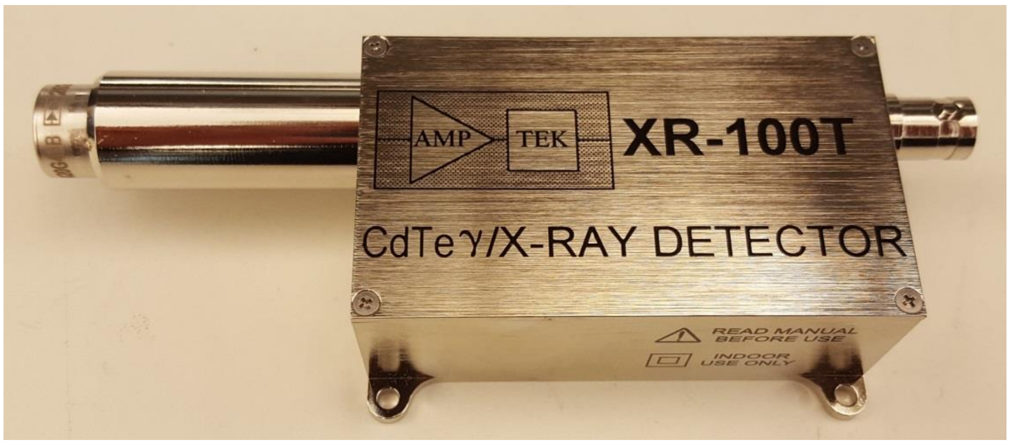
User Operating Manual

XR-100CdTe

X-Ray Detector & Preamplifier



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Certificate #: CU 72072412 02
Tested to: UL 61010-1: 2004 R7 .05
CAN/CSA-C22.2 61010-1: 2004

Rev B1 – Sept 2017

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1 Warnings and Precautions

CAUTION: READ MANUAL BEFORE USING THE XR-100CdTe

DOUBLE INSULATED. FOR INDOOR USE ONLY.

DO NOT DROP THE DETECTOR, CAUSE MECHANICAL SHOCK TO THE DETECTOR, OR CAUSE DAMAGE TO THE DETECTOR

- Mechanical shock can damage components inside the TO-8 package.
- There is vacuum inside the TO-8 for cooling. Damage to the package can cause a vacuum leak, preventing good cooling. DAMAGE TO THE PACKAGE IS NOT COVERED UNDER WARRANTY.

DO NOT TOUCH THE THIN WINDOW ON THE END OF THE DETECTOR

- **BROKEN WINDOWS DAMAGED BY IMPROPER HANDLING WILL NOT BE COVERED BY WARRANTY.**
- The detector window is made from either thin beryllium (13 µm or less) or from thin carbon (1 µm). The windows are extremely brittle and shatter easily.
- Do not permit any object to come into contact with the window.
- The window cannot be repaired or replaced. If the window breaks, the detector must be replaced.
- Keep the red protective cover installed when not in use.

AVOID RADIATION DAMAGE TO THE DETECTOR

- **A RADIATION DAMAGED DETECTOR WILL NOT BE COVERED UNDER WARRANTY.**
- The detector will experience radiation damage if it is exposed to a high flux environment, e.g. directly from a synchrotron.
- If the flux is low enough for spectroscopic operation, e.g. a count rate of a few hundred kcps, there will be no radiation damage in many years of continuous operation. But there are beams that produce a flux many orders of magnitude higher than this, and these will cause damage.
- Also, avoid radiation exposure to the electronics, the preamplifier and signal processor.

High voltage is present inside the preamplifier. This is typically 500 to 800V. The current is limited to <100 µA so is not a personnel hazard.

For best performance the detector and preamplifier should be mounted to a heat sink. They should be kept away from incandescent lamps and not held in the hand. The thermoelectric cooler dissipates up to 2 W. A low thermal resistance path to a heat sink is needed to keep the detector cool, which is needed for the lowest electronic noise and for spectrum stability.

For best performance pay attention to possible sources of electromagnetic interference. Use a single point electrical ground, use the shortest length cables possible, and keep the system far from sources of electromagnetic interference, such as computer monitors, high power high voltage power supplies, etc. The signals from the detector are very small so performance can be degraded by EMI.

WARNING

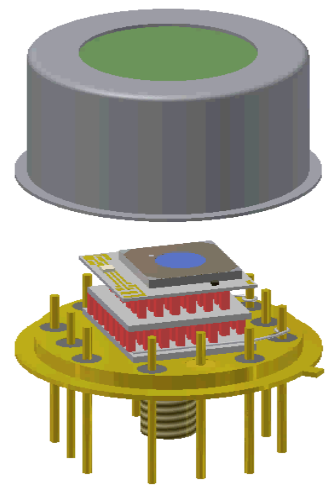
This product contains the following chemicals, which are known to the State of California to cause cancer, birth defects or other reproductive harm if exposed to them through improper use, storage, or disposal of the product:

Prop 65 Chemical	Type of Toxicity	CAS No.	Product part containing the chemical
Beryllium	Cancer	--	Detector window
Cadmium compound	Cancer		CdTe detector

Please consult this owner's manual for proper use, storage, care and disposal of the product. For more information, go to: www.p65warnings.ca.gov

2 Description

2.1 Core detector technology



Amptek provides a family of high performance, compact X-ray detectors and associated signal processing electronics. The radiation detectors are custom photodiodes, including the traditional Si-PIN diodes, **S**ilicon **D**rift **D**etectors (SDDs), and CdTe Schottky diodes. The detector is mounted on a two-stage thermoelectric cooler along with the key preamplifier components. The cooler keeps the detector and key components at -25°C or below, reducing electronic noise without cryogenic liquid nitrogen and drawing <1W. This cooling permits high performance in a compact, convenient package, and has been critical to the development of portable XRF analyzers and of high performance, benchtop XRF and EDS systems.

Amptek's detectors represent the state-of-the-art in X-ray spectroscopy, delivering the best energy resolution, best efficiency at low energies, highest count rates, highest peak to background ratios, all at low cost and suitable for portable systems, vacuum systems, etc. They are used by OEMs and by laboratory researchers. The core enabling technologies include the detectors themselves (which are designed and manufactured by Amptek), the low noise JFET and CMOS technology, and the packaging which enables good cooling in a robust system.

The sketch above illustrates a detector mounted on a thermoelectric cooler, on a TO-8 header. The input FET and other components are also mounted on the cooler. A nickel cover (also shown) is welded to the TO-8 header with vacuum inside the enclosure for optimum cooling. In the cover is a window (shown green above) to enable soft X-ray detection. This is typically beryllium for energies > 2 keV. The entire assembly shown above is sometimes called the "detector", though strictly speaking it is the photodiode which detects the X-rays.

2.2 Preamplifiers and signal processors

The detector assembly shown above must be connected to a preamplifier (a circuit board containing those portions of the preamp not in the TO-8). Amptek uses reset-style charge sensitive preamplifiers for the lowest noise and highest count rates. Each type of Amptek detector (FAST SDD®, SDD, Si-PIN, and CdTe) requires its own preamp circuit. These are available in several different standard package options: as an XR-100 box, as a standard OEM preamp (PA210 or PA230) or in a custom board.

The output of the preamplifier must be connected to signal processing electronics (which includes pulse shaping and a multichannel analyzer) and power supplies. Amptek has several different options for these, including the X123 (where all are integrated in a single, small box), the DP5/PC5 board stack (bare boards, for integrating into customer systems), and the PX5 module (usually used in the laboratory). Please refer to Amptek's website for more information.

2.3 CdTe Detector Options

This manual is focused on the standard CdTe detector, which uses a reset style preamplifier for good energy resolution and count rates. Amptek also provides CdTe detectors with resistive feedback, and for many years used a transistor feedback (now obsolete). These two configurations are described in sec 3.7.

3 Amptek CdTe Specifications

3.1 Specification Table

General	
Detector Type	CdTe Schottky diode
Detector Size	25 mm^2 (square)
Collimated Area	Not collimated
Thickness	0.75 or 1.0 mm
Preamplifier Type	JFET reset type
Energy resolution	
<1.5 keV FWHM at 122 keV (1.2 keV typical)	
<0.8 keV FWHM at 59.5 keV (typical)	
Other Performance	
Signal risetime	Up to 300 ns (typical)
Maximum input count rate	~ 50 kcps
Throughput count rate stability	Determined by signal processor & its settings
Window Options	
Be Carbon	4 mil (100 µm) 1 mil (25 um)
Signal Output	
Sensitivity	0.8 mV/keV
Polarity	Positive signal
Reset range	-5 to +5 V (typical)
Cooling	
Cooling performance	$\Delta T > 85^oC$
Cooler type	Two stage thermoelectric
Temp monitor	Diode
Power	
HV Bias	500 to 1,000V @ 25 µA
Max cooling power	3.5 V / 0.45A
Total power	< 2 W (full cooling)

Other	
Operating range	-35 ^oC to +80 ^oC Performance degrades at elevated detector temperatures.
Storage & shipping	-40 ^oC to +85 ^oC, 10% to 90% RH noncondensing
RoHS	Compliant
Lifetime	Typical 5 to 10 years, depending on use
Warranty Period	1 year

Feedback Options

Amptek's standard CdTe detectors, with reset feedback, provides the best resolution and operates well up to about 50 kcps.

Amptek also offers CdTe detectors with resistive feedback; these operate at much higher count rates but resolution is degraded. Amptek used to offer a transistor feedback option but this has been superseded by the reset feedback. See sec 3.7.

Preamplifier Options

Amptek's CdTe is available with the XR-100 preamplifier, with the PA210 or PA230 OEM preamplifiers, or as part of the X-123.

Signal Processing Options

Amptek's CdTe may be used with Amptek's DP5 or DP5-X, or the PX5, or as part of the X-123 or X-55.

Specification Notes

- Performance listed here is measured at T_{pk} = 2.4 µs, T_{flat} = 0.4 µs, 700V bias, and at 230K.

Operating Notes

- Detector must be operated with an appropriate heat sink.
- The CdTe detector is suitable for vacuum applications. Amptek provides several system configurations.

3.2 Comparison with other X-ray and gamma-ray detectors

Planar CdTe detectors are not the most common detectors for X-ray or gamma-ray spectroscopy. They have some clear advantages over the other types, in particular applications, but they also exhibit certain unique characteristics. A user with a great deal of experience using other detectors may fail to appreciate both the advantages and disadvantages of the CdTe detector so a quick comparison is given here. The plot below compares spectra taken with a 25 mm^2 x 0.5 mm silicon drift detector (SDD) and a 25 mm^2 x 1 mm CdTe detector, using ^{241}Am and ^{57}Co sources. There are three key differences:

- The efficiency of the CdTe detector is much better than the SDD above 20 keV. This is the primary advantage of CdTe: at 60 keV, it is 20x as efficient, which can greatly improve counting statistics.
- The resolution of the CdTe is worse than that of the SDD. At low energy, where noise is most important, the SDD has much better resolution. At moderate energies, where Fano broadening dominates, the difference is much smaller
- The CdTe photopeaks are clearly not Gaussian; they are asymmetric with a tail on the low energy side. The importance of the tail increases at high energies. This tail arises from partial charge collection: the holes have a relatively short trapping lifetime, leading to a pulse height deficit and thus to the asymmetric photopeak.

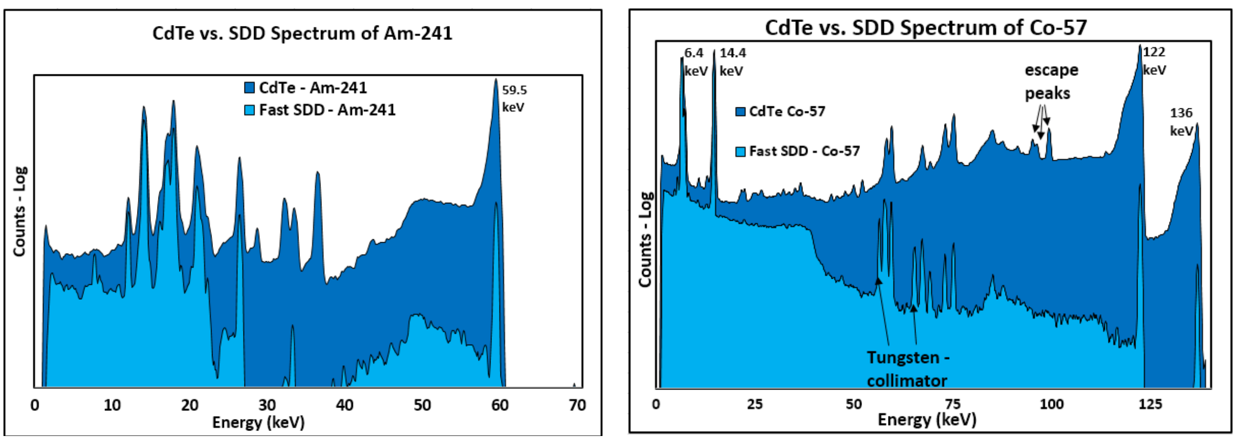


Figure 1. Typical ^{241}Am and ^{57}Co spectra, illustrating the key differences between CdTe and silicon detectors.

3.3 Photopeak shape

The asymmetric shape of the CdTe photopeak is termed "hole tailing" and arises from incomplete charge collection in the CdTe crystal. In all planar semiconductor detectors, an X-ray interacts and creates free charge, with total charge proportional to deposited energy. The bias voltage across the devices causes the charges to move, creating a current pulse. The electrons measure this current and integrate it to obtain the charge. In a compound semiconductor, intrinsic defects in the crystal form trapping sites. As the electrons and holes transit the device, a fraction are trapped, resulting in a signal current that decays exponentially with time. The time integral of the charge measures a pulse height deficit due to the reduced charge.

The plot below illustrates the effect. The sketch on the left shows interactions at three depths. In the first one, close to the front contact, most of the signal arises from electrons which travel quickly with little charge loss. The pulse height reflects all charge produced. Deeper in the crystal, holes contribute more to the current, leading to a current pulse which is slower and has less integrated charge, i.e. exhibits a pulse height deficit. The result is a pulse height which varies with the depth of X-ray interaction.

In a typical CdTe crystal, the maximum hole transit time is ~250 nanoseconds and the hole lifetime is 2 to 3 μs; this leads to a pulse height deficit that depends on depth in the crystal, is negligible for interactions near the front contact, but can be 3-5% at the rear contact. The electron transit time is a maximum of 15 ns, so electron trapping is negligible.

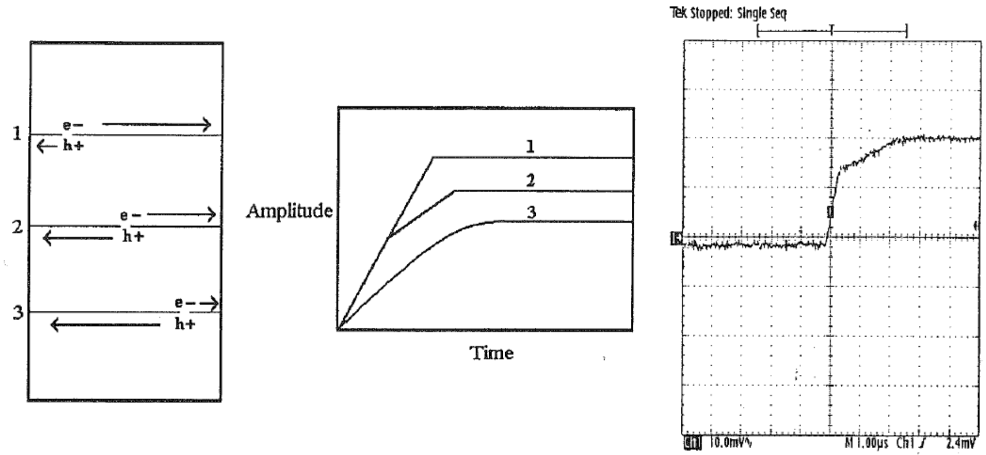


Figure 2. Figure illustrating incomplete charge collection which leads to hole tailing, as discussed in the text. The sketch on the left shows interactions at three depths in the detector. The middle sketch illustrates, qualitatively, the expected preamp pulses. The right plot shows an oscilloscope trace.

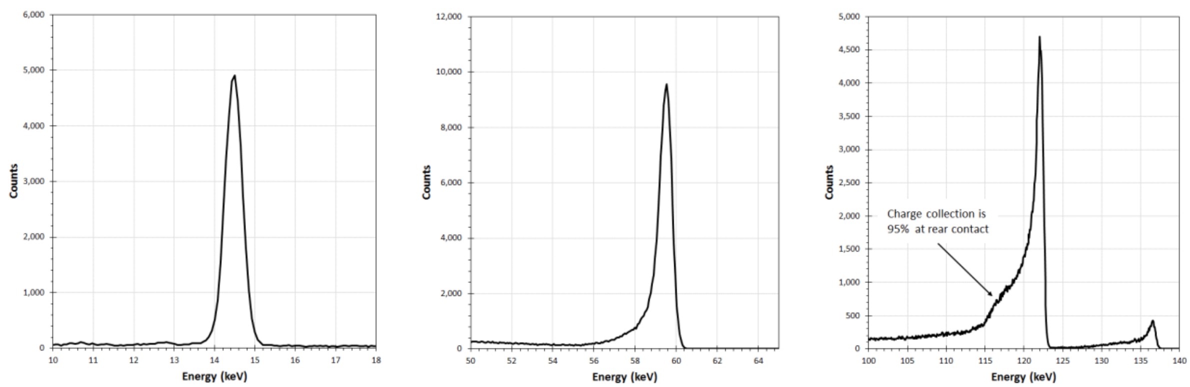


Figure 3. Typical photopeak shapes at 14.4 keV (left), 59.5 kev (center), and 122 keV (right). At lower energies, all the X-rays interact near the same depth so there is no variation in charge collection efficiency (CCE); the photopeak is nearly Gaussian, with FWHM arising from noise and Fano broadening. At higher energies, more X-rays interact near the rear contact; the variation in CCE with depth is more important, leading to an increasing important tail and a non-Gaussian photopeak. Note that the tail does not extend smoothly to zero but terminates at the CCE of the rear contact (here 95%).

Key points:

- A digital processor with a flat top of at least 0.4 μs is recommended. The longer flat top is needed to properly process pulses with the slower risetime caused by the charge collection time. Shorter flat tops will lead to extra pulse height deficit, arising from ballistic deficit.
- As shown in Fig 3, at low energies, nearly all X-rays interact near the front contact, so variation in charge collection is negligible. The photopeak is Gaussian, with width arising from electronic noise and Fano broadening. At higher energies, more X-rays interact deep in the detector, leading to more variation in charge collection, i.e. a more important tail. This tail is important for understanding the detector's photopeak efficiency, its resolution, and the photopeak shape (needed for processing spectra).

- Note that it is the peak channel rather than the centroid of the peak which should be used to estimate the energy of a spectral line. The centroid gets shifted down when counts are in the tail. Note also that the width should described by the actual FWHM rather than using a Gaussian approximation.

Charge collection effects in CdTe are discussed in more detail in several references:

- XR-100CdTe Efficiency Application Note (From Amptek, AN-CdTe-001)
- XR-100CdTe Charge Transport Application Note (From Amptek, AN-CZT-2)
- R.H. Redus, J.A. Pantazis, T.J. Pantazis, A.C. Huber, B.J. Cross, *Characterization of CdTe Detectors for Quantitative X-ray Spectroscopy,* in IEEE Trans. Nucl. Sci., Vol 56, No 4, p 2524, Aug 2009.

3.4 Efficiency

The intrinsic efficiency is the probability that an X-ray incident on the detector window (in the active region) will interact in the detector and thus deposit its energy, creating a signal pulse. It is the product of (a) the probability of transmission through the window and (b) the probability of interacting in the 500 μm silicon depth (the detector is fully depleted). The low energy portion of the curves is dominated by the stopping in the window, while the high energy portion is dominated by transmission through the active depth of the CdTe detector. The plot below shows the computed intrinsic efficiency for a CdTe detectors, both 0.75 and 1.0 mm thick, with the standard 4 mil Be window. Also shown is the efficiency of a 0.5 mm Si detector with a 12 μm Be window. See the Amptek website for more information.

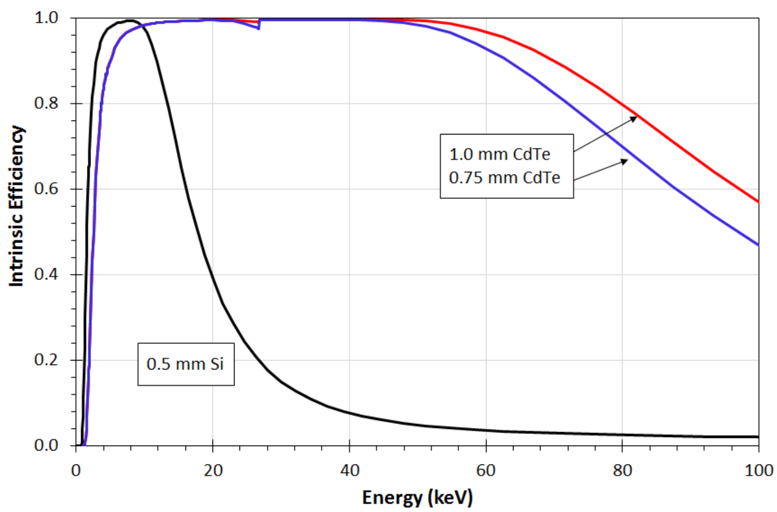


Figure 4. Plot showing the efficiency of a 1 mm thick CdTe detector versus energy and comparing it to the efficiency of a 0.5 mm thick silicon detector.

The advantage of the CdTe detector over SiPIN and SDD detectors is its efficiency at high energies. The efficiency of the 0.5 mm silicon detectors decreases above 10 keV, reaching 10% at 35 keV. The CdTe detector has much better efficiency at high energies. Note that, in CdTe at energies above 30 keV, a fraction of the X-rays are in the tail due to incomplete charge collection. When computing the efficiency and the expected count rates, counts in the tail must be considered.

Escape peaks are important in CdTe. As with all X-ray detectors, when an X-ray undergoes photoabsorption, the photoelectron stops in the detector's active volume. The atom is left in an excited state, decaying to the ground state with emission of a characteristic X-ray having energy E_c. Some of these X-rays will exit the active volume; the result is an "escape peak", an artifact an E_c below the main peak.

All detectors exhibit escape peaks, but most users are familiar with silicon detectors, where E_c is 1.75 keV. The X-rays have a short range so most are captured in the silicon. In a CdTe detector, one observes four escape peaks (from the Cd K_α, Cd K_β, Te K_α, and Te K_β lines) and with energies of 23.2, 26.1, 27.5, and 31.0 keV, more escape the detector. The effects on the spectrum are more significant than with Si detectors.

3.5 Energy resolution

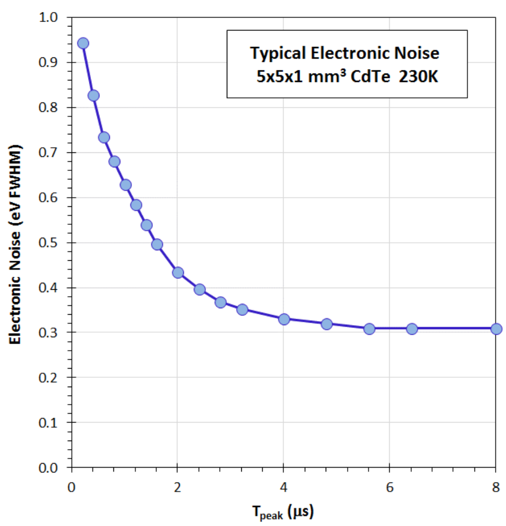
The energy resolution, δE (eV FWHM), is given by three terms for CdTe. The first two are important in all semiconductor detectors while the third, arising from partial collection, is important in CdTe.

$$(\delta E)^2 = ENC^2 + K_F E + +K_T E^2$$

where

- *ENC* is electronic noise. As shown below, it depends on T_{peak} and on detector temperature.
- $K_F E$ is due to "Fano broadening"; it is the theoretical limit for a noiseless detector. It is approximately 115 eV at the 5.895 keV K_α line of Mn.
- $K_T E^2$ models the effect of hole tailing on FWHM; its contribution to FWHM is approximately linear with energy. It depends on bias voltage: increasing bias voltage will reduce the tailing (improving resolution at high energies) but add to noise (degrading resolution at low energies). K_T, the tailing factor, varies considerably from one detector to the next.

The first plot below illustrates typical electronic noise. The second plot shows how the combination of noise and Fano broadening for typical detectors.



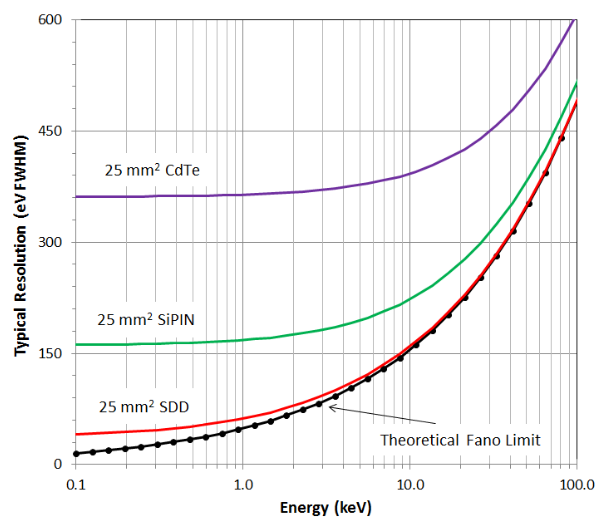


Figure 5. Left: Plot showing electronic noise versus peaking time for a typical CdTe detector at 230K. Right: Plot showing the combined effects of electronic noise and Fano broadening versus energy. Note that the contribution of hole tailing is not included

Interference

All radiation detectors exhibit some susceptibility to electromagnetic interference, due to the small current pulses produced in the detectors. Most detectors also exhibit some susceptibility to microphonics, acoustic vibrations that induced currents through biased electrodes. CdTe is particularly susceptible to microphonics, due to the piezoelectric properties of the crystal. Minimizing high frequency vibrations may be needed for best performance.

3.6 Typical Performance

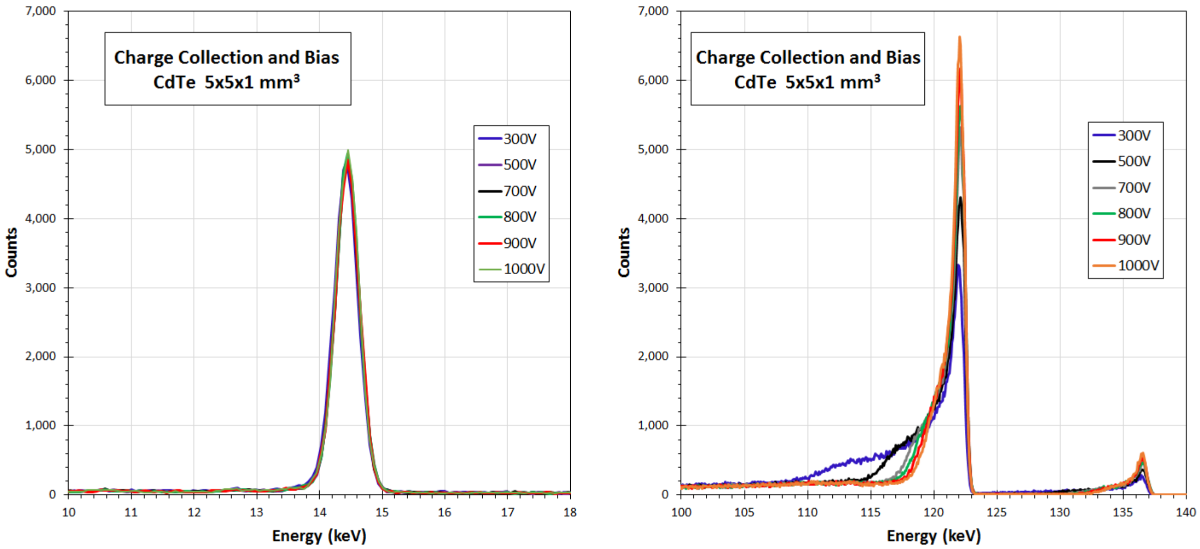


Figure 6. Typical spectra with 25mm^2 x 1 mm CdTe, showing the effect of bias voltage on photopeak shape at 14.1 keV (left) and 122 keV (right). Higher voltages lead to improved charge collection but at the cost of increased electronic noise.

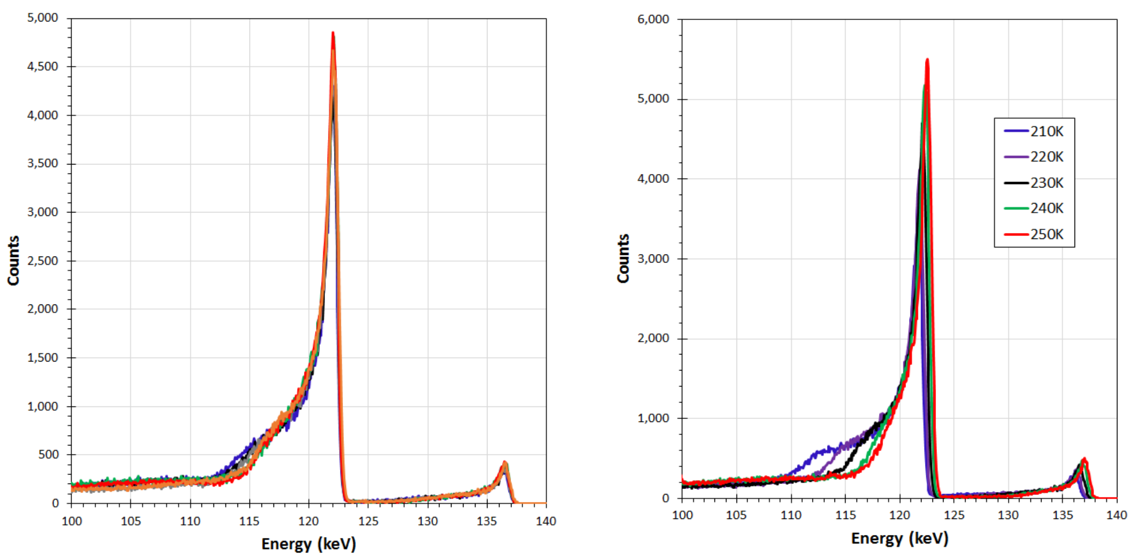
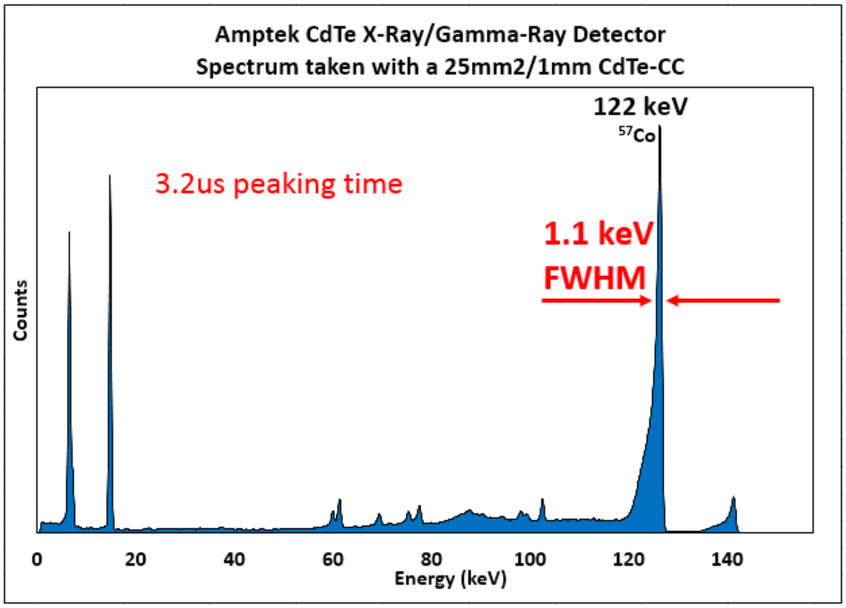


Figure 7. Left: The charge collection efficiency varies from one detector to the next. The plot shows the 122 keV peak in ^{57}Co spectra measured from several detectors. Right: The charge collection efficiency is also a function of temperature. Higher temperatures lead to improved charge collection but at the cost of increased electronic noise.

3.7 Spectra

The plots below show typical spectra measured with a 25 mm^2 x 1mm CdTe detector.



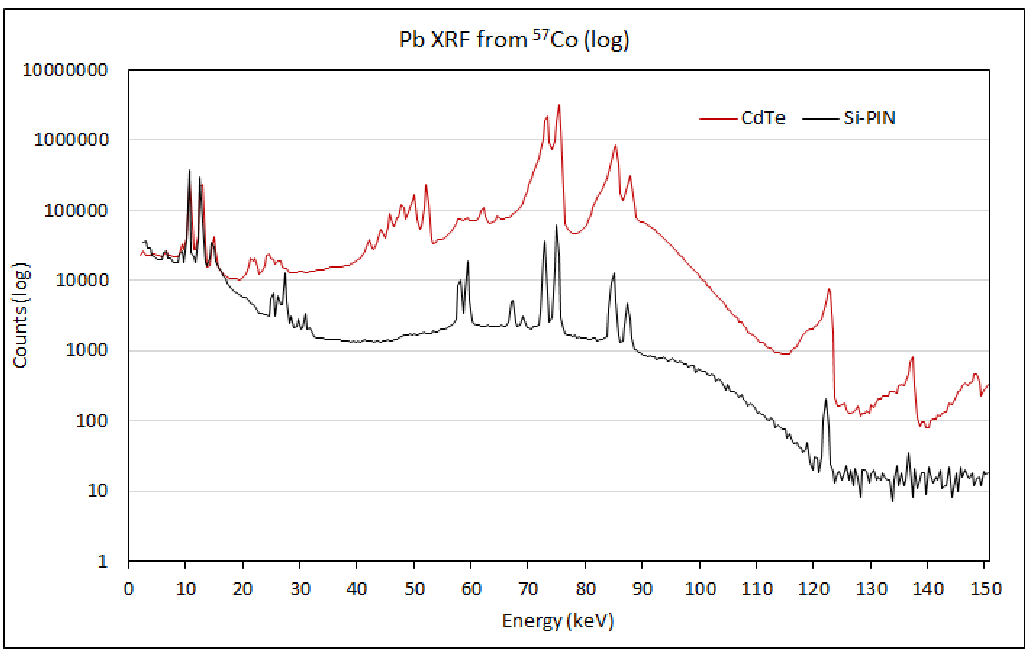


Figure 8. Typical spectra with 25mm^2 x 1 mm CdTe (reset)

4 XR-100 Preamplifier Specifications

General	
Preamp Type: Reset style charge sensitive preamplifier.	
Power	
HV Bias	500V to 800V @ 25 µA
Max cooling power	3.5 V / 0.45 A
Low voltages	+/- 8 to 9 V @15 mA. No more than 50 mV p-p
Mechanical	
Case size (without extender)	3.00” x 1.75” x 1.13” 7.6 cm x 4.4 cm x 2.9 cm
Weight	4.4 oz (125 g)
XR-100 Power Connector	
Type	6 pin LEMO
Pin 1	Temperature monitor diode
Pin 2	Detector Bias.
Pin 3	-9 V power
Pin 4	+9 V power
Pin 5	Cooler power return
Pin 6	Cooler power

Case	Ground and shield
XR-100 Signal Connector	
Type	BNC Coax
Other	
Operating range	-35 ^{o}C to +80 ^{o}C - @components
Storage & shipping	-40 ^{o}C to +85 ^{o}C, 10% to 90% RH noncondensing
TUV Certification	Certificate #: CU 72072412 02 Tested to: UL 61010-1: 2004 R7 .05 CAN/CSA-C22.2 61010-1: 2004
RoHS	Compliant
Warranty Period	1 year

XR-100 Options

- The XR-100 preamplifiers are available with extender lengths of none, 1.5”, 5”, and 9”.
- The XR-100 is available with a circuit to regulate the detector temperature when not used with Amptek power supplies.
- The XR-100 may be used inside a vacuum chamber or with a vacuum feedthrough. Contact Amptek for more information.

4.1 XR-100 Mechanicals

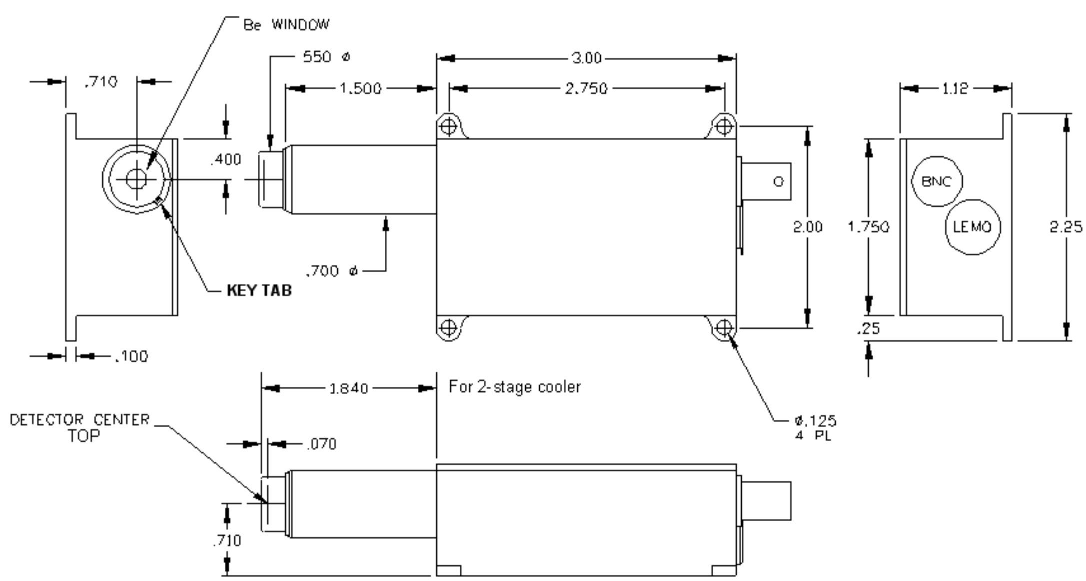
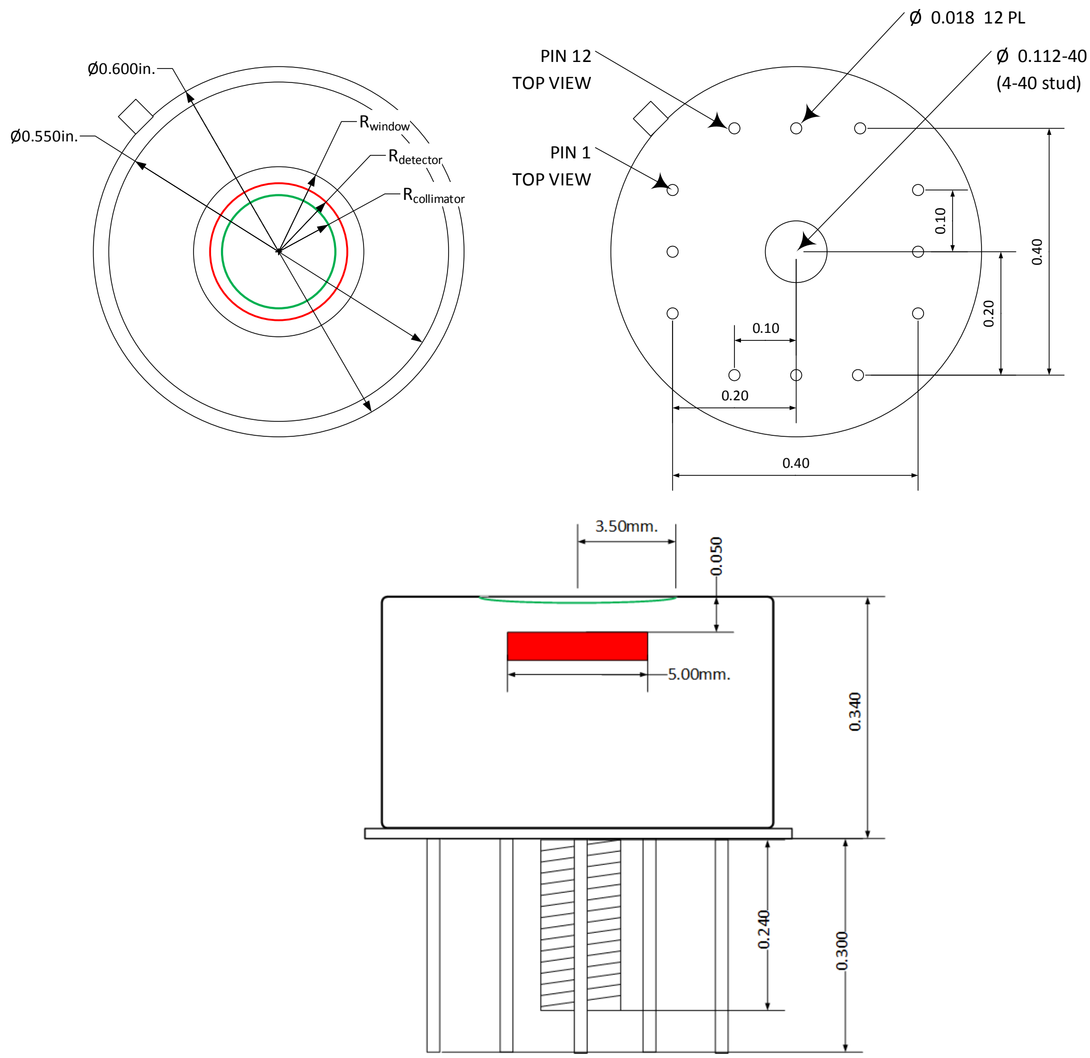


Figure 9. Mechanical design of standard XR-100 (1.5” extender). Visit www.amptek.com or contact Amptek for dimensions of the other configurations (5” extender, 9” extender, etc.).

5 Amptek CdTe Detector Mechanical Specifications

- All dimensions shown are in inches unless otherwise specified.
- All dimensions are "typical" unless a tolerance is listed.

5.1 Dimensions



25 mm^2 x 1 mm CdTe

25 mm^2 CdTe detector with Be window r

Figure 10. Key dimensions of a 25 mm^2 x 1 mm thick CdTe detector.

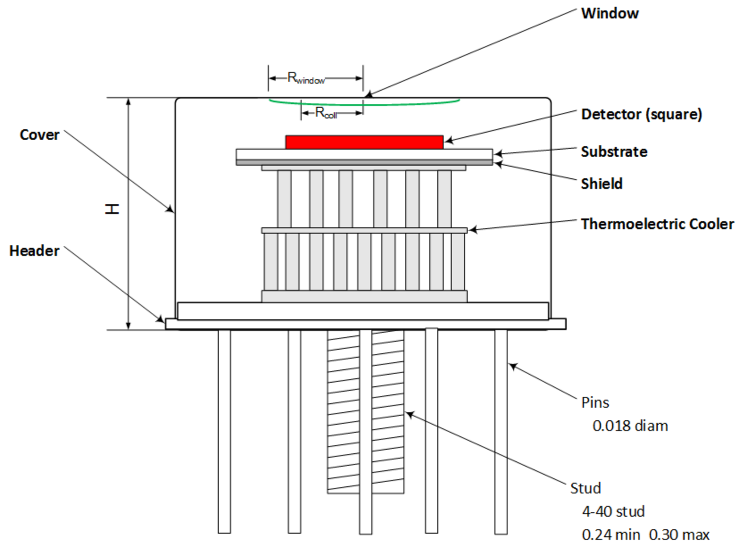
Compatibility

- The reset CdTe detector is NOT electrically compatible with Amptek's SiPIN, SDD, or FAST SDD® detectors.
- The transistor (-T) and resistive (-R) feedback configurations are not compatible with any of Amptek's other configurations.

5.2 Construction

The detector element (the CdTe diode itself) is a square chip, mounted on a substrate, which is mounted on a thermoelectric cooler, which is attached to the TO-8 header. Over this assembly is a cover (typically nickel) containing a window (typically beryllium) through which low energy X-rays pass.

- *CdTe detector:* The detector is a square CdTe Schottky diode with no guard ring.
  - The top contact is 20 nm of Pt.
  - There is a dead layer of approximately 200 nm CdTe below.
  - The thickness of the detector has a tolerance of +/- 50 µm.
- *Window*: The Be windows are attached to the cover with a lead-free solder. The carbon windows are epoxied (so should not be used in a helium environment)
- *Cover:* Standard units are 0.25 mm (10 mils) thick nickel, with an O.D. of 0.55".
- *Header:* Made of Kovar. O.D. is 0.60".
- *Substrate:* Alumina (Al_2O_3)



All dimensions in inches except as noted.
All dimensions typical.

6 Electrical Interface

6.1 Detector Output Connection Diagram

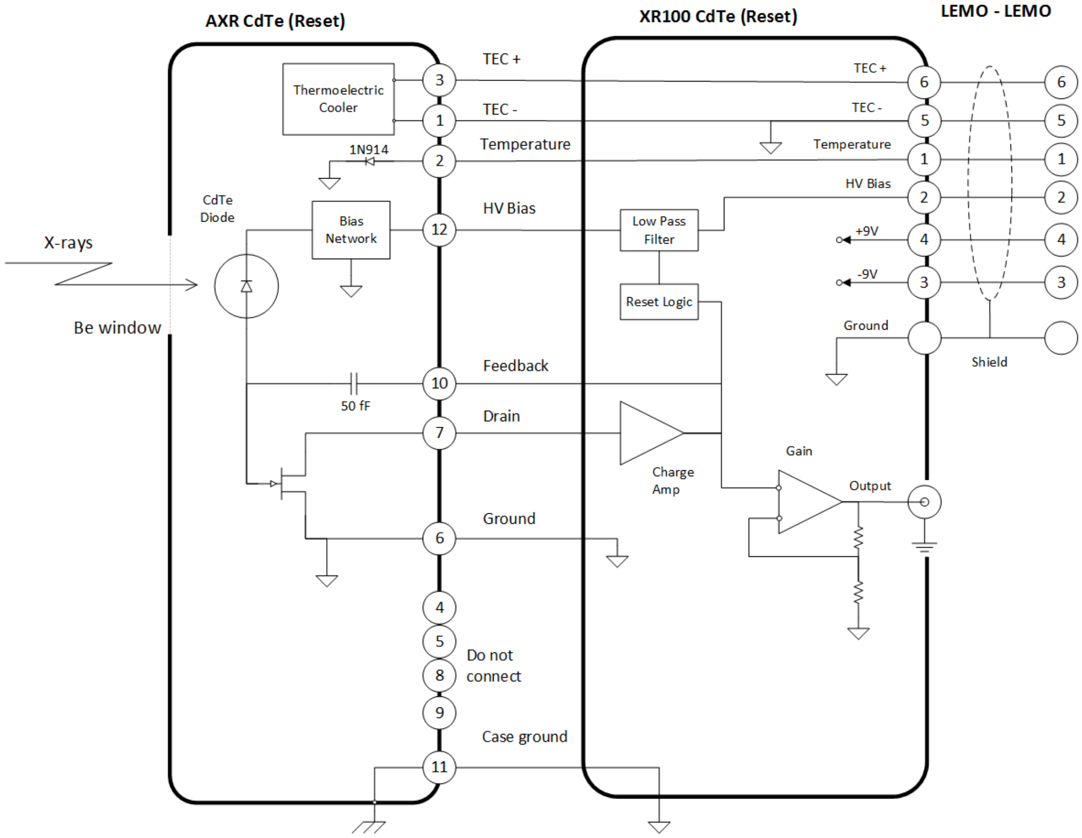
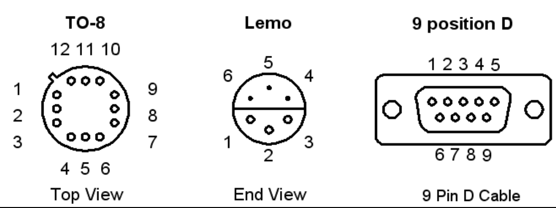


Figure 11. Block diagram of the XR-100CdTe and its electrical interface.

6.2 XR-100 Preamplifier Output Connection Diagram



	6 pin LEMO on XR-100 LEMO P/N ERA.1S.306.CLL		**9 pin D Connector on ACH-403 cable** Standard 9-pin D
1	Temperature Monitor	1	+9 V Preamp Power
2	HV Bias (-130 V)	2	+9 V Preamp Power
3	-9 V Preamp Power	3	Cooler power (3.5 V / 0.45 A MAX)
4	+9 V Preamp Power	4	Temperature Monitor
5	Cooler power return	5	HV Bias (-130 V)
6	Cooler power (3.5 V / 0.45 A MAX)	6	Ground (signal & chassis)
Shield	Ground (signal and chassis)	7	Cooler power return
		8, 9	Ground (signal & chassis)

6.3 Preamplifier Output Signal

The plots below illustrate the typical signals seen from a reset CdTe preamplifier and DPP.

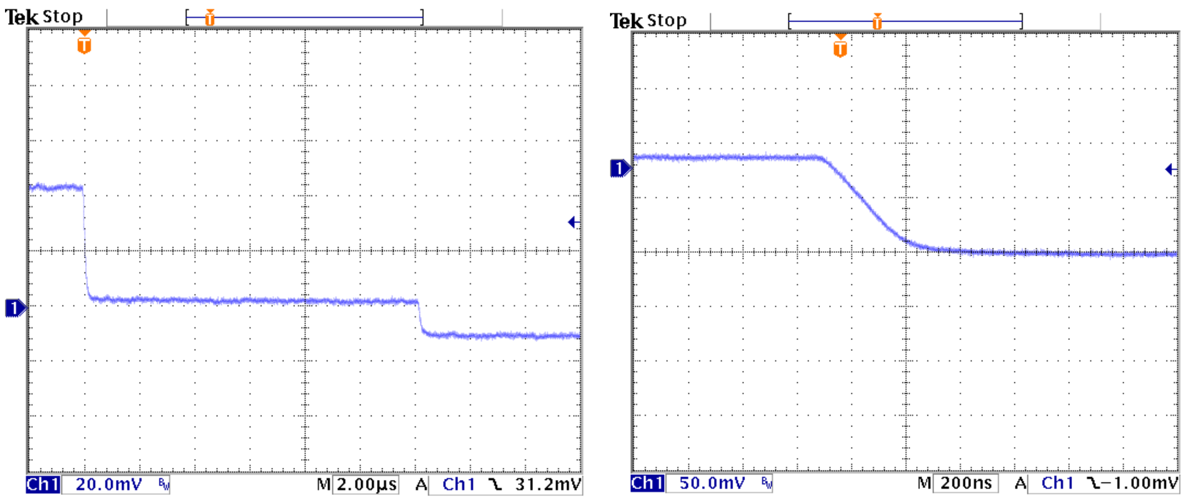


Figure 12. These traces illustrate typical output pulses with a reset CdTe detector. Each X-ray interaction results in a positive going step of ~0.8 mV/keV. Some preamplifiers have a custom gain so the step size may differ.

6.4 Preamplifier Reset Signal

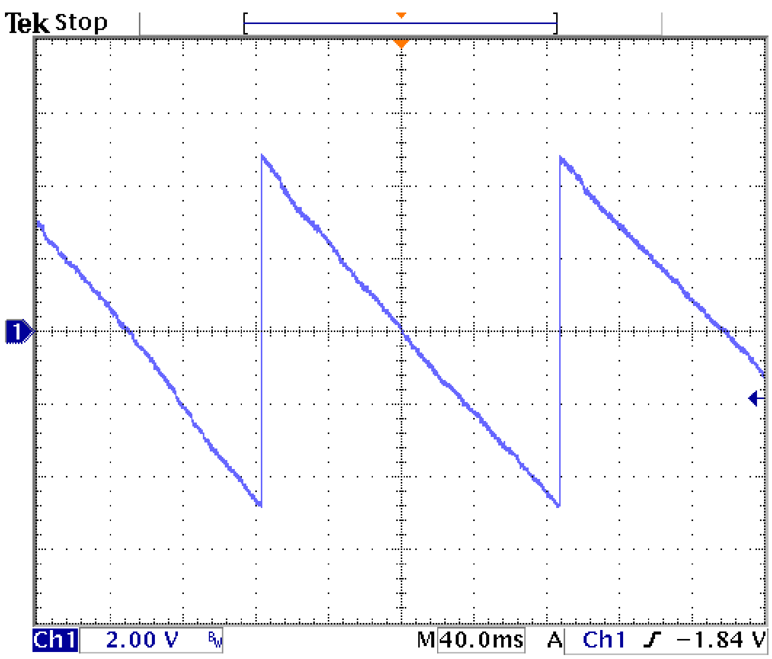


Figure 13. These traces also show the preamp output but on a different voltage and time scale to illustrate the reset. The small steps from each signal integrate towards the negative rail, where a reset signal is generated. This results in a sawtooth of several volt amplitude. The period depends on the total current through the detector (signal current plus leakage current

This was measured using an XR-100, which has a reset range of about +/-5V. The PA210 and PA230 have reset ranges of about +/- 2.5V.

6.5 Shaped peak and input to the ADC Signals

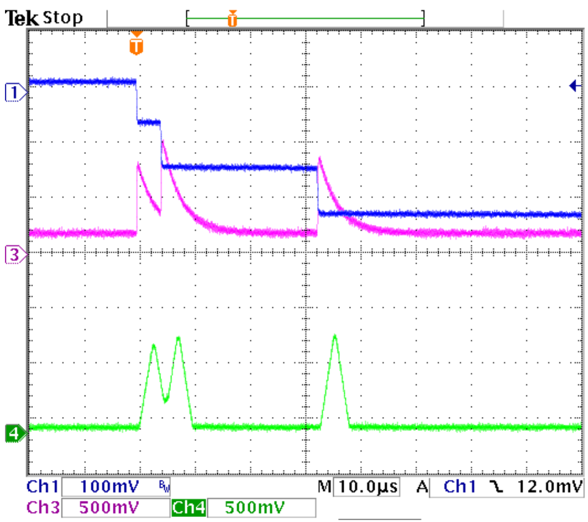


Figure 14. This trace show the preamplifier output (blue), the input to the ADC (ink), and the shaped output (green) for typical pulses.

Note that the ADC input has an offset of approximately 0.2 V, with positive going pulses exhibiting an exponential 3.2 us tail. A 1V step into the ADC corresponds to a full scale event in the histogram.

6.6 Cooling

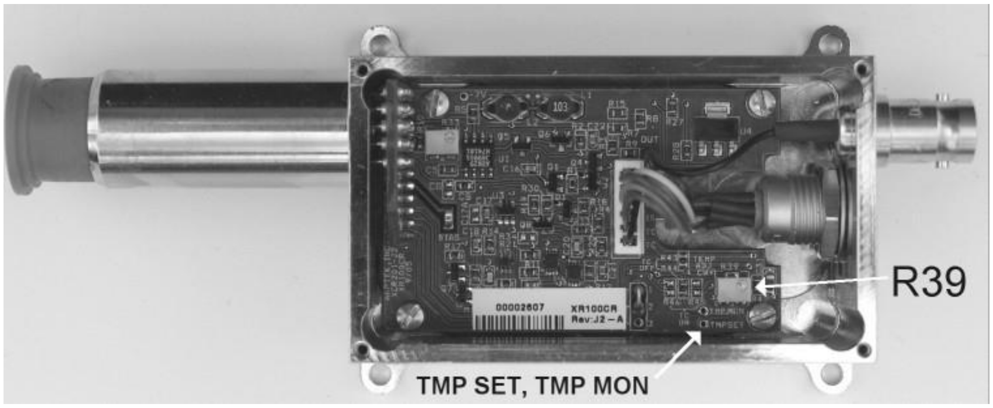
Recommended temperature

For CdTe, we recommend a temperature between 230 and 240K.

Temperature controller

The XR-100CdTe includes a closed loop temperature controller that regulates the cooler temperature. By default it is enabled and set for maximum cooling and therefore does not regulate on its own. The thermoelectric cooler can achieve 85 ^{o}C temperature differential, so at room temperature the detector can reach 220 K to 230 K.

The PX5 includes a power supply for the thermoelectric cooler which provides its own regulation. When the XR-100CdTe is to be used with a PX5, set the XR-100CdTe control to maximum cooling and let the PX5 regulate. If the PX5 and XR-100CdTe are set to different temperature set points, whichever set point is set the warmest will control the detector temperature.



The figure above shows how to adjust the controller on the XR-100CdTe. Remove the top cover and adjust the R39 pot to achieve the desired TMP SET value. This is the set point temperature. It reads in mV with the calibration curve shown in the next section. TMP MON shows the measured temperature in mV with the same calibration curve.

Temperature sensor

The temperature sensor in Amptek's detectors is a forward connected 1N914 diode. At a fixed current the forward voltage is a function only of temperature as shown below. Amptek's standard processors use a 730 μA current yielding the calibration curve shown. The calibration will change if a different current is used.

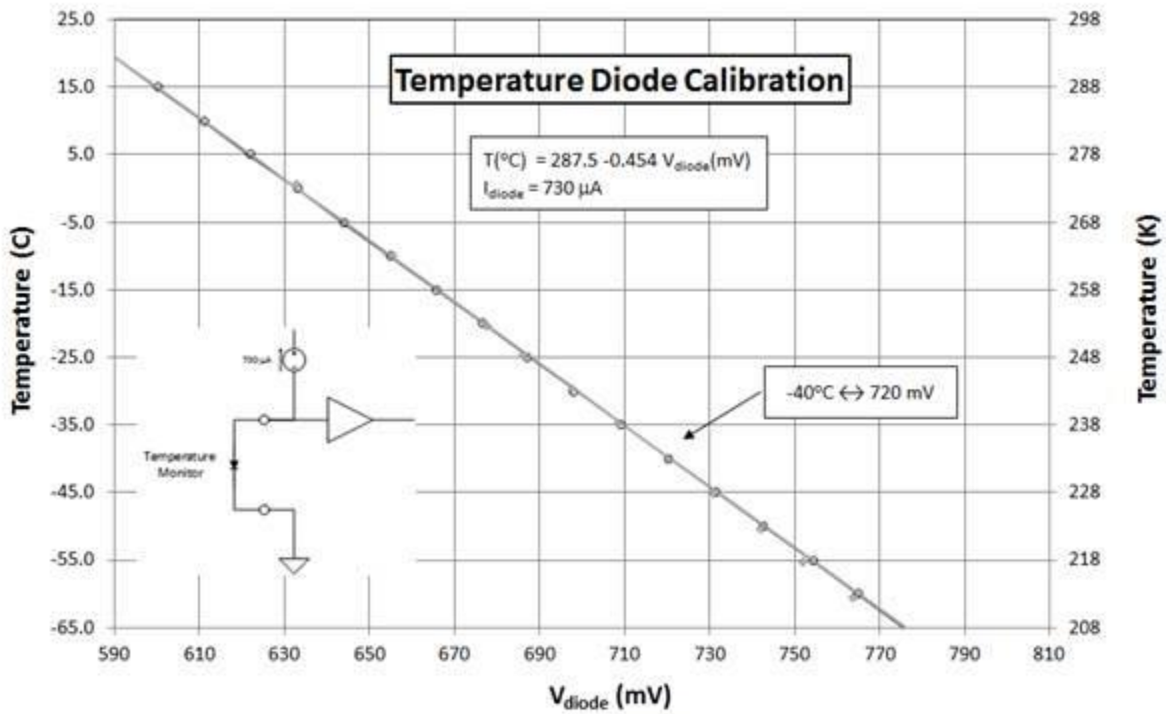


Figure 15. Temperature diode calibration curve (with a 730 μA current).

Thermoelectric cooler

The plot below shows the typical voltage across the cooler and the current through the cooler, as a function of the temperature across the cooler at a base temperature of 30 °C. Cooling is improved at a higher base temperature.

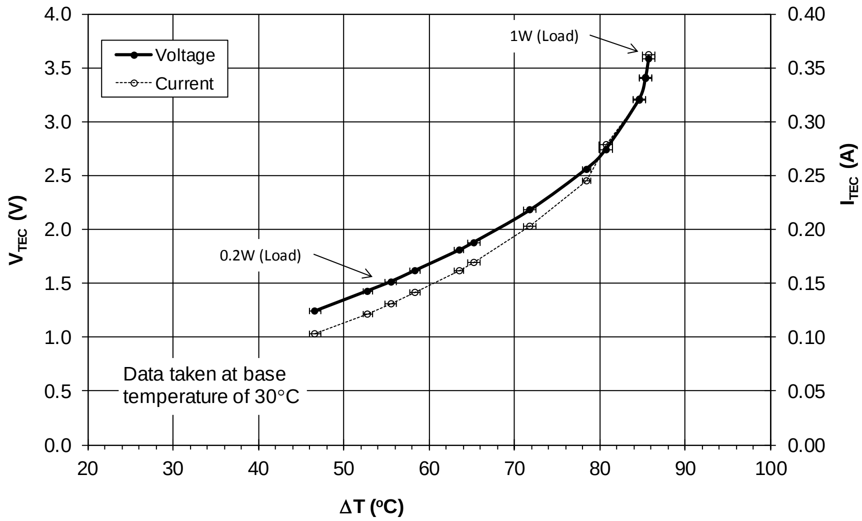


Figure 16. Typical characteristics of Amptek's thermoelectric cooler.

Note that ΔT is difference between the temperature of the detector and that of the base, the TO-8 header and stud. This is typically warmer than the ambient environment. Good performance requires the base to be kept as cold as feasible. Note that the power drawn by the cooler decreases rapidly with ΔT. If maximum cooling (ΔT = 85 °C) occurs at 1 W, at 0.5 W ΔT is about 78 °C, and at 0.2 W, ΔT is 55 °C.

6.7 Supply Voltages

High Voltage

Bias voltage for Amptek's CdTe detectors typically range from 400 to 800V at a current of a few 5 μA. Amptek measures performance at 500V. In general, increasing the bias voltage will improve charge collection (thus reducing the hole tailing and giving a more Gaussian peak) but the electronic noise will increase (thus increasing FWHM at low energies). The optimum bias depends on the application. As a general rule, higher X-ray energies benefit more from higher bias.

There must be very low noise and ripple on the HVPS. Amptek's power supplies include several low pass filter stages.

Low Voltage Supplies

The preamp power should be between +/- 8 and 9 VDC at 15 mA. There must be < 50 mV p-p noise (lower noise is recommended).

7 Operating Notes with Amptek power supply

If the XR-100CdTe is to be used with a power supply from Amptek, e.g. a PX5, PC5, or X-123, then follow the instructions in the “Quick Start” guide provided to you and in the “User Manual” for your power supply.

8 Operating Notes without Amptek power supply

If the XR-100CdTe is to be used with your own power supplies, then follow these instructions.

CAUTION: SUPPLY VOLTAGES MUST BE PROPERLY CURRENT LIMITED when using the XR-100CdTe without a PX5 power supply. Current should be limited to values listed in section 7.2

8.1 Equipment Required

- Power Supplies
  - A dual tracking +/-9 VDC @ 35 mA with voltage meter & current limit
  - A zero to +3.5 VDC @ 0.7 A adjustable with voltage and current meter
  - A zero to +500 VDC adjustable @ 25 µA (see HV requirements)
  - Equivalent supplies, such as Amptek’s PX5 or PC5, may be used.
- Multimeter with high input impedance (>1000 MΩ).
- Signal processing electronics. For a CdTe detector, a digital pulse processor such as Amptek’s PX5 or DP5 is strongly recommended. The signal processing electronics should include pulse shaping and multichannel analysis functions.
- Oscilloscope
- Low energy radioactive x-ray source (preferably ^{241}Am or ^{57}Co)
- AC power outlet strip (preferably with surge suppression & EMI/RFI filtering).

8.2 Absolute Maximum Ratings

- Cooler power.............+0.7 AMPS
- Preamp power...........+/- 9 VOLTS
- Detector Bias (HV).... +1,000 VOLTS

8.3 Connections and Turn-On Procedure (without PX5 or other Amptek DPP/supply)

1) Turn all power supplies OFF. Plug all equipment to be used into one common AC power outlet strip. This will help prevent ground loops, which is crucial in getting good performance.
2) Set voltages and current limits on all power supplies as noted above. Turn supplies off.
3) Connect the LEMO CONNECTOR cable to the XR-100CdTe, according to the pin assignments given in section 6.1 of this manual.
4) Attach the OUTPUT of the XR-100CdTe to the INPUT of the signal processor. A BNC connector is provided on the rear panel of the XR-100CdTe. The output pulses of the XR-100CdTe are NEGATIVE.
5) Attach the OUTPUT of the XR-100CdTe to one oscilloscope input and the OUTPUT of the shaping amplifier to a second oscilloscope input.

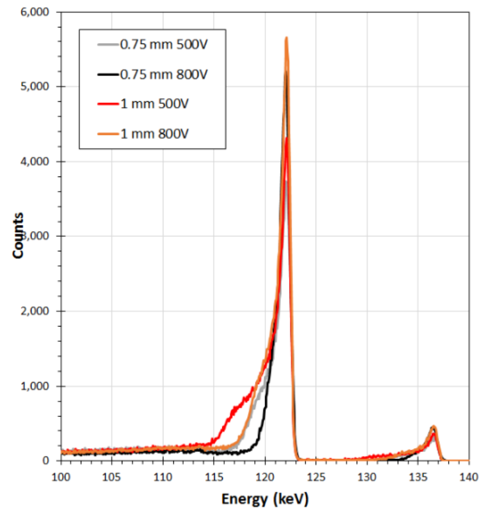
6) Turn ON the +/-9 VDC power supplies to power the charge sensitive preamplifier. Verify that both the + and - Volt outputs are between 8 and 9 Volts. NEVER EXCEED 9 VOLTS.
7) ALWAYS INCREASE THE HV POWER SLOWLY TO PROTECT THE INPUT FET. WHEN TURNING OFF THE XR-100CdTe, DECREASE THE HV SLOWLY TO ZERO VOLTS BEFORE TURNING OFF THE XR-100CdTe. IF THE FET IS DAMAGED DUE TO HIGH VOLTAGE TRANSIENTS, THE WARRANTY WILL BE VOID.
8) Increase the HV supply to +400 V. The output of the preamplifier should exhibit a sawtooth waveform as in section 6.3 at a fairly high frequency.
9) Power the temperature sensor using a current source, as shown in section 0, and monitor $V_{temperature}$ (mV) with a meter.
10) While observing the meter slightly increase the cooler supply current until the temperature reading starts to change on the meter. Observe that the voltage is increasing, indicating that the temperature is decreasing. The reset frequency will decrease as the detector cools.
11) Once the temperature gets below -40 °C the performance of the XR-100CdTe system will not change with a temperature variation of a few degrees. Now the XR-100CdTe is fully operational.
12) THE COOLER IS FRAGILE AND WILL BE PERMANENTLY DAMAGED IF EXCESSIVE CURRENT OR IF REVERSE POLARITY IS APPLIED. THE WARRANTY WILL BE VOID IF THE COOLER IS DAMAGED DUE TO EXCESSIVE CURRENT OR REVERSE POLARITY, OR IF THE THIN Be WINDOW IS DAMAGED.
13) Remove the red protective cover from the detector of the XR-100CdTe. Place the X-ray source in front of the detector.
14) The output of the signal processor should show the X-ray pulses as shown in section 6.3.
15) Once the temperature has stabilized (about one minute), start taking data on the MCA. For normal operation there is no need to monitor the temperature.

9 CdTe Variations

The standard CdTe detector offered by Amptek and described in this manual has a volume of 5x5x1 mm^3 and uses a reset-style preamplifier. This has proven to provide very good performance for a wide range of application. Nevertheless, Amptek provides some variants. And there are two variants, now obsolete but documented here for completeness.

9.1 Thickness and area options

0.75 mm thick

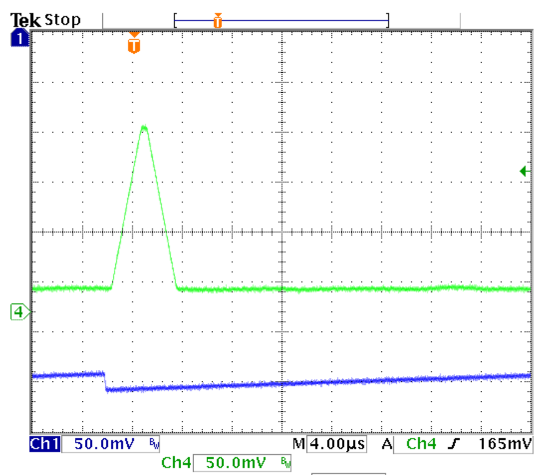


Amptek can make custom units with a thickness of 0.75 mm. As shown in section 3.4, up to 60 keV, the efficiency is almost the same as 1 mm, and the difference is small up to 100 keV. The thinner detector gives better charge collection (for the same bias), as seen in the plots to the right. The electronic noise is, however, about 30% higher due to the increased capacitance. For applications in the 20-60 keV range, it can be better than the 1 mm thickness.

7 x 7 mm

Amptek can make custom units with an area of 7 x 7 mm, almost twice that of the standard units. This increases the count rate in low flux applications and the charge collection efficiency is about the same (determined by thickness). The electronic noise, however, is about twice that of the 25 mm^2, due to the increased capacitance and generation volume. The resolution at low energies is considerably degraded.

9.2 Resistive feedback



The reset-style preamplifier function well up to a count rate of about 50 kcps. Above this, however, the throughput drops because CdTe detectors require a relatively long reset recovery period. For higher rates, Amptek provides CdTe detectors with conventional resistive feedback. The feedback resistor increases the noise at long peaking times but at short peaking times the noise is similar to that shown in Fig. 5 for the reset preamp. As shown in the plot below, count rates over 200 kcps are feasible.

The oscilloscope trace on the right shows the preamp output in dark blue; the RC time constant is about 350 µs. The sensitivity of the preamp is about 0.16 mV/keV (a factor of five lower than the reset).

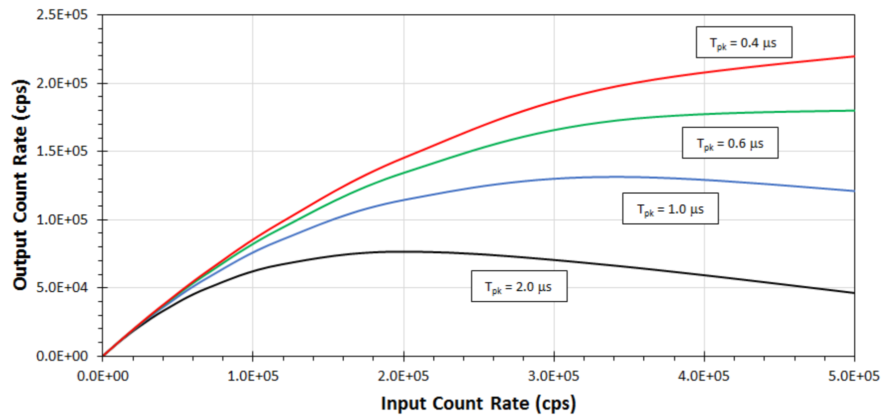


Figure 17. Plot showing output versus input rate for various peaking times, with a 0.4 µs flat top to minimize ballistic deficit.

The oscilloscope traces below show the important of pole zero compensation. In both plots, the dark blue trace shows the preamp output where the RC time constant is clear. The green trace shows the shaped output. The plot on the left is without pole zero compensation; an 300 µs undershoot follows each pulse, and if a subsequent X-ray occurs during this undershoot, the peak amplitude is incorrect causing a tail towards lower amplitudes. The plot on the right is with a 350 µs compensation.

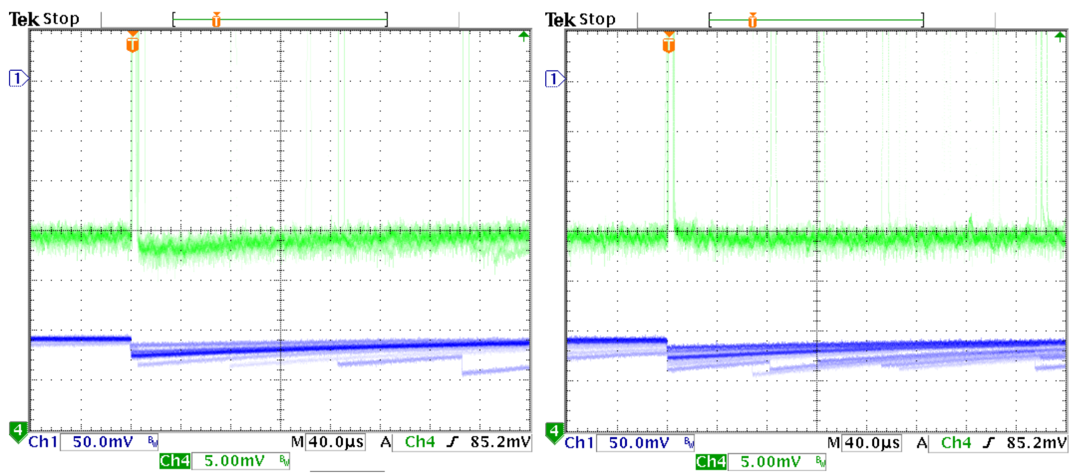


Figure 18. Plots showing pole-zero compensation for the Amptek's CdTe with resistive feedback.

9.3 Transistor feedback (obsolete)

For many years, Amptek sold CdTe detectors using a “transistor feedback” preamplifier. This design used a transistor in place of a feedback resistor. It’s advantage was lower noise, thus giving better energy resolution. The disadvantage is that the it does not have a fixed time constant: the time constant gets shorter at higher count rates. This can be seen in the oscilloscope traces below, where the blue trace shows the preamp output. The plot on the left, at low rate, shows a very long tail while the plot on the right, at higher rate, shows clear tail. The changing tail makes pole zero compensation problematic and so the transistor feedback is limited to count rates of <10 kcps. The reset preamplifier provides both better resolution and higher count rates and has thus superseded the transistor feedback.

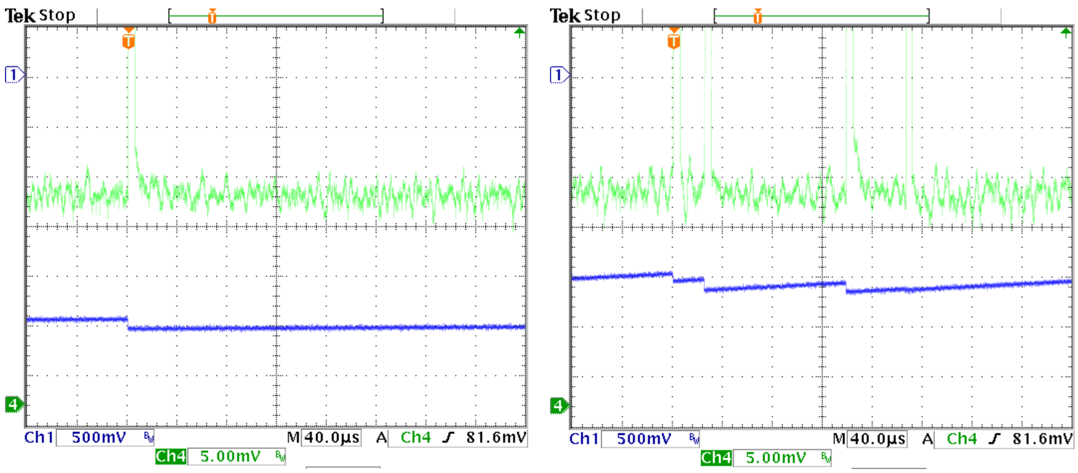


Figure 19. Plots showing typical outputs for Amptek’s now-obsolete transistor feedback, at low rate (left) and at high rate (right).

10 Troubleshooting

The XR-100CdTe has undergone extensive testing and burn-in before leaving the factory. If the performance of the system is not similar to the one recorded at the factory before shipping please perform the following tests:

If no spectrum is observed and no counts are observed:

- Double check all the power supply voltages and the signal connection.
- Make sure the XR-100CdTe output is connected to a high impedance (not 50 Ω).
- Using an oscilloscope verify the presence of the periodic reset signal shown in section 6.3. If there is no reset sawtooth the detector is not functioning.
- Verify that the reset period decreases when you place a source in front of the detector.
- Check your signal processor. There are many settings in a modern signal processor (gain, input offset, thresholds, etc.) which can prevent the processor from observing the X-rays.

If a spectrum is observed but the resolution is worse than expected or the spectrum is otherwise distorted:

- Check the detector temperature and the heat sink.

  First, make sure that cooling is properly enabled. Observe the temperature the detector reaches.

  Second, check the heat sink. The thermoelectric cooler draws up to 1.5 W from the detector to the XR-100 box. If this box is thermally isolated, it will heat up and the detector will heat up.

Third, inspect the Be window on the detector. There is vacuum inside the detector. If the seal on the window is damaged and air enters the detector will not cool fully.

- Look for interference noise.

  Connect the XR-100CdTe output to its signal processor and this to an oscilloscope. Remove all X-ray sources.

  Look for periodic noise pick-up on the scope by changing the time-base dial on the scope back and forth. If you find any periodic signal on the scope (other than the Reset Waveforms), try to eliminate its source or place the XR-100CdTe away from the pick-up area. Any periodic signal detected on the scope will degrade the resolution of the XR-100CdTe.

  The XR-100 produces very small signals which are susceptible to electromagnetic interference.

  PLACE THE XR-100CdTe AWAY FROM ANY COMPUTER TERMINAL OR CRT MONITOR. KEEP THE XR-100CdTe DETECTOR AWAY FROM MAGNETIC FIELDS.

- If you are using an Amptek signal processor and/or power supply refer to its User Manual and to Amptek's "Troubleshooting guide" and to Amptek's "Grounding and shielding" application note.
- IF ANY QUESTIONS REMAIN CONTACT THE FACTORY FOR FURTHER ASSISTANCE AND RETURN PROCEDURES. If you are using an Amptek signal processor please follow the instructions for "Saving a .MCA file and obtaining diagnostic data," which can be found on your installation CD.

11 Warranty and Technical Questions

11.1 Warranty

AMPTEK, INC. warrants to the original purchaser this instrument to be free from defects in materials and workmanship for a period of one year from shipment. AMPTEK, INC. will, without charge, repair or replace (at its option) a defective instrument upon return to the factory. This warranty does not apply in the event of misuse or abuse of the instrument or unauthorized alterations or repair. AMPTEK, INC. shall not be liable for any consequential damages, including without limitation, damages resulting from the loss of use due to failure of this instrument. All products returned under the warranty must be shipped prepaid to the factory with documentation describing the problem and the circumstances under which it was observed. The factory MUST be notified prior to return shipment. The instrument will be evaluated, repaired, or replaced, and promptly returned if the warranty claims are substantiated. A nominal fee will be charged for unsubstantiated claims. Please include the model and serial number in all correspondence with the factory.

11.2 Technical Questions

- Please refer to http://amptek.com/technical-support/
- Please have the model and serial numbers of your Amptek device(s) available. Please have available a description of the signal processing and other electronics used with the device.
- Contact Amptek at amptek.sales@ametek.com or +1 781-275-2242.