THE ROLE OF PHOTONICS IN FINNISH VOCATIONAL AND HIGHER EDUCATION

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This article reviews the role of photonics in Finnish vocational and higher education, examining how photonics-related topics progress across these pathways. The focus is on university education, particularly the opportunity to study photonics as a primary subject, its integration into broader science and engineering programmes, and its presence in international master's programmes and key educational and research networks. Finally, the article discusses the growing importance of photonics in technology and society, and makes the case for strengthening photonics education through curriculum development, teacher training, and the pedagogical use of artificial intelligence.

In this century, photonics has become a key enabling technology, often seen as the successor to the electronics-driven 20th century. Light-based systems underpin communication, information processing, healthcare and manufacturing: optical fibres enable global connectivity, while lasers drive applications from medical diagnostics to industrial production. As photonics shapes society, basic literacy is needed at all levels, while advanced expertise enables new devices and applications.

Finland stands out through a coordinated national ecosystem, Photonics Finland, linking companies, universities, research institutes and public authorities. The PREIN Flagship[1], Finland's national photonics research and innovation network, unites leading institutions and supports long-term development. Finland's photonics industry grows at almost twice (12%) the global average of 7%, with over 340 companies, more than €2.5 billion in turnover and over 7,500 employees[2]. Strengths include optical sensing, imaging, micro- and nanophotonics, lasers, fibre-optic technologies and extended-reality applications, supported by close academia–industry ties. The National Photonics Roadmap 2025–2030 highlights these assets for future competitiveness.

Finland's strong basic and upper secondary science education provides a foundation for photonics. Building on this, the following section reviews

[1] The Research Council of Finland's Flagship Programme is an instrument that supports high-quality research and increases the economic and societal impact emerging from the research.

[2] At the end of 2025, Finland's population stood at approximately 5.66 million, and the country hosted about 1,800 companies in the technology industry.

vocational, university of applied science (UAS) and university-level studies, international master's programmes and cooperation networks from a photonics perspective. The discussion addresses skills needs and economic priorities and argues for strengthening photonics education—especially in universities—based on workforce forecasts, national priorities, European trends and the growing role of AI.

VOCATIONAL AND HIGHER EDUCATION

This section overviews photonics education at various levels, starting with vocational and UAS pathways. The focus is on university education, international joint master's programmes and cooperation networks that support advanced learning.

VOCATIONAL EDUCATION

In Finland, vocational education and training (VET) provides practical, competence-based training closely linked to industry, preparing students for employment or further study. Although photonics is mainly taught at universities, VET supports the field by supplying skilled professionals in related technical roles such as electronics, automation, ICT, and precision manufacturing. These competencies enable tasks like assembling optical instruments and maintaining photonics equipment. Targeted initiatives—such as the Joensuu pathway developed with local VET, UAS, and university partners—add photonics basics, laser safety, cleanroom skills, and manufacturing fundamentals, helping meet the sector's growing technical workforce needs.

UNIVERSITY OF APPLIED SCIENCE EDUCATION

UASs provide vocationally oriented higher education aligned with industry needs. While universities offer programmes explicitly titled photonics, UASs complement them by educating application-focused engineers, technicians and opticians. Degree programmes in electronics, electrical engineering, ICT, automation, mechanical and precision engineering equip students for optical instrument assembly, laser and measurement system integration, cleanroom work and precision manufacturing. UASs also offer continuing education in cleanroom practice, machining, instrumentation and quality control, supplying industry-ready talent for photonics-related applications.

UNIVERSITY EDUCATION

At Finnish universities, bachelor's physics includes photonics-related topics such as wave motion, electromagnetism and optics, with an introductory photonics course at University of Eastern Finland (UEF). As no university offers a bachelor's degree specifically in photonics, emphasis is on master's-level studies. Photonics can be studied as a main subject at UEF, Tampere University (TAU) and Aalto University, each offering dedicated or specialised master's options, with PhD studies available at all three. Photonics-related content also appears at several other universities.

University of Eastern Finland

At UEF, photonics focuses on advanced optics and light-based technologies. The National Master's Programme, integrated with the two-year International Master's in Photonics, combines rigorous theory with extensive laboratory training, including micro- and nanofabrication in clean rooms. The curriculum covers light–matter interaction, waves, scattering, quantum and applied photonics, supported by strong experimental work and a thesis. Teaching and research are centred in Joensuu, a long-established photonics hub, and graduates are well prepared for international careers with versatile scientific and technical skills.

Tampere University

At TAU, photonics is part of the Physics Unit in the Faculty of Engineering and Natural Sciences. Research spans communications, lasers, energy, sensing, environmental and health applications. It is offered as a specialisation in the Master's Programme in Science and Engineering, developing expertise in light–matter interaction, materials and optical devices through theory and labs. Facilities include laboratories for optical characterisation, nonlinear optics, fibre lasers and metamaterials.

Aalto University

At Aalto, photonics is embedded across the School of Electrical Engineering. The Department of Electronics and Nanoengineering hosts the Photonics and Nanotechnology specialisation within the Master's Programme ● ● ●

Figure 1. A girl exploring colours through experiments at the Light for Families event. Photo: Anne-Maria Kankaisto, Photonics Finland.

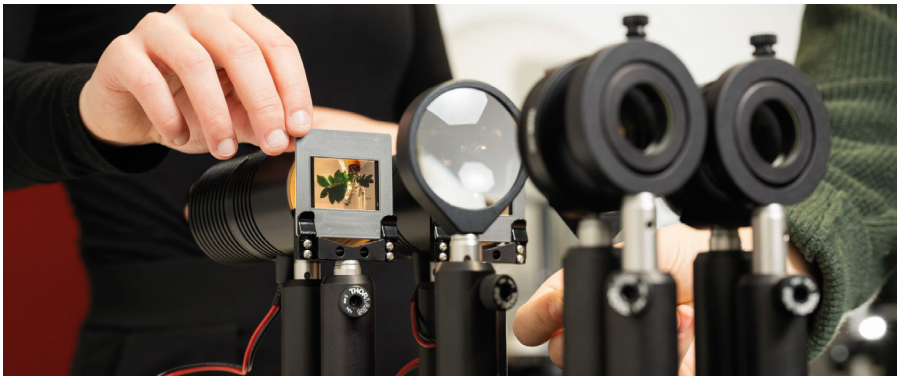

Figure 2. A setup for studying the principle of a 3D movie based on polarisation. Photo: Niko Jouhkimainen, UEF.

in Electronics and Nanotechnology, covering light–matter interaction, optical systems and device fabrication. Students take courses such as Photonics and Optoelectronics and gain hands-on experience in the cleanroom. Aalto also offers a Photonics and Nanotechnology minor open to all students. Research focuses on integrated photonics, optoelectronics, semiconductor lasers, nanomaterials and advanced optical phenomena.

Other universities

Several universities integrate photonics within broader programmes rather than as a separate major. The University of Jyväskylä includes photonics-related content in its multidisciplinary Master's in Nanoscience. At the University of Oulu, photonics is embedded in electrical engineering, with options in photonics and measurement technology. The University of Helsinki's materials research master's offers a specialisation in optics and photonics. The University of Turku includes photonics within its Master's in physical and chemical sciences, preparing students for R&D roles.

INTERNATIONAL JOINT MASTER'S DEGREE PROGRAMS

International and joint Master's programmes strengthen Finland's talent base and global appeal. By combining expertise from leading universities, they widen access to skilled students, serve industry needs and enhance quality, while helping retain international graduates in Finland's research and innovation ecosystem. UEF participates in three Erasmus Mundus programmes and TAU in one, all two-year degrees with European and global partners, preparing students for high-tech careers and doctoral studies.

iPSRS – Intelligent Photonics for Security, Reliability, Sustainability and Safety

A Master's integrating photonics and AI to address challenges in security, safety, reliability and sustainability. It trains students in intelligent photonics, imaging, sensing and machine learning. Coordinated by Université Jean Monnet (UJM) with UEF, Vilnius University and University Paris-Est Créteil, it includes coursework, projects, seminars and internships.

IMLEX – Imaging and Light in Extended Reality

A multidisciplinary Master's combining imaging, lighting and IT with a focus on extended-reality applications. Coordinated by UEF with UJM, KU Leuven and Toyohashi University of Technology, it blends theory and practice through international mobility for XR-industry roles and applied research.

COSI – Computational Colour and Spectral Imaging

A Master's specialising in computational colour science and spectral imaging, combining photonics, optics, image processing, computer vision and data science for applications from multimedia to biomedical and industrial imaging. Coordinated by NTNU with UJM, the University of Granada and UEF, it features strong industry collaboration, applied research, internships and thesis work.

EuroPhotonics – International Master's Programme in Photonics Engineering, Biomedical Imaging, Quantum Optics, Laser Optics, Optics for Astronomy, Nanophotonics and Biophotonics

A long-running Erasmus Mundus programme offering advanced education from fundamentals to cutting-edge research. Training spans photonics engineering, laser and quantum optics, nanophotonics, biophotonics, biomedical imaging and astronomy optics, combining theory, labs and a research-focused thesis. Coordinated by Aix-Marseille University with TAU, KIT, the University of Barcelona, Vilnius University and other partners, its mobility and joint degree prepare graduates for high-tech industry and research careers.

NATIONAL AND INTERNATIONAL EDUCATIONAL COOPERATION NETWORKS

Educational cooperation networks connect universities, industry and other partners to deliver flexible, high-quality learning. They enable joint courses, shared expertise and coordinated programme development, especially in emerging technologies, and support lifelong learning.

FiTech and LUMA Centre Finland

FiTech unites Finnish universities offering engineering education and provides free courses in AI, machine learning, energy engineering and wood materials. Although

multidisciplinary, it currently offers no dedicated photonics courses.
LUMA Centre Finland is a national STEM network of 13 university-based centres. It inspires young people in STEM and supports teacher development from early childhood to higher education. Appointed by the Ministry of Education and Culture for 2025–2028, it promotes equitable, research-based STEM education through study visits, teacher training and pedagogical innovation. Reaching about 400,000 learners and educators annually, LUMA works with schools, universities, industry and international partners. Its StarT initiative is a recognised project-based learning model. In Joensuu, the local LUMA centre runs the Light for Families event with PREIN and UEF.

FysNet and EduQ

FysNet unites university physics educators to develop a joint national study offering with high-quality online and hybrid teaching. It shares best practices across 15 thematic groups, including one on optics and photonics, *e.g.* creating an optical design course.
EduQ, part of Institute Q (the Finnish quantum institute), coordinates master's and PhD-level education in quantum science by combining partner programmes and offers open resources such as QPlayLearn and MOOCs, with planned courses on quantum optics.

Phortify – European photonics network between degree programmes

Phortify, launched in 2025, is a European photonics education initiative linking universities, research organisations and industry. It harmonises training across seven Master's programmes, with UEF among 12 partners. Through shared curricula, short modules, mobility and recognised certification, Phortify provides up-to-date skills across the photonics value chain, including integrated photonics, optical communications and related technologies, helping companies address skill gaps.

DISCUSSION

Photonics plays an increasingly important role in Finnish vocational and higher education, especially at universities. With Finland's technology sector expected to need around 13,000 new experts annually—many in photonics-related roles—the need to strengthen photonics education is clear.
In the EU, photonics underpins major Finnish growth sectors such as digitalisation, manufacturing, healthcare, environmental monitoring and emerging quantum technologies. As reliance on optical solutions increases, so does demand for expertise. Photonics also drives advances in precision sensing and next-generation computing. Expanding photonics education would help address skills shortages, support innovation and maintain competitiveness.
Although light-related topics appear in early science education, photonics remains largely invisible as a coherent field. Clearer links between content, applications and study pathways would raise awareness, increase interest and support university recruitment. Teacher training and curriculum development are critical, as national curricula guide practice even with strong teacher autonomy.
AI is transforming photonics learning through adaptive tools, automated design and data-driven optimisation, but expert knowledge remains indispensable: accurate modelling, meaningful problem-setting and interpreting results still require human judgement, and core skills—experimental intuition, understanding light–matter interactions and making informed design choices—cannot be automated.
Across Europe, education systems and the adoption of AI-enhanced tools vary, so integrating photonics should follow nationally tailored approaches while benefiting from European cooperation. To turn laboratory innovations into scalable applications, education must align research, industry and digital competencies, and emphasise interdisciplinary skills that combine photonics with data science, machine learning and systems engineering, grounded in strong physical understanding.
Within this context, Finland can build on its strengths—flexible curricula, research-based teaching and strong industry links—while integrating computational and AI-assisted tools into studies. By developing strategies tailored to national needs yet aligned with European objectives, Finland and other countries can cultivate experts capable of leading, rather than merely adapting to, future technological change.

Figure 3. Two photonics engineering students wearing the distinctive overalls that serve as the student association's informal uniform. Photo: Niko Jouhkimainen, UEF.