MIRION TECHNOLOGIES

Radiation Safety. **Amplified.**

Single element HPGe X-ray detector

A new device for synchrotron high count rate x-ray spectrometry applications

- ✓ Unmatched energy resolution of Germanium similar to SDD
- ✓ Wide energy range up to 200 keV
- ✓ Compact footprint for easy integration in the beamline
- ✓ No liquid nitrogen needed

CANBERRA has been developing a wide range of cutting edge technologies for high purity germanium (HPGe) and Silicon detectors, and has a long history of designing state-of-the-art, turnkey systems to fit the most challenging applications:

- Ultimate x- and gamma-ray spectroscopy (with high count rates)
- LN_2-free cooling, using most reliable electric cryogenic cooler with no performance degradation
- Detection efficiencies ranging from 0.1% to 1300% arrays
- Highly segmented detectors for imaging and gamma tracking
- Ruggedized sealed HPGe detectors for harsh environments, space, airborne or under water

CANBERRA introduces in this document a new compact detector for high throughput x-ray spectrometry with unprecedented energy resolutions at high count rate: at 2.5 Million counts per second, an energy resolution below 200eV and reasonable down time (30%) have been measured.

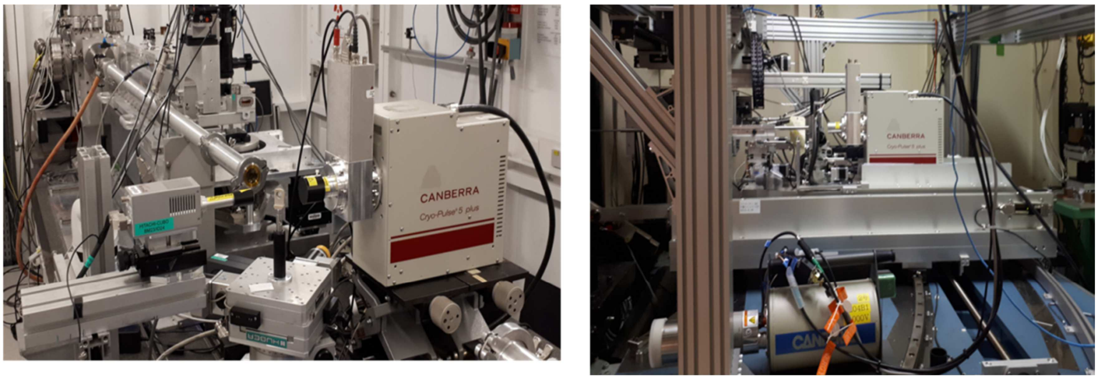

Fig. 1 - CANBERRA single element detector for performance testing at ESRF (BM23) for an EXAFS experiment and at Spring8 (BL04) on an energy-dispersive diffraction experiment

SYSTEM DESCRIPTION

The standard detector uses an HPGe crystal 10mm in diameter (collimated to 8mm in diameter) and 6mm thickness. Although other dimension can be offered on request, these dimensions have demonstrated excellent performances in energy resolutions, peak to valley and timing.

The crystal is located in a cryostat which can be fully customized (nose shape, length, orientation). The standard design is shown of Fig. 2. The cryostat is cooled down using a highly reliable electrical cryocooler, presenting a lot of benefits for the user compared to LN2 Dewars, as detailed below.

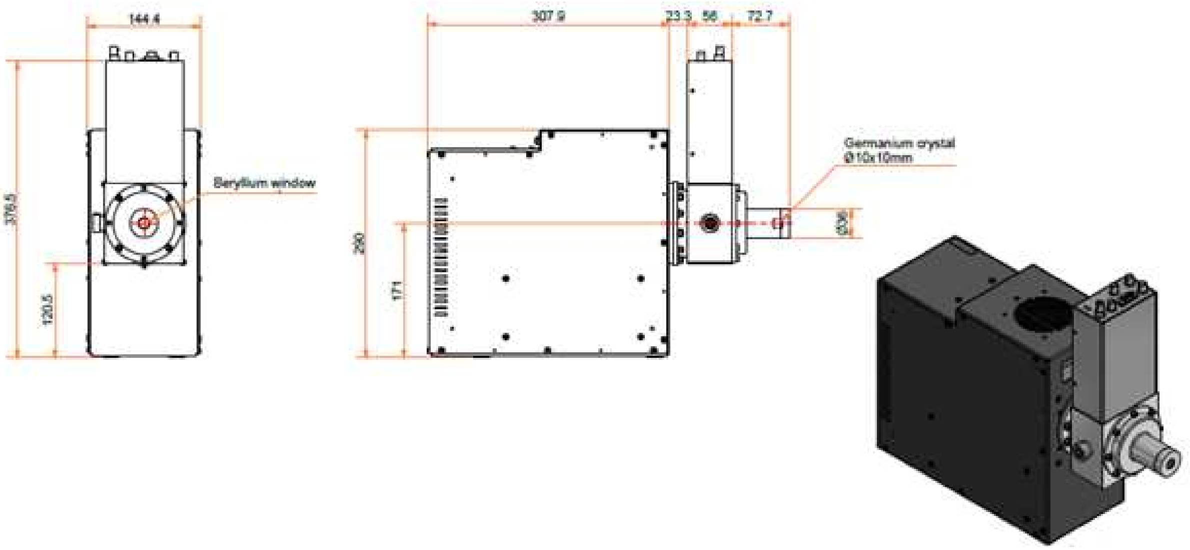

Fig. 2 – Typical detector drawing

A High purity Beryllium entrance window is included with 50µm thick (other thickness available).
Materials selected for the absence of fluorescence in the user's area of interest of the spectrum can be proposed.
Mirion can customize the cryostat design if there are any dimensional or mechanical constraints (orientation and position of the cryocooler, footprint of the detector head, support plate, etc.).

A complete standard cable set of 3.5 meter is also supplied for power supply and high voltage shutdown, high voltage bias, signal, and controller command.

KEY FEATURES

✓ Large energy range

High Purity Germanium (HPGe) detectors are widely used in scientific applications (nuclear and high energy physics, spectro-imaging) and industrial (radiochemistry labs, fuel cycle, environmental monitoring, ultra-low background measurement, nuclear medicine). For x-ray spectroscopy, they are of superior interest thanks to their excellent energy resolutions capabilities and high energy range coverage: at low energy, thin entrance windows and thin electrodes can be used to perform measurement less than 3 keV (down to 1 keV in option). At the high energy side, thanks to the density of 5,3 g/cc of Germanium, and because thick crystals can be used (typically HPGe thickness ranges from 5mm to 10 mm for x-ray detectors), photons of several hundreds of keV can be detected with good efficiency, which is not the case for alternative Silicon-based detectors, limited to energies below 15-20 keV.

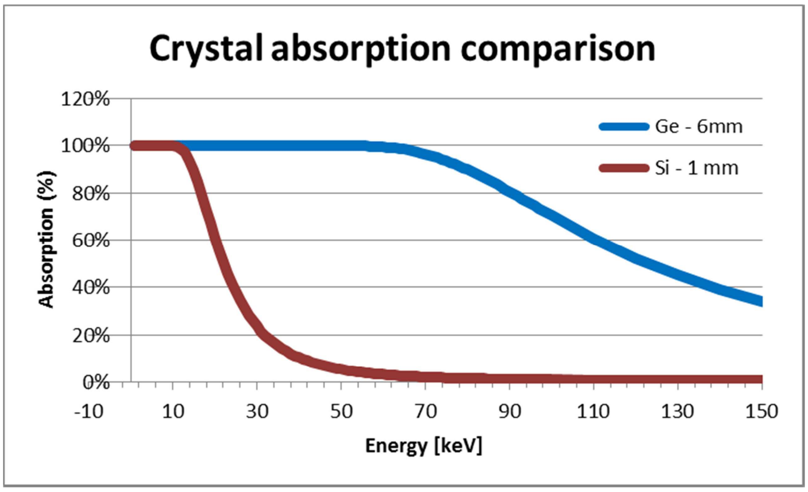

Fig. 3 - Comparison of crystal photoelectric absorptions for 6mm thick Germanium as well as 1mm thick Silicon (Silicon diodes are usually between 0,5mm and 1mm thick). HPGe is the most appropriate technology after 15keV

✓ Unmatched energy resolutions of Germanium at high count rate

The design of our count rate x-ray HPGe detectors have recently hugely improved thanks to new preamplifiers designs, new contacting methods and overall cryostat improvement.

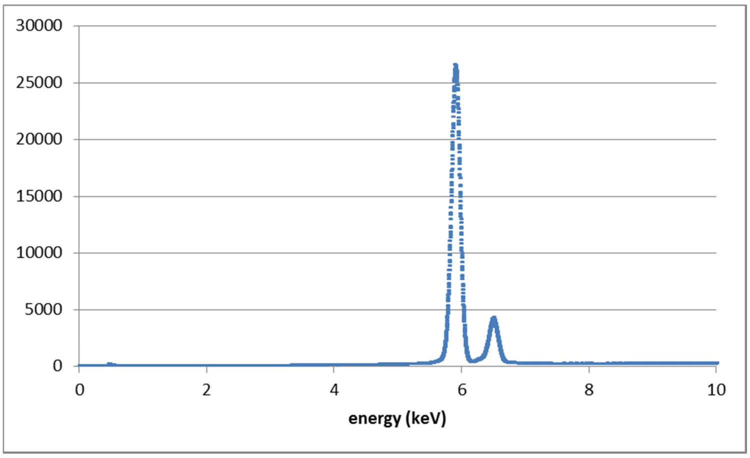

Fig.4 - Example of spectrum recorded with a Fe55 source at 550kcps at the detector, with a Canberra Lynx® digital MCA. The Gaussian shaping time is set at 0.1µs and the FWHM at 5.9 keV is 150eV

	Typical energy resolutions	Typical dead time	Guaranteed energy resolutions
1000 counts per second	< 110 eV	< 1%	< 130 eV (6µs)
100k counts per second	< 120 eV	< 2%	< 145 eV (0.5µs) < 170 eV (0.1µs)
1 Million count per second	< 175 eV	< 15%	< 190 eV
2.6 Million count per second	< 200 eV	< 36%	

Table 1. Energy resolutions guaranteed and regularly measured

Measurement conditions are:

- Below 100 000 cps the measurement are made using analog CANBERRA electronics and acquisition system (2026amp or equivalent with MPII) with Gaussian shaping time (in bracket), or Lynx, XIA FalconX or Quantum xspress3 mini. Above 100 000 cps XIA FalconX or Quantum xspress3 mini have been tested and qualified.
- A point source of 55Fe (5,9keV) is used.

The current energy resolutions are therefore similar to Silicon Drift Detectors (SDD), which used to be the best x-ray spectrometry devices so far, although often of smaller sensitive area and much less stopping power.

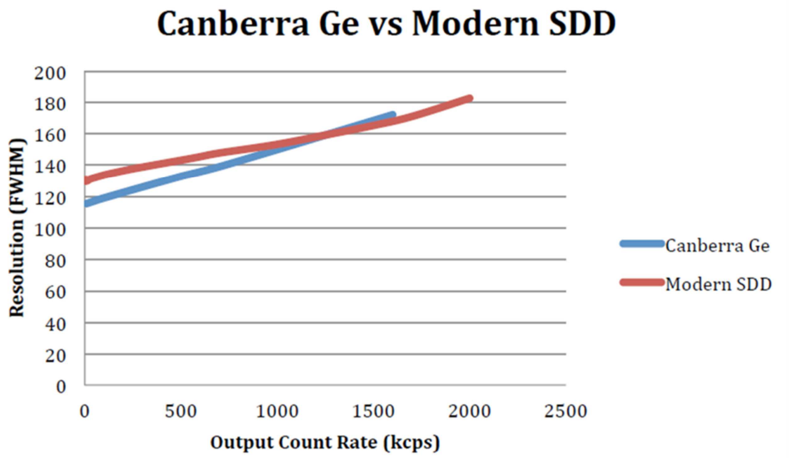

Fig. 5 - Energy resolutions of the HPGe demonstrator compared to a SDD of similar sensitive area (by courtesy of Quantum detector)

Energy resolution have also been recorded at high energies, below is presented performances of 60keV (Am241) source.

Output count Rate (kcps)	Energy resolution	Dead time
9	323 eV	0,5%
18	329 eV	1,2%
72	343 eV	3,0%

Table 2 – energy resolutions with an Am241 (60keV) source

Linearity data up to 7 Million count per seconds are also available, and their comparison with SDD.

- ✓ LN2 free Cryocooler

- The detector is cooled using a liquid nitrogen free, electrical cryocooler. There is no performance degradation compared to a LN2 cooling technique.
- The cryocooler CP5+ is remotely controlled by a module CP5+CO. The cable between the detector and the controller is 3.5m (other length available). More information on the cryocooler is available http://www.canberra.com/products/detectors/cryostats-coolers-cryopulse.asp
- The weight of the detector is 19kg. The cryocooler controller is 6 kg.

Fig.6 - Views of the single element typical detector

Compared to standard LN2 cooling technique, an electrical cryocooler features multiples key benefits, among them:
- Highly level of integration providing the smallest footprint
- No maintenance required; extremely reliable pulse tube technology (11+ years of mean time before failure)
- No risk of LN2 refill oversight
- No need for LN2 supply infrastructure
- No risk of burning for the user during LN2 refill (labs safety regulations become more and more stringent even regarding small injuries hazards, with long experiment shutdown if an accident occurs)
- No risk of anoxia
- Low vibration level: identical performance if compared to LN2 cooled detectors
- For experiments requiring no air displacement and no heat dissipation, the cooler can be sealed and the fans of the cooler can be replaced by an external water chiller (Fig.7), which can be located outside the hutch. The internal electronics also benefits from the water circuitry with temperature stabilization.

✓ <u>Multiple channel detector</u>

Such high count rate, electrically cooled x-ray detectors are available in more than one channel configurations in order to increase the beam coverage. Some are examples are provided below.

Fig.7 - Example of detector array (8 individual crystals) electrically cooled with an external water chiller (not represented)

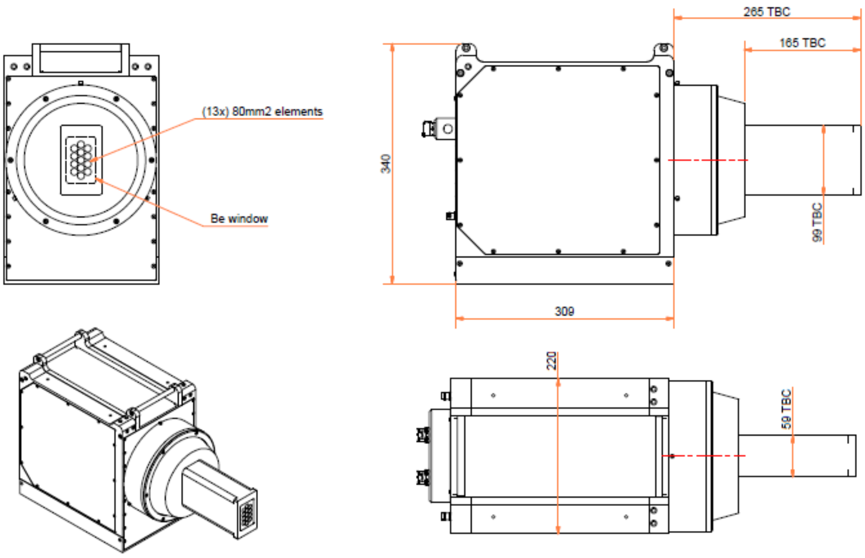

Fig. 8 – Example of 17 element detector array design, electrically cooled

SPECIFICATIONS

Parameter	*Value*
HPGe crystal	10mm diameter x 6mm thick Collimated to 8mm (optional)
Detector overall dimensions	377 x 145 x 460 mm^3
Detector weight	19 kg
Entrance window	50µm Beryllium
Cooling	Fully automatic electrical cryocooler (no LN2) Batteries can be provided on request Water chiller option available
Cooler MTTF	> 11 years
Power consumption	250 W maximum
Time to reach temperature of operation	1,5 hour
Count rate capability	> 3 million count per second
Guaranteed energy resolutions	1 kcps: <130eV (6µs) 100 kcps: < 145eV (0.5µs) and < 170 eV (0,1µs) 1 Mcps: < 190 eV
Preamplifier	Transistor reset type included in the detector Gain 6 mV/keV (adjustable on request)
Alarm card	For automatic HV shutdown Included in the probe housing
Typical high voltage	-1000V
Connections	Cables supplied: - High voltage input (SHV) - Signal output (BNC) - Preamplifier power (DB9) - Cooler controller (DIN5) These connectors can be customized on request.
Cable length	3.5 (can be adjusted on request)

Mirion can provide a full set of accessories:

Parameter	*Value*
Factory Acceptance Test (FAT)	Detector comprehensive characterization on Lingolsheim (France) factory
Detector operation and maintenance training	Training at the factory
On- site installation and acceptance test (SAT)	Detector installation at user's site
Detector readout electronics	Include fine tuning between the detector and the electronics and training

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For more information, please contact your local Mirion representative or email at
lingolsheim_support@canberra.com