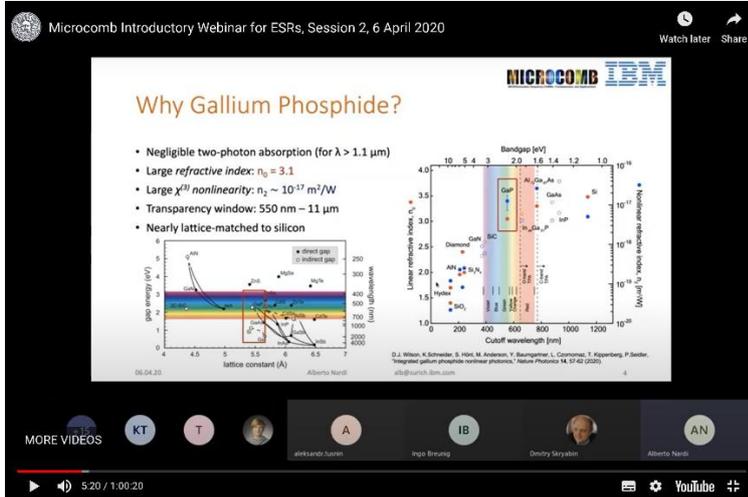


Figure 8: Presentation by Zhiwei Fan - ESR 6 (Bath) at the Introductory webinar for ESRs, Session 1

³ <https://www.microcomb-eu.org/esr-intro-webinar>

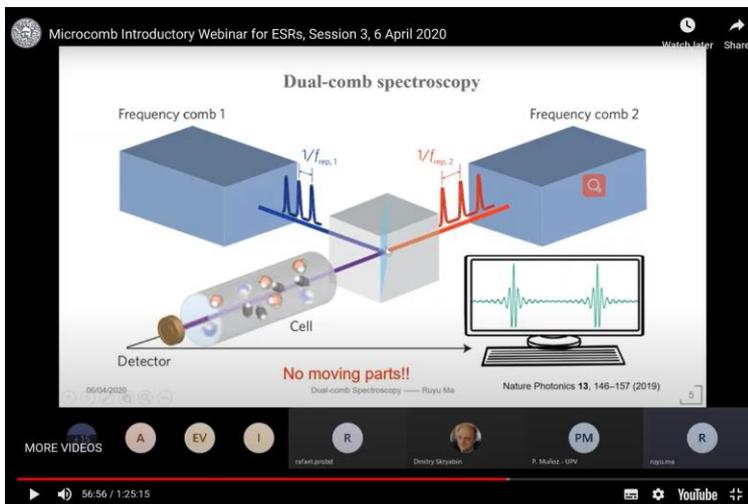


Why Gallium Phosphide?

- Negligible two-photon absorption (for $\lambda > 1.1 \mu\text{m}$)
- Large refractive index: $n_0 = 3.1$
- Large $\chi^{(3)}$ nonlinearity: $n_2 \sim 10^{-17} \text{ m}^2/\text{W}$
- Transparency window: 550 nm – 11 μm
- Nearly lattice-matched to silicon

06.04.20 Alberto Nardi

Figure 9: Presentation by Alberto Nardi - ESR 12 (IBM) at the Introductory webinar for ESRs, Session 2



Dual-comb spectroscopy

Frequency comb 1 $\nu f_{\text{rep},1}$

Frequency comb 2 $\nu f_{\text{rep},2}$

Cell

Detector

No moving parts!!

Dual-comb Spectroscopy — Ruyu Ma

Nature Photonics 13, 146–157 (2019)

06/04/2020

Figure 10: Presentation by Ruyu Ma - ESR 9 (MPQ) at the Introductory webinar for ESRs, Session 3



3.2 Webinars from consortium members and virtual visitors, event 2

Monday 4 May 2020

The second webinar of the series was divided into two sessions by Prof Victor Torres-Company from Chalmers Tekniska Högskola AB, Sweden, titled *Dark solitons in optical microresonators* and Prof Pascual Munoz from Universitat Politècnica de València, Spain, titled *Silicon nitride photonics ecosystem: technologies, challenges and opportunities*.⁴ The event was chaired by Prof Dmitry Skryabin and included a Q&A session.

Participants

14 MICROCOMB ESRs
6 Consortium members
2 Speakers
2 Non-ESR researchers from a beneficiary group

3.3 Webinars from consortium members and virtual visitors, event 3

Monday 1 June 2020

Professor Alex Gaeta from Columbia University, USA was a guest speaker on the third webinar of the Microcomb series. Prof. Gaeta delivered two 40 min talks in the subject of *Microresonator-Based Optical Frequency Combs*⁵ followed by Q&A sessions. The talk was very well received and had the highest attendance so far. The event was a highlight of the webinar series so far.

Participants

14 MICROCOMB ESRs
6 Consortium members
1 Speaker
10 Non-ESR researchers from beneficiary groups

3.4 Webinars from consortium members and virtual visitors, event 4

Monday, 22 June 2020

Prof Tobias Kippenberg shared a video made in 2019 in San Jose, California at CLEO USA, a major conference for the microcomb community, where he gave a talk titled: *Chipscale Soliton Microcombs*. The details can be found on the MICROCOMB and although the talk is available on YouTube, Prof Kippenberg preferred to share the content with the MICROCOMB community only as it was recorded by the CLEO organisers⁶.

⁴ <https://www.microcomb-eu.org/4-may-webinar>

⁵ <https://www.microcomb-eu.org/1-june-webinar>

⁶ <https://www.microcomb-eu.org/22-june-webinar>



3.5 Webinars from consortium members and virtual visitors, event 5

Monday, 13 July 2020

Dr Ingo Breunig from Albert-Ludwigs-University of Freiburg, Germany, delivered an hour long talk titled *Frequency conversion in microcavities made of non-centrosymmetric crystals*⁷ followed by a Q&A session. The webinar was chaired by Prof Dmitry Skryabin and it was the last webinar in the current academic year 2019/20.

Participants

- 9 MICROCOMB ESRs
- 4 Consortium members
- 4 Non-ESR researchers from beneficiary groups

3.6 Future webinars (7 September – 30 November 2020)

The webinar series will start again after the summer break on 7 September 2020, with talks by Professor Dmitry Skryabin from the University of Bath, United Kingdom and Professor Katia Gallo from KTH, Sweden.⁸ A variety of internal and external guest speakers from the field are or will be invited to participate in the webinars as well as the ITN ESRs, who by then will be in the position to talk about their research in more detail and demonstrate to the audience some results of their work to date. One of the confirmed external speakers so far, is Professor Luigi Lugiato mentioned in the section [2.1 External Speakers](#). He was invited to give a talk to the consortium on Monday, 5 October together with Dr Pascal Del'Haye from Max Planck Institute for the Science of Light.

Feedback received so far has been positive with constructive suggestions for improvement. As a result, from September 2020, we are going to introduce virtual breakout rooms incorporated into the webinars, so ESRs and guests to have more opportunities for in depth discussions with the speakers and other participants.

4. The highlights and lessons learned

The webinar series consisted of high-quality talks from the consortium members, ESRs and an external guest speaker, with more external speakers scheduled in the future.

The Project Manager conducted an event evaluation after the last webinar in the academic year 2019/20. 14 attendees participated in the survey as per graph in Figure 11 below.

⁷ <https://www.microcomb-eu.org/13-july-webinar>

⁸ <https://www.microcomb-eu.org/7-september-webinar>

3. You participated as

[More Details](#)

● Microcomb student	8
● other group member of PI on ...	1
● PI	3
● Industrial partner	2
● Other guest	0

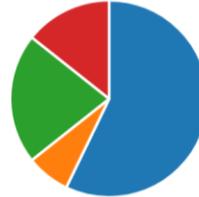


Fig. 11

The events evaluation received from the webinar audience so far is positive and the majority of respondents found excellent or good the following aspects of the webinars (Figure 12, 13, 14):

4. How many stars would you give for the information provided on the website:
<https://www.microcomb-eu.org/webinars?>

[More Details](#)

14
Responses



Fig. 12

6. Rate usefulness of a series of 5 webinars we had between 6th of April and 13th of June

[More Details](#)

● Extremely relevant	3
● Very relevant	11
● Somewhat relevant	0
● Not so relevant	0
● Not at all relevant	0

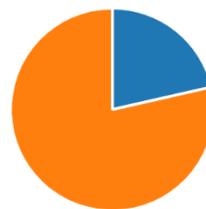


Fig. 13

7. Webinar series

[More Details](#)

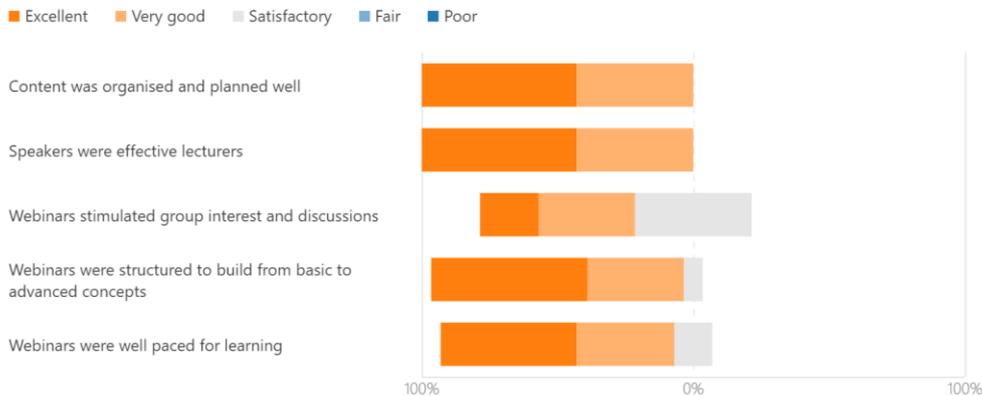


Fig. 14

The circumstances we have experienced since the Covid-19 outbreak in January 2019 helped us to remain flexible in our approach to deliver quality training regardless of the format. We had high hopes to deliver the first scientific conference at Bath as this would have been an excellent opportunity for the Coordinator's team, the Consortium PI's and ESRs to meet for the first time in person and experience high quality speakers giving talks in the area of microcombs. However, with the help of technology we were able to replace some aspects of the face-to-face conference in the form of webinars, which were received very positively amongst the Microcomb ITN cohort.

Although, the online events became "the new normal", there are pros and cons of organising them. The pros are the organisational costs of the online events and the reduced environmental impact (reduced travel and carbon footprint etc.) but the face-to-face networking, which had to be put on hold until further notice, helps the group to bond and establish closer relationships between the early stage researchers, which may have a positive impact on their future collaborations as established scientists.

Online events seem more strenuous on the audience and the organisers must plan them carefully in a bite-size format with plenty of rest breaks to ensure a quality learning process for Early Stage Researchers.

We have received some constructive feedback too, such as the need for lecture handouts and more time with the lecturers for informal Q&A session, which will be implemented in the next round of the webinar series in the academic year 2020/21.