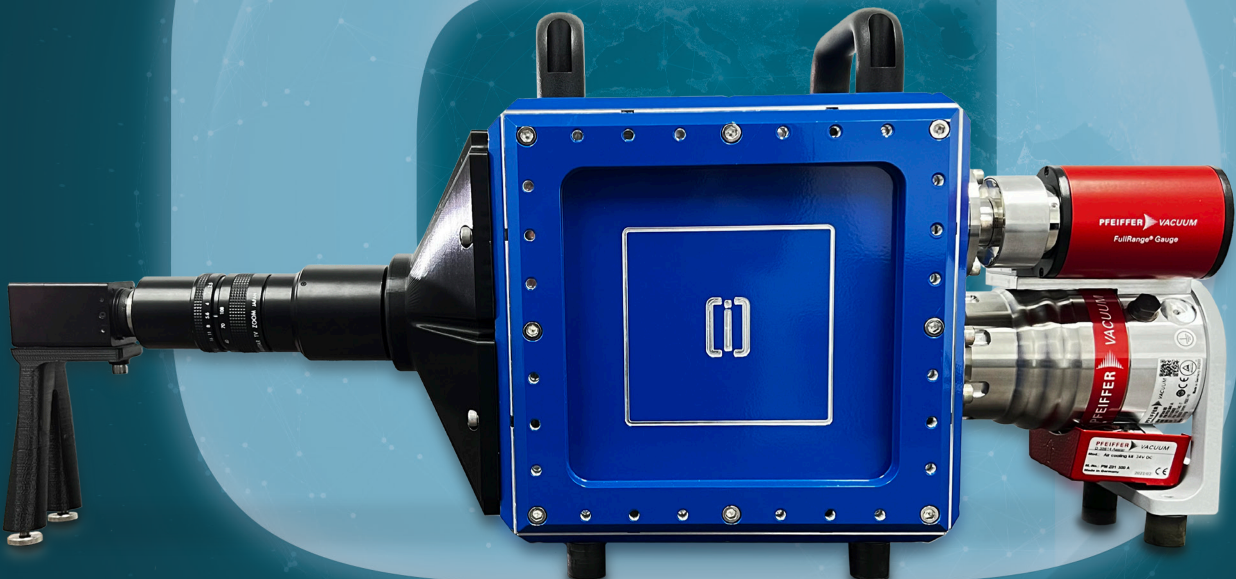
PHOTONIS
EXOSENS GROUP

Neutronic[i]



HIGH EFFICIENCY THERMAL NEUTRON IMAGING SYSTEM BASED ON PATENTED MICROCHANNEL PLATE TECHNOLOGY

Detect What X-Rays Cannot

Neutron imaging and tomography is gaining ground as an imaging modality, owing primarily to its high contrast of light elements. It is indispensable, for instance, in research on sustainable technology such as battery development, hydrogen storage and fuel cells.

Contrary to X-rays, which interact with a sample's electron shells, neutrons interact with its nuclei. This makes neutrons isotope-sensitive, a fact that can be exploited to enhance or suppress certain contrasts. A neutron's spin enables you to probe magnetic fields. In recent development, time-resolved neutron imaging opened the door to energy sensitive radiography and neutron resonance imaging.[1]

At the heart of a neutron radiography instrument is the imaging detector. Conventional detectors are based either on photographic plates or powder scinctillators. The former prohibits neutron tomography, and the latter suffers from camera limitations and image retention. Both methods trade off resolution against detection efficiency. As a consequence, few neutron imaging detectors have more than a few percent detection efficiency for thermal neutrons.

MCP-based neutron imagers have an estimated detection efficiency over 50% for thermal neutrons, and can have a resolution of 50 µm and better. The Photonis Neutronic[i] is a complete imaging system, equipped with a 100×100 mm^2 neutron sensitive MCP. The system also includes a vacuum chamber, high-voltage power supply, and controller.

The Neutronic[i], with significantly higher sensitivity than present-day techniques, enables new sorts of imaging studies. Neutron tomography can be done so quickly that many samples can be scanned the same day, making more efficient use of precious beam time.

Neutron imaging can also be applied to dynamic processes, opening the door to neutron video recording. The fact that many times, less neutron flux is integrated to attain a certain image quality also comes with benefits. Samples activate less, proportionally to exposure time. Rare artifacts and valuable museum pieces can be imaged and still return to their owner. Small, low power nuclear reactors running on conventional low-enriched uranium become suitable neutron sources for imaging. Ultimately, neutron imaging can be done with neutron generators as a neutron source, bringing these capabilities to labs in academia and industry.

[1] M. Zimmer et al., "Demonstration of non-destructive and isotope-sensitive material analysis using a short-pulsed laser-driven epi-thermal neutron source", *Nature Communications* 13, 1173 (2022).

WHAT MAKES PHOTONIS YOUR PREFERRED PARTNER

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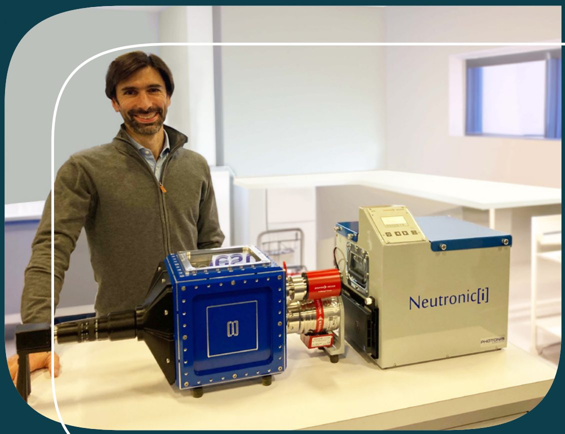
Photonis provides award-winning innovation in every detection product and system we offer. Our extensive experience in vacuum, photocathode, and microchannel plate technologies means we can provide you with a custom solution, complete with read out techniques that best supports your project.



THE PHOTONIS DIFFERENCE

PHOTONIS, part of the EXOSENS Group, is a global organization with experience in innovating, developing, manufacturing, and selling electro-optic components used to detect and amplify photons, ions, electrons, and neutrons.

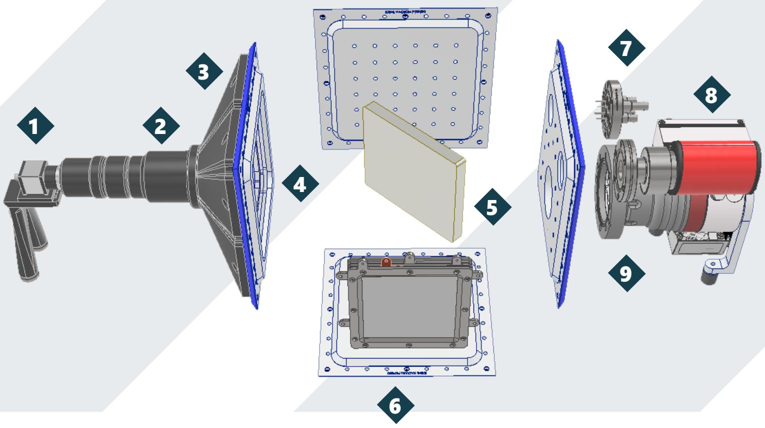
Our philosophy is to be a trusted technology partner in your R&D process; listening, collaborating, designing and manufacturing highest standard, truly outstanding, world-leading detection solutions. The researchers, technology experts, and scientists at PHOTONIS are dedicated to working with your research, product, and technology teams to create a specialized solution for your desired application.

For over 30 years, Photonis has consistently set the standard in election multipliers and related products. Today, an extensive R&D program, coupled with unsurpassed expertise in microchannel plate (MCP) technology continues to deliver a succession of product and process improvements that push aside previous technology limits.

OUR MARKETS INCLUDE

- Analytical Instrumentation
- Defense
- Medical
- Nuclear Instrumentation
- Non-Destructive Testing
- Security and Surveillance
- Space and Physics

WHAT IS IN THE **NEUTRONIC[i] VACUUM CHAMBER**?



1. **CAMERA**
2. **LENS**
3. **SHROUD**
4. **OUTPUT WINDOW**
5. **45-DEGREE MIRROR**
6. **MCP-PHOSPHOR SCREEN ASSEMBLY** (WITH NEUTRON-SENSITIVE MCP TECHNOLOGY)
7. **HIGH-VOLTAGE FEEDTHROUGHS**
8. **PRESSURE GAUGE**
9. **TURBO PUMP**

THE VACUUM CHAMBER houses the imaging assembly, which consists of at least one neutron sensitive MCP and a phosphor screen. A mirror placed on the optical axis behind the imaging assembly allows the camera to be placed outside the neutron beam acceptance.

THE CONTROLLER

The controller houses all the ancillary components: a roughing pump, high voltage power supplies, readout of the pressure gauge, controller for the turbo pump; and an on-board computer. The controller is usually up to a few meters away from the vacuum chamber, connected to it by a few cables and a vacuum hose. The on-board computer connects to the camera and allows you to control the system remotely.

THE OUTPUT

The Neutronic[i] is a configurable detector, which can be used with any camera or lens. Gain is controlled by the high voltage applied, or by having more or less MCPs in the imaging assembly. This can always be modified in case of a change of needs, and each part can be easily replaced in the event that an MCP reaches the end of its lifetime, or the screen starts to burn in, for example.

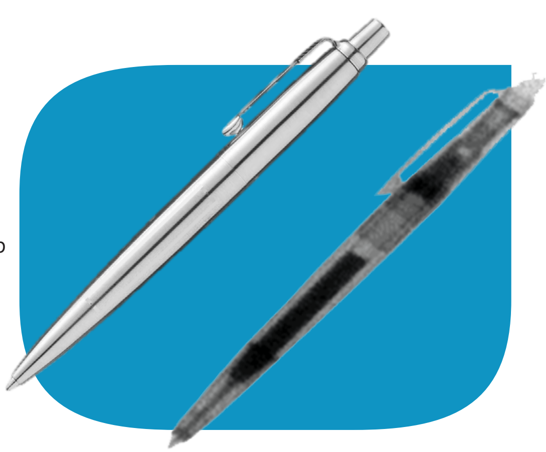
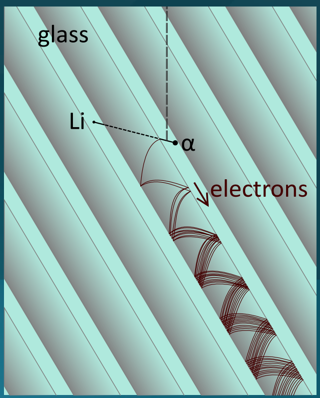


Photo of a steel ball pen (left) and neutron image (right), revealing ink level. Hydrogenous materials show up very clearly — a property that can be utilized to check hydraulics or other fluid channels.

PATENTED TECHNOLOGY
THAT IS UNIQUE AND TIME SAVING

The Neutronic[i] is a 100×100 mm² thermal neutron imager based on Photonis patented microchannel plate technology. This detection mechanism gives our neutron-sensitive MCPs their revolutionary detection efficiency, more than an order of magnitude higher than conventional neutron imaging techniques.

To make MCPs that are sensitive to neutrons, the glass is doped with boron-10 and gadolinium; materials that have a high probability to capture neutrons and that undergo a nuclear reaction upon neutron capture. If at least one of the reaction products makes it to the nearest microchannel, it will instantly set off a secondary electron cascade, which will cause a light spot on the phosphor screen.



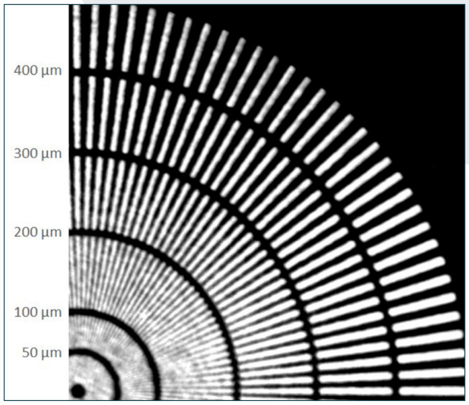
Neutron detection in our patented MCPs: boron neutron capture of the incoming neutron sets off a secondary electron cascade

To learn how the Neutronic[i] works, scan the QR code

The Neutronic[i] is also intrinsically fast, with attainable time resolution of the order of nanoseconds, making energy sensitive time-of-flight imaging possible. The whole system is designed to be modular and configurable, serving as a technology platform that can house a different size and shape of imaging assembly, or a different type of readout, to name just a few examples. The detector build materials are carefully selected to minimize the scattering or absorption of neutrons; they do not become radioactive, and contribute negligibly to background.

EXPOSE EVERY DETAIL WITH PHOTONIS

Microchannel Plates (MCPs) have for years been a critical technology for Mass Spectrometers and image intensifiers, among many other applications. For a detailed description of a smaller size prototype, see: S. Duarte Pinto et al., "Neutron imaging and tomography with MCPs", 2017 *Journal of Instrumentation* 12 C12006



A neutron image of a Siemens star test target demonstrates the imaging resolution; line spacing is indicated at the markings.

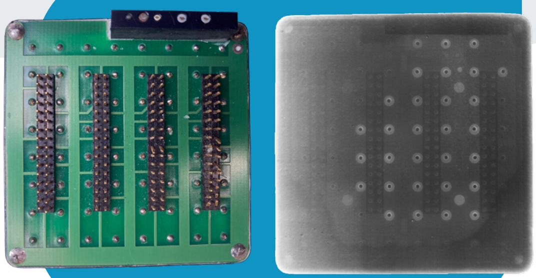


Photo and neutron image of a Photonis Planacon™ photodetector, revealing incomplete filling of cavities with silicone potting compound.

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