GaAs radiation-degraded detectors: gamma spectrometry at lowered temperatures

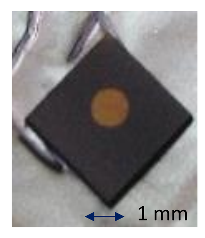
Andrea Šagátová[1,*], Norbert Gál[2], Andrej Novák[1], Soňa Kotorová[1], Eva Kováčová[2] and Bohumír Zaťko[2]

[1] *Slovak University of Technology in Bratislava, Institute of Nuclear and Physical Engineering, Ilkovičova 3, 812 19, Bratislava, Slovak Republic*
[2] *Institute of Electrical Engineering , Slovak Academy of Sciences, Dúbravská cesta 9, 841 04, Bratislava, Slovak Republic*
** Corresponding author, andrea.sagatova@stuba.sk*

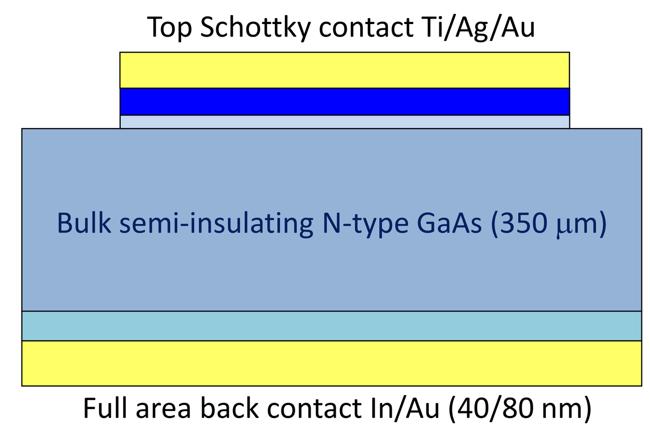
Motivation

- Semi-insulating (SI) GaAs is a wide band gap (1.42 eV) semiconductor material suitable for preparation of detectors of ionizing radiation operating at room temperature.
- It was shown that GaAs detectors are radiation hard against a few MGy of high-energy (MeV) electrons. The main reason of detector functionality degradation was the reduction of charge collection efficiency (CCE) together with reverse current increase, raising the total noise of detector. Both factors lead to drop of the signal to noise ratio (S/N) down to close to 1 disabling detector functionality. Thus, the measuring ability of degraded detector depends on how large signal the registered radiation creates [1, 2].
- Less ionizing particles, like ~keV gamma rays, might not be detectable with degraded detector.
- In this paper we improve the ability of SI GaAs detectors degraded by 8 MeV electrons to measure the gamma spectra of 59.5 keV photons by reducing the noise level in spectra by cooling the detector.

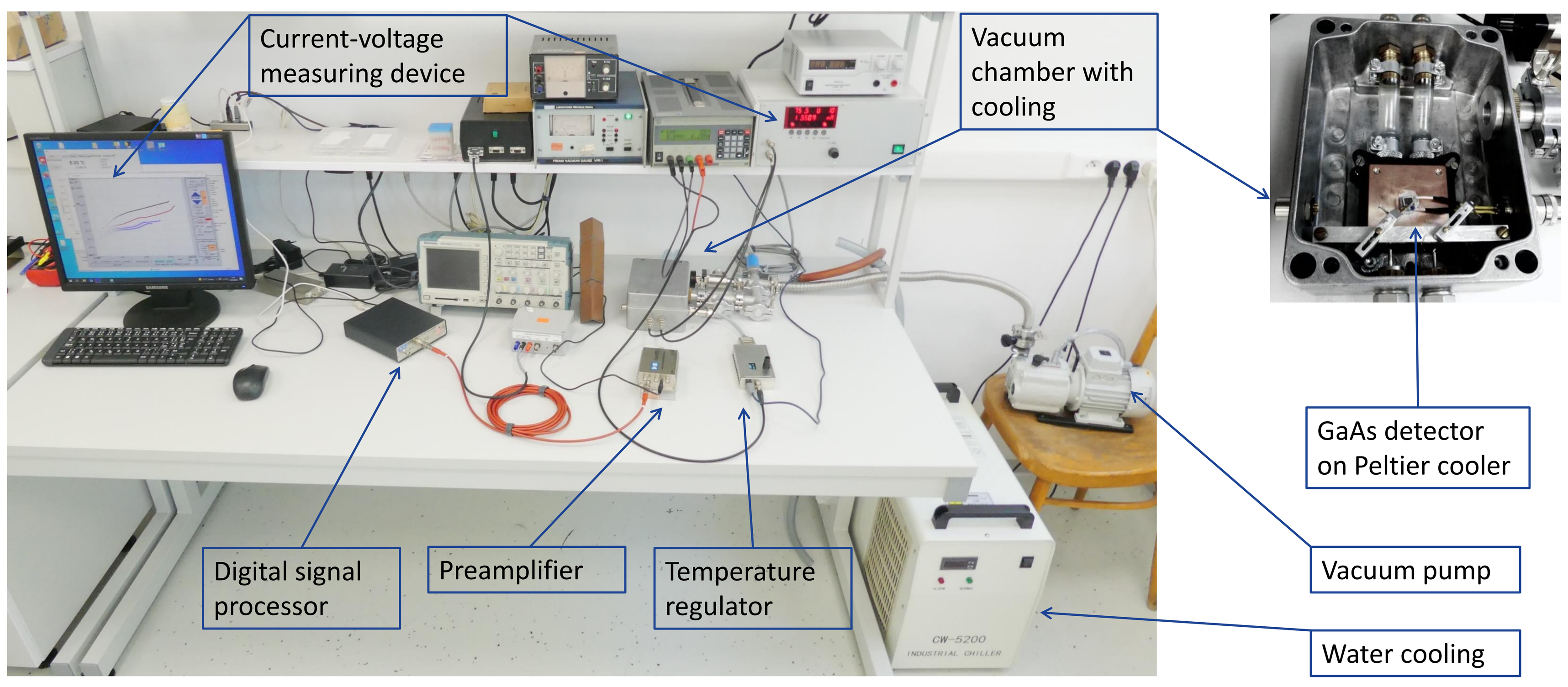
SI GaAs detectors



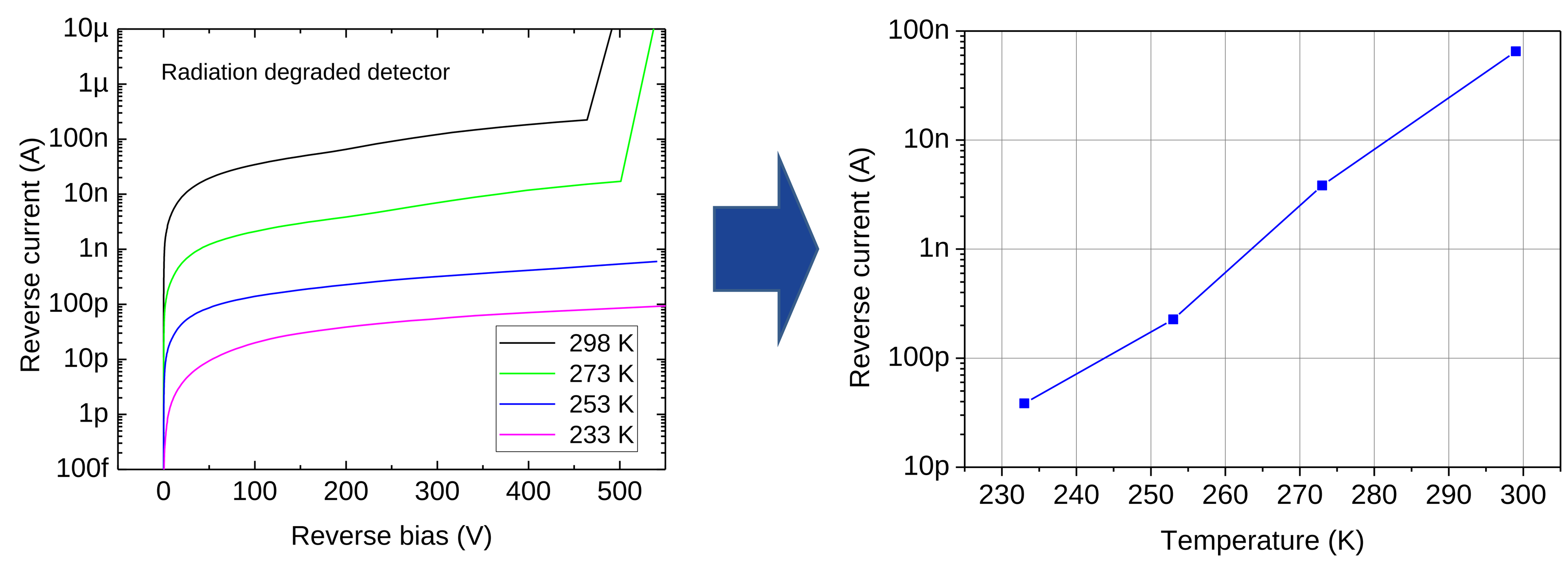
- VGF SI GaAs 350 μm substrate made by Wafer Technology Ltd.
  Resistivity @ 300K: 9.1 × 10^7 Ωcm
  Hall mobility @ 300K: 6250 cm^2/Vs
- *Top Schottky circle contact:* ∅ 1 mm Ti/Ag/Au (05/50/50 nm)
- *Back ohmic contact:* full-back-side, In/Au (40/80 nm)
- Prepared at the Institute of Electrical Engineering SAS in Bratislava, SK



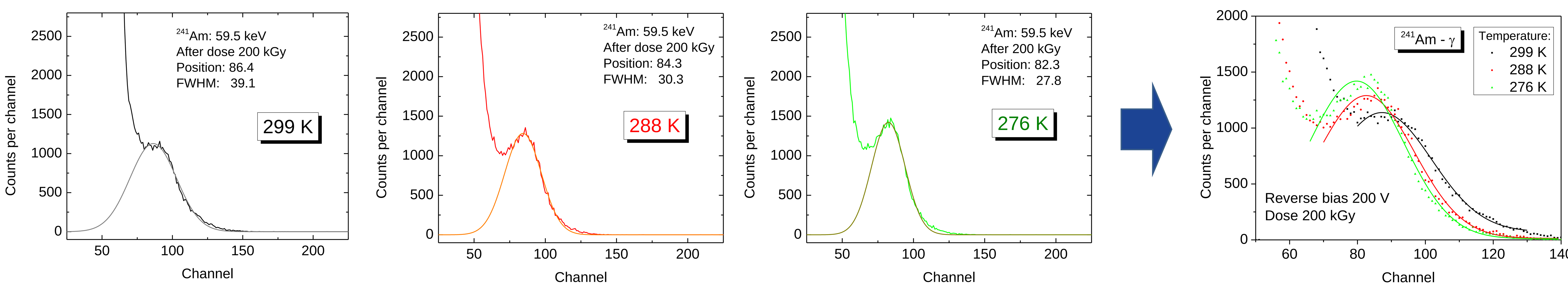
Experiments at lowered temperatures



Current-voltage measurements:



Spectra measurements:

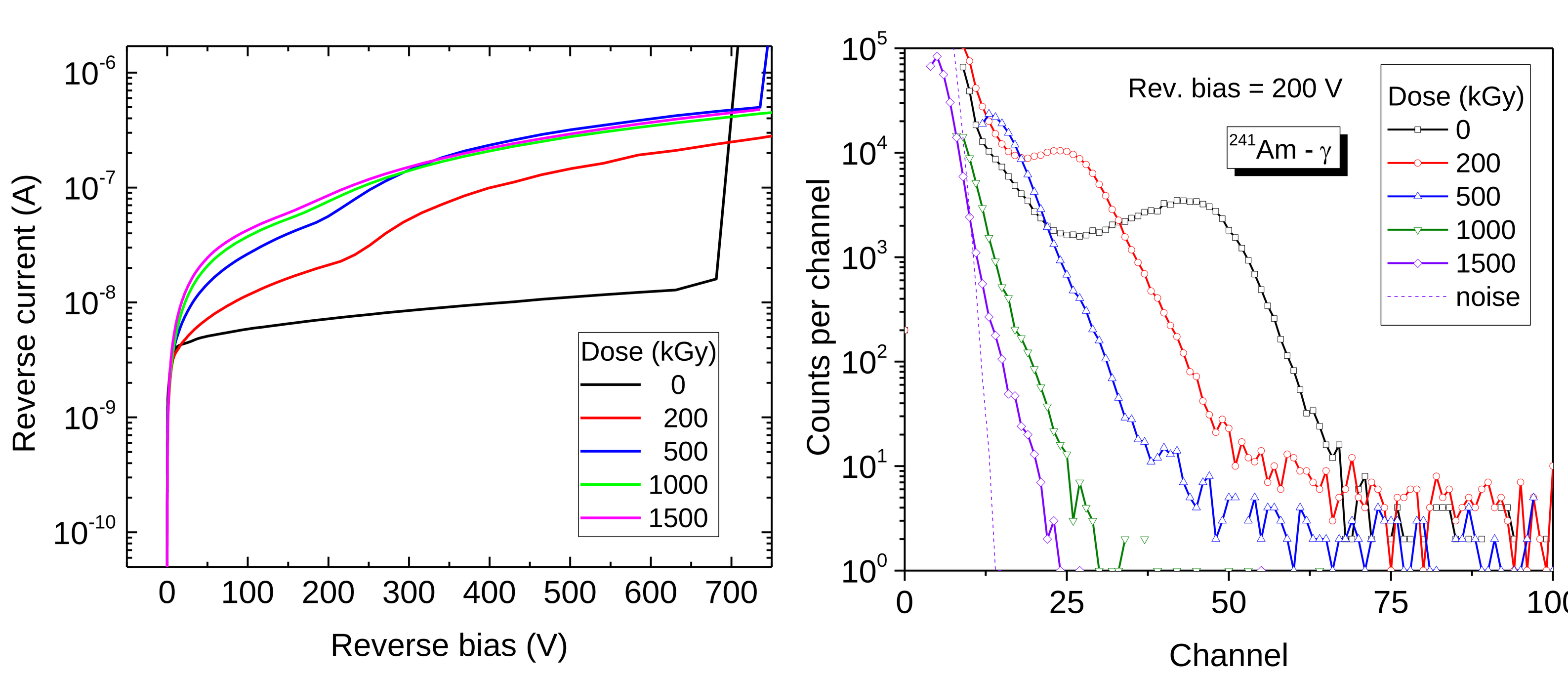


Radiation degradation

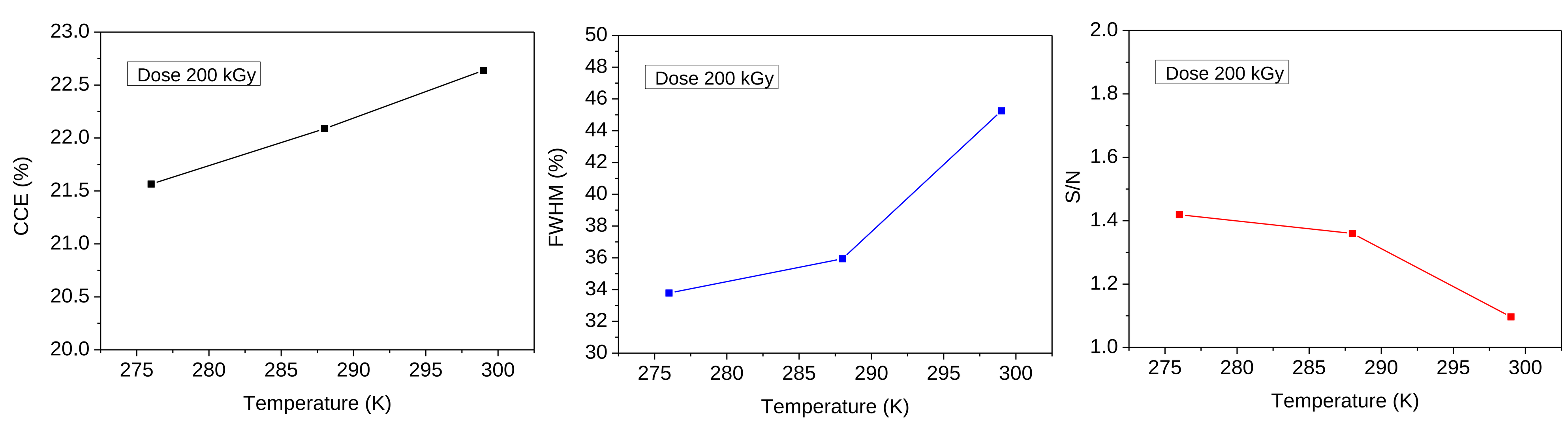
- Samples were degraded by 8 MeV electron beam from 10 kW LINAC at UFU, Ekaterinburg, RU[3].
- Used electron flux was of 1.86×10^{12}/cm^{2}s:

Dose [kGy]	Fluence [cm^{-2}]
200	1.12 ×10^{15}
500	2.79 ×10^{15}
1000	5.58 ×10^{15}
1500	8.37 ×10^{15}

Room temperature:



Results and conclusions



- We prepared Schottky contact radiation detectors based on semi-insulating GaAs.
- Detectors were irradiated with 8 MeV electron beam with doses up to 1500 kGy.
- Degradation with electrons causes an increase of reverse current and a decrease of detector CCE.
- Degraded detectors have too high reverse current which gives rise to noise and signal blends in it.
- We designed and prepared cooling system based on Peltier cooler with temperature stabilization. With cooling we can suppress the noise to acceptable value which affects following detector properties:
  - The detector reverse current dropped from 100 nA at RT to 100 pA at 233 K.
  - Calculated relative energy resolution improved from 46% at RT to 34% at 276 K.
  - Detector CCE mildly decreased by about 5% at 276 K.
  - The signal to noise ratio improved by about 40%, when cooling from RT to 276 K.
- Detector cooling improves its parameters (S/N, energy resolution) and increases the maximum usable dose and also the SI GaAs detector operability.
- In the future we plan to continue with testing at even lower temperatures down to 220 K.

References: [1] Šagátová, A. Zaťko, B., *et al.*, AIP Conference Proceedings **2411** (2021), 080013. [2] Šagátová, A., *et al.*, Materials Today: Proceedings **53** (2022) 293–298. [3] Department of Experimental Physics, Ural Federal University, Ekaterinburg, Russian Federation.
Acknowledgements: Work was supported by the Slovak Research and Development Agency with grants Nos. APVV-18-0273 and APVV-18-0243 and by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences through grant No. VEGA 2/0084/20.