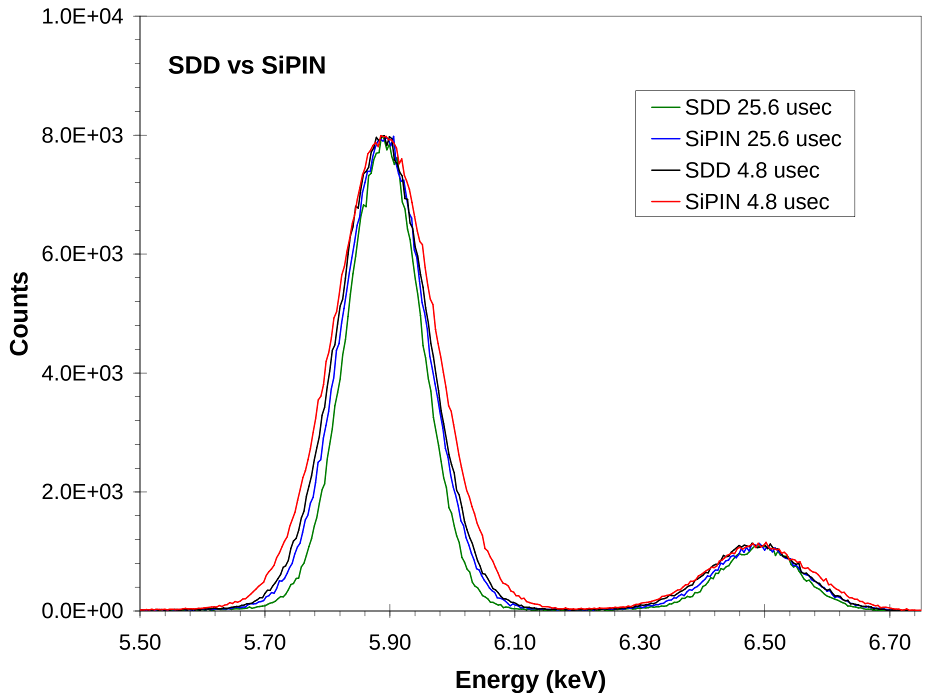
A COMPARISON OF SILICON DRIFT (SDD) AND SI-PIN DETECTORS

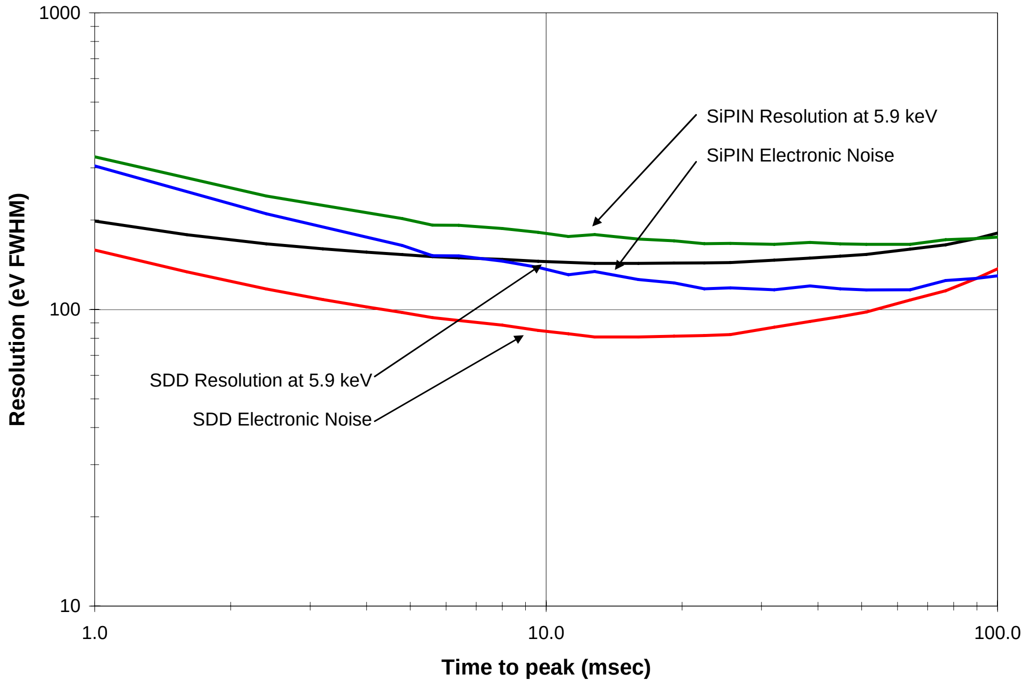
Amptek manufactures X-ray detectors using both Si drift detectors (SDD) and Si-PIN sensors, each of which has advantages in certain applications.

The key points are:

- The SDD has better energy resolution than a Si-PIN of the same area. The SDD has much better energy resolution at short peaking times, which is particularly helpful at high count rates. At the noise corner (the peaking time where the noise is minimal) the SDD's resolution is still better. So where the highest resolution is needed, or where good resolution is needed at high count rates, the SDD is the detector of choice.
- The Si-PIN is available with a larger active area and thicker depletion depth. Where resolution is not critical but high detection efficiency is important, the Si-PIN is the detector of choice.
- The SDD is a more complicated device to manufacturer so is more expensive than a Si-PIN. Where cost is critical, a Si-PIN may be the detector of choice.



Plot comparing ^{55}Fe spectra taken with an SDD (7 mm^2 active area) and a SiPIN (6 mm^2 active area) at 4.8 and at 25.6 μsec peaking time. The resolution of the SDD is better than that of the SiPIN, particularly at the shorter peaking time but the importance of this improved resolution depends on the application.



Plot comparing both resolution at ^{55}Fe (5.9 keV) and electronic noise, versus peaking time, for an SDD (7 mm^2 active area) and a SiPIN (6 mm^2 active area).

What is a "silicon drift diode"?

A silicon drift diode (SDD) is a type of photodiode, functionally similar to a PIN photodiode but with a unique electrode structure to improve performance. Amptek's SDDs are optimized for X-ray spectroscopy.

The key advantage of the SDD is that it has much lower capacitance than a conventional diode of the same area, reducing electronic noise at short shaping times. For X-ray spectroscopy, an SDD has better energy resolution while operating at much higher count rates than a conventional diode. The SDD uses a special electrode structure to guide the electrons to a very small, low capacitance anode.

The active area of Amptek's SDDs is comparable to that of Amptek's conventional Si-PIN diodes, e.g. we offer a 7 mm^2 SDD and Si-PIN devices of 6, 13, and 25 mm^2. Like the Si-PIN diodes, these are fully depleted 500 µm thick devices. Like all of Amptek's X-ray detectors, the SDD is mounted on a Peltier cooler in a small, hybrid package. The detector and its input components are cooled to 250 K at 50˚C ambient, or 220 K at 20˚C ambient, with low power dissipation and no cryogenics. Amptek's SDD's are available with the same windows, collimators, digital processors, etc as Amptek's other detectors. They do require a different preamplifier and a high voltage supply configured for negative bias.

How does a drift diode work?

A conventional Si-PIN photodiode is sketched in Figure 1. There are two planar contacts, the anode and the cathode, with a uniform electric field between them. An X-ray interacts at some location, ionizing the Si atoms and producing electron-hole pairs. The electric field sweeps the carriers to their respective contacts, causing a transient current pulse I(t) to flow through the diode. The cathode is connected to a charge sensitive preamplifier and to pulse processing electronics, which detect the pulse and measure its amplitude. The traces at the bottom illustrate the pulse shapes at the various signal processing stages.

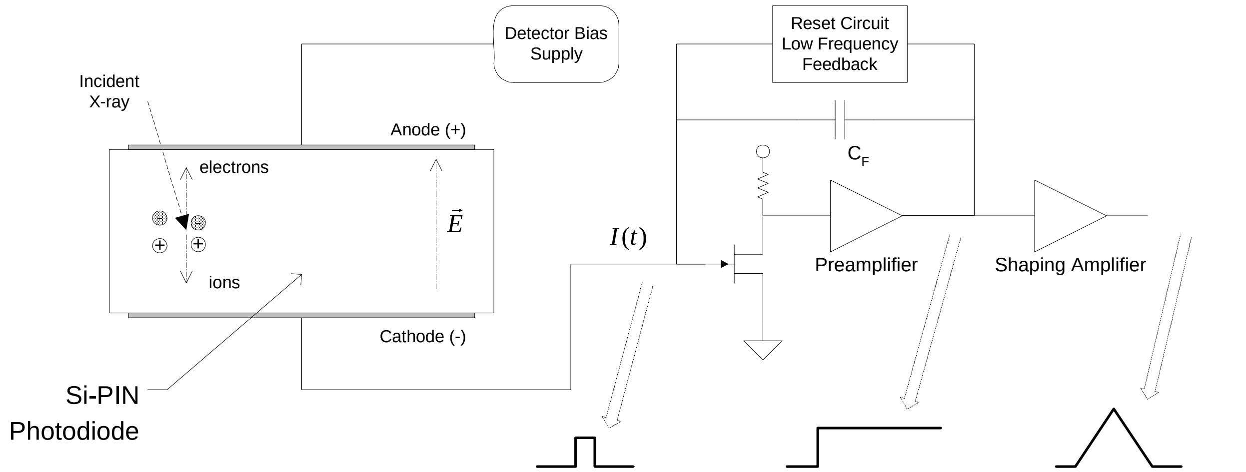


Figure 1. Sketch illustrating the operation of a conventional photodiode.

The drift diode, sketched in Figure 2, uses a planar cathode but the anode is very small and surrounded by a series of electrodes. The SDD is cylindrically symmetric, so the anode is a small circle and the drift electrodes are annular. These electrodes are biased so as to create an electric field which guides the electrons through the detector, where they are collected at the anode. The rest of the signal processing electronics is nearly identical to that used with the Si-PIN diode.

The small area of the anode keeps the capacitance very small. Since the active volume of the diode is enlarged by adding more electrodes with the same anode area, the input capacitance is independent of detector area. This is important because the dominant noise source in silicon X-ray spectroscopy is voltage noise, which is proportional to the total input capacitance and increases at short shaping times. The SDD, with its low capacitance, has lower noise, particularly at very short shaping times.

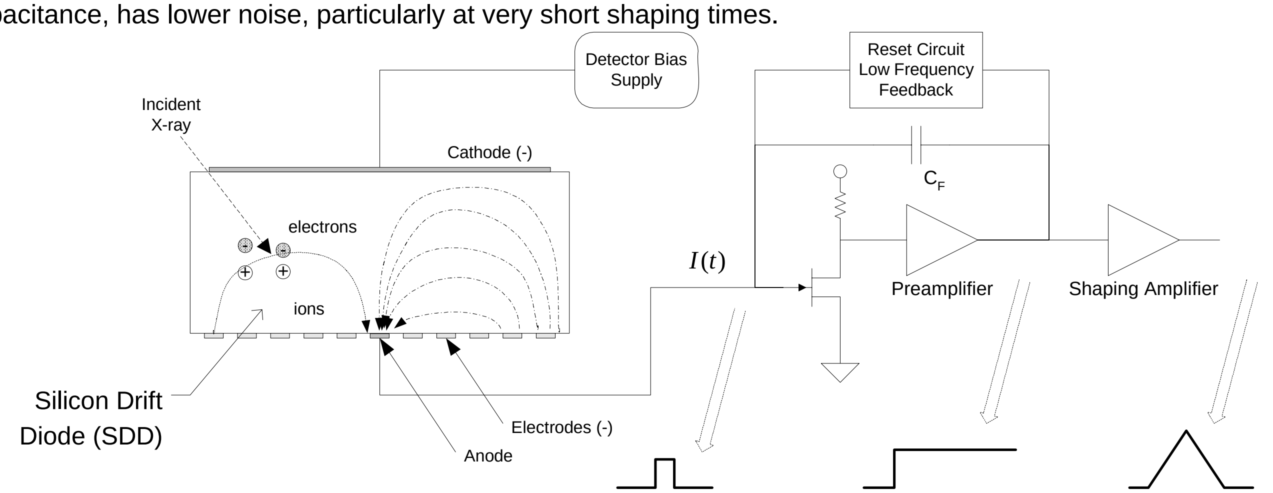


Figure 2. Sketch illustrating the operation of a silicon drift diode.

What are the advantages of drift diodes?

The key advantage of the drift diode is its low capacitance, which results in very low series noise. We measured the resolution of a 6 mm^2 Si-PIN and a 7 mm^2 SDD at 5.9 keV using an ^{55}Fe source under the same conditions. At 4.8 μsec peaking time, the SDD had a resolution of 152 eV FWHM, while the Si-PIN had a resolution of 195 eV FWHM. At the optimum shaping time, the noise corner, the SDD has better resolution: 142 eV FWHM for the SDD vs. 161 eV for this particular Si-PIN, which is typical. This implies that the electronic noise of the SDD at the noise corner is 67 eV FWHM vs. 101 eV FWHM for the Si-PIN. But the SDD's optimum resolution is at a shorter shaping time, 9.6 μsec versus 32 μsec for the Si-PIN. **This enables the SDD to simultaneously deliver lower electronic noise and higher count rates, which is its primary advantage.** This comparison is for the smallest area detectors fabricated by Amptek. Since capacitance scales with area for the Si-PIN but not the SDD, the SDD's advantage will be even greater for larger areas, but at this time the SDDs are only available in the smaller areas.