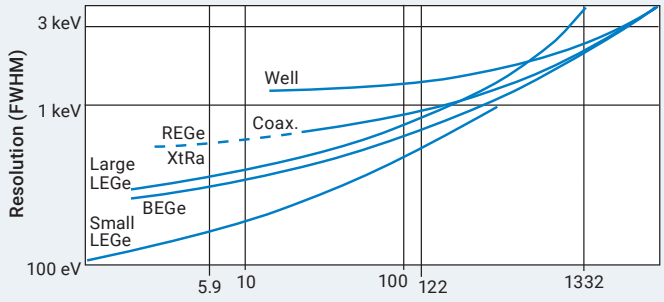
MIRION
TECHNOLOGIES

Germanium Detectors

Germanium detectors are semiconductor diodes having a p-i-n structure in which the intrinsic (i) region is sensitive to ionizing radiation, particularly x rays and gamma rays. Under reverse bias, an electric field extends across the intrinsic or depleted region. When photons interact with the material within the depleted volume of a detector, charge carriers (holes and electrons) are produced and are swept by the electric field to the p and n electrodes. This charge, which is in proportion to the energy deposited in the detector by the incoming photon, is converted into a voltage pulse by an integral charge sensitive preamplifier.

Typical Resolution vs. Energy



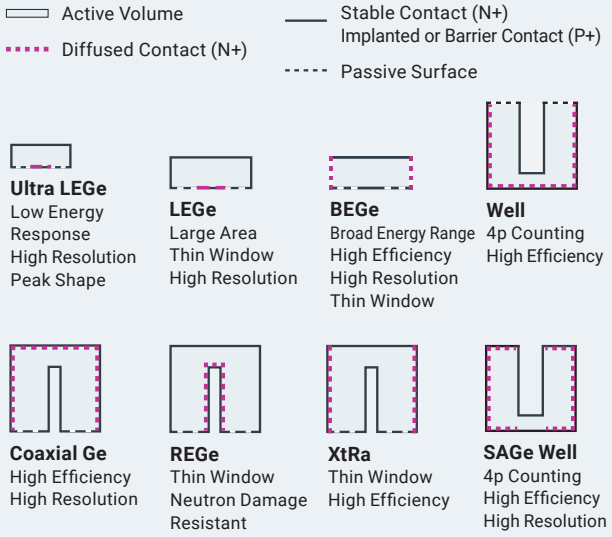
Because germanium has relatively low band gap, these detectors must be cooled in order to reduce the thermal generation of charge carriers (thus reverse leakage current) to an acceptable level. Otherwise, leakage current induced noise destroys the energy resolution of the detector. Liquid nitrogen, which has a temperature of 77 K has traditionally been the common cooling medium for such detectors. The detector is mounted in a vacuum chamber and is cooled by one of two cooling sources: either the vacuum chamber is attached to or inserted into an LN_2 Dewar, either the vacuum chamber is attached to an electrically cooled cryostat. The sensitive detector surfaces are thus protected from moisture and condensible contaminants.

TYPES OF GERMANIUM DETECTORS

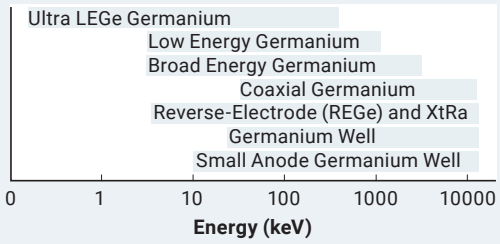
Mirion offers the widest choice of detector types in the industry. Employing the appropriate technology in both materials and processing techniques, Mirion can offer the optimum detector for a wide range of applications. We use both p-type and n-type germanium and we use diffused, implanted, and barrier contacts to achieve this product variety.

The following illustrations and charts depict the various detector geometries that are available from Mirion, the energy range they cover, and their salient performance characteristics. Consult the individual specification sheets for detailed descriptions, performance ranges, and model availability of each type.

Structure Code:



Detector Type:



CRYOSTATS

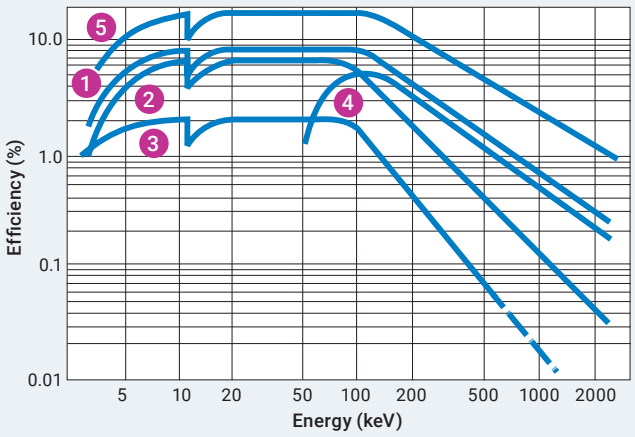
The cryostat is the most important, and perhaps the least appreciated, component in assuring reliable long term performance of a Ge detector system. Mirion manufactures its own cryostats to exacting quality standards to ensure long detector life under the harshest operating conditions.

Depending on the detector configuration, the standard Mirion cryostat is either the Slimline™ or the Flanged™ design. The Slimline design has the detector chamber and the preamplifier packaged together in a compact cylinder. The Flanged design has the vacuum chamber and the preamplifier connect to a flange.

The Ultra-LEGe low-energy detectors always use our Flanged™ cryostats which are compatible with the small diameter (25 mm) end-caps associated with this type of detector.

For applications requiring liquid nitrogen free operation, Mirion offers the Cryo-Pulse® 5 Plus model. This electrically cooled cryostat uses a pulse tube cooler with a CFC-free refrigerant and is well suited for use in industrial and laboratory applications. Since its introduction in 2006, our installed base has demonstrated a cryocooler lifetime which is at or even above the level of the detector lifetime.

Finally, Mirion offers a hybrid cryostat solution with the Cryo-Cycle cryostat. The hybrid solution combines the advantages of electric cooling with the reliability of liquid nitrogen.



Typical absolute efficiency curves for various Ge detectors with 2.5 cm source to end-cap spacing

1. REGe, 15% Relative Efficiency
   XtRa, 15% Relative Efficiency
2. LEGe, 10 cm^2 x 15 mm thick
3. LEGe, 200 mm^2 x 10 mm thick
4. Coaxial Ge, 10% RelativeEfficiency
5. BEGe, 5000 mm^2 x 30 mm thick

PREAMPLIFIERS

There are only two basic types of preamplifiers in use on Ge detectors. These are charge sensitive preamplifiers, which employ either dynamic charge restoration (RC feedback), or pulsed charge restoration (Transistor reset) methods to discharge the integrator. The following figure illustrates the energy rate limitation of dc-coupled RC feedback preamps, which is a function of the feedback resistor value and the dynamic output voltage range of the integrator, which is limited to about 20 volts.

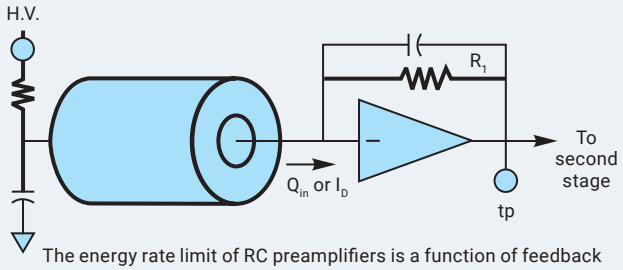
Charge carriers produced by Ge per unit energy deposited = 1/2.98

$$\text{Detector Current} = \text{Energy Rate}\left(\frac{eV}{s}\right) \times \frac{\text{charge (Q)}}{\text{energy (eV)}} \times 1.6 \times 10^{-19}\frac{\text{Coulombs}}{Q}$$

Charge per charge carrier

$$\frac{\text{Detector Current (A)}}{\text{Energy Rate (MeV/s)}} = 10^6 \times \frac{1.6 \times 10^{-19}}{2.98}$$

$$= 5 \times 10\text{-}14 = 0.05\ \text{pA/ (MeV/s)}$$



The energy rate limit of RC preamplifiers is a function of feedback resistor value (R_f) and dynamic range.

$V_{tp} = I_D \times R_f$

Assuming V_{tp} = 20 V (max)

$$\text{Energy Rate Limit (MeV/s)} = \frac{400\,000}{\text{R (Gigohms)}}\ \text{MeV/s}$$

For 2 Gigohms - Limit is 200 000 MeV/s
For 0.5 Gigohms - Limit is 800 000 MeV/s

The energy rate limit can be increased very substantially by choosing a lower value feedback resistor with, of course, an accompanying increase in noise. Actual performance data on a typical detector is given in the following table:

Resolution vs. Feedback Resistor		
Experimental Results with Detector Model GC-1019		
Resistor Value	^{57}Co (122 keV FWHM)	^{60}Co (1332 keV FWHM)
2 Gigohm	1.00	1.81
1 Gigohm	1.02	1.85
0.5 Gigohm	1.08	1.93
0.2 Gigohm	1.25	2.13

The Intelligent Preamplifier (iPA) is Mirion's standard RC-feedback preamplifier designed for high-resolution gamma spectroscopy and timing measurements. Many critical preamplifier and detector parameters are digitized enabling them to remotely monitor.

While the RC feedback preamplifiers are used for the majority of detectors, certain specific applications can profit from a Transistor Reset preamplifier in which the feedback resistor is eliminated.

The Model 2101 Transistor Reset preamplifier is used to ensure the signal throughput in high energy, high rate systems. The feedback capacitor is discharged by means of a transistor switch connected to the FET gate eliminating the need for a feedback resistor. This transistor adds capacitance and corresponding noise to the input circuit, but this is tolerable in most applications involving high count or energy rates. Compared to an RC-feedback preamplifier with selected feedback resistor for high rate performance, the Transistor Reset Preamplifier will exhibit less noise and, hence, better resolution but will sacrifice dead time because the amplifier will require 2-3 amplifier pulse widths to recover from the periodic reset of the preamplifier. Thus, in applications demanding high throughput rates, the Transistor Reset Preamp is not a good choice. It will be rather used in situations where the energy rate is so high that an RC preamp might saturate – but the throughput rate may be diminishingly small in this case.

Integrated Transistor Reset preamplifiers (i-TRP) having a built-in transistor switch are widely used on low-energy detectors where resolution is of utmost consideration. Eliminating the feedback resistor and minimizing the input capacitance decreases noise without a serious impact on dead time, so long as the average energy per event is low to moderate. As a consequence, i-TRP systems are not generally used with coaxial detectors.

SYSTEMS

Mirion also offers many options and accessories that are designed to complement our line of germanium detectors. Below is a partial listing of the equipment and systems that we offer. Some of these systems are described in separate specification sheets and brochures while others are custom tailored. We stand ready to propose and supply systems that will meet your specific requirements. Contact your local Mirion representative or the factory, describing your problem or application, and we will send you a proposal immediately.

ACCESSORIES

- Liquid nitrogen supply Dewars
- •LN_2 transfer devices
- LN_2 level controller
- Lead shields for low level counting
- Compton suppression spectrometers
- Cosmic Veto systems

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