

## Optics and **PHOTONICS**



### CSEM

Since its creation, CSEM has been a cornerstone of technology development and transfer for precision micro- and digitalization technologies. These innovative technologies are the foundations on which smart systems are built, promising all industries new opportunities for economic growth.

CSEM has long been renowned as one of Switzerland's major research institutes—in the precision manufacturing domain as well as in low-power microelectronics and microtechnology—with our innovations being eagerly adopted by several key partners, including the watchmaking industry.

Pushing ahead into the new digital economy, our expertise extends into advanced technologies, analytics, and algorithms, which enable the Industrial Internet of Things (IIoT) and strengthen manufacturing processes. In domains as diverse as health, energy, aeronautics, space, security, agriculture, and consumer electronics, we provide our partners with the personalized tools, hardware, and software they need to take them forward into the digital age.

From precision manufacturing and sustainable energy to digitalization, we provide the expertise, technologies, processes, and services that can deliver a decisive advantage to all our industrial partners. CSEM is committed to advancing digital technologies in the economy across a competitive and global industrial environment. With 500+ employees, we are passionate about helping our partners achieve success in our rapidly evolving world.

Photonics is a core technology for CSEM, enabling and enhancing other innovative fields, such as Data & AI, Quantum Technologies, Industry 4.0, MEMS or Photovoltaics.





## **Optics and Photonics**

For over 35 years, CSEM has been at the cutting-edge of photonics technologies. Exploiting every possible aspect of light, our specialties lie in integrated photonics, free-form micro-optics, novel diffractive optical elements, AI vision systems, high-performance laser sources, laser-based instruments, and processing tools. With our solutions benefiting our customers in the communications, imaging, lighting, energy, manufacturing, life sciences, healthcare, security, safety, metrology, and mobility domains.

We are experts in generating, shaping, and steering light, and have a proven track record in building single-frequency lasers, ultra-large bandwidth frequency combs, micro-lenses, waveguides, grating-based interference filters, and Fabry-Perot or ring resonators. Moreover, our ASIC and optical front-end know-how benefit the development of low-power imagers with a high-dynamic-range, fast line scanners, as well as metrological systems and application-specific multispectral cameras.

Our hybrid technology expertise in optical MEMS technology (design, fabrication, coating, assembly, and packaging) is generating components with previously unseen functionalities; the development of which is facilitated by access to an in-house, state-of-the-art cleanroom, where we offer pre-feasibility studies alongside small to medium series production. Whether it be design, modeling, advanced simulation, manufacturing, assembly, or packaging, we provide in-depth testing and characterization for all our technologies to enable end-to-end improvements.

Lastly, we work on integrating photonic functions to build miniaturized, complete systems using the latest signal processing technologies i.e., machine learning. By bringing together these state-of-the-art components and subsystems into complete systems, CSEM can meet the challenges posed by the IoT, industry 4.0, and more.





01: Photonic Integrated Circuits (PICs) manufactured in 150 mm wafer-scale process
02: Optical image of the TFLN PIC area
03: SEM of an electro-optical modulator (metal in yellow)
04: Overlay of two TFLN waveguide layers
05: TFLN PIC with smooth facets
06: Densely patterned TFLN waveguide layer with smooth side walls
07: A 5x5 mm<sup>2</sup> TFLN PIC encompassing multiple EO modulators and switches

# INTEGRATED PHOTONICS

Photonic Integrated Circuits (PICs) are revolutionizing the optics industry by enabling enhanced performance in a wide range of applications. Compared to traditional bulk optical setups, PICs feature increased system integration, miniaturization, and increased bandwidth, while being both cost-effective and scalable. Their adoption is rapidly spreading, bringing substantial advancements efficiency and reliability in across various domains, including sensing, lidar, spectroscopy, metrology, communications, nonlinear optics, and quantum computing.

CSEM develops PICs using thin film lithium niobate (TFLN) on insulator and silicon nitride (SiN). Our TFLN platform foundry services based on a dependable process design kit (PDK) combine both passive, nonlinear, and active electro-optic components. They allows us to achieve novel functionalities and on-chip systems that go beyond the capabilities of commercially available PIC platforms, specifically in the field of data and telecommunication. Additionally, our TFLN foundry offers unique solutions tailored specifically for quantum applications.

In parallel, our SiN platform expertise focusses on the integration, testing, and validation of transducers for sensing applications, such as ultrasensitive seismic sensors, biosensors, or magnetic force sensors. CSEM support our clients in PIC design, simulation, micro-fabrication, characterization, and PIC packaging know-how. Specifically, our services include:

- TFLN PIC foundry service (in multi-project wafer or customized RUNs)
- Design and simulation of PIC components (passive, nonlinear, and active electro-optical PIC)
- Design of PIC systems combining different building blocks for specific functions
- Consulting on photonic packaging concepts (including fiber-to-chip and electro-optical integration)
- Integration of various transducers for advanced sensor applications (optical MEMS, biochemical MEMS, magnetic, nano-magnets, and more)





01: RUN+<sup>®</sup> diffuser by Regent Lighting GmbH based on free-form micro-optical structures
02: Back-illuminated CMOS image sensor equipped with micro-lens arrays
03: CSEM cleanroom facility for the prototyping and piloting of micro-optics
04: Micro-optical films for light management in solid-state lighting
05: Semi-hemispherical micro-lens arrays for super-resolution imaging
06: Free-form micro-optical solution for 90° light in-coupling from an optical fiber into a photonic integrated circuit

# MICRO-OPTICS

Micro-optics, which were initially used predominantly in the telecom and smartphone industries, are now integrated in ever more products, pushing the development of these miniaturized optical components to unprecedented levels. At CSEM, we are masters of the sub-millimeter range, advanced micro-optic innovation, design, development, and fabrication. We exploit the possibilities offered by micro-optics to enhance and develop optoelectronic devices with novel or improved functionalities, by taking full advantage of our miniaturization, replication, manufacturing, and integration expertise to find flexible, cost-effective solutions for our partners.

Recent advances in computing and ultra-precision micromachining are now also enabling us to design and manufacture a new generation of free-form micro-optical components. By removing nearly all restrictions to the shape of components, these powerful tools enable optical designers and engineers to boost device miniaturization and performance, and create new functionalities, while decreasing manufacturing cost.

Our expertise includes the design and fabrication of micro-lenses and micro-lens arrays with industrial UV imprint manufacturing processes. This enables us to offer services along the whole micro-optic value chain, including:

- Complete design, for both manufacturing and tolerancing
- Origination by standard technologies and advanced micro-machining techniques
- Tooling up to an A3 scale
- Wafer-scale UV imprinting up to 8 inches
- Roll-to-plate UV imprinting up to an A3 scale
- Industrial-grade and custom/R&D UV imprint materials, and their adaptation to applicationspecific requirements
- Characterization and metrology for quality control and fabricated device simulation
- Integration and testing

We are the ideal partner for companies searching for prototyping and/or piloting of advanced micro-optical components. In particular, we offer on-chip microlens engineering and foundry services from single chips to super-reticles or wafers. Moreover, through our extended ecosystem, we can support our partners in industrializing, ramping-up and scaling the volume production of their products.

















- 01: Laser projection for an automotive application based on diffractive elements
  02: Color filter pixelated array based on subwavelength Mie resonators for spectral filtering
  03: Scanning light guide with diffractive couplers imaging in ultra-narrow environments
  04: In-house design and simulation
  05: Optical security feature with smartphone interaction
  06: Resonant waveguide gratings for document security. Credit: ©SURYS
  07: Hexagonal subwavelength antireflective structures optimized for infrared light

# NANO-OPTICS

Nano-optics uses light-matter interaction with nanostructures to enable unique optical effects and has recently become an essential part of many consumer devices and photonic instruments. CSEM benefits from decades of experience in the transfer of nanoscale optical technologies to the industrial sector, from optical document security features to components of photonic systems. Its activities focus on:

- Diffractive waveguide and light guide couplers
- Diffraction gratings, high-contrast gratings, and laser mirrors
- Resonant waveguide gratings
- Plasmonic nanostructures for filtering, sensing, and optical security
- Diffractive optical elements for beam shaping and brand protection

The full value chain for nano-optics and diffractive optics is addressed, from design to prototyping, characterization, and from tooling to pilot production. This is supported by a large variety of simulation models and a dedicated cleanroom infrastructure. CSEM develops its own processes for nano-optics mastering, transfer, and replication while formulating a wide range of materials for specific requirements. Our excellent knowledge of industrial manufacturing processes and materials, as well as a large network of industrial partners always ensures an offer of solutions with a short time to market.





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01: Low-noise packaged mode-locked laser emitting femtosecond pulses at 1560 nm with 600 MHz repetition rate
02: Optics and metrology laboratory
03: Ultra-high-quality factor, fiber-based microresonator for nonlinear cavity optics
04: Supercontinuum generation in a fiber-coupled silicon nitride PIC fabricated by Ligentec SA for frequency metrology
05: Semiconductor mode-locked laser with above 0.5 W of output power
05: A microresonator for active proversion of the active provention of the active proves

- 06: An optical frequency comb imaged on an astronomical spectrometer for calibration

# LASERS

Today, most advanced optical systems include at least one laser; they are the engines that bring optical systems to life. At CSEM, our competencies span across the entire laser technology spectrum. We specialize in developing ultra-stable continuous-wave and femtosecond laser sources, high-power laser systems, modeling of laser physics, optical system design, and electronics. Our work has benefited applications from the manufacturing, metrology, sensing, and optical communication domains.

With our clients and partners, we develop both miniature and large-scale laser sources, including:

- Mode-locked semiconductor lasers
- Quantum cascade lasers for spectroscopy
- Ultra-narrow linewidth continuous-wave lasers
- Mode-locked femtosecond optical pulse sources and frequency combs
- Electro-optic frequency combs and Kerr frequency combs
- Amplified high-power femtosecond sources for manufacturing

Through nonlinear spectral broadening, our experts can achieve more than octave-spanning spectra using fiber optics and integrated optics. We also understand the importance of ultrashort pulsed laser sources in the field of material processing, and we have already realized laser systems generating femtosecond pulses with average power levels above 150 W.

As well as developing laser sources, we are also experts in laser metrology and can characterize lasers in our state-of-the-art optics laboratory using the latest metrological test equipment. CSEM can stabilize the critical parameters of any laser system such as optical frequency, pulse repetition rate, and optical power using high-performance analog and digital electronics.



![](_page_11_Picture_1.jpeg)

01: Expanded view of SpectroX, a handheld multispectral system
02: Ultra-low-power image system
03: Heatmap from a multimodal (audio, video and infrared) system
04: Feature extraction for face and state detection

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05: Neural network

06: Sub-milliwatt CMOS sensor for IoT cameras

07: Vision-in-package system with embedded intelligence

# VISION SYSTEMS

Vision systems are an integral part of most industries. By combining them with data driven tools, such as embedded machine learning algorithms or artificial intelligence, businesses can gain new insights from their data. At CSEM, we create custom systems across the entire vision chain, from opto-electronic and CMOS image sensor design to data transfer, combined with state of-the-art machine learning algorithms embedded in AI accelerator hardware to optimize data processing.

We leverage more than 25 years of experience in the field of embedded artificial intelligence to develop vision systems that work with industrial requirements: real-time, ultra-low-power, high-speed, high-dynamic range, compact, and highly integrated.

We are actively working on imagers that are sensitive not only to visible light but also X-rays and THz spectra, along with new spectral decomposition leading to chemical imaging. capabilities. Moreover, our metrology through imaging systems offer best-in-class performance in terms of precision, speed, and robustness to harsh environments. CSEM's leading expertise in machine learning provides high-performance and real-time classification, and we are experts in embedding algorithms in dedicated hardware accelerators for edge computing and IoT compatibility. Alongside these capabilities, we also offer strategic IP deployment.

From design and prototyping to complete industrial level vision systems and components, CSEM's competencies include:

- Embedded machine learning
- Authentication and classification
- High-speed machine vision
- Chemical imaging
- Metrology
- Non-contact life sign monitoring
- Human-machine interaction
- Custom imager for visible, SWIR, MIR, THz, or X-ray domain
- Defect detection and quality inspection
- People presence and emotion detection
- CMOS sensor design

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![](_page_13_Picture_1.jpeg)

![](_page_13_Picture_2.jpeg)

![](_page_13_Picture_3.jpeg)

![](_page_13_Picture_4.jpeg)

![](_page_13_Picture_5.jpeg)

![](_page_13_Picture_6.jpeg)

![](_page_13_Picture_7.jpeg)

- 02: Prototype of an optical spectroscopy system for airborn etrace gas detection 03: In-flight test of a spectrometer system for precise measurements of methane in the atmosphere 04: Optical sensor head developed for the characterization of mechanical watch movements

05: Miniature atomic clock featuring a diffractive light guide to interrogate hot rubidium vapor inside a MEMS cell

06: Optical pH sensor for wound monitoring

07: Fluorescence lifetime imaging (FLIM) reader for anti-counterfeiting

![](_page_13_Picture_15.jpeg)

# INSTRUMENTS & SENSING

CSEM's core strength lies in our hybrid technology expertise, which extends beyond photonics to software, AI, electronics, and mechanics. This multifaceted knowledge allows us to develop components alongside engineering high-performance optical instruments for a variety of applications. We cover the entire development chain, from design and feasibility studies to final tests for general environmental and even space qualifications.

We have a proven track record of developing high-performing instruments for space missions and industrial settings throughout Switzerland and Europe. Obtaining reliability and outstanding performance at these levels, even for one-of-a-kind devices, requires an understanding at the system level, as well as an eye for detail and precision-qualities CSEM is known for.

Our services include:

- Specialized lidar devices of different architectures e.g., for bathymetry and object detection on satellites
- Photonics sensors, photonic integrated circuits (PICs), fiber-optical sensors, broadband spectrometers, and quantum sensors
- Miniature atomic clocks with atomic vapor MEMS cells

- Quantum magnetometers and gyroscopes
- Laser frequency combs for different applications including astronomy (astrocombs)

- Quantum light sources for quantum-enhanced microscopy and clocks
- Integration of PICs with mechanical transducers for advanced hybrid sensors such as nano-g optomechanical accelerometers for seismic applications
- Compact, optoelectronic systems for biosensing, environmental, and process monitoring, for use in fluorescence-based sensors, or nano- and microparticle detection

We use our PIC and MEMS expertise to develop customized scientific instruments and hybrid photonic sensing components for space, science, watchmaking, industrial and medical applications.

# What our customers say matters to us

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### Brolis Sensor Technology

## Optical semiconductors

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As an SME our resources to investigate and develop applications far outside our core expertise are very limited. This is why CSEM with its broad expertise in many different areas of photonics and beyond is a perfect partner for us. Our projects with CSEM have enabled us to assess new technologies and markets which we had not been able to target before.

Augustinas Vizbaras CTO Vilnius (Lithuania) www.brolis-photonics.com

### **Bühler Group**

Compact vision system

![](_page_15_Picture_11.jpeg)

CSEM was the ideal partner for this project, expert in intelligent systems and algorithms, pragmatic and flexible when we had to change the data collection plan, and fast! This was our first project with CSEM—and it won't be the last.

Mario Urbisaglia Team Manager R&D Uzwil (Switzerland) www.buhlergroup.com

Eblana Photonics

Semiconductor laser products

![](_page_15_Picture_16.jpeg)

We've had several projects with CSEM, which have advanced our semiconductor laser products substantially and opened up new commercial opportunities in the area of low linewidth lasers for lidar applications. The discussions with the experts at CSEM have provided us with many new ideas as well as valuable feedback for different applications such as metrology and sensing.

Richard Phelan Head of laser design Dublin (Ireland) www.eblanaphotonics.com

### ESA – ESTEC

**LISA** mission

![](_page_15_Picture_21.jpeg)

In the context of the LISA mission, CSEM successfully delivered upon the challenging development of a laser system breadboard and of the associated metrology setups. As a result CSEM was able to demonstrate the excellent performances of its system and its cutting edge laser system metrology expertise. ESA thanks the team for the hard and excellent work as well as the positive and proactive collaboration.

Brian Shortt Head of the Payload Validation Section Noordwijk (The Netherlands) www.esa.int

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ORYL Photonics

### Nonlinear pump-probe microscopy

CSEM accelerated our prototype development by identifying exactly the problem that needed to be solved and providing practical solutions that are supported by simulations and analysis.

## NKT Photonics

High-power femtos<u>econd lasers</u>

![](_page_16_Picture_6.jpeg)

In the fast-paced field of highpower femtosecond lasers for industrial applications, NKT Photonics teamed up with CSEM to develop a cutting-edge technology. Thanks to the dedication and good communication the within the team, all the objectives have been reached and the technology is now implemented in our commercial systems.

Carsten Thomsen Senior VP of Ultrafast Lasers Birkerød (Denmark) and Regensdorf (Switzerland) www.nktphotonics.com

Working with CSEM has been very helpful technically and also geographically, with our proximity and the advantages of an all-Swiss partnership adding to the project's overall value.

Fabrice Schertenleib Managing Director Renens (Switzerland) www.tesatechnology.com

Orly Tarun Co-Founder & CEO Lausanne (Switzerland) www.orylphotonics.com

## Regent Lighting

Flexible light diffuser – RUN+

![](_page_16_Figure_14.jpeg)

CSEM and Regent share a passion for innovative solutions lighting and products. From the very beginning, we established an excellent relationship based on mutual trust and respect. In turn, this has led to many follow-up collaborations. We have recently completed a project closely related to RUN+ and hopefully, this will soon materialize in another innovative product release from Regent.

Thierry Dreyfus Head of Technology Basel (Switzerland) www.regent.ch TESA-Hexagon

spaceCoder

![](_page_16_Picture_19.jpeg)

## What our customers say matters to us

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Massachusetts Institute of Technology

Integrated quantum photonics

We are strong supporters of CSEM's efforts to build up a foundry service for lithium niobate integrated photonics since we believe it will have a major impact on both industry and the scientific community. It is really a fortunate situation for us to get in early and work with CSEM as their capabilities expand and accelerate our research in integrated quantum photonics.

Mikkel Heuck Research Scientist Quantum Photonics Laboratory Cambridge, MA (USA) www.mit.edu

![](_page_17_Picture_7.jpeg)

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Hamilton Bonaduz AG

Liquid handling

Having CSEM as a cooperation partner on this project opened the door to us in finding the required vision technology. Their extensive experience in high-speed imaging systems means together we have developed an excellent piece of equipment that can precisely quantify even the smallest liquid volumes.

Hanspeter Romer Head of Research & New Technologies Bonaduz (Switzerland) www.hamiltoncompany.com

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# Ready to face your challenges together?

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