H2 detection in nuclear waste environments

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NDT for the nuclear industry seminar
Friday 24 January 2020 at the Watermill Hotel, Paisley, UK

INTRODUCTION TO FRAUNHOFER CENTRE FOR APPLIED PHOTONICS

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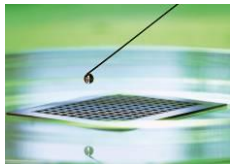
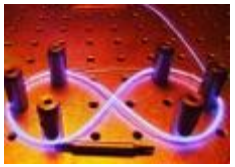
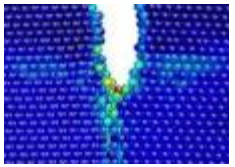
Fraunhofer Centre for Applied Photonics: Our Mission






- Not for profit Research and Technology Organisation (RTO)
- **Our key mission**
  - **Support industry**
  - **by developing and exploiting photonics technology**

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H2 SENSING IN NUCLEAR WASTE ENVIRONMENTS

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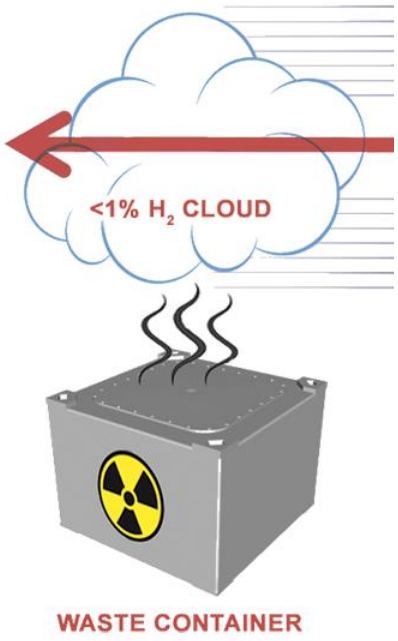
Why measure hydrogen?



- Nuclear waste emits hydrogen
- Measuring the amount of hydrogen emitted provides insight into the state of the waste and its containment
- This may be used to test models, or schedule further investigation if a variation in hydrogen levels is detected

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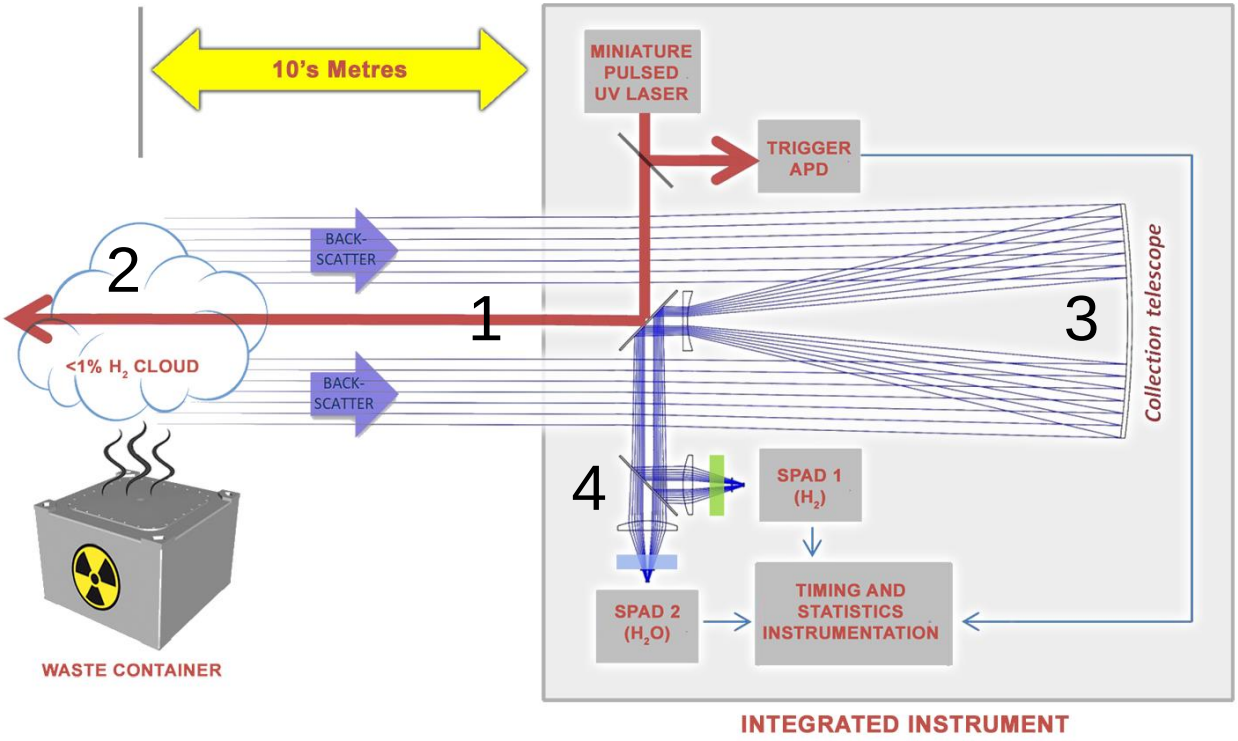
Measurement process – high level overview

1. Laser beam emits pulse of light towards gas at the point to be measured
2. The gas interacts with the light pulse and some of the light is scattered
3. Some of the scattered light is collected by a telescope
4. The collected light is analysed, and hydrogen concentration calculated



(left) a simplified diagram illustrating the measurement process

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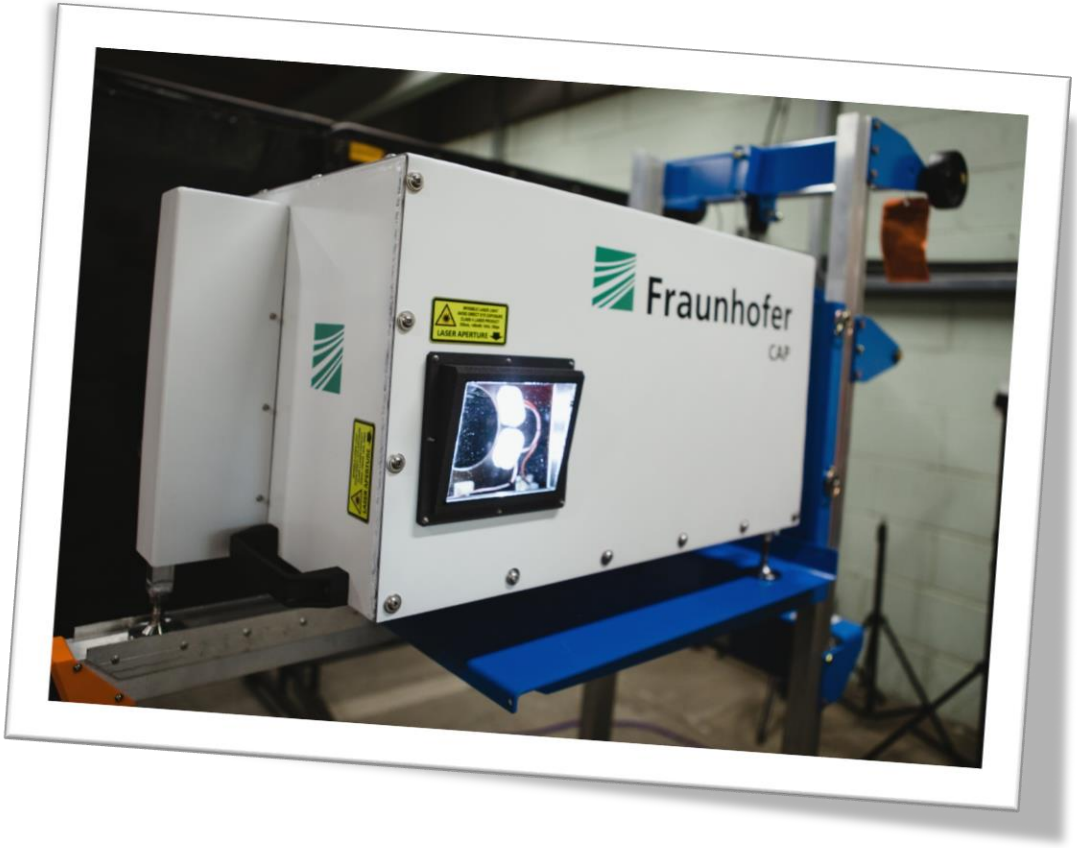
Why use lasers to measure hydrogen?

Ranged measurement

- Measure in hard-to reach, or dangerous locations
- Measure in multiple locations with one sensor

Non-extractive



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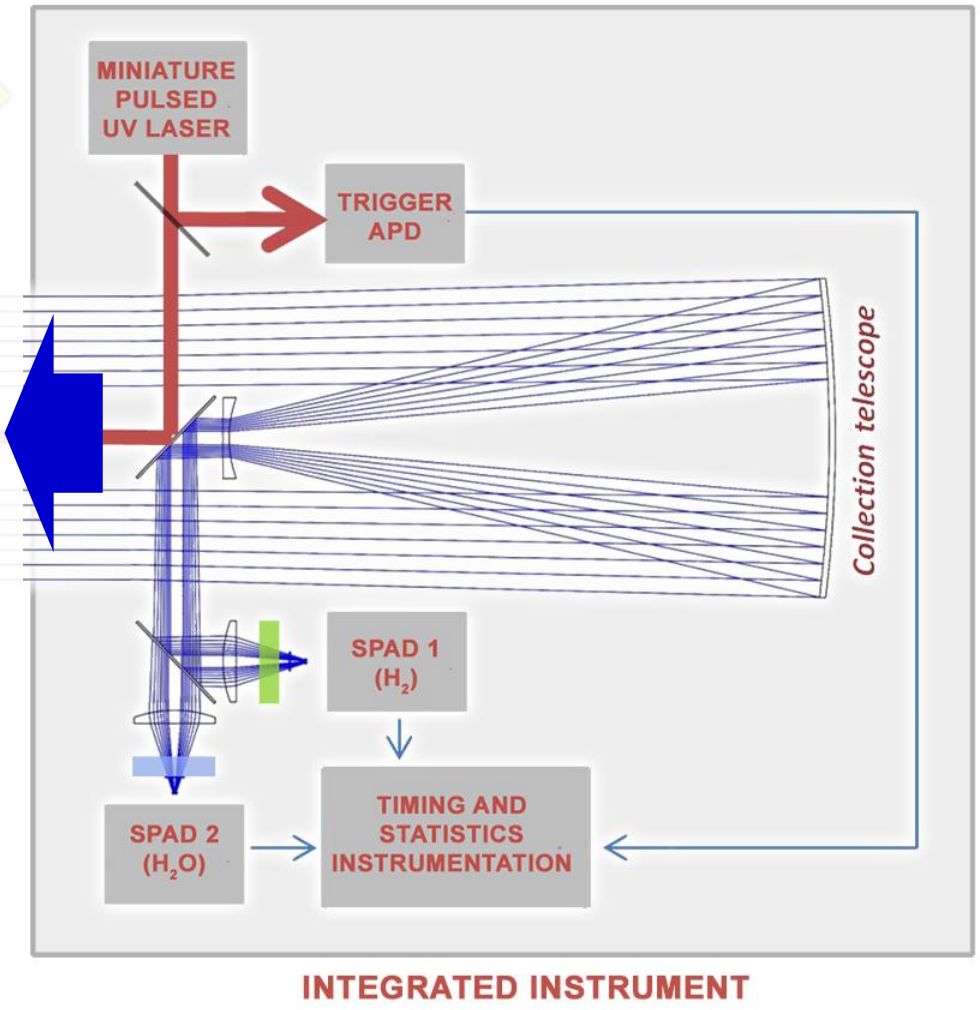
Magnitude of the Returned Signal

RAMAN (10^0)

EXCITATION (~ 10^{17})



One of the main technical challenges we needed to overcome was the very small amount of light that must be detected. The 'Raman scattering' process that we use to distinguish between different gas molecules is very weak. A typical outgoing laser pulse may contain about 10^{17} photons, but on average we receive only 1 photon of Raman scattered light back.

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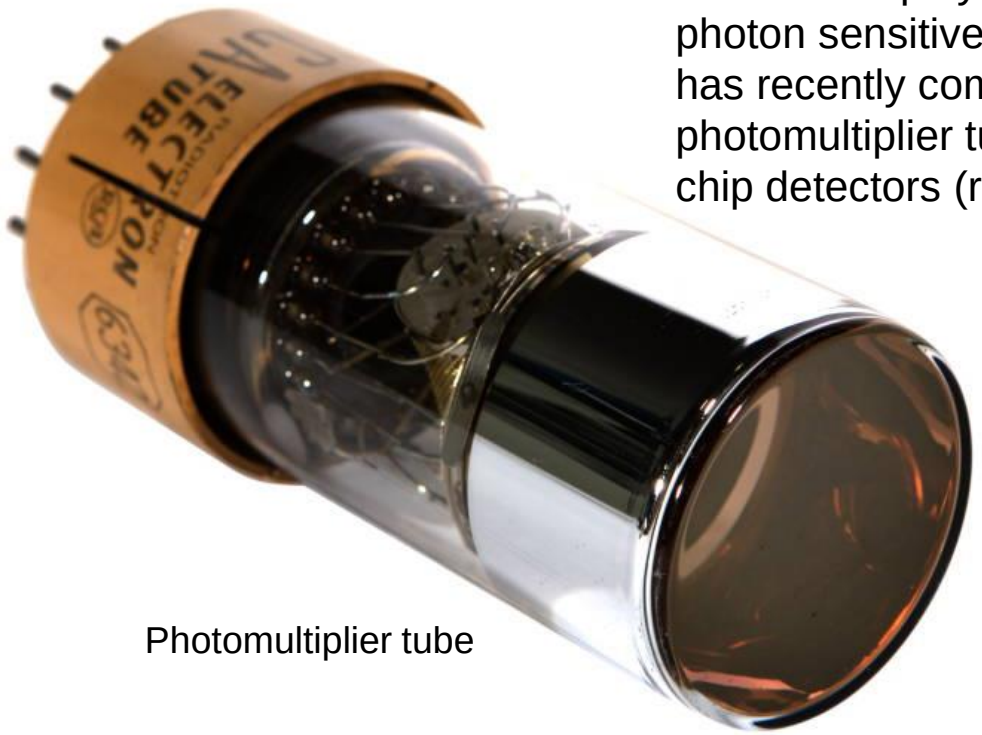
Single photon detectors: a technology come of age

To accurately measure the very small amount of backscattered light, we rapidly average over measurements by emitting multiple laser pulses.

We also employ the latest in ultra-sensitive, single photon sensitive detectors. This is a technology that has recently come of age, maturing from photomultiplier tubes (left) to mm-sized integrated on-chip detectors (right).



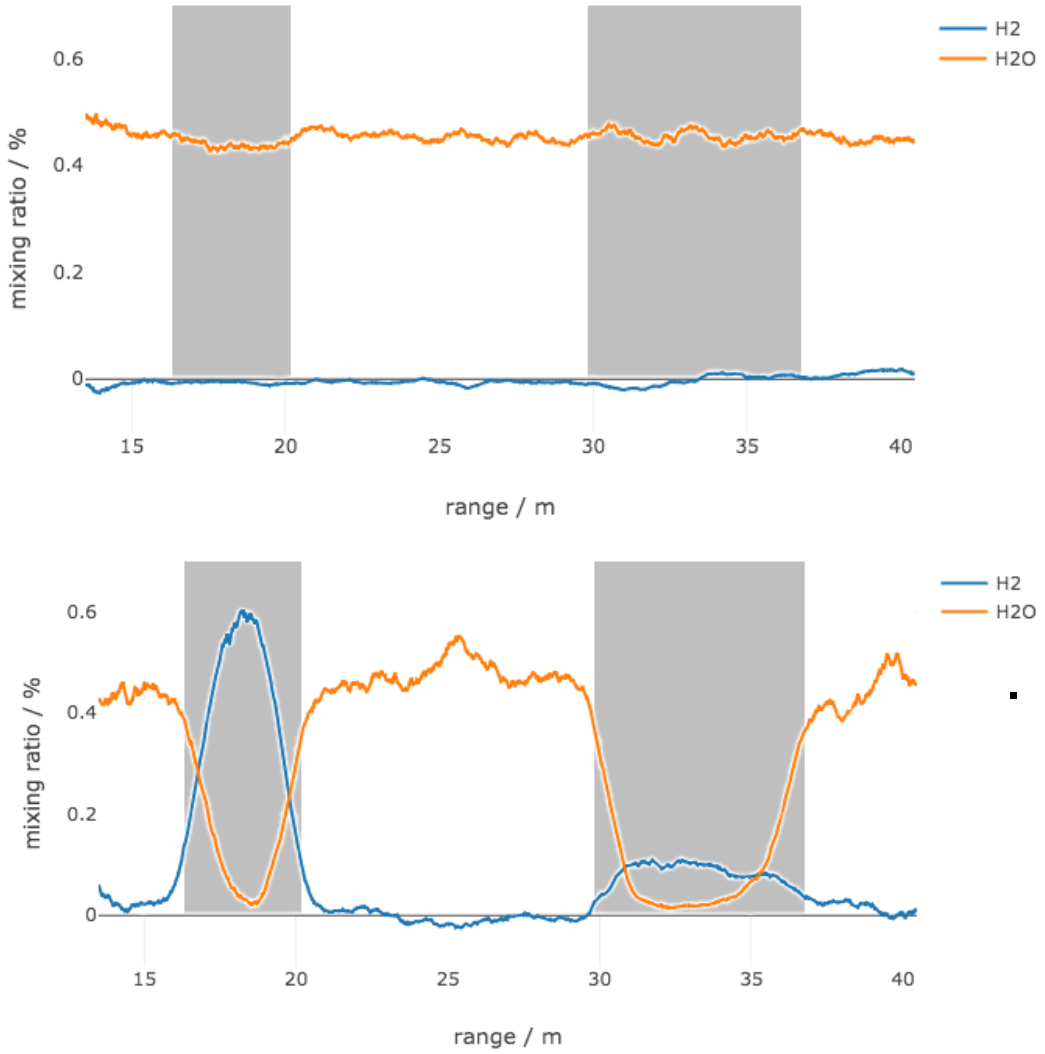
Photomultiplier tube

Modern single photon sensitive detectors

Example measurement: Multiple sources of hydrogen

(left) photograph of an early-stage demonstrator system at Fraunhofer's labs.
(right) photograph of a test setup used to verify device performance. Gas mixtures with known concentrations of hydrogen were injected into the black tubes, and the device arranged to measure hydrogen concentration throughout the length of the tubes.

Detection of multiple sources of hydrogen



Example measurements of hydrogen gas concentration along a line through two of the black tubes shown in the previous slide (location indicated by the grey shaded areas). Water vapour concentration is also measured.

(above) measurements before gas injected into tubes.
(below) measurements after different concentrations of hydrogen in dry air injected into tubes.

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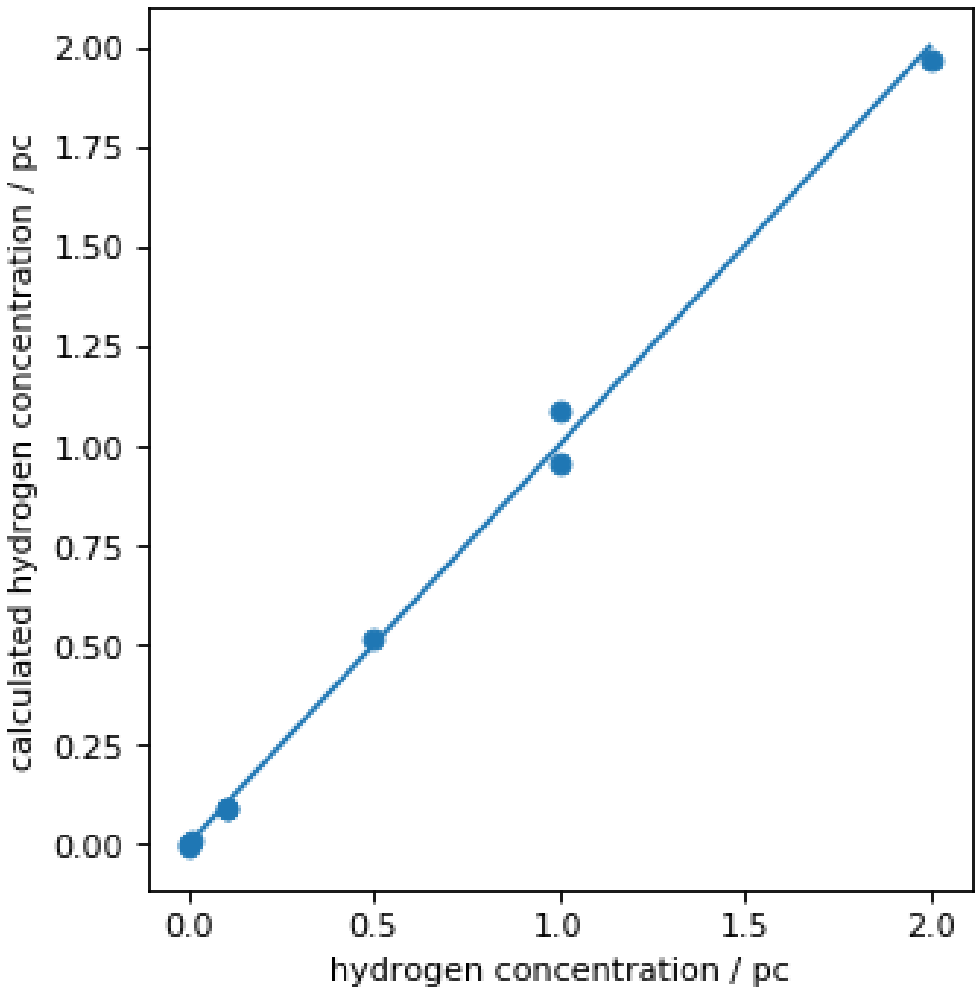
Linearity



Example measurements demonstrating the linearity of the measurement response. These measurements were taken by sequentially injecting hydrogen gas of several different known concentrations into a tube, and measuring the concentration in the tube.

Short range device

A short range hydrogen sensing device, developed by Fraunhofer CAP.

Summary

- Developed a proof-of-concept system to investigate the viability of Raman back-scatter as a means of range-resolved H_2 detection.
- Developed an enclosed, short-range hydrogen sensing device.
- **We have detected H_2 at 0.1% concentrations at >30m range with ~metre range resolution**

This work has been performed in conjunction with Sellafield Ltd. and the Game Changers programme.
Watch the video to learn more.

GAME CHANGERS