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Continuous Gd/Water Monitoring With Gadolinium Absorbance Detector (GAD)

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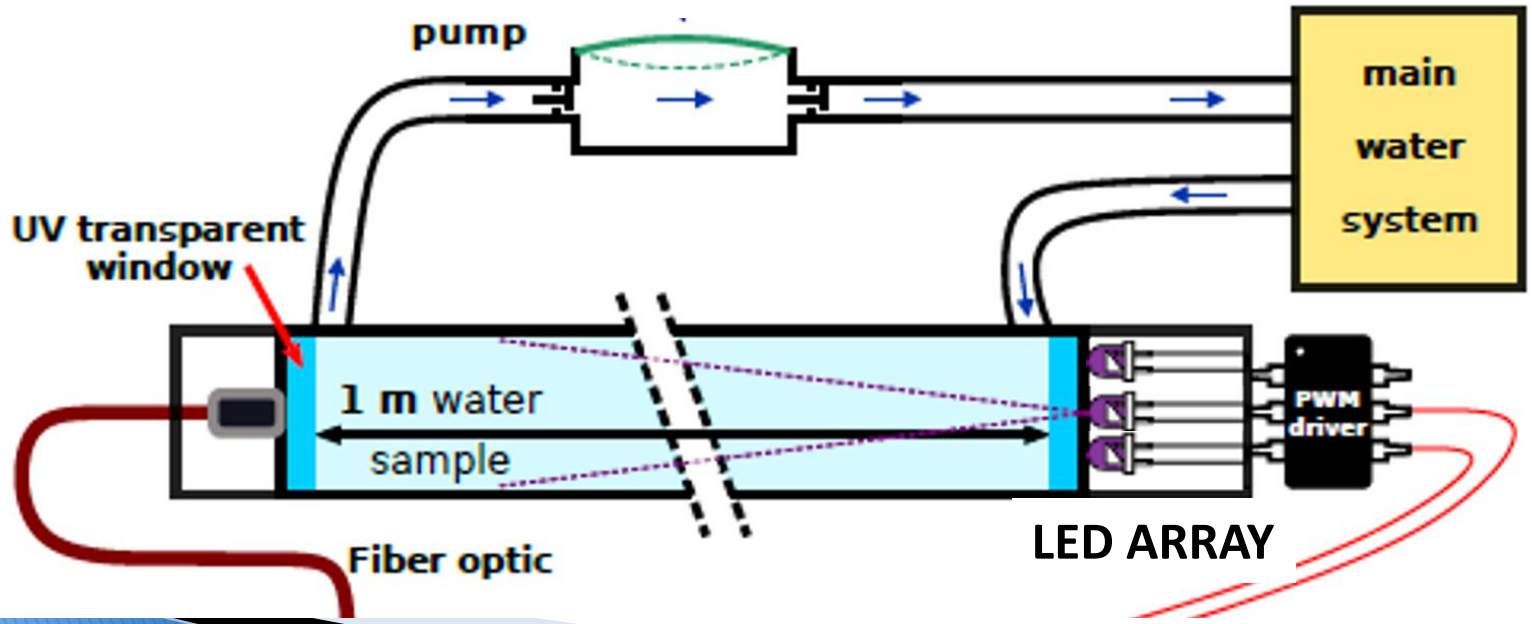
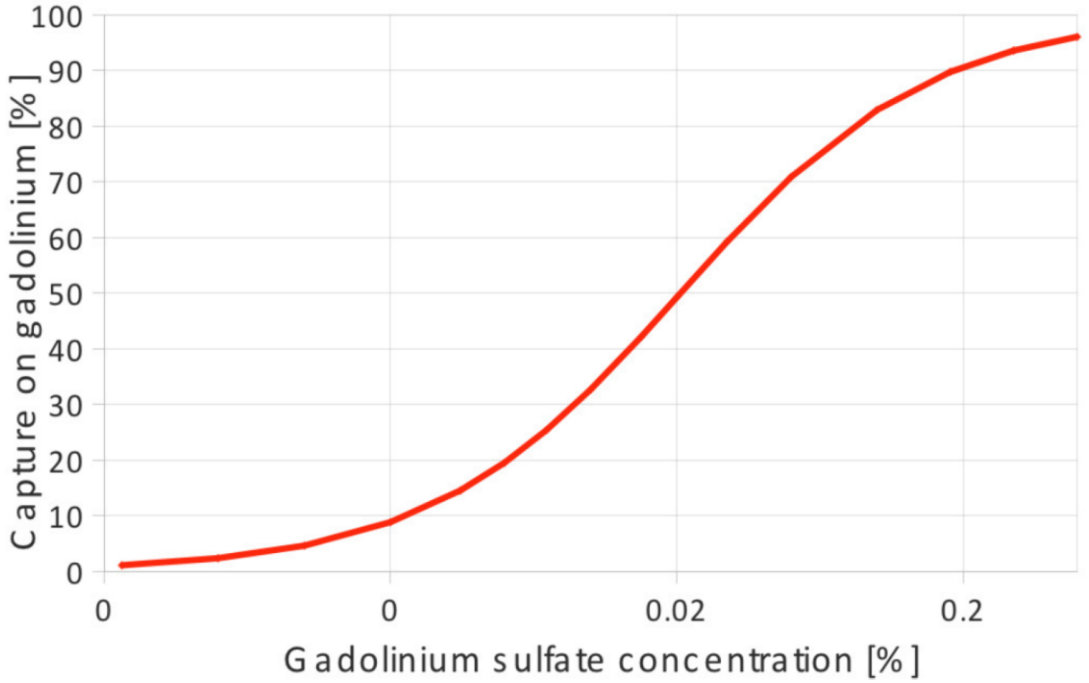
GAD Development

- GAD is continuous water monitoring device that has been under developed in the UK for the past 4+ years
- I comprises of a modular fluid flow cell (~1.3m) and an led array with a collimated fibre coupled spectrometer
- It was originally designed to measure Gd concentration



Measuring Gd Concentration $Gd_2(SO_4)_3$%

The concentration of Gd affects the **efficiency** and **timing** of neutron captures. It can change inside the tank with **temperature** and **flow**.



T. Mori, PhD Thesis, The University of Okayama, 2015

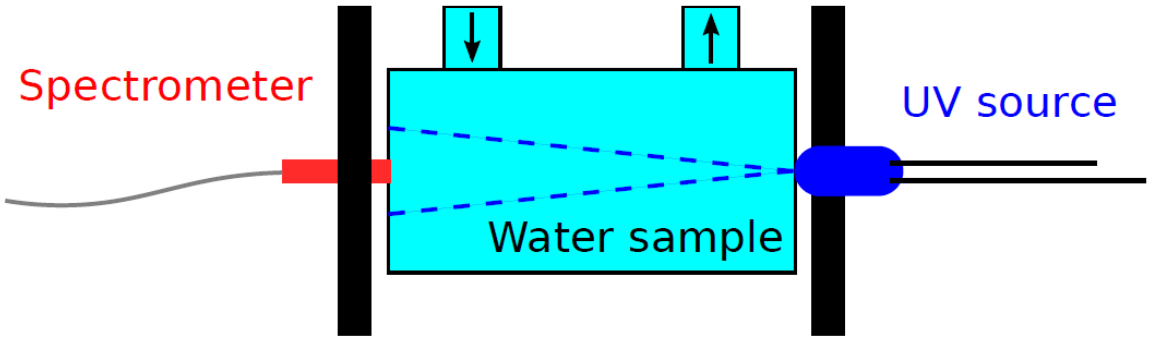
- It is therefore important to track the concentration of Gd over time to know capture efficiency to a high accuracy (~1%)
- Current determination via offsite mass spec and has **3.5% error** on a concentration determination
- Would also be useful to measure the spatial distribution of Gd

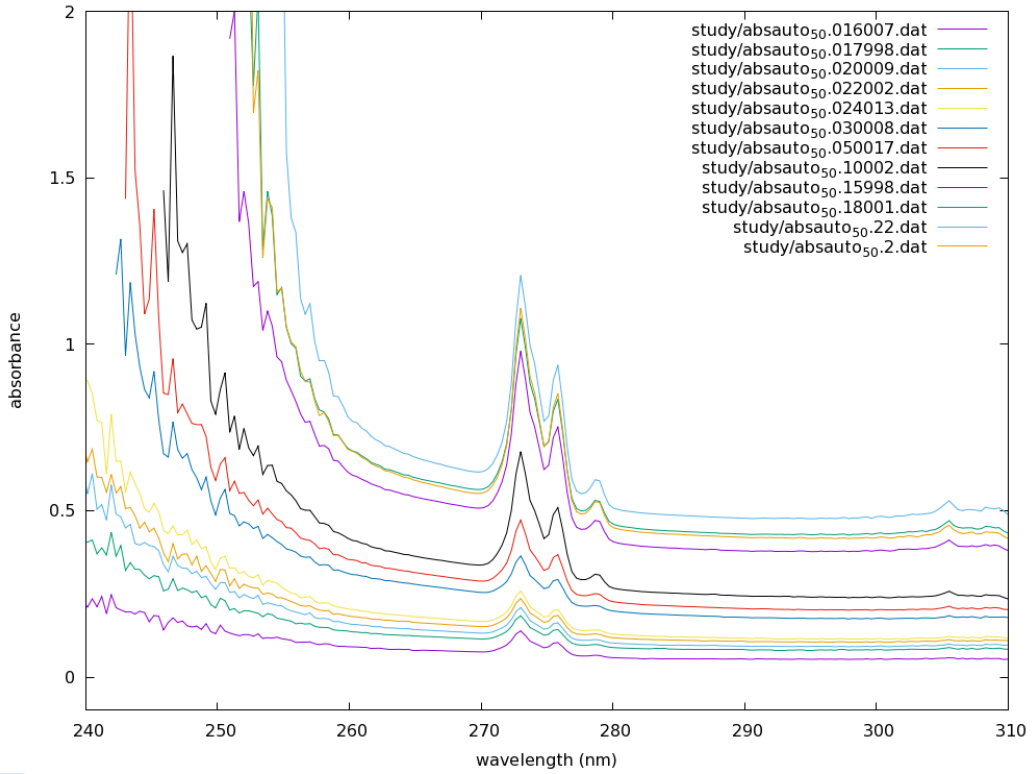
Measurement Technique

- Gd has strong **absorption lines** near 275 nm.
- Measure the absorbance $\mathcal{A}$.
- It is directly **proportional** to Gd[%].

$$\mathcal{A} = \log_{10}\left(\frac{I_0}{I_{\mathrm{Gd}}}\right)$$

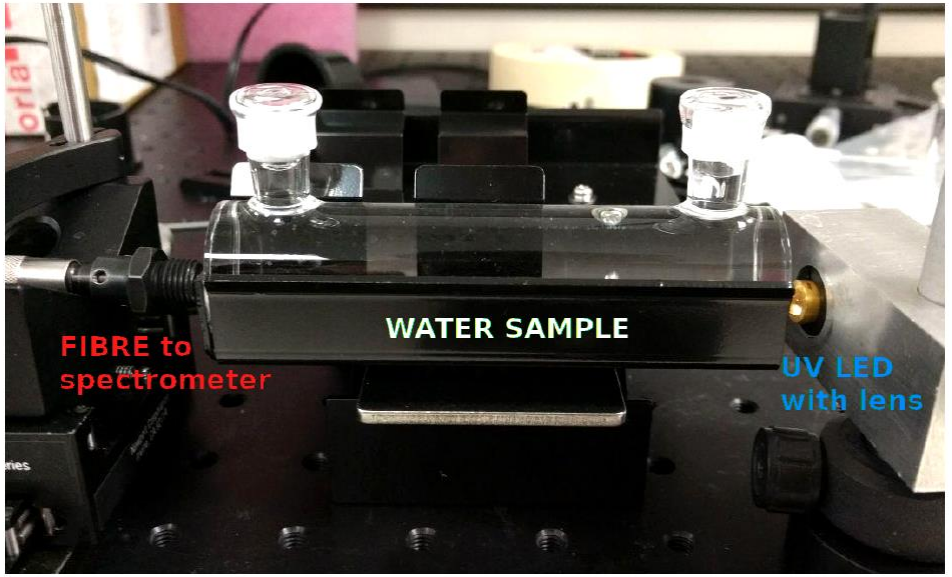
I_0 is the reference, I_{Gd} is the Gd-loaded sample.

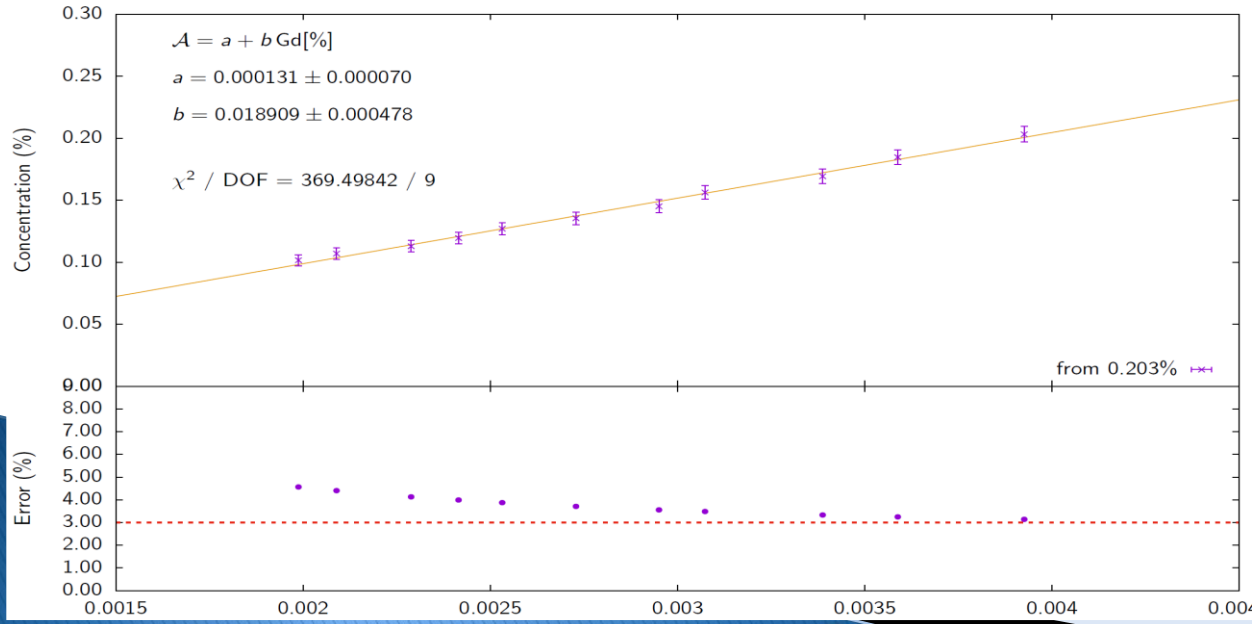




Evolution

- V1.0 10cm flow cell
  - 0.2% $Gd_2S_3O_{12}$
  - ~1% neutron capture efficiency error (at 0.2%)

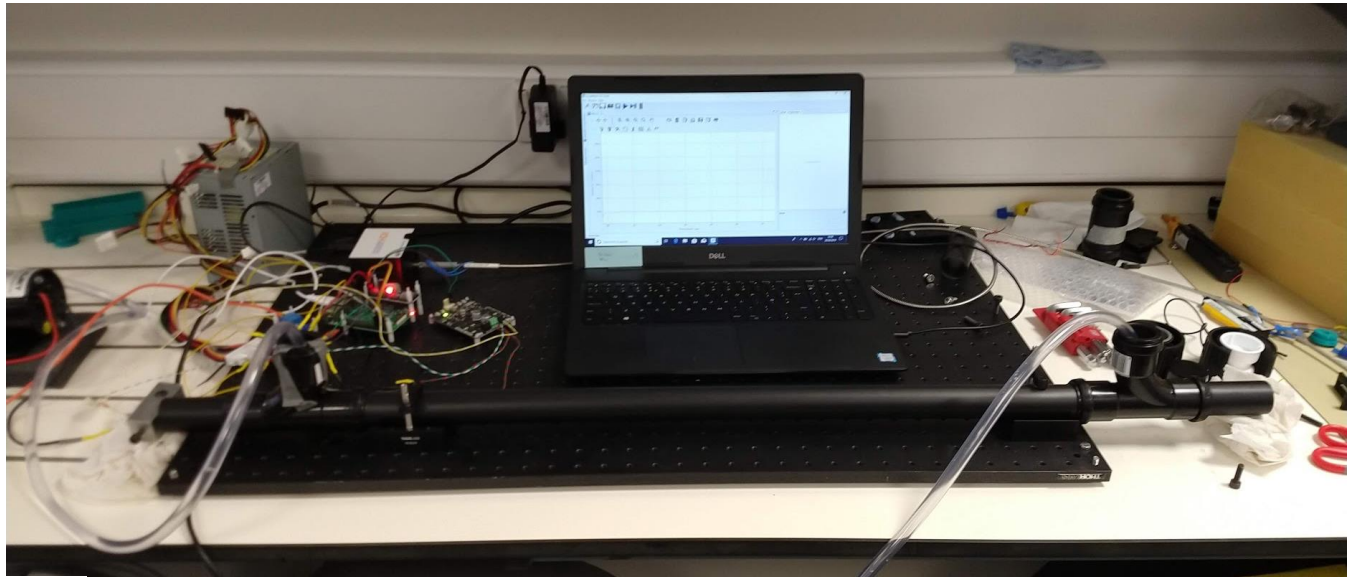




- Able to achieve <**3%** error on concentration at 0.2% $Gd_2S_3O_{12}$ loading
- Stable automated operation with regular measurements using **ToolDAQ** DAQ framework

Evolution

- V2.0 1m flow cell
  - 0.02% $Gd_2S_3O_{12}$
  - ~0.5% neutron capture efficiency error (at 0.2%)



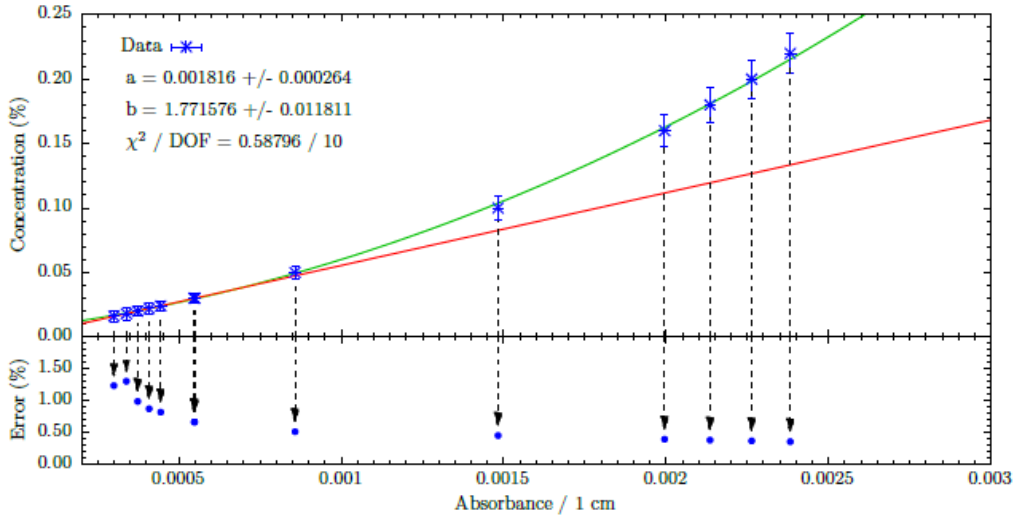


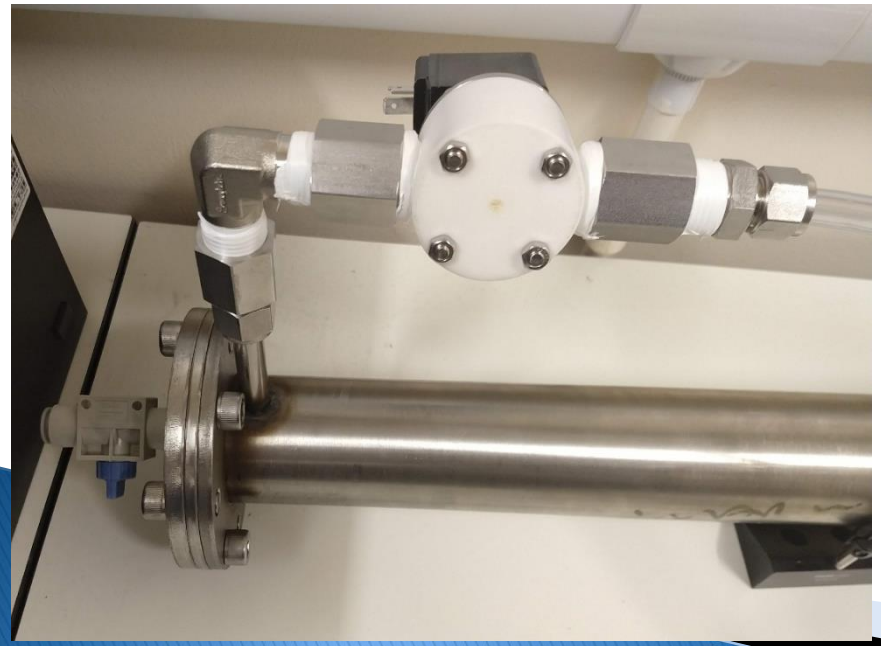
Fig. 2.16: The inverse linear fit (red) between concentration and absorption is shown togwther with data (blue) on the top panel for the 100 cm water sample. The absolute values of the errors is enlarged by a factor of 20. The linear fit is done only with the six leftmost points. The beahviour appears to be quadratic (green) than linear. The relative error (bottom panel) is well below the 3 % limit, even for a concentration of 0.02 %.

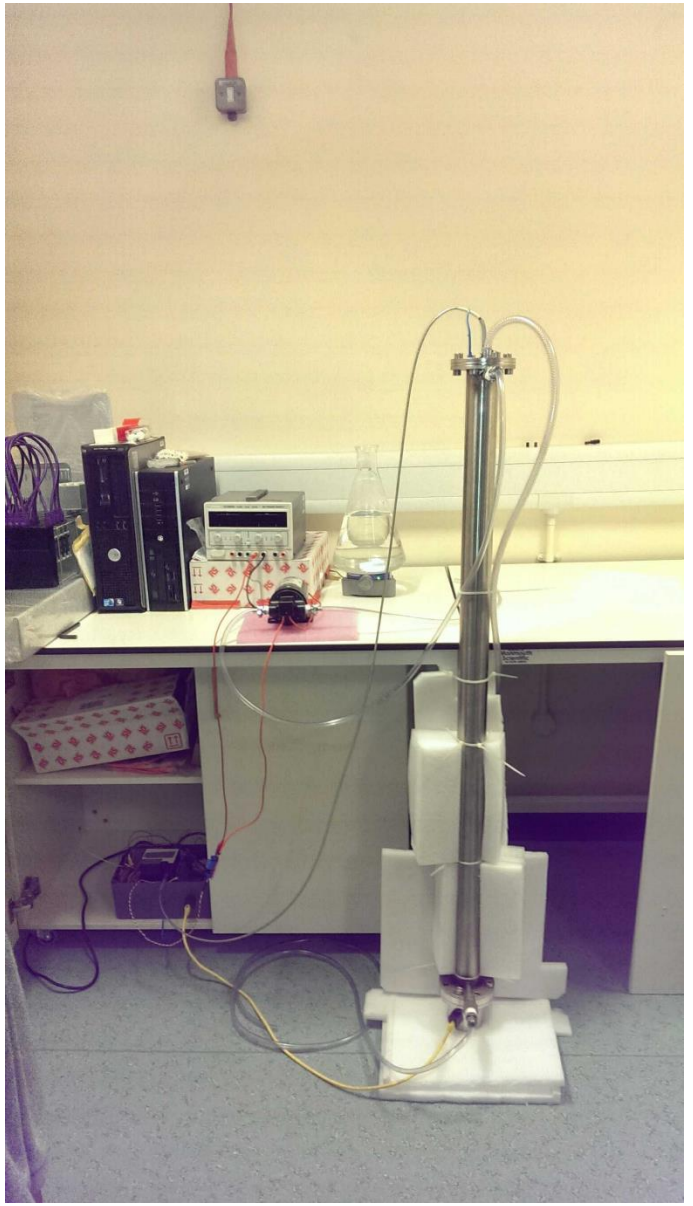
~1% error at 0.02% $Gd_2S_3O_{12}$ concentration

~1% error at 0.2% $Gd_2S_3O_{12}$ concentration

V3.0

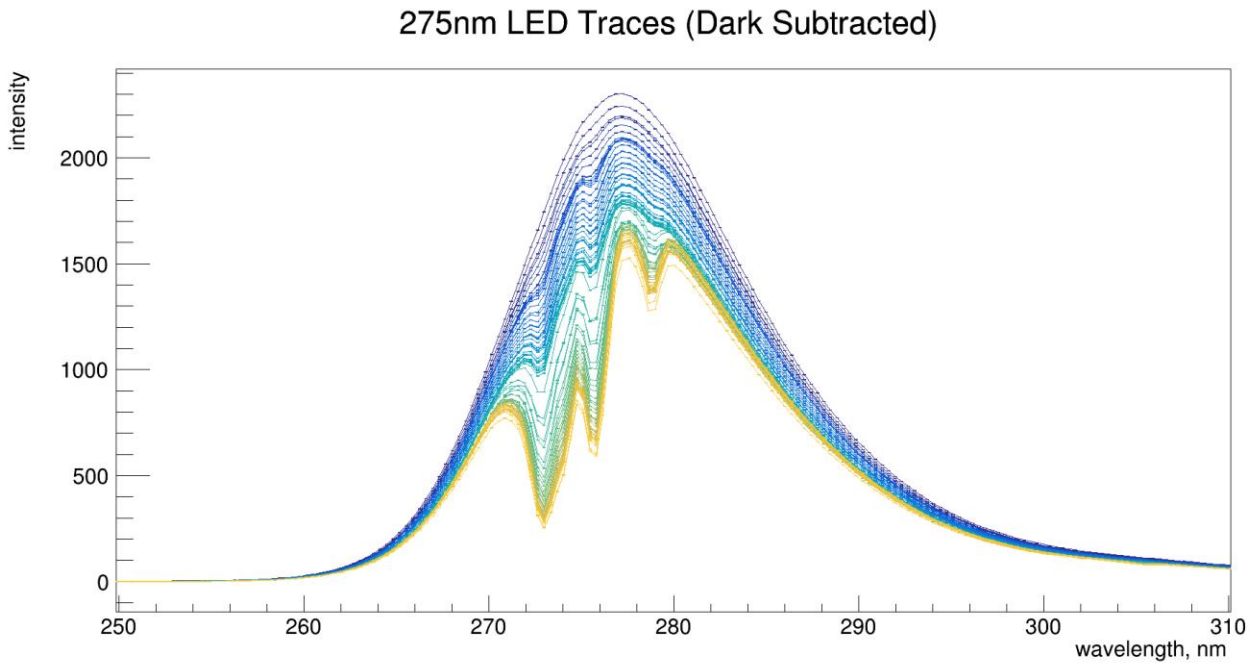
- 1.3 m flow cell
- 316 stainless steel
- Solenoid valves
- Fully integrated electronics (ToolDAQ+ web control)
- Fully modular construction

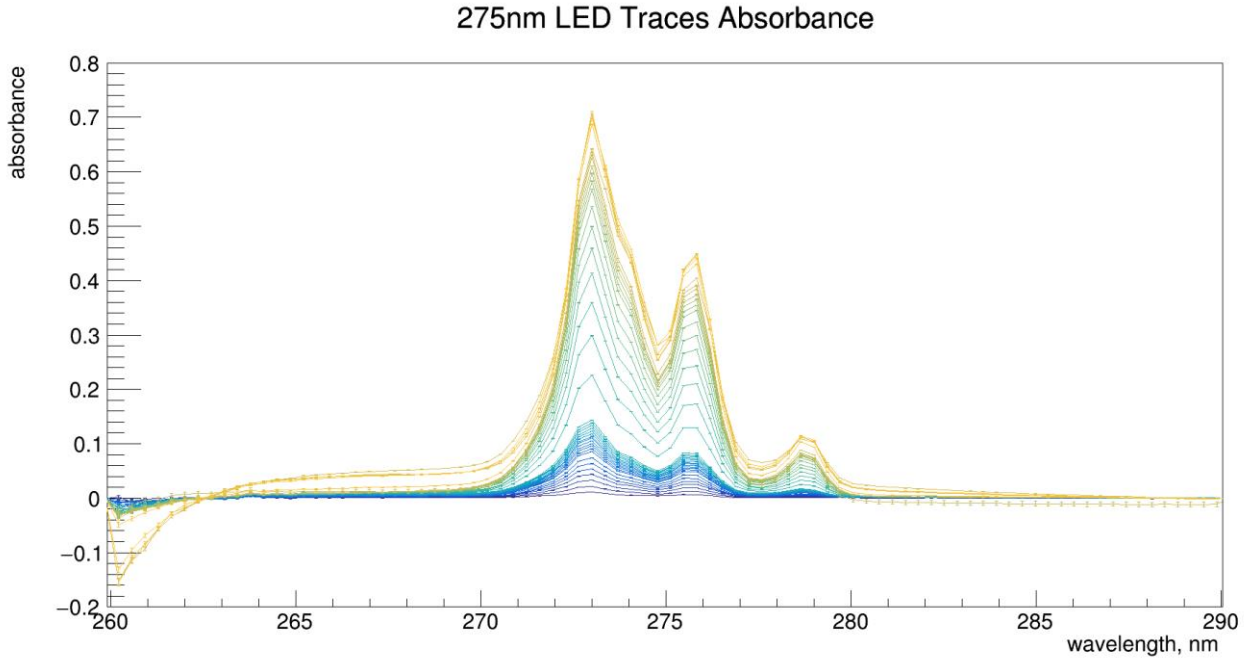




V3.0 Precision

- Calibrated for a range of concentrations from 0.005% to 0.23%, regions of interest at 0.02% and 0.2%.
- We have achieved ~0.8% precision on concetraion determination over this region (Current SK method is 3%)



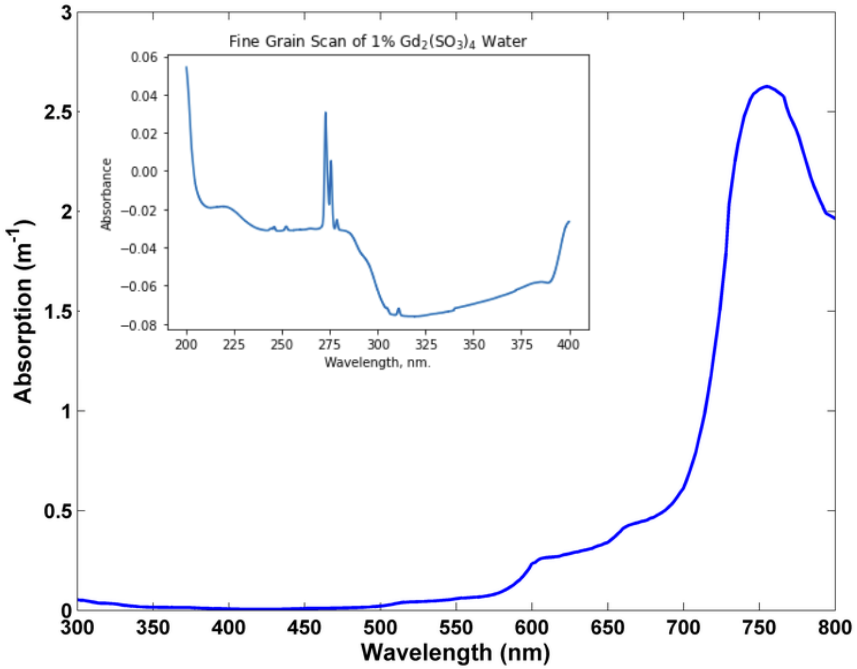


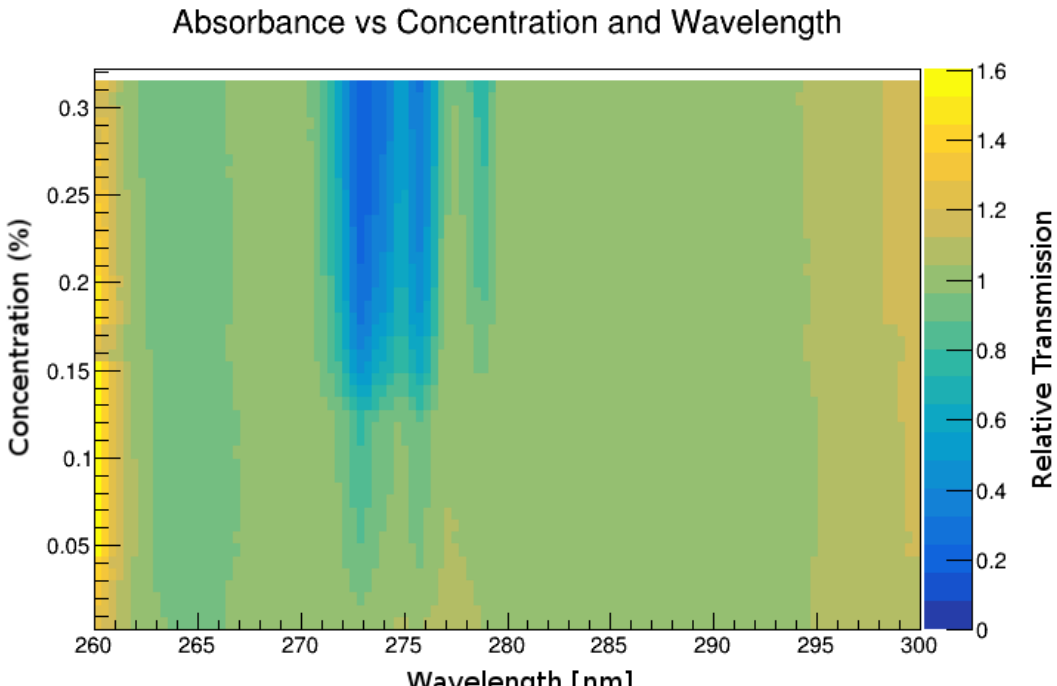
V3.0 Water Transparency Measurements

- Version 3.0 also added an entire array of LEDs covering range of 200-800 nm

- As we have a full spectrometer readout we can determine the real time relative transmission properties of the water at any wavelength

- This is means we can monitor water properties over time to see adverse effects (rust, bacterial growth etc) and determine what the causes are.





Installation in EGADS

- GAD V3.0 was ready to install in EGADS 2 years ago, with the intention to install a second device in Super-K before the latest Gd fill 0.02% -> 0.03%
- However COVID delayed that plan until July 2022
- Please to say it's now installed and taking data in EGADS!!

Next Steps

- We plan to install further devices at other Cherenkov detectors:
  - Super-K
  - IWCD
  - WATCHMAN/BUTTON
  - ANNIE

- Already started construction on next version V4.0
  - fabrication finished currently assembling
  - Expandable absorption length
  - General hardware/ mechanical improvements

- Design concepts for V5.0 started