



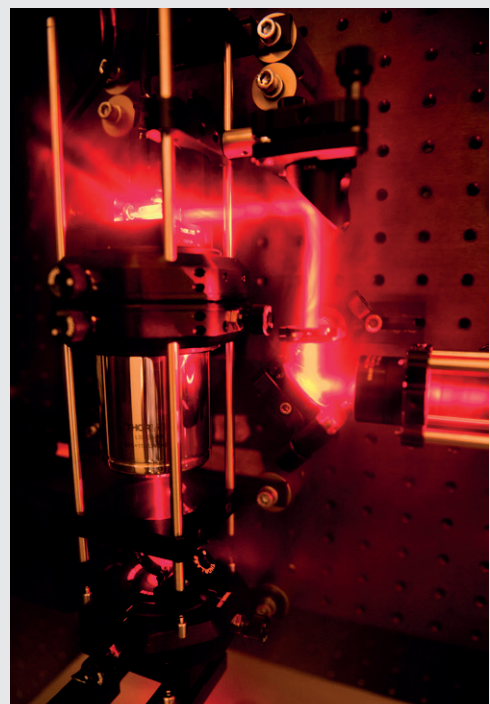
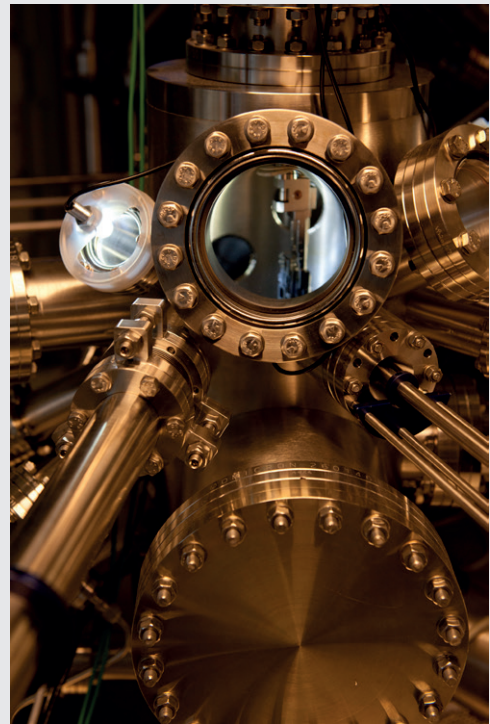
**PREIN**

Flagship for Photonics Research  
and Innovation (PREIN)

Annual Report 2019

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# 2019 Summary

Goëry Genty & Jyrki Saarinen

**The fact that the Flagship for Photonics Research and Innovation, PREIN, has been selected by the Academy of Finland as part of its Flagship program is not a coincidence. It is the result of many years of investment into photonics research.**

Earlier success stories, like Nokia in the 1990s helped building Finland's high-tech reputation and laid the foundations for Finland to be at the forefront in the development of technologies of the future.

It is then perhaps not surprising that photonics, which is the technology of the 21st century, is now perceived as one of the most promising areas of research and technology development in Finland. Photonics has strong potential to drive the economic growth and improve our well-being.

PREIN is a unique opportunity for us to develop disruptive solutions and have a genuine impact on the Finnish innovation ecosystem.

In the following pages, looking back at 2019, you will see that it has been a very busy year! The PREIN partners have previously had, of course, ad hoc collaborations. But this initiative is unprecedented both in size and volume at the national level.

Special initiatives call for special measures! We have therefore, initiated multiple actions which we hope will have laid the foundations for many future successes.

The first of these measures was to establish a formal framework and structure for our collaboration and PREIN organization. We have assembled external boards composed of highly reputed people to evaluate and provide feedback on our research on one hand, and on our interactions with society on the other hand.

Beyond top-notch research, an important rationale is that our Flagship serves as a springboard to strengthen our collaboration with the industry. With this in mind, we have started a partnership with Photonics Finland, the industry driven platform that develops new business opportunities for the Finnish photonics-related companies. Together we have begun to organize a series of joint thematic events intended to increase the synergies between our very active research community and a rapidly growing industrial sector.

Another important mission of the Flagship is to promote education. The younger generation of school children and students represent the researchers and professionals of tomorrow. It is thus paramount to raise awareness of photonics, its applications, and its importance for the society. This can be done in various ways, and several actions have already been implemented. Among others, one can mention for example collaboration with the LUMA centers to raise awareness of light and associated technologies among young children, participation in the



Shaking up Tech national event to promote scientific careers to high school girls, and the development of our education programs to anticipate the needs of the strongly rising Photonics industry in Finland.

Of course, it is also important to have a platform opened towards the outside world. This is the role of our website [prein.fi](http://prein.fi) where all necessary information, including the latest news and updates, can be found.

For those interested in hearing about the latest developments, actions, and upcoming meetings or events, we have launched a bi-monthly newsletter.

Finally, one should bear in mind that our success will be measured in the light of several key performance indicators, including the number of degrees and publications produced, the volume of external funding, our economic impact, and solutions to address global and national challenges. Here, we are delighted to say, that all the key indicators show green light!

In our first year of operation we have produced a considerable number of MSc and PhD degrees, published a large amount of publications with many in top-rate scientific journals, and our volume of external funding has grown. Some of our researchers have also received national or international distinctions, a clear sign that our Flagship is performing world-class research.

Detailed analysis of our scientific production shows that, while all the partners are performing extremely well individually, we should emphasize in the coming years our collaborative efforts in order to fully take advantage of our added value and increase further our impact as a community. We are proud to take this challenge as the most diversified Flagship program, both as the number of partners involved and their geographic location in Finland.

Last but not least, we wish to acknowledge all of you who have made this Flagship a reality and bring every day your valuable contribution to ensure that we fulfill our mission. Special mention goes to our administrative coordinators Tea Vellamo and Hanna Kivisaari, and Impact manager Juha Purmonen who have been taking great care of all practical aspects, making sure that we can focus on our ambitious targets.

2019 was just the beginning of a great adventure, and we are convinced that the coming years will be even more successful. Let's get to work together to bring more light to our lives!

# In Brief - The Flagship for Photonics Research and Innovation (PREIN)

The Flagship for Photonics Research and Innovation (PREIN) is one of the six flagships currently funded by the Academy of Finland. The Flagship initiative launched in 2018 is an eight-year program that aims at supporting future knowledge, know-how, and sustainable solutions to societal challenges as well as advancing economic growth by developing new business opportunities.

PREIN is a research and innovation platform focusing on light-based solutions covering the entire innovation value chain from fundamental and applied research to prototype and technology development, industrial collaboration and start-ups. PREIN is a national initiative between four partners:

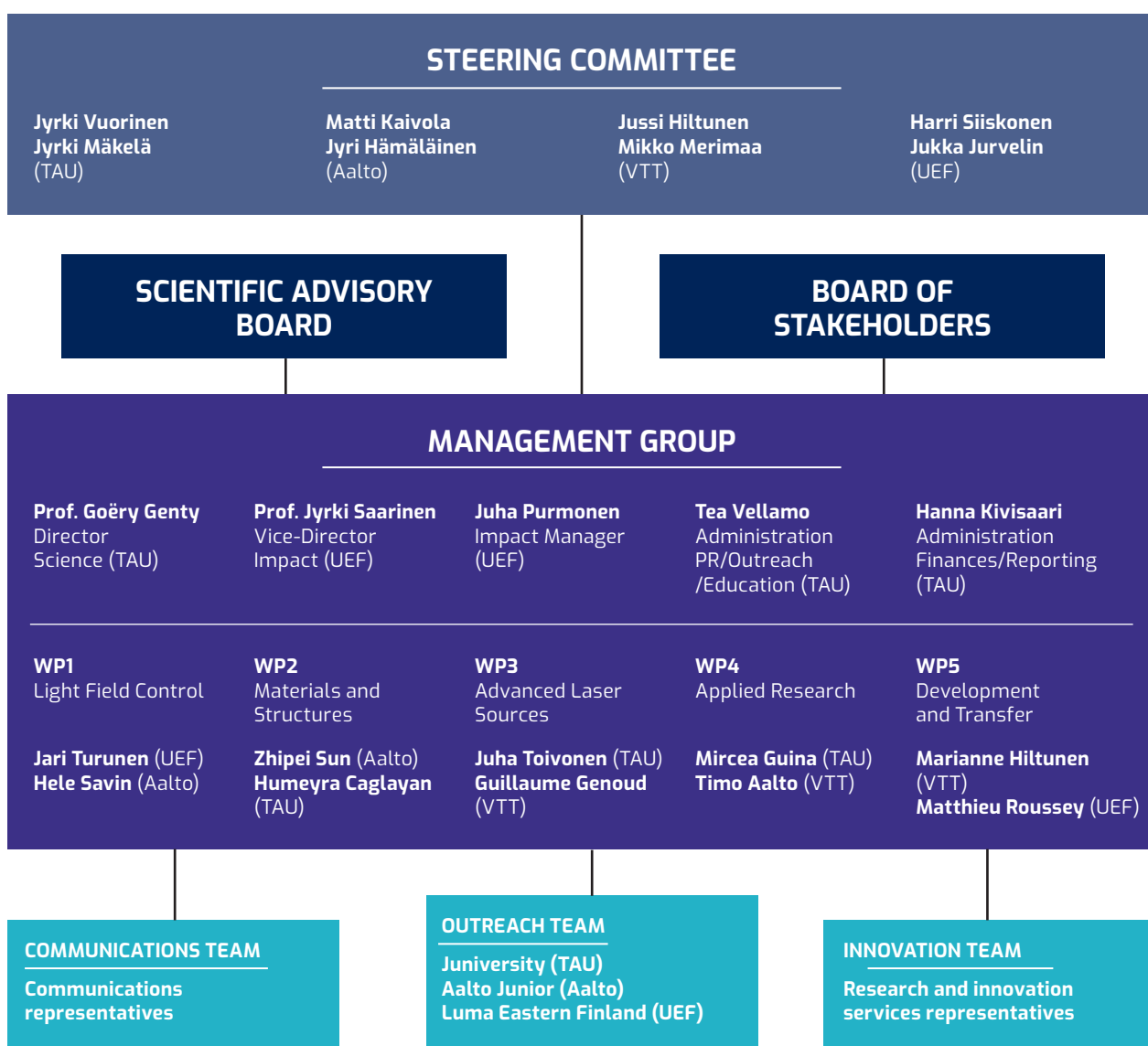
- Tampere University (TAU) – coordinator
- University of Eastern Finland (UEF)
- Aalto University (Aalto)
- VTT Technical Research Centre of Finland (VTT)

Beyond its scientific objectives, PREIN also has societal impact through its outreach activities and education objectives. In particular, PREIN aims at educating the next generation of professionals in the sector, reaching out to schools to raising interest of children in photonics and promoting careers in science and technology for women. On a more general level, informing the general public on the importance of light science and technologies for the society is another objective of PREIN.



# PREIN structure 2019

The PREIN organization has been formed and its activities have been ramped up during the first year. The members and roles of the different bodies have been confirmed and regular meetings have been started including Steering Committee meetings, Management Group meetings and support teams meetings to ensure smooth operation. In addition, an annual PREIN meeting has been launched to update all members about the status of PREIN and provide them an opportunity to present their views on research development, education and other activities of the flagship.



## Organization

The Steering Committee takes decisions concerning the general operation of PREIN, including the allocation of major resources and possible changes in strategy. The committee also follows the resource and infrastructure development.

The Management Group consists of the directors, work package leaders and vice leaders, the administrative coordinators, and the impact manager. The Management Group has the authority to make decisions regarding the everyday activities of PREIN, including recruitment and initiating new research topics.

PREIN is led by Professor Goëry Genty from TAU who is responsible for the overall management of PREIN. The Vice-Director Professor Jyrki Saarinen from UEF is responsible for the activities related to economic growth and other societal impacts.

The research and technology transfer are organized into different work packages (WPs). Each WP is led by a leader and a vice-leader who are responsible for the WP management and scientific progress.

The administrative coordinators were employed in March to facilitate everyday management, acting as the link to the supporting teams. The member organizations named the representatives of the supporting teams, which mostly started their activities in the autumn of 2019. Their task is to monitor the potential of research results and promote their transfer to the innovation pipeline. In addition, they promote PREIN activities to the general public and schools.

The PREIN Impact Manager was hired in November to promote the economic and societal impact in close collaboration with Photonics Finland. Photonics Finland is a platform for Finnish industry related to photonics, and other key actors of the photonics ecosystem in Finland and Europe.

## Advisory boards

PREIN is further supported by a Scientific Advisory Board comprising high-level international scientists that provides feedback on the research strategy of PREIN. The Scientific Advisory Board members represent top-level photonics research centers considering geographical distribution and diversity.

In addition, the Board of Stakeholders that includes representatives from national funding agencies, ministries, large corporations, SME's, start-ups, and venture capitalists, links the Flagship to both public and private sectors. This allows PREIN to affect policymaking and get feedback on industrial needs.

### Scientific Advisory Board

**Prof. Yasuhiko Arakawa**  
University of Tokyo, Japan

**Prof. Michal Lipson**  
Columbia University, USA

**Prof. Christine Silberhorn**  
Paderborn University, Germany

**Prof. Lluís Torne**  
Institute for Photonic Sciences, Spain

**Prof. Sergei Turitsyn**  
Aston University, UK

### Stakeholder Committee

**Pirjo Kutinlahti**, Ministry of Economic Affairs and Employment in Finland

**Mika Klemettinen**, Business Finland

**Laura Juvonen**, Technology Industries

**Risto Linturi**, Futurist

**Timo Ahopelto**, Investor

**Jyrki Huttunen**, Oplatek

**Tomi Salo**, Vaisala

**Eero Salmelin**, Huawei

**Antti Sunnari**, Dispelix

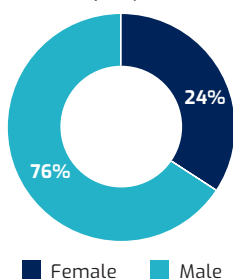
# Research & researchers

PREIN has identified application areas where the partners' joint expertise is expected to lead to significant breakthroughs: Life sciences, where we aim at advances in diagnostics and treatments; Energy, where both energy-efficient and energy-saving technologies are developed; ICT, where communications, augmented and virtual realities, as well as quantum technologies can benefit from PREIN research; and Sensing and Monitoring, where the targets are in LIDAR for environmental and industrial monitoring.

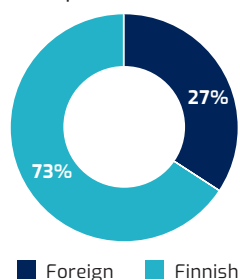
Progress in these application areas rely on advances in various sub-areas of photonics which form the basis of the five PREIN work packages (WPs). All the WPs have specific research sub-themes, in line with research groups in the different partner organizations. Altogether, there are 350 researchers and other staff working in PREIN. In 2019, there were 26 new researchers recruited by the PREIN partners.

Postdoctoral researchers and PhD students form the largest group in the PREIN staff. In VTT most of the researchers work for several different projects and thus dedicate only part of their working hours to PREIN.

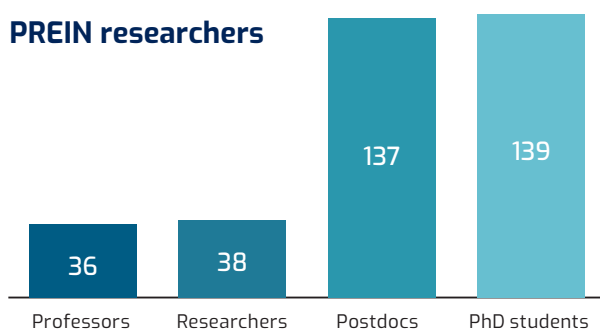
Gender division of employees



Foreign personnel



PREIN researchers



## Work packages

### WP1 Light Field Control

- Polarization and coherence control
- Temporal and spectral control
- Nanoscale localization

### WP2 Materials and Structures

- Advanced optoelectronic alloys
- Nanomaterials, metamaterials and nanostructures
- Photonics integration platforms

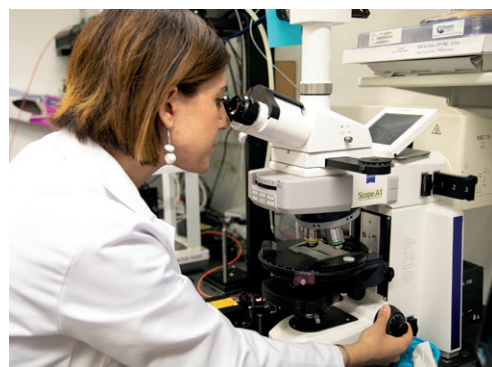
### WP3 Light Sources

- Mid-infrared laser sources
- Visible laser sources
- High-energy pulsed sources for eye-safe wavelengths
- Single photon sources

### WP4 Applied Research

- Portable and disposable sensors
- LIDAR technologies
- Smart photovoltaic modules

### WP5 Tech Transfer

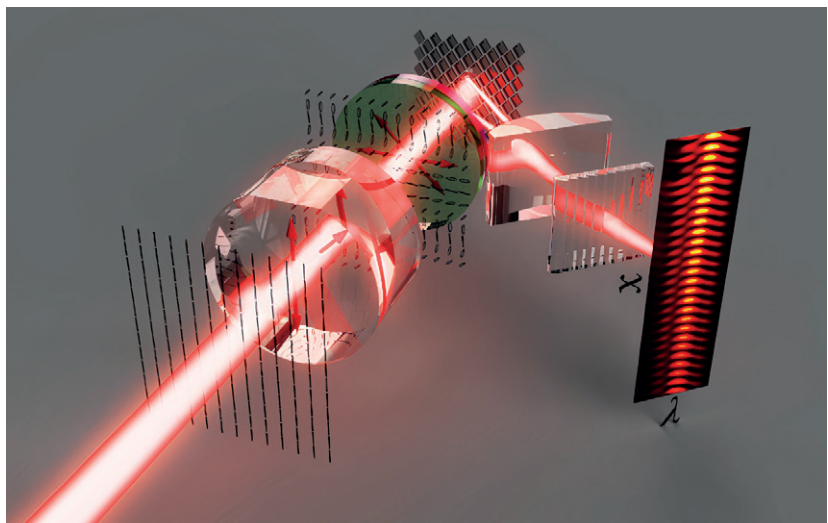


# Research highlights from 2019

## WP1: Light Field Control

- Polarization and coherence control (UEF/Aalto): highly birefringent and spatially dispersive metamaterial structures that can be used as ultra-thin wave retarders, tunable partial polarizers, and planar optical waveguides were successfully demonstrated. Theory and experimental methods for ultrafast random and deterministic polarization variations of unpolarized or partially polarized light was also demonstrated and a novel concept of aberration-insensitive interferometric microscopy was introduced.
- Polarization splitting and rotation on 3  $\mu\text{m}$  SOI platform (UEF/VTT): a full-vectorial 3D analysis of polarization effects in total-internal reflection mirrors and Euler bends on 3  $\mu\text{m}$  SOI waveguide platform was conducted. Results were found to be in excellent agreement with the measurements. Two novel polarizations splitting concepts were also experimentally demonstrated. Two patent applications were filed at VTT relating to novel polarization rotation concepts.
- Spatial/angular control of 3D fields in excitation of metasurfaces (TAU/UEF): the possibility to exploit and controllably excite the collective responses of nanoparticles using specifically engineered 3D fields was studied. The first sample has been designed and fabricated.
- Ultrafast Ge photodiodes for silicon photonics (VTT): germanium photodiodes were monolithic integrated on the 3  $\mu\text{m}$  silicon-on-insulator (SOI) waveguide platform using epitaxial growth of Ge into Si cavities, chemical-mechanical polishing, implantation and metallization. Low-loss and self-aligned coupling from SOI waveguides enabled 1 A/W responsivity, while the 1  $\mu\text{m}$  wide Ge waveguide photodetector reached 40 GHz bandwidth.
- Advanced manipulation of the spatio-temporal properties of photonic quantum states (TAU): a novel near-perfect measure was introduced to analyze the wavefront of a given light field in terms of transverse spatial modes. A scheme that can perform any unitary operation between two sets of modes, enabling advanced manipulation of transverse light modes was further developed.

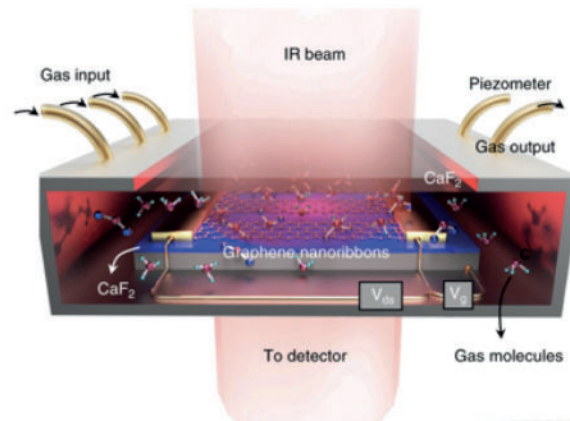
**Apparatus for measuring ultrafast random and deterministic polarization variations of unpolarized or partially polarized light.**





## WP2: Materials and Structures

- Development of GaInNAsSb heterostructures (TAU): significant progress towards the fabrication of high quality GaInNAsSb heterostructures with high N content (6–7%) was achieved. These materials can be utilized as efficient photovoltaic structures absorbing photons with an energy down to 0.7eV.
- New fabrication and integration methods for 2D materials (UEF/Aalto): a general approach for synthesizing thin layers of two-dimensional binary compounds has been demonstrated and applied to obtain high quality epitaxial MoS<sub>2</sub> films. Applications of the method have also been extended to the synthesis of a wide range of other materials both well-known and never-before isolated including transition metal sulfides, selenides, tellurides, and nitrides. Furthermore, a new hybrid material, graphene based photonic crystal fiber with length up to half a meter was fabricated using a chemical vapor deposition method. Label-free identification of gas molecules SO<sub>2</sub>, NO<sub>2</sub>, N<sub>2</sub>O, and NO by detecting their rotational vibrational modes using graphene nanostructure was also demonstrated.
- Thin films for on-chip photonics (UEF/Aalto): ultra-high on-chip optical gain in erbium-based hybrid slot waveguides with a monolithic CMOS-compatible and scalable atomic-layer deposition process was demonstrated. The unique layer-by-layer nature of atomic-layer deposition enables atomic scale engineering of

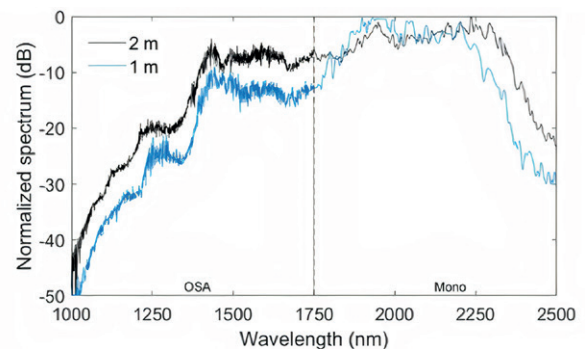


Graphene plasmonic gas sensor.

the gain layer properties and straightforward integration with silicon integrated waveguides. A net material gain of  $52.4 \pm 13.8$  dB/cm per unit length was achieved, which is the highest performance achieved from erbium-based planar waveguides integrated on silicon. Er-ions were incorporated for compensating and exceeding plasmonic losses. Sample fabrication was successful and preliminary emission data have been collected. These results show significant advances towards efficient on-chip amplification, opening the route to large-scale integration of various active functionalities on silicon.

## WP3: Advanced Laser Sources

- Mid-infrared supercontinuum (TAU): octave spanning supercontinuum was generated in a 1 m long step-index multimode InF<sub>3</sub> fiber with 100  $\mu$ m core diameter, paving the way towards high-power broadband mid-infrared sources. The supercontinuum extends from 1000 nm to 2500 nm. This result is promising for applications in remote sensing where high average power is more essential than the beam quality.



Octave-spanning short wavelength infrared supercontinuum generated in an InF<sub>3</sub> multimode fiber.

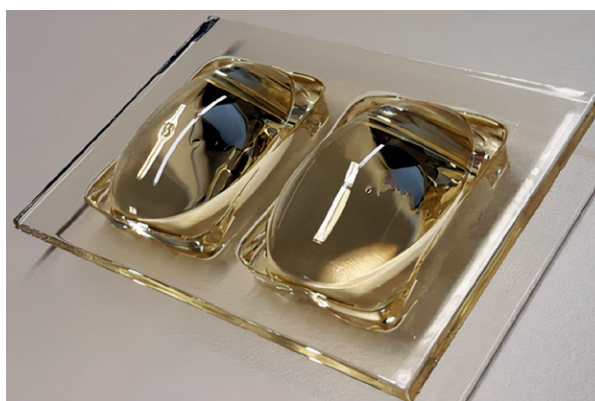
- Ultrafast laser based on saturable absorber nanowire (Aalto): Indium arsenide (InAs) nanowires were used for passively Q switching an all solid-state laser system from 1 to 2  $\mu\text{m}$ . Furthermore, ultrafast optical modulation for laser mode-locking was achieved at 1  $\mu\text{m}$ , paving the way for their applications in the field of ultrafast optics. These exotic optical properties indicate that InAs nanowires have significant potential for various optoelectronic and

photonic devices, especially in the mid-infrared wavelength range. Plasmonic nanolasers (TAU/UEF): all-optical reversibly switchable plasmonic nanolasers have been developed, based on photochromic molecules that act as tunable absorbers in the nanoscopic mode volume of the plasmonic nanoparticle lattices. Such lasers have the potential for ultrafast switching.

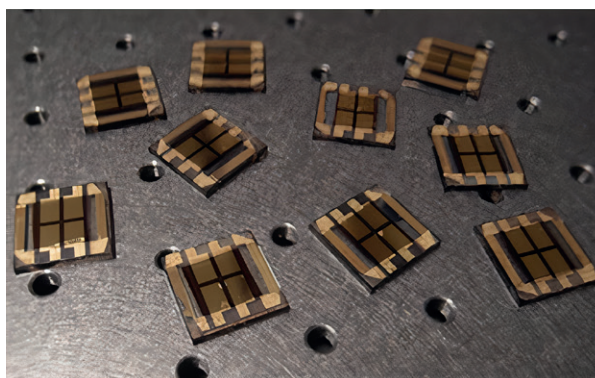
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## WP4: Applied Research

- Mid-IR gas sensors based on GaSb/SiPh integration (VTT): the first step towards the fabrication of the sensor platform was realized with the demonstration of a hybrid integrated III-V/silicon laser emitting around 2.6  $\mu\text{m}$  with a record-high output power. The gain is provided by GaSb-based heterostructures, which are also acting as output couplers. Tuning was achieved by using a tunable ring resonator as high reflectivity back mirror realized on a broad waveguide silicon-photonics platform. When operating in pulsed mode to reduce heating effects, peak power of 10 mW, average power of 1 mW, and tuning range of 70 nm were demonstrated.
- Optical phased arrays on 3  $\mu\text{m}$  SOI combined with 3D lenses direct-writing for LIDAR applications (VTT/UEF): silicon photonic chips with optical phased array antennas were designed, fabricated and tested. Horizontal (1D) beam steering was demonstrated with both thermal tuning and wavelength tuning. The first versions of directly written 3D printed lenses were designed and fabricated for vertically collimating the horizontally steerable optical beams from the 3  $\mu\text{m}$  SOI chips.
- Hybrid organic-inorganic solar cells (TAU/Aalto): designed and synthesized two novel lead-free halide perovskite materials based on copper-antimony and tin-germanium in bulk and nanocrystals, respectively, and several new organic hole-transporting materials. Mastered the fabrication of perovskite solar cells (record power conversion efficiency of 20%, which is state-of-the-art for the specific architecture we are focusing on) on glass substrates and started some experiments on flexible (PET) substrates.



**First prototype of directly written 3D lenses.**



**Halide perovskite solar cells with state-of-the-art power conversion efficiency.**

# Research outputs

## Publications

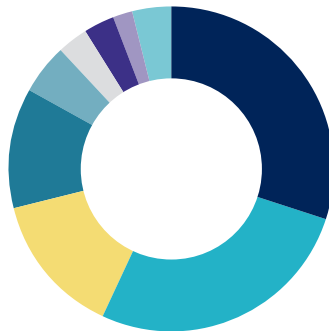
PREIN shows strong impact in bibliometric analysis and the field-weighted Citation Impact for PREIN publications is consistently higher than the national average. Journal articles by PREIN researchers are published in high-quality journals more regularly than the national average, with approximately 42 % of articles being published in top 10 % journals in their respective fields.

252

Number of peer-reviewed scientific publications in 2019

## Fields of science for PREIN publications in Scopus/SciVal

- Physics and Astronomy 30%
- Materials Science 27%
- Chemistry 14%
- Engineering 12%
- Chemical Engineering 5%
- Biochemistry, Genetics and Molecular Biology 3%
- Energy 3%
- Computer Science 2%
- Other 3.8%

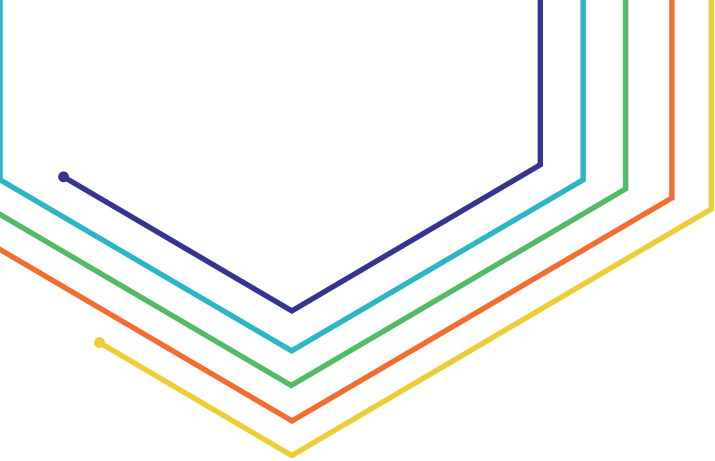


42%

articles published in top journals

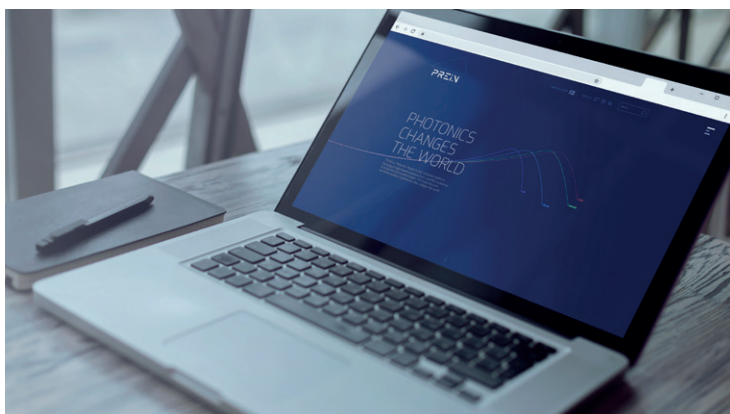
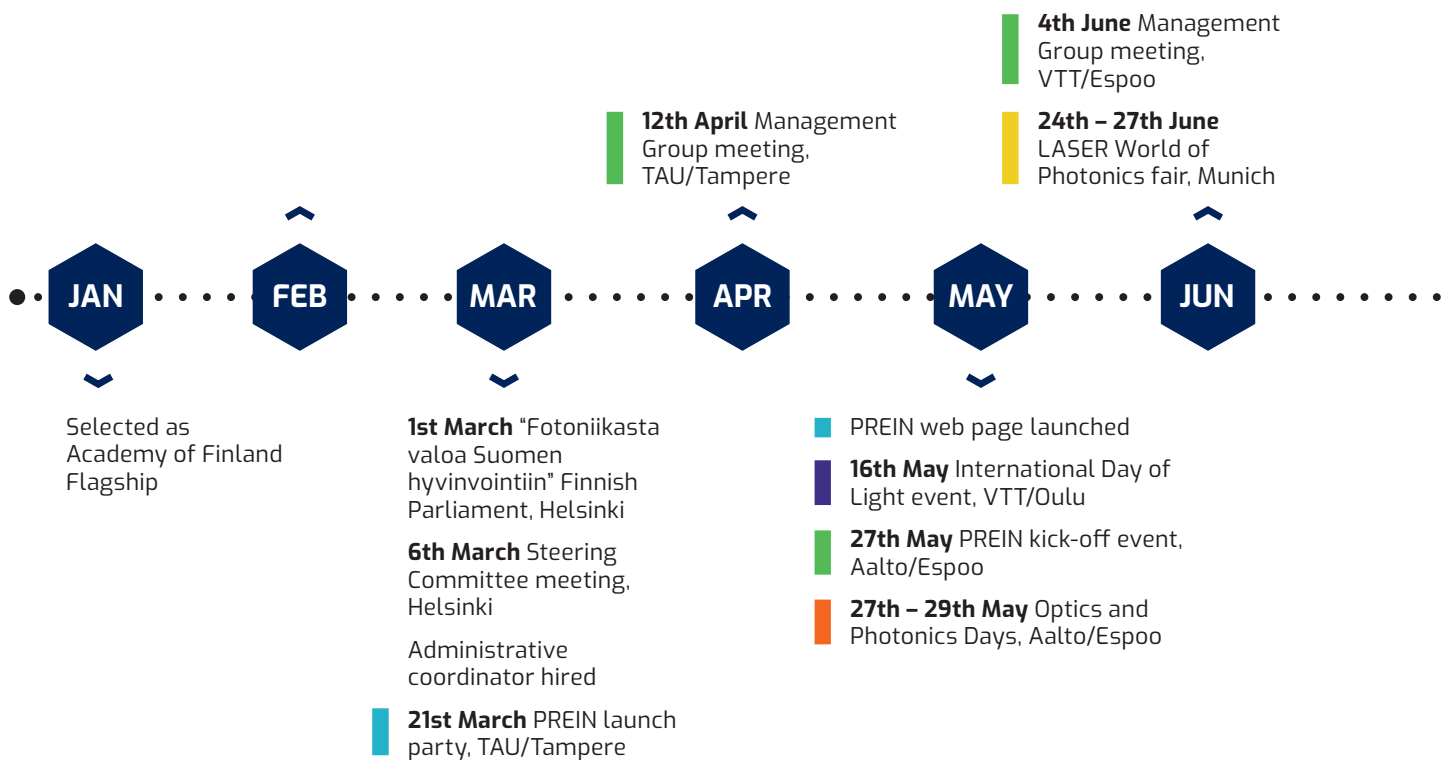


Key phrase analysis of the research published in 2019, highlighting the most active research areas.



# PREIN timeline 2019

- MEETINGS
- THEMATIC EVENTS
- OUTREACH EVENTS FOR PUBLIC
- FAIRS
- COMMUNICATION





- PREIN newsletter launched
- **5th – 9th August** Summer School: New Frontiers in Optical Technologies, TAU/Tampere
- **19th – 24th August** Summer School: Experience Your Reality, UEF/Joensuu

- **7th – 8th October** Forest and Photonics, UEF/Koli
- **10th October** Shaking up Tech -event, TAU/Tampere and Aalto/Espoo
- PREIN newsletter
- **29th October** Management Group meeting, VTT/Espoo

- PREIN newsletter
- **3rd December** Photonics for Imaging – Tampere Imaging Ecosystem networking event, Business Tampere/ Tampere
- **10th December** Laser Security Training, UEF Joensuu
- **13th December** Board of Stakeholder meeting, VTT/Espoo



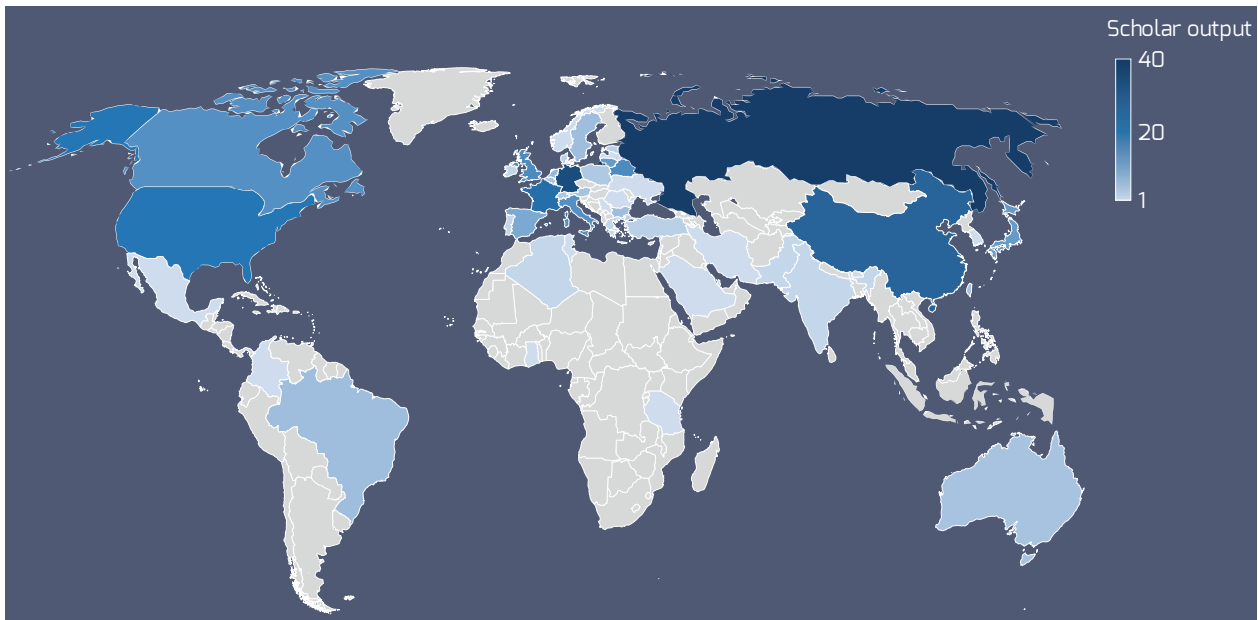
**Steering committee meeting with representatives of all partner institutions.**



# International network

PREIN has an extensive international network of collaborators on all continents. Our researchers collaborate on a regular basis with many key Universities in Russia, China, Germany, France, USA, and UK and 75% of PREIN publications included at least one international collaboration. PREIN partners also host regularly international research visitors and several of our researchers carry out both short and long-term research visits abroad every year within the framework of many joint international projects.

**75%**  
International collaborative publications



**PREIN international collaboration network. Color indicates the number of joint scholarly outputs with institutions of a particular country.**

## 6 Long-term research visitors

Technological University of Dublin, Ireland  
 Tyndall Institute, Ireland  
 Universidad Complutense de Madrid, Spain  
 Ioffe Institute, Russia  
 CRTI, Algeria  
 UNSW Sydney, Australia

### Top 10 countries:

1. Russia
2. Germany
3. China
4. France
5. United States
- 6./7. United Kingdom/Belarus
- 8./9. Canada/Italy
10. Japan

# Events

The first year of the flagship activities were marked by initiating activities, celebrating the start of the project and intensifying the cooperation between the partners and the main stakeholders.

During the first year of its operation the PREIN flagship organized more than 10 events and participated in several events either directly related to photonics research and industry or various themes as part of its outreach activities. The events targeted to the photonics industry and thematic events with photonics and different industrial sectors where photonics is applied, were organized in cooperation with Photonics Finland. There were also events where cooperation between the other Academy of Finland funded flagships was initiated, particularly the Forest and Photonics event.

## Event highlights from 2019

### “Fotoniikasta valoa Suomen hyvinvointiin” in March

The report “Fotoniikasta valoa Suomen hyvinvointiin: selvitys alan vaikuttavuudesta ja kasvunäkymistä” on the status and impact of photonics in Finland was officially released and presented at the Finnish Parliament in the Parliament House on March 1st. The same event included an exhibition on photonics innovations by Finnish companies.

### PREIN Flagship kick-off event in May

The main event in the spring 2019 was the Optics & Photonics Days in Aalto University where PREIN had its own sessions presenting the different work packages, research themes and the official launch party. The Optics & Photonics Days was chosen as the event where the annual PREIN event targeted to all PREIN researchers would be organized. The 2019 PREIN kick-off event attracted over 150 researchers and stakeholders to hear about the flagship innovation network, its organization, scientific objectives, societal and economic impact, as well as education and outreach targets.

The Optics & Photonics Days itself attracted 250 participants. The conference consisted of parallel sessions for academy and industry. There was also an exhibition with a record number of 34 companies, a job fair, a pitching session dedicated to start-ups, as well as a panel discussion with high profile speakers (Laura Juvonen from Technology Industries of Finland; Mika Klementtinen from Business Finland; and Riitta Maijala from the Academy of Finland).



**Marianne Hiltunen (VTT) and Matthieu Roussey (UEF) discussing the impact of stakeholders in the PREIN flagship technology transfer cooperation with the participants of the work package session.**



**The auditorium at Aalto University was full for the PREIN kick-off event at the Optics and Photonics Days 2019.**

## Forest and Photonics in October

Forest and Photonics is a unique professional event that brings together the forest and technology experts to network, collaborate and share their experiences and solutions. The event was organized in collaboration with Photonics Finland and Business Joensuu. The themes in 2019 included artificial intelligence in forest bioeconomy, advanced technologies for preventing forest fires. The event brought together four flagships. In addition to PREIN the flagships for Material Bioeconomy FinnCERES, the Finnish Center for Artificial Intelligence FCAI and the Enabled Wireless Smart Society & Ecosystem 6Genesis

## Photonics for Imaging in December

The Photonics for Imaging – Tampere Imaging Ecosystem networking event hosted by Business Tampere was organized as part of the Photonics for Industry - series in cooperation with Photonics Finland and PREIN. The programme included overviews of the PREIN flagship and Photonics Finland. Several imaging related companies from Finland, including such as NSION and Sony Europe, Fastems, Valmet Automation and Glaston, participated in the event

## Funding for Photonics in December

The event in Business Finland Espoo was aimed to bring together funders and photonics-related start-ups, companies and research projects in the development phase. Funders included venture capitals, business angels, and public funding both national and international. The event was specially designed to help Finnish photonics companies find financial partners and to raise the awareness of investors and funding bodies on the advancement of companies in the field delivering top-notch and groundbreaking technologies and products. The event included start-up and research project pitches.

## International Fairs

PREIN has decided to participate in the largest and most important photonics fairs to promote research activities and offer services and expertise to potential international industrial partners. These include LASER World of Photonics exhibition organized bi-annually as the main European event and Photonics West fair in the United States.



**Forest and Photonics brings together the forest and photonics technology experts.**

## LASER World of Photonics event in Munich June 24–27

Seven individual conferences and more than 5 000 experts from around the world gathered together for the LASER World of Photonics Exhibition in Munich in 2019. There were more than 1 300 exhibitors from around 45 countries in different thematic areas. PREIN researchers participated in the scientific conferences to present their latest research results. The flagship outreach and technology transfer aspects were featured in the exhibition and fair area at the Finnish Pavilion organized by Photonics Finland together with eight Finnish photonics companies.



**PREIN participated in the LASER World of Photonics conference and fair at Munich.**



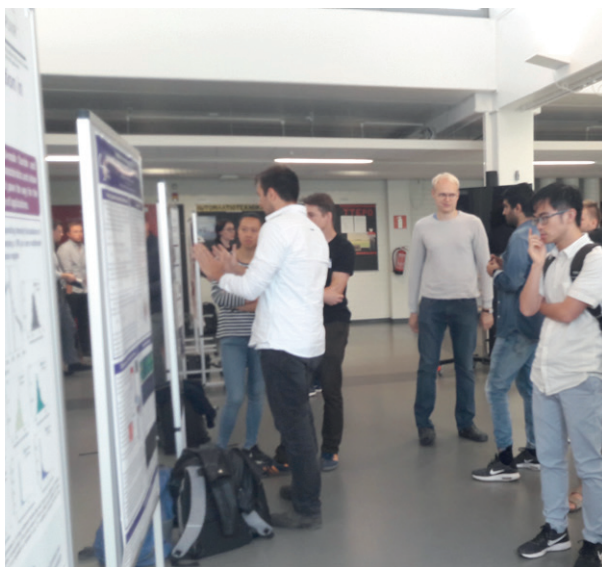
# Impact

Several important impact activities have been launched in 2019 and the focus has been to establish regular procedures for these activities as given in the short summary below. In the coming years, the focus will gradually shift towards increasing the number of impact related activities.

## Scientific impact and research collaboration

In order to increase the overall scientific impact of photonics research in Finland, the flagship aims at merging the leading-edge photonics research activities in the partner institutions. With this in mind, during the first year, particular emphasis has been put on increasing the collaboration between different research groups within the flagship framework. Increased cooperation will also contribute towards unifying the Finnish photonics research community.

One of the first and most practical steps is the collection and sharing of information on the research themes and available infrastructures at each institution. The work package leaders have defined in detail the joint research themes between the partner organizations and prioritized different subtopics of common interest. This work also contributes to the constant updating of the flagship's research roadmap.



**Poster sessions are organized for presenting scientific impact and increasing research collaboration between the PREIN partners.**

## Societal impact

There is a growing demand for educated workforce in photonics. To fulfill the current and future needs, new degree programmes have been launched together with the flagship initiative. This also increases the visibility of education in photonics within the partner universities. In order to increase the competency of professionals working in photonics and related fields, the flagship offers short courses in photonics specifically targeted to industry. The themes of these courses are defined in close collaboration with Photonics Finland and its member companies.

The flagship has formed close ties with the university level outreach actors (LUMA centers) to cooperate and promote photonics and light-related technologies to school children and youngsters. In 2019, the model for cooperation has been established and the first events were organized including the International Day of Light in May and the Shaking up Tech -event in October, with the objective to make these recurring events. The cooperation will also allow creating reusable material and content for regular outreach activities.

Reaching out to the public to raise their interest in photonics is realized by increasing the visibility of photonics research and its everyday applications in popular media. In 2019, visibility has been achieved in newspapers, television, radio and social media. The flagship has established a communications plan including social media strategy together with the organization's communications experts. PREIN research and activities have received visibility in local, national and international media. In 2019 there were over 20 news articles or other media coverage in television and radio about photonics and the PREIN flagship.

## Innovation

The flagship organization and links between the different work packages have been especially designed especially with the aim to improve the connection between fundamental and applied research. In particular, the Research and Innovation services representatives from the partners, the Impact Manager and WP5 on Technology Transfer operate jointly to move research results to the innovation pipeline. A particular role here is played by the Research and Innovation services from each partner who have been involved in developing a common innovation model that benefits other joint research projects.

## Economic impact and industry collaboration

Collaboration with photonics companies and companies utilizing photonics technologies is essential to the growth in the sector and related fields. In order to boost the collaboration with industry, the flagship has established a formal partnership with the stakeholder organization Photonics Finland. The first stakeholder meeting took place in December. On this occasion, entrepreneur and futurist Risto Linturi presented his vision of the impact of photonics on the economy and society, highlighting that photonics plays a part in nearly 40% of technology impact across all sectors.

Together with Photonics Finland, PREIN has organized several thematic events to promote the research and innovation PREIN platform to companies with business related to photonics. Participating in international fairs together under the Finnish photonics brand further showcases the close connection between photonics research and industry. In order to increase the funding related to photonics research, events such as Funding for Photonics gathering researchers, industry stakeholders and investors have been organized.

4  
technology  
patents filed  
in 2019

19  
new international  
company  
collaborations  
initiated in 2019



**International Master's degree programmes in photonics attract students from around the world**

# Education

One of the aims of the flagship programme is to promote education in the field of photonics and related technologies, especially increasing the number of master's and doctoral degrees. PREIN has set quantitative targets in raising the number of both MSc and PhD degrees. All the PREIN partner universities cover photonics in their educational portfolios, but the activities are mainly focused in University of Eastern Finland (UEF) and Tampere University (TAU).

In UEF, there is one international master's degree focused in photonics and three others which cover a more multidisciplinary combination with photonics applications. Three master's programmes at UEF have been selected for the European Commission Erasmus Mundus funding, two of them in 2019.

TAU has launched its own international MSc degree programme in Photonics Technologies with the first intake in 2019 and is also involved in a joint Erasmus Mundus, where the first intake was in 2019.

The fact that there are four Erasmus Mundus funded master programmes related to the flagship is a clear indication of the high quality of our education in photonics. Increasing educational cooperation by developing joint courses and profiling the degree programmes to offer different kinds of specializations in photonics is also a future aim of the flagship.

## Tampere University:

- Master's Degree Programme in Photonics Technologies (first intake 2019)
- Erasmus Mundus Joint Master's Degree EUROPHOTONICS (first intake 2019)

## Aalto University:

- Master's Programme in Nano and Radio Sciences (specialization in photonics)

58

Master's degrees

22

Doctoral degrees

## University of Eastern Finland:

- Master's Degree Programme in Photonics
- Erasmus Mundus Joint Master's Degree Programme in Computational Color and Spectral Imaging COSI
- Erasmus Mundus Joint Master's Degree of Science in Imaging and Light in Extended Reality IMLEX (selected in 2019)
- Erasmus Mundus Joint Master's Degree Programme Photonics for Security Reliability and Safety (PSRS) (selected in 2019)
- UEF's Double Master's Degree Program in "Advanced Materials and Technologies of Photonics" with ITMO University in St. Petersburg, Russia

## Summer Schools

PREIN partners arrange summer schools and symposia directed to both doctoral and post-doctoral researchers. The following events were organized in 2019:

- International Summer School "New Frontiers in Optical Technologies" in Tampere (August 5–9, 2019) is one of the largest photonics-related summer schools in Europe.

- Summer School Optics 2019 "eXpeRIence your reality" in Joensuu (August 19–23, 2019). The Summer School focused on topics related to virtual and augmented reality glasses from theory to practice.
- Annual Symposium of the Finnish PhD students in photonics, "Future Prospects for Photonics" (November 5–7, 2019). The Symposium offers the opportunity for students of the Photonics community in Finland to get an overview of the current trend in research and technology development.

## Continuous education and courses

University of Eastern Finland has been actively involved in the regional development of photonics training path from secondary education to doctoral

degrees. The Joensuu Photonics Education Path Project (JFK) is a cooperation with the Universities of Applied Sciences Riveria and Karelia and the Joensuu Science Park.

In addition, to degree education PREIN organizes short courses targeted to students, researchers and employees from industry, in order to tackle specific industrial needs. In 2019 the following short courses were carried out:

- Zemax Optics Studio Training in October in Espoo
- Working in Clean Room Facilities Training (in Finnish) in November in Joensuu
- Laser Security Training (in Finnish) in December in Joensuu

## Outreach

Within the flagship framework, events and workshops have been organized to raise public awareness of the critical role of photonics and light-based technologies.

In 2019, the events have been mostly directed towards the younger population with special emphasis on children and high school girls. Events organized by PREIN in 2019 include:

- International Day of Light event in May was organized by VTT. The event introduced photonics to 200 students from comprehensive and secondary school students who visited the VTT Oulu site. The students participated in workshops and saw demos on 3D displays, biosensors, photovoltaics and measurement systems.
- Shaking up Tech event in October is a national event to promote technical studies and careers to high school girls. Tampere University organized a photonics themed workshop in the event.

In addition to specific events, PREIN has also released a video on the flagship and its activities.

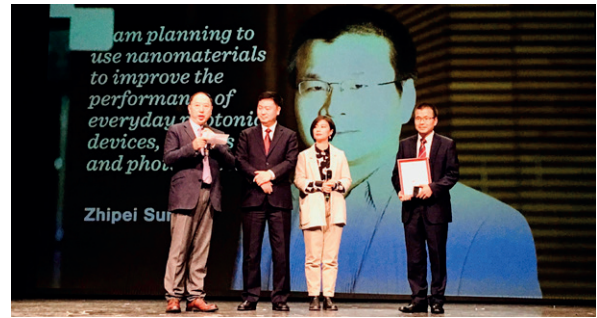


**PREIN participated in the Shaking up Tech event to increase interest in studying photonics among female high-school students.**

# Prizes and Acknowledgements

The PREIN flagship researchers in the field of photonics have been acknowledged during 2019 with significant awards and prizes:

- Professor Zhipei Sun (Aalto University) received the Chinese scholar of the year in Finland
- Professor Mircea Guina (Tampere University) was nominated a Fellow of the Optical Society
- Professor Goëry Genty (Tampere University) received the Väisälä prize of the Finnish Science Academy



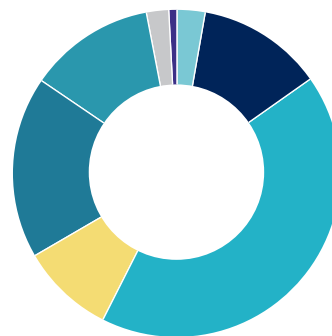
From top to bottom: Zhipei Sun, Mircea Guina and Goëry Genty receiving scientific prizes.

# Funding

The Academy of Finland flagship funding is a leverage to increase other sources of funding. The institutional funding from all the participating organizations is also very important in the beginning of the flagship project period. Both the Academy of Finland funding and the institutional contribution will increase during the flagship programme period.

2019 FUNDING DISTRIBUTION	
Academy of Finland flagship funding	3%
Other Academy of Finland funding	12%
University/research institute's funding	42%
Business Finland	9%
EU	18%
Business companies	13%
Other Finnish & foreign	2,25%
External in-kind contribution to the flagship	1%

## 2019 Funding sources



- Academy of Finland flagship funding
- Other Academy of Finland funding
- University/research institute's funding
- Business Finland
- EU
- Business companies
- Other Finnish & foreign
- External in-kind contribution to the flagship

# Where to find us

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**PREIN and photonics featured in media**

The Forest and Photonics –event held in October at Koli was featured in the local [YLE news](#). [Tekniikka & Talous](#) and [YLE news](#) highlighted the research of Thomas Kerst on detecting radioactive material with prospects for decommissioning nuclear plants.

PREIN Impact Manager Juha Purmonen will start as columnist in [Tekniikka & Talous](#) in November 2019. PREIN director Goëry Genty was interviewed in October by [Radio Moreeni](#) on the analogy between the propagation of light waves in optical fibers and the emergence of rogue waves in the ocean that has driven many experiments in both systems in the past decades.

All PREIN news in Finnish media can be found from the [PREIN web site](#)

Follow our website: [prein.fi](http://prein.fi)

**PHOTONICS - THE SCIENCE OF LIGHT**

PREIN is a Photonics Research and Innovation platform focusing on light-based solutions from scientific excellence to industrial and societal impact. PREIN partners are worldwide leaders in photonics.

Photonics and light-based technologies play a central role in all areas of modern life, including in telecommunications, biomedicine, health care, energy and environment, manufacturing, and consumer products.



## For direct inquiries:

**Goëry Genty**  
PREIN Director  
Tampere University  
[goery.genty@tuni.fi](mailto:goery.genty@tuni.fi)

**Jyrki Saarinen**  
PREIN Vice-Director and  
Industry Specialist  
University of Eastern Finland  
[jyrki.saarinen@uef.fi](mailto:jyrki.saarinen@uef.fi)

**Juha Purmonen**  
Impact Manager  
University of Eastern Finland  
[juha.purmonen@uef.fi](mailto:juha.purmonen@uef.fi)

**[prein.fi](http://prein.fi)**



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