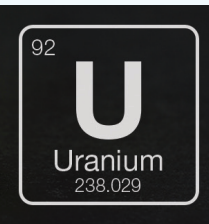
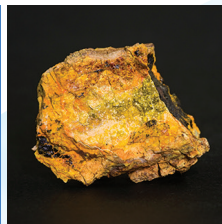


## Detection of Uranium-based Compounds using Laser-Induced Photoluminescence Spectroscopy



### Introduction

Exposure to uranium-based compounds and uranyl ions, even at ultra-low concentrations, can lead to severe health-related problems in humans and damage ecosystems. Therefore, detection in ultra-low concentrations and routine monitoring of water streams and other potential sources is critical. Detection of uranyl ions at ultra-low concentrations in urine is crucial for mitigating irreparable damage to kidneys and other organs. However, since uranyl ions and most uranium-based compounds are colorless, odorless, and tasteless, their detection in ultra-low concentrations poses a challenge. Typically, detection at ultra-low concentrations is carried out using various mass spectroscopy methods. These methods typically require elaborate sample preparation such as separations, extractions or fusions. Moreover, mass spectrometers for uranium detection require significant capital investment which limit their use for routine monitoring at numerous sites.<sup>[1]</sup>

A spectroscopic method that can detect uranium-based compounds and uranyl ions at ppb and sub-ppb levels without elaborate sample preparation and low initial investment can solve these problems. To address this gap, researchers have been utilizing photoluminescence (PL) spectroscopy and conducting routine and reliable monitoring. However, there are some bottlenecks that remain unaddressed.

1. Most PL spectrometers use an Xe-arc lamp as their excitation source. The lamp energy output is not enough to excite the uranium ions and utilize its intrinsic PL properties for detection.
2. Consequently, fluorescent tags are often used to enhance the PL signal from these species. However, fluorescent tags are seldom highly specific in complex mixtures. Moreover, they can leave uranium-based compounds in certain oxidation states undetected.
3. At ppb and sub-ppb levels, the PL signal is often hidden in the electronic dark noise of the detector, making detection at ultra-low concentrations a challenging task.

### How is HORIBA Solving these Problems?

At HORIBA, we have developed the Fluorolog®-QM-LAS, a novel PL spectrometer that can address these problems head-on utilizing Laser-Induced-Fluorescence and -Phosphorescence techniques. It can be used to detect and quantify uranium-based compounds and uranyl ions in water, urine, and other environmental samples, such as contaminated groundwater and sediment.



Figure 1. The Fluorolog-QM-LAS shown with sample compartment lid open

The Fluorolog-QM-LAS is compatible with a wide array of laser sources of customizable wavelength and output energy which can be employed for utilizing the intrinsic PL properties of uranium-based compounds and uranyl ions. Since the need for fluorescent tags is redundant in this method, detection of uranium-based samples in various oxidation states is possible.

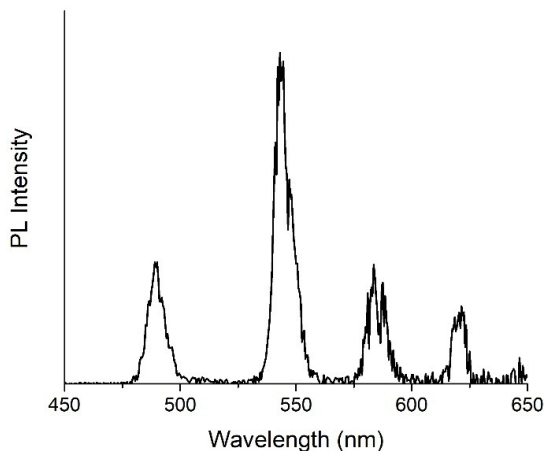


Figure 2. Optimized for detection and characterization of lanthanide- and actinide-based materials: The Fluorolog-QM-LAS delivers unrivaled sensitivity, spatial resolution, and dynamic range.

Additionally, the excitation source can be used in continuous or pulsed mode to acquire steady state and time-resolved measurements. The standard Fluorolog-QM-LAS allows users to employ gating and acquire measurements at very high speeds using the single-shot transient digitizer (SSTD) method. Capitalizing on different phosphorescence decay rates, it is also possible to differentiate between various uranium isotopes.<sup>[2]</sup>

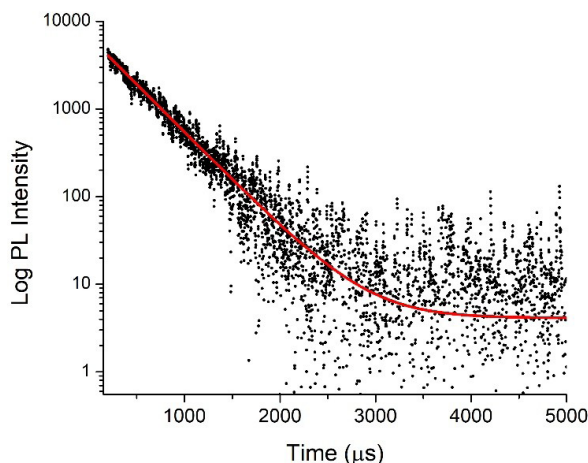


Figure 3. Gated phosphorescence acquired using the SSTD mode on the Fluorolog-QM-LAS

To address the detection limitation, the HORIBA Fluorolog-QM-LAS has been equipped with a TE-cooled photomultiplier tube detector. The enhanced cooling of the detector enables it to detect as low as 10 counts per second all the way up to 10 million counts per second linearly. This wide linear dynamic range of the detector enables the ppb, and possibly sub-ppb detection of uranium-based compounds and uranyl ions.

## Conclusion

The Fluorolog-QM-LAS's ability to detect uranium-based compounds and uranyl ions at ultra-low concentrations without elaborate sample preparation and at a lower cost enables routine monitoring for public health and environmental protection. By utilizing the inherent PL properties of the uranium-based compounds and uranyl ions, the Fluorolog-QM-LAS overcomes the need for fluorescent tags, which allows for more direct and reliable detection and quantification of analytes. Using the high speed SSTD enabled phosphorescence measurements, and made it possible to differentiate between various isotopes.

## References

- [1] Miley, Sarah, Anne Hylden, and Judah Friese. "Resolution of uranium isotopes with kinetic phosphorescence analysis." *Journal of Radioanalytical and Nuclear Chemistry* 296.2 (2013): 923-925.
- [2] Sadergaski, Luke R., and Hunter B. Andrews. "Simultaneous quantification of uranium (VI), samarium, nitric acid, and temperature with combined ensemble learning, laser fluorescence, and Raman scattering for real-time monitoring." *Analyst* 147.18 (2022): 4014-4025.

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