QUOKKA, the Pinhole Small-Angle Neutron Scattering Instrument at the OPAL Research Reactor, Australia: Design, Performance & Operation

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QUOKKA was the first small angle neutron scattering instrument to be in operation at the Australian research reactor, OPAL [1]. It is a 40 m pinhole instrument operating with a neutron velocity selector, an adjustable collimation system providing source-sample distances of up to 20 m and a two dimensional $1m^2$ position-sensitive detector, capable of measuring neutrons scattered from the sample over a secondary flight path of up to 20 m. Also offering incident beam polarization and analysis capability as well as lens focusing optics, QUOKKA has been designed as a general purpose SANS instrument with a large sample area, capable of accommodating a variety of sample environments.

Instrument Description & Control

OPAL is Australia's multipurpose research reactor with a thermal power of 20 MW. OPAL routinely operates for 300 days per year with typical shutdowns between reactor cycles of less than one week. A 20 L vertical liquid deuterium cold source operating at ~20 K provides cold neutrons to eight neutron instruments, including QUOKKA.

A photo of QUOKKA in the neutron guidehall is shown in Figure 1 and the general layout in Figure 2. A neutron velocity selector (NVS) from Airbus is housed directly downstream of the instrument shutter in shielded housing (B. in Figure 2). The selector is mounted on a tilt stage and may be tilted to vary the accessible wavelength and wavelength spread.

After the NVS housing, neutrons enter a vacuum vessel, the collimation tank shown in Figure 2C. The first element in the collimation tank is a wheel of Plexiglas used to attenuate the beam as required (Figure 3a). After the attenuator wheel, nine translation tables can be driven independently to insert either guides or apertures into the beam and enable source to sample distances between 1 and 20 m.

The sample position is designed to accommodate a range of equipment, described below.

QUOKKA currently operates with a 1 m^2 multi-wire 3He proportional detector (ORDELA), which can be translated up to 20 m from the sample position. To exploit the count rate potential on QUOKKA a significantly higher count rate detector was installed in November 2018.

Polarised neutron experiments are possible on QUOKKA, with a polarising guide in the incident beam and the possibility to have post-sample analysis using a ^3He analyser before the detector.

The instrument is controlled using the SINQ Instrument Control System (SICS) from the Paul Scherrer Institute, Switzerland. The user interface for neutron beam instruments at ANSTO is Gumtree and a QUOKKA-specific multi-sample workflow has been designed. The workflow is extremely flexible and user friendly. Data reduction is performed with Igor Macros from NIST with QUOKKA specific modifications [2].

Event mode acquisition, where every neutron is time stamped has been successfully used on QUOKKA over the past few years.

Figure 1. Photo of the neutron guidehall at ANSTO. QUOKKA is the SANS instrument on the left, adjacent to the BILBY the time-of-flight SANS instrument on the right of the photo.

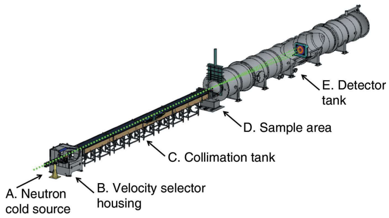

Figure 2. QUOKKA instrument layout.

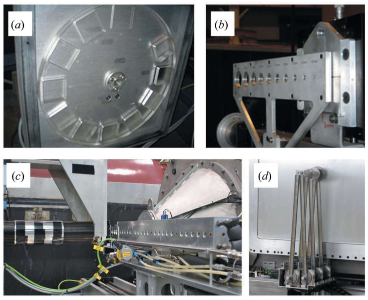

Figure 3. Instrument components: (a) Attenuator wheel, (b) Automatic aperture changer, (c) Sample environment area, showing extendable bellows on the left which maintain a vacuum up to the sample position and the 20-position sample changer on the right., (d) Beamstop mechanism.

Instrument Performance

QUOKKA is able to cover the Q range shown in Figure 4. Focusing optics allow QUOKKA to measure down to a Q value of 5 x 10^{-4} $Å^{-1}$ (Figure 4). The maximum Q value, for 5 Å neutrons, that can be measured with the detector in a central position is 0.6 $Å^{-1}$, which is often extended to greater than Q = 0.7 $Å^{-1}$ by offsetting the detector 300mm perpendicular to the beam. Q_{max} can be further increased by reducing the wavelength as shown in Figure 4.

Neutron brightness as a function of guide setting is reported in Figure 5.

In 2018, a new high count rate detector from Brookhaven National Laboratory was installed on QUOKKA, capable of measuring up to 1 million counts per second. Figure 6 shows the improvement in quality of high Q data.

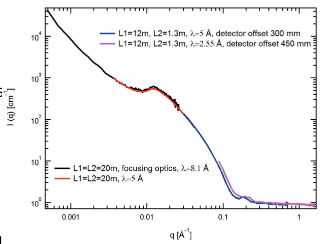

Figure 4. QUOKKA data taken at various configurations to show accessible Q-range. No scale factors have been applied.

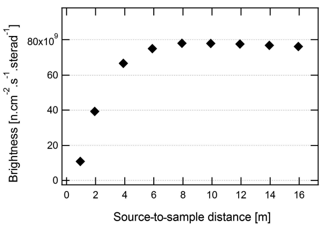

Figure 5. QUOKKA brightness at available source to sample distances.

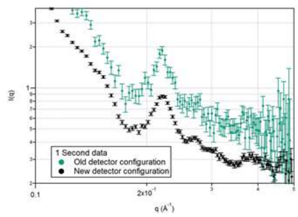

Figure 6. Data measured on a paraffin sample with a new high count rate detector, traces offset for clarity.

Sample Environments

QUOKKA has access to a broad range of sample environments: two temperature controlled automatic sample changers, a rotating sample changer, a rheometer, a stop-flow cell, two superconducting magnets, an electromagnet and a cryofurnace.

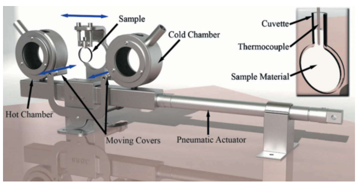

Figure 7. Photo of the Rapid Heat-Quench Cell.

QUOKKA also has several unique sample environments:

- A 'Rapid Heat-Quench Cell' has been designed in-house, enabling SANS to be measured immediately on rapidly cooling or heating a sample (Figure 7) [2].
- Rapid viscoanalysis (RVA) is a technique used in the food-industry to determine viscous properties. A commercial RVA instrument has been modified so that SANS measurements can be made simultaneously [3].
- An in-beam Differential Scanning Calorimetry (DSC) device has been developed in-house. The DSC crucible has been redesigned from a standard geometry to one that has a vertical section [4].

References

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For more information on Small Angle Neutron Scattering at ANSTO, please visit https://www.ansto.gov.au/research/facilities/australian-centre-for-neutron-scattering