



National press release

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# Nuclear power plants: a scintillating sponge for monitoring radioactive gas emissions

**A scintillating aerogel enabling real-time measurements with excellent sensitivity to certain radioactive gases, essential to monitoring the proper functioning of nuclear power plants, has just been developed by a group of physicists, chemists, and metrologists from the CNRS, the University Claude Bernard Lyon 1, the CEA, and the ENS de Lyon. This method proposes an alternative that is both quicker and more economical than the current ones, which are often complex and costly. This research was published in the journal *Nature Photonics* on 2 September 2024.**

Tritium ( $^3\text{H}$ ), krypton-85 ( $^{85}\text{Kr}$ ) and carbon-14 ( $^{14}\text{C}$ ) are among the most common radioactive gases emitted by the nuclear industry during electricity production or recycling of radioactive waste<sup>1</sup>. Although these radionuclides<sup>2</sup> do not present a major hazard, their accurate measurement is a key indicator for monitoring the proper functioning of nuclear power plants and preventing accidents. However, the radionuclides are among those whose radioactive decay does not come with gamma rays emissions, they are pure beta emitters, and require specific procedures for detection and measurement. The technologies used today are based on the principles of either gas-liquid mixing or gas-gas mixing, and remain costly and complex. Furthermore, they cannot distinguish between radionuclides quickly, they generate waste, and are not particularly effective for some of the radioactive gases under analysis.

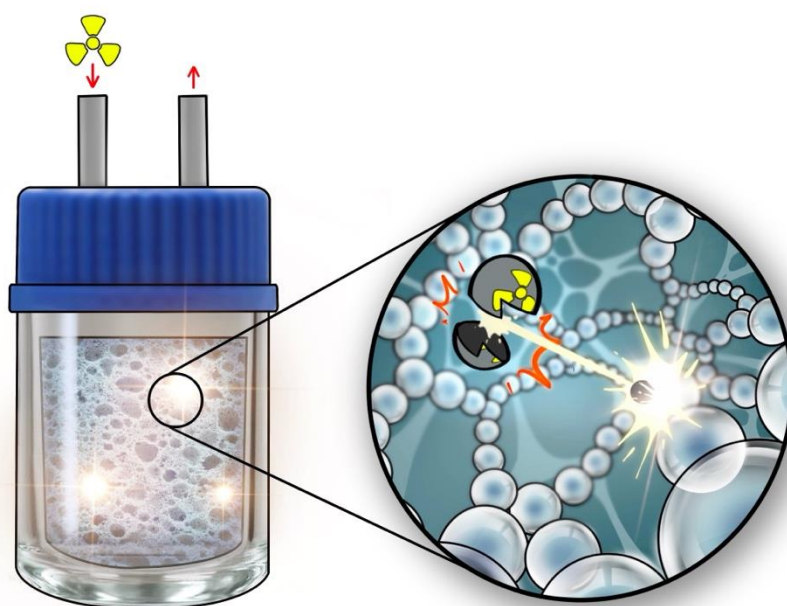
Research carried out by scientists from the Institute of Light and Matter (ILM - CNRS/University Claude Bernard Lyon 1), the ENS de Lyon Chemistry Laboratory (LCH - CNRS/ENS de Lyon/University Claude Bernard Lyon 1) and the Henri Becquerel National Laboratory (CEA) has led to the development of a real-time detection technology based on gas-solid mixing that is both reliable and cost-effective. It is based on synthesising an aerogel about one centimetre thick and a few centimetres in diameter, using nanoparticles of scintillating materials about 5 nanometres in size. This composite has a highly porous structure similar to a sponge, consisting of only 15% solids, while remaining transparent. This unique architecture allows the gas to diffuse very easily. When the gas penetrates the scintillation vial and comes into contact with the aerogel, the latter converts the energy produced by the emission of electrons during radionuclide decay into visible light. This flash of light is immediately captured by a highly sensitive detection system that can measure each photon almost instantaneously.

Fine-grained analysis of these light emissions helped develop an innovative method to distinguish and measure the pure beta emissions of different energies online, such as that of tritium and krypton-85 within the same gas sample. These discoveries were developed and confirmed both theoretically and experimentally thanks to a

state-of-the-art experiment on radioactive gases. The detection efficiency was 20% for tritium and nearly 100% for krypton. In addition, because it is not contaminated by the radioactive gases, the inorganic scintillator is reusable, thereby limiting waste, unlike other techniques.

This new approach to detecting radioactive gas has paved the way for the widespread use of sensors for monitoring civilian nuclear activities. It could be extended to other beta-emitting radionuclides that are critical for area monitoring, such as carbon-14 ( $^{14}\text{C}$ ), xenon-133 ( $^{133}\text{Xe}$ ), and argon-37 ( $^{37}\text{Ar}$ ), which would broaden its scope to include civilian, medical, and military applications.

This discovery was made as part of the European SPARTE<sup>3</sup> project, and has led to several patent applications.



The scintillating aerogel is inserted into a scintillation vial. The gas to be analysed penetrates the vial and the aerogel via diffusion. Each decay emits an electron that interacts at very short distance with the “scintillating” nanoparticles that make up the aerogel. This results in a flash of light that is then detected, signalling the presence of the radionuclide. (© Zoé Dujardin)

### Notes :

- 1- An average of 400 terabecquerels ( $400 \cdot 10^{12}$  becquerels) per electrical gigawatt per year for the production of electricity.
- 2- An atom with an unstable nucleus.
- 3- Funded by the European Union as part of the Horizon 2020 FET – OPEN programme.  
<https://www.sparte-project.eu>

### Bibliographie :

*Real-Time Detection and Discrimination of Radioactive Gas Mixtures Using Nanoporous Inorganic Scintillators*. Raphael Marie-Luce, Pavlo Mai, Frédéric Lerouge, Yannis Cheref, Sylvie Pierre, Benoit Sabot, Frédéric Chaput, Christophe Dujardin. *Nature Photonics*, 2 septembre 2024.

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