Fibre Optic Based Sensing of Alpha and Beta Particles in Liquids

J.L.H.Mik[a,c,*], C.A. Whittaker[a], C.A.G. Kalnins[a,c], H. Ebendorff-Heidepriem[a,c], D.J. Ottaway[a,c] and N.A. Spooner[a,b,c]

[a] Institute for Photonics and Advanced Sensing (IPAS) and the School of Physical Sciences, The University of Adelaide, Adelaide, South Australia, 5005, Australia, [b] DST Group, PO Box 1500, Edinburgh, SA, 5111, Australia, [c] ARC Research Hub for Australian Copper-Uranium
*jarrah.mik@adelaide.edu.au

Radiation Monitoring in Mineral Processing

- Improvement in IOCG-U ore processing requires knowledge of contaminant materials and current lab techniques are limited in their capability.
- Sensors are required to measure low levels of activity (< 1 Bq/ml) in mixed radionuclide (RN) liquids that have low pH, high temperature and agitated solids, ideally *in-situ* and real-time.

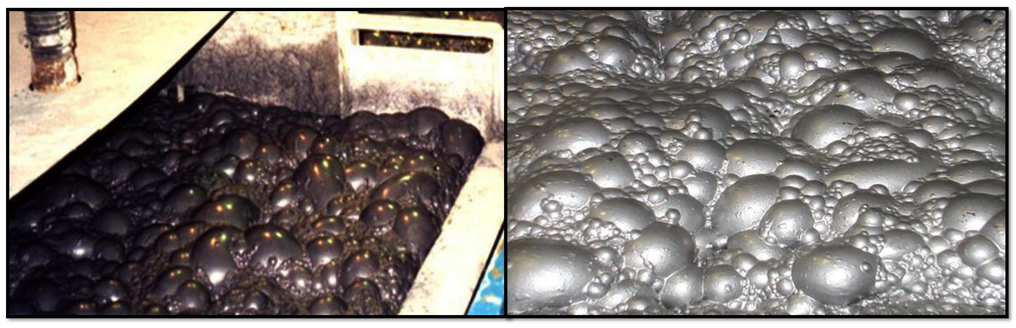

Figure 1. Examples of Mineral Processing liquids.

Why Fibre Optic Scintillators?

- Scintillation allows for *in-situ*, real-time, semi-continuous measurements.
- Large surface areas maximise possible interactions with RNs.
- Geometries allow discrimination between alpha and beta particles.
- The robust nature of optical fibres allows for long service duration.
- Commercially available materials are low cost and easy to match to various detection systems.

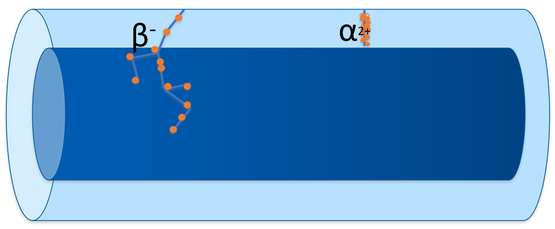

Figure 2. Visualisation of a scintillating optical fibre where the fibre cladding is used to discriminate between alpha and beta particles.

Beta particle sensor

- Multiple fibres spaced apart, based on the range of beta particles in RN liquids
- > 50 µm cladding discriminates against alpha particles (Figure 2)
- 1mm+ diameter fibres for maximum energy deposition from beta particles

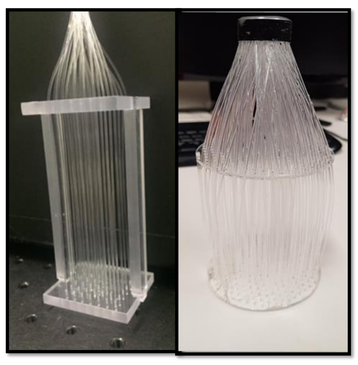

Figure 3. Two examples of the beta particle sensor.

Alpha particle sensor

- Multiple fibres grouped together, based on the range of alpha particles in RN liquids.
- < 10 µm cladding allows energy deposition from alpha particles.
- 250 µm diameter fibres due to commercial availability, discriminates against beta particles.

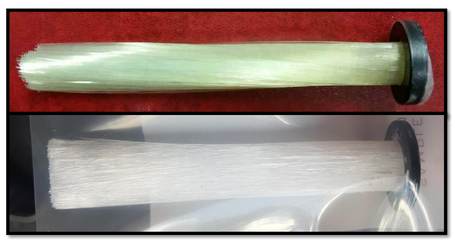

Figure 4. Two examples of the alpha particle sensor.

Further Reading

1) Whittaker, C.A., Kalnins, C.A., Ebendorff-Heidepriem, H., Spooner, N.A. and Ottaway, D., 2019. A fibre optic based approach and device for sensing beta radiation in liquids. *Sensors and Actuators A: Physical*.
2) Whittaker, C.A., Kalnins, C.A., Ebendorff-Heidepreim, H., Ottaway, D. and Spooner, N.A., 2019. A fibre optic based approach and device for sensing alpha particles in liquids. *Sensors and Actuators A: Physical*, *299*, p.111573.

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Sensor Performance in Liquids

- Semi-continuous measurements. Integration times of 100s allows determination of activity concentrations below 1 Bq/ml.
- Contamination of the alpha particle sensor during measurements requires a duty cycle approach.
- Background measurements are taken between 100s integrations, allowing for a differential measurement.

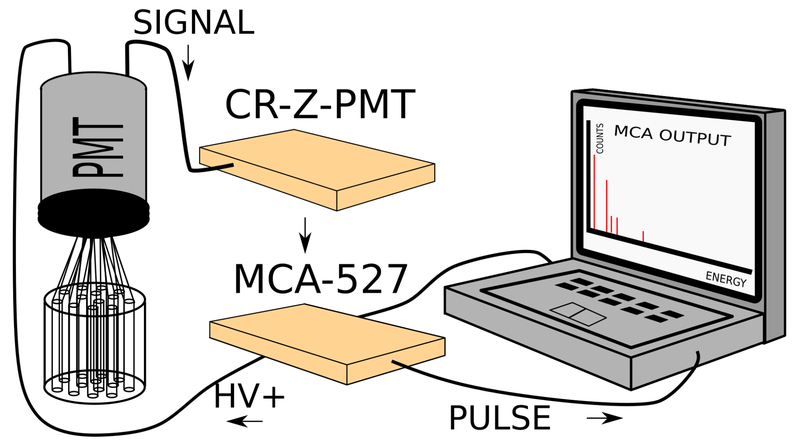

Figure 5. The detector face of either sensor is coupled to a PMT via a SM1 threaded cap. The signal is sent to a charge sensitive preamplifier (CR-Z-PMT) whose output is interpreted by a MCA (MCA-527) using WinSPEC software on a nearby laptop, producing a Pulse Height Spectrum (PHS).

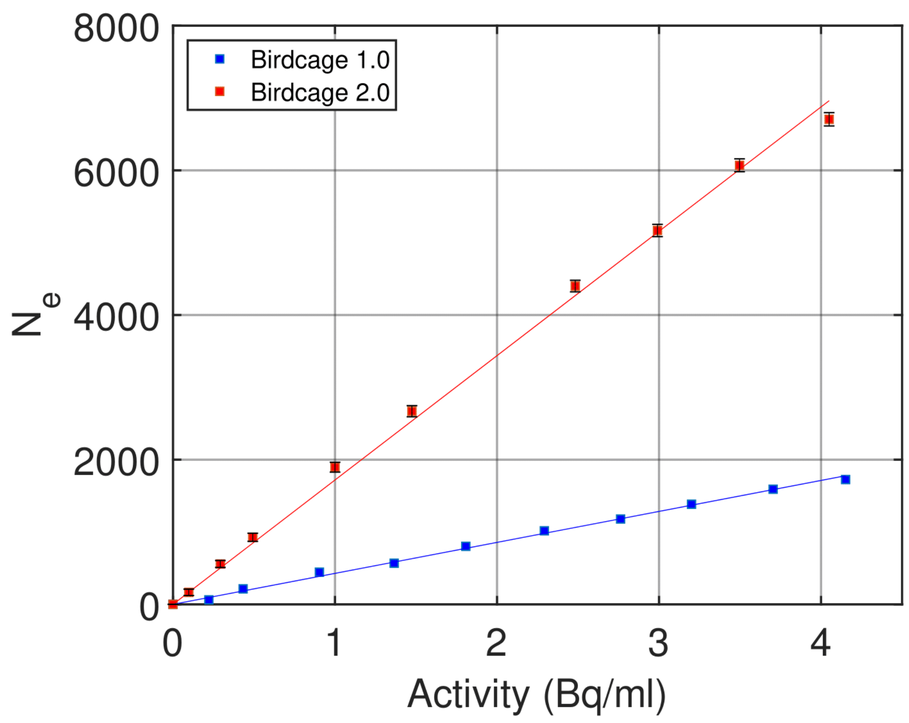

Figure 6. Current generation of beta sensor (red) performance in solutions containing K-40. Increasing the detector volume, compared to the previous generation (blue) found in 1), increased the sensitivity limit past 0.09 Bq/ml.

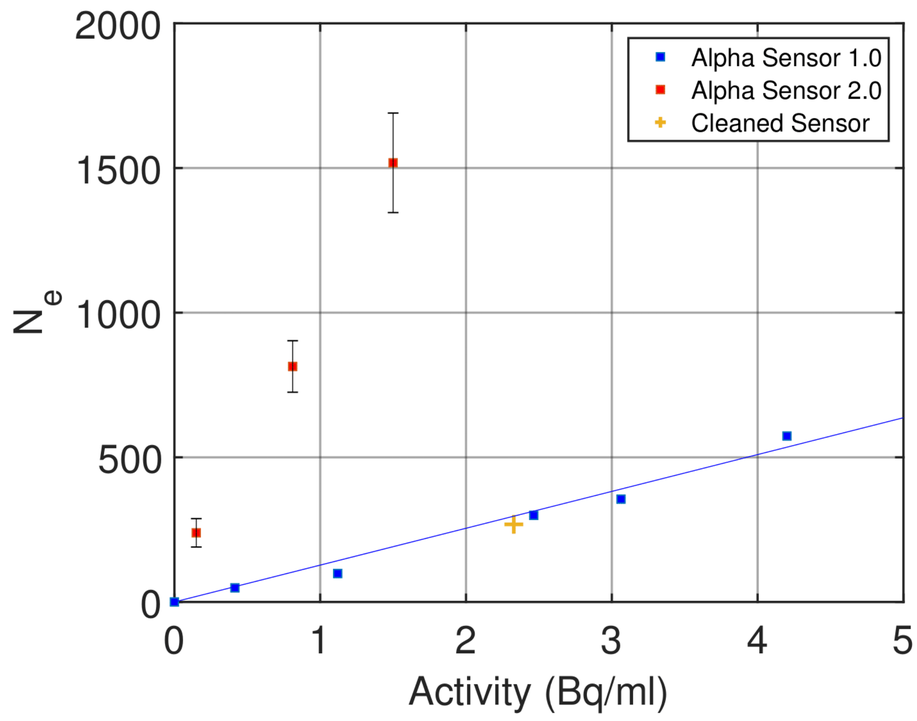

Figure 7. Testing of the next generation alpha sensor in progress (red). The number of data points is currently limited by liquid standard availability. Current capability of the alpha sensors is 0.42 Bq/ml (blue) using solutions containing Po-210. Decon 90 allows contamination removal and the sensor has the same result (orange +).

Conclusion

Sensors that provide *in-situ*, real-time, semi-continuous measurements have been constructed and tested with the sensitivity to measure gross alpha and beta particles well below the activity level of 1 Bq/ml.