

## **Construction of an Alpha- Beta and Gamma-Sensitive Radiation Detector on the Basis of a Low-Cost PIN-Diode**

Bernd Laquai, 12.6.2012

Encouraged by the observation, that the Am241 alpha source of an old smoke detector and a BPW21R PN-diode in an opened TO-5 package (glass window removed) generates a signal strength that drives the measuring amplifier deeply into saturation, I started to re-consider the possibility of constructing a detector from a low-cost PIN diode that also is sensitive to alpha radiation with high spatial resolution. The issue is that opening the TO-5 package of a photo detector exposes the silicon and the very thin bonding wire to many other unwanted influences. It is not only the light sensitivity but also the mechanical sensitivity that may cause some challenges. What would be required is a small detector window made from a low density material transparent to alpha radiation but not transparent for light and that additionally protects the silicon chip against dust and other polluting substances.

I checked the thickness of regular aluminum foil available from the supermarket more thoroughly. In agreement with numbers from literature I measured a thickness between 10 and 20  $\mu\text{m}$ . This however is also the approximate half value thickness of a 5MeV alpha particle, emitted for example from the Am241 source of an old smoke detector. Since the absorption law shows an exponential characteristic it can be concluded that only a portion of the alpha particles will be absorbed by such a foil and a large amount will still pass through the foil just reduced in energy.

Therefore I first tested the already opened BPW21R detector and inserted such a foil between source and the detector comparing the results before and after insertion. And indeed, the strong alpha pulses were still visible at the output of the amplifier and only appeared to be reduced in strength a bit. Most of the pulses did not drive the amplifier in the saturation anymore but were much stronger than beta- or gamma pulses.

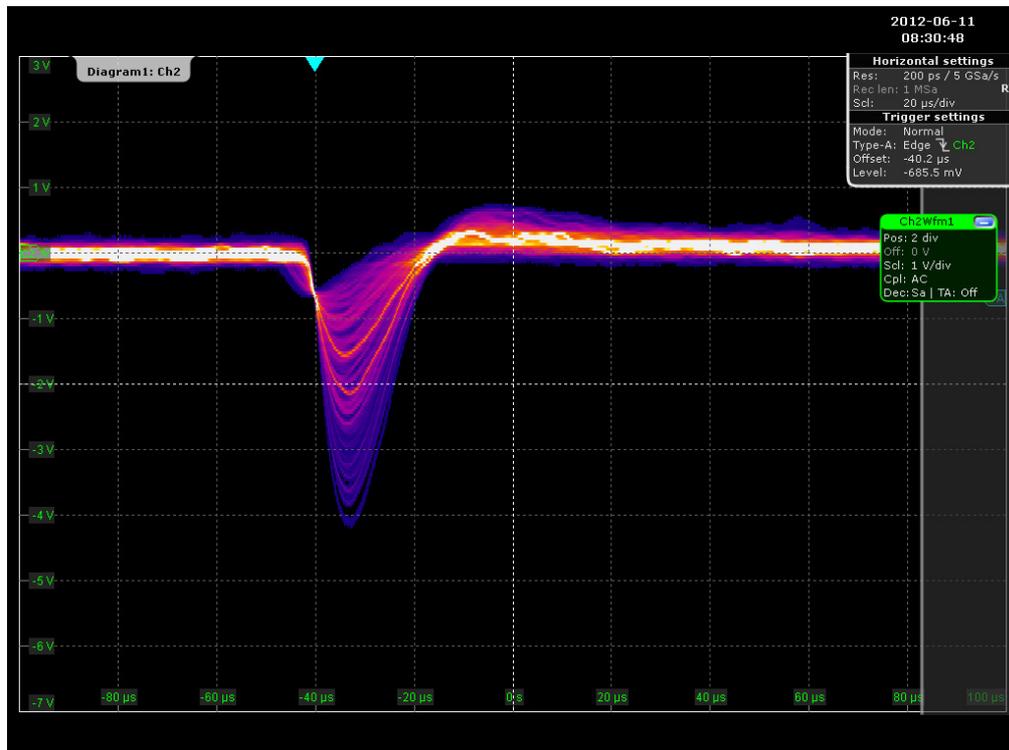
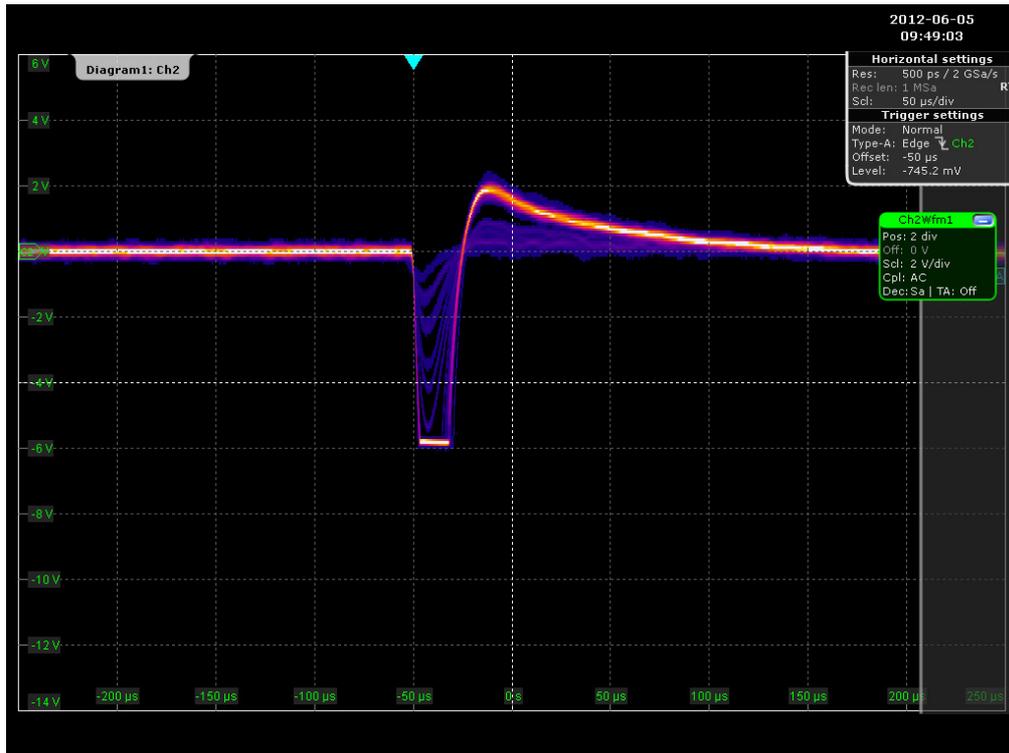


Fig. 1a, b: BPW21R with opened package. Alpha pulses without (above, 2V/div) and with foil (below, 1V/div)

However, the BPW21R is a photo detector with a regular PN-junction and therefore its sensitivity for beta and gamma radiation is pretty limited compared to the BPW34 PIN diode used so far. For this reason I ordered a S1223 PIN diode manufactured by Hamamatsu that is available in a TO-5 package with glass window. This device is marketed as a low noise and fast IR sensitive PIN detector with low capacitance and small dark current. The plan was now to replace the glass window with the aluminum foil to construct an  $\alpha$ -,  $\beta$ -,  $\gamma$ -sensitive PIN detector. I succeeded with this plan and I believe with a bit of a feeling for precision mechanics this is a feasible do-it-yourself solution.

First I cut the top of the package with a small cutting wheel (about 0.5 mm below the top surface). I broke the glass and removed it carefully. Then I soldered the top again to the package body with a fine soldering tip forming a continuously solid solder seam. The advantage of this approach is that the top provides a much better support for the foil than the wall of the body.



Fig. 2a, b: An opened S1223 PIN photodiode and its removed top

Then I coated the support of the top with instant adhesive using a super fine screw driver and attached a small piece of aluminum foil with some overlap to it. After drying of the adhesive I cut back the overlap to about 2mm with a small pair of scissors. I flipped down this overlap covering the solder seam and I fixed it with a thin wire-wrap wire such that the resulting container of the diode is absolutely tight against light.

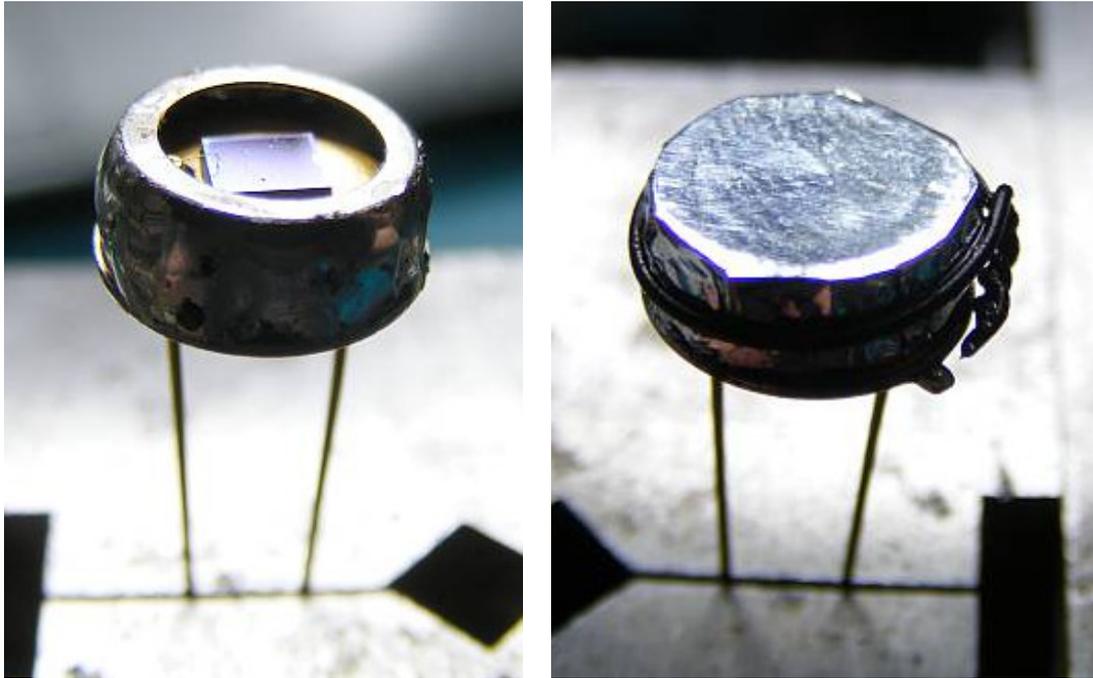


Fig. 3a, b: Closed TO-5 package with removed glass and final S1223 alpha- beta- gamma-detector

Finally I soldered this detector on a PCB with the TIA amplifier developed for the „Stuttgarter Geigerle“ and connected it to a scope. In this amplifier I used the LTC6241HV OP from Linear Technology, but I believe that the AD8666 from Analog Devices certainly will show the same results.

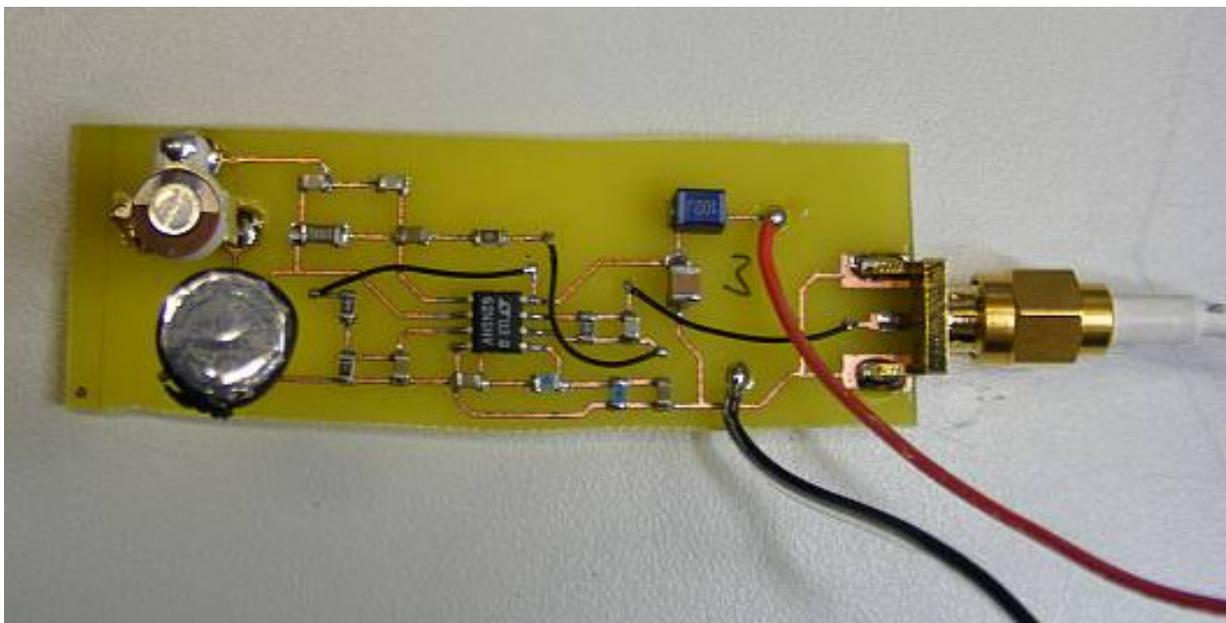


Fig. 4: Amplifier using the S1223 alpha- beta- gamma-detector

During operation the S1223 showed very small noise values (ca. 13mV rms), a little better than using the BPW34. Also the bandwidth is broader (approx. 33MHz) compared to the BPW34. A measurement with the thorium-containing mantle of a petroleum lantern yielded the well-known pulses of about 1.6V height as with the BPW34. The mantle was enclosed in a paper envelope absorbing certainly all of the alpha radiation.

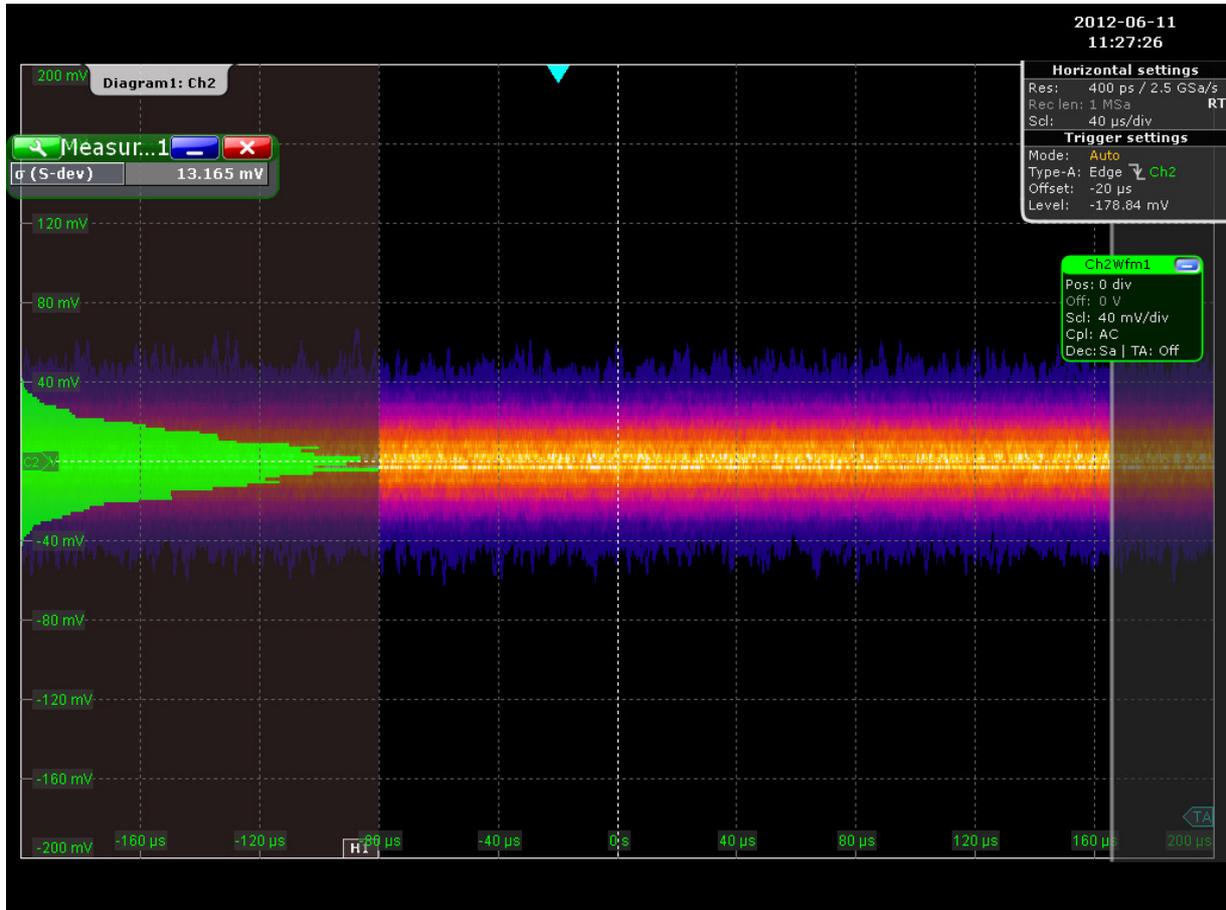
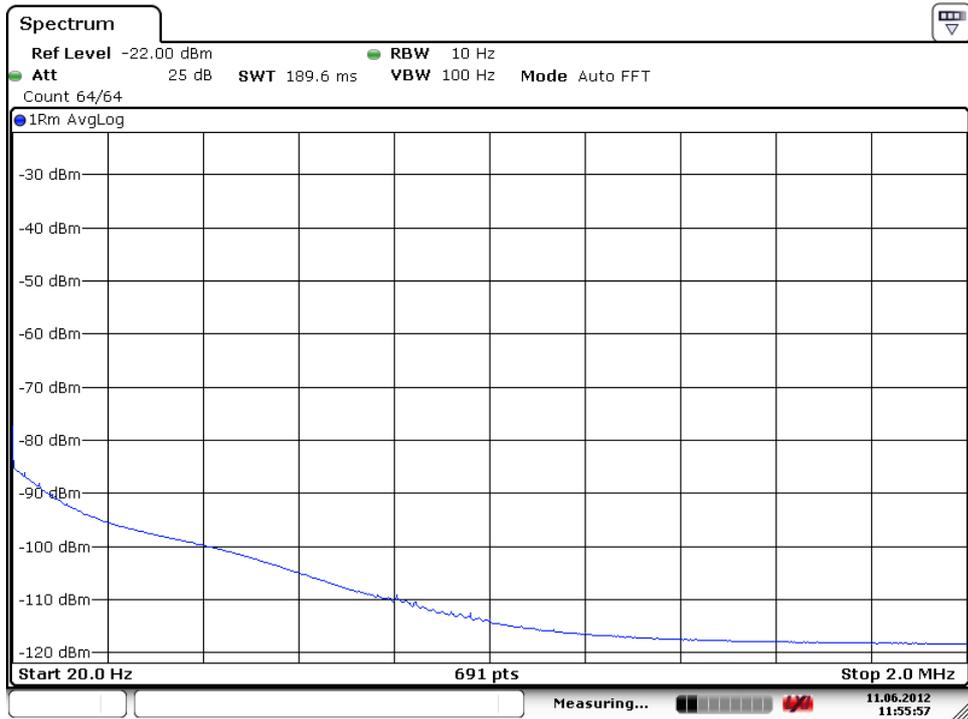
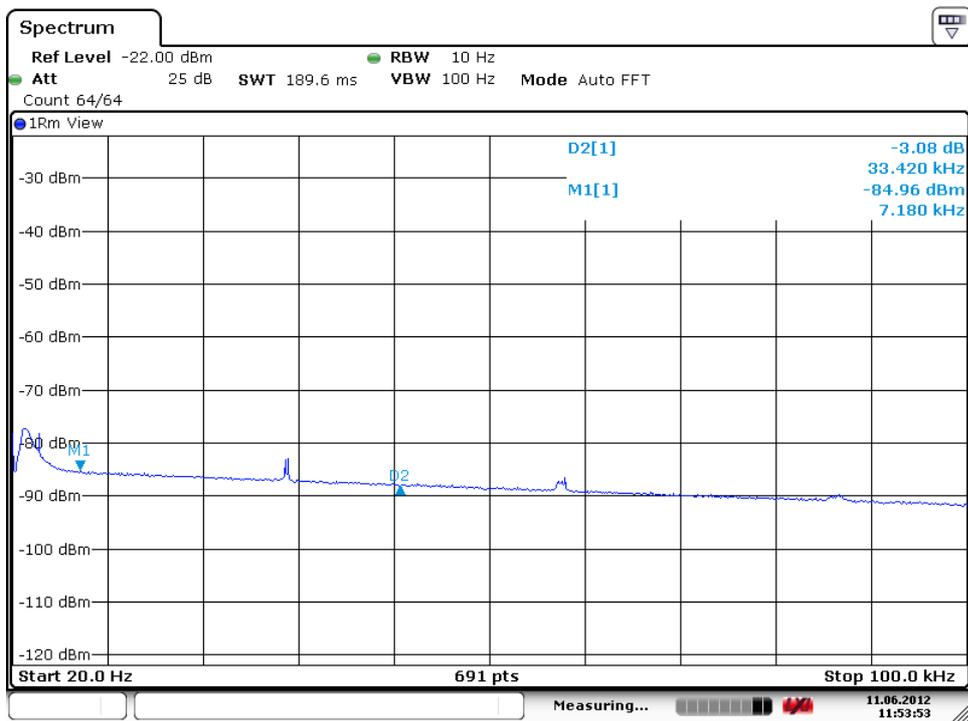


Fig. 5: Noise of the S1223 without signal (40mV/div, measured: 13.165mV rms)



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Fig. 6a, b: Bandwidth determined from the intrinsic noise of the amplifier with the S1223 PIN-Diode from Hamamatsu

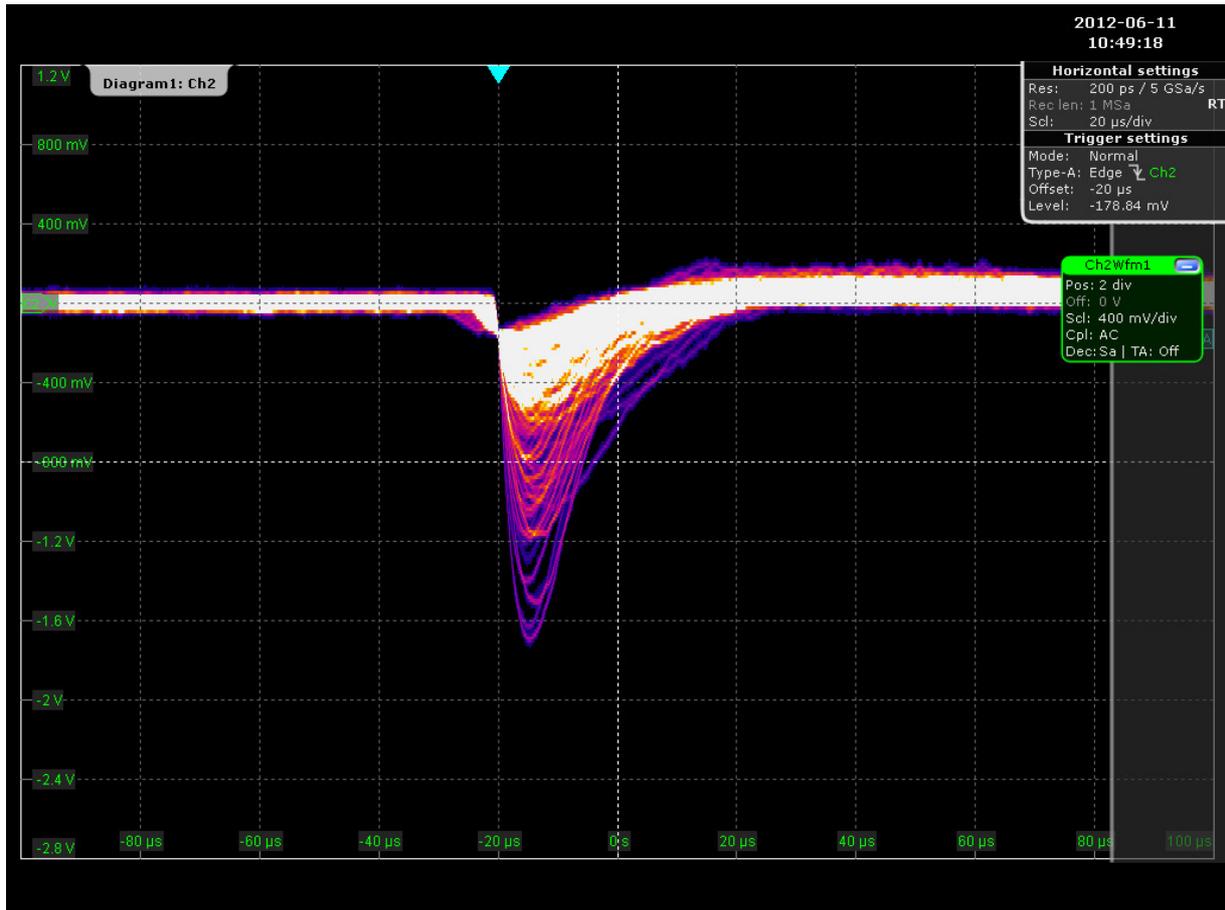


Fig. 7: Beta-/gamma-pulses of up to 1.6V induced by the thorium containing mantle at the measurement amplifier output (400mV/div)

Exposed to the Am241 source the expected effect showed up. In a clearly visible contrast to the beta- and gamma pulses other pulses of about 5V height popped up with high rate, obviously originating from the alpha activity of the source. A second additional foil almost completely stops these strong pulses. This proves that the constructed S1223 detector is sensitive to alpha radiation in addition to the beta- and gamma sensitivity. Therefore this detector is even more universally applicable than the BPW34. The higher cost of the S1223 (approx. 13Euro, status June 2012) and the effort for construction appears to be well justified in presence of the extended sensitivity spectrum. With respect to the cost it should be kept in mind that a Geiger-Mueller tube with alpha sensitivity is more expensive too compared to a regular one sensitive to only beta- and gamma radiation. There is a further advantage of the PIN diode detector: just by changing the comparator threshold one can electronically switch between alpha- and beta/gamma sensitivity. However adding a removable copper window covering the alpha detector additionally is recommendable for this purpose anyway. It protects it as long as alpha sensitivity is not needed.

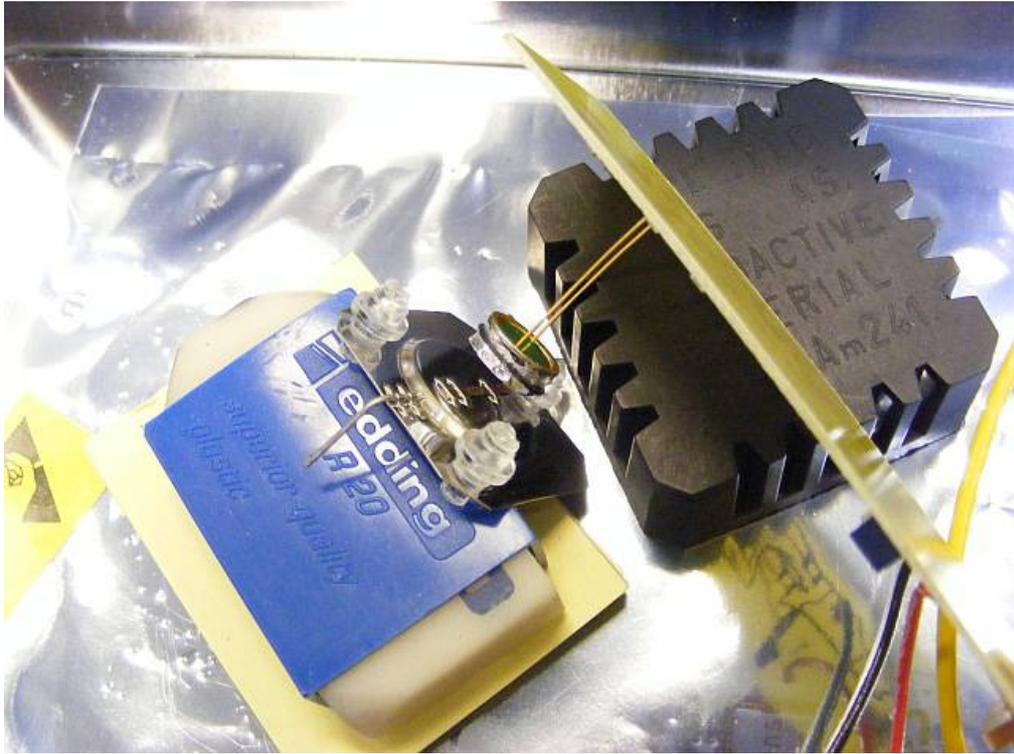


Fig. 8: Measurement setup for the Am241 source of the smoke detector

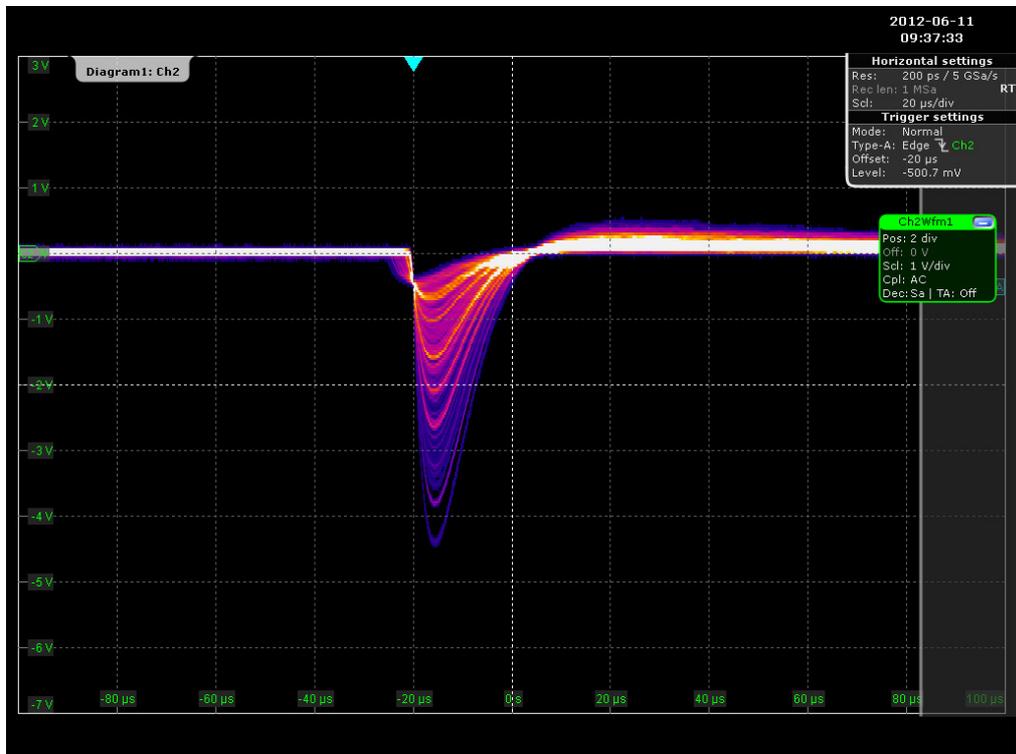


Abb. 9: Alpha-pulses of up to about 5V from the Am241 smoke detector source (2V/div)

A different result is obtained when putting the alpha sensitive detector on the surface of an uranium containing granite stone. It looks like the alpha energy is much stronger but the activity appears to be smaller. As with the BPW34 one can see the beta/gamma pulses as well, which pop up with heights of up to about 1.6V (AC coupling to the scope). In addition strong alpha pulses appear partly driving the amplifier into saturation at -6V.

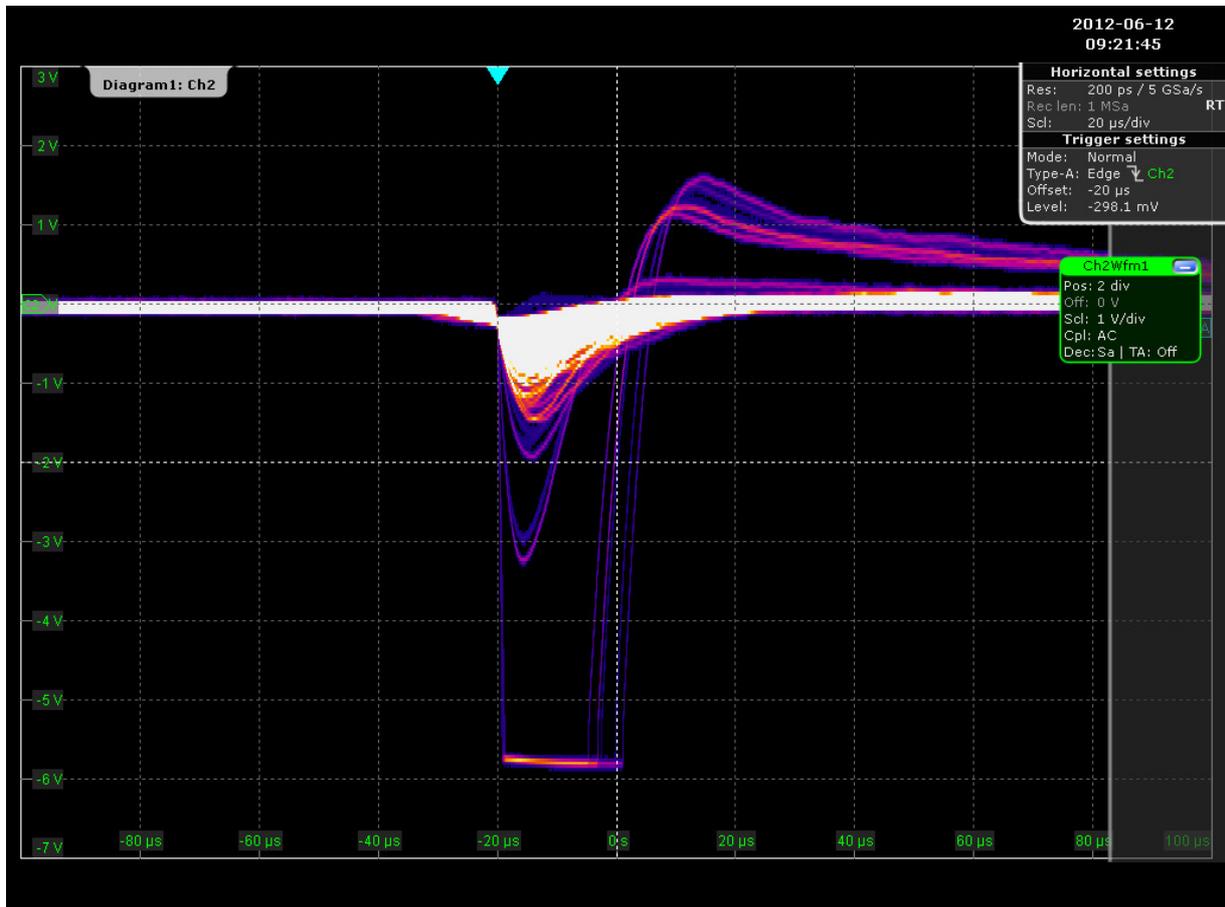


Fig. 10: Mixed alpha-, beta- and gamma-radiation of a granite stone from the Black Forest area

When a histogram of the pulse heights is produced now, limited to the heights of the alpha radiation, it clearly becomes visible that some heights appear more frequent than others and partly there are empty areas of amplitude that are not hit. From this one can recognize that the discrete energies of the alpha radiation are mapped directly into the height of the pulses and an energy spectrum is formed that is characteristic for the isotopes being present.

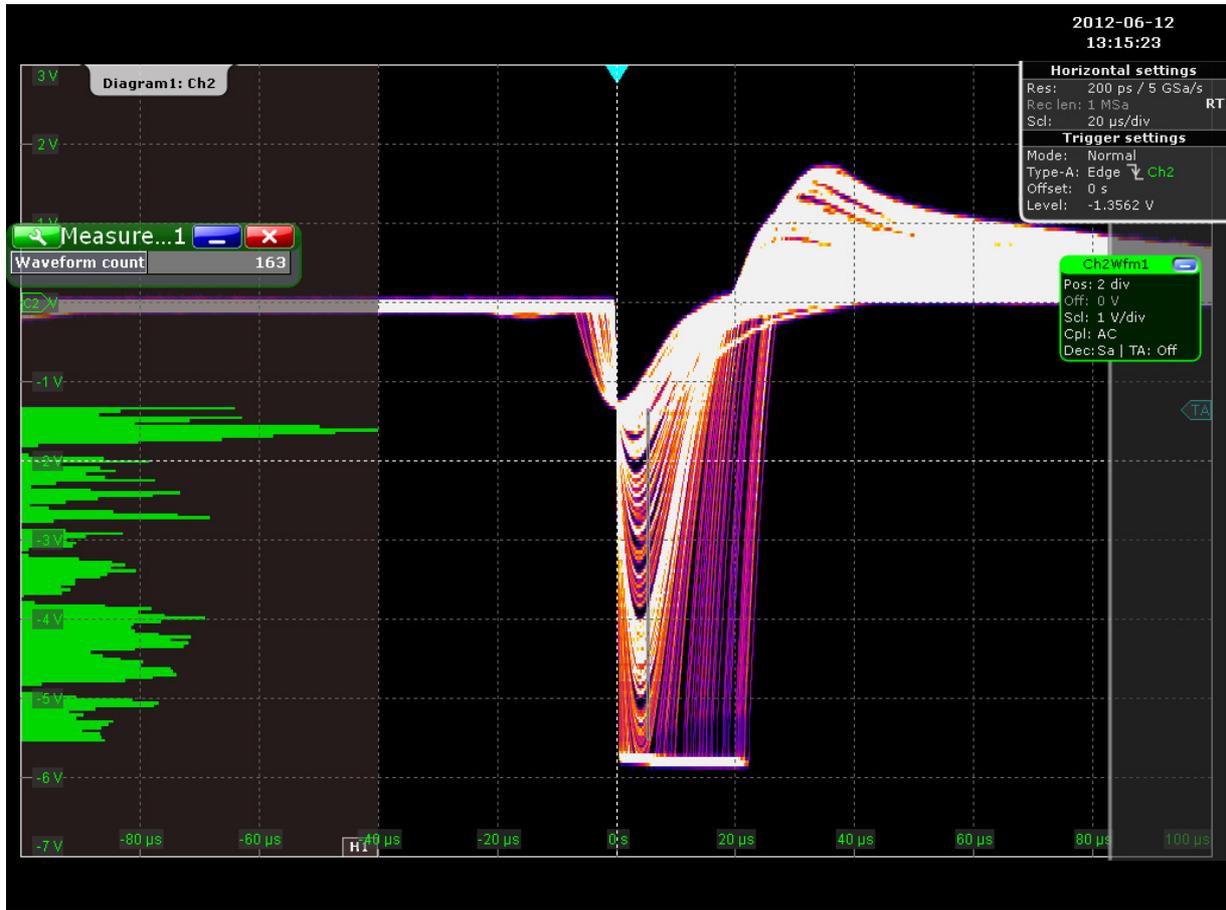


Fig. 11: Characteristic energy distribution in the histogram of the alpha radiation of a uranium containing granite stone