

Users Guide

GDM 10

Version 1.1



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GDM 10™ User's Guide

Version 1.1

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1 Introduction

GDM 10 is a measurement system for detection and energy determination of gamma radiation from radioactive sources or samples. The system makes use of an IBM compatible computer but is designed in such a way that no advanced computer knowledge is necessary for its use.

The detector is a scintillation detector, which consists of a cylindrical NaI crystal with a height and a diameter of 5 cm. When the gamma radiation hits the crystal it creates a weak light. The light is collected and converted to electrical pulses by a photo multiplier tube (PM). The pulses are amplified in an amplifier. An A/D converter converts the size of the pulses to digital information, which is processed by the computer. The result is presented on the screen of the computer in the form of a frequency diagram of the energy distribution of the detected gamma quanta, i.e. a spectrum. Figure 1 shows a simplified block diagram of the system.

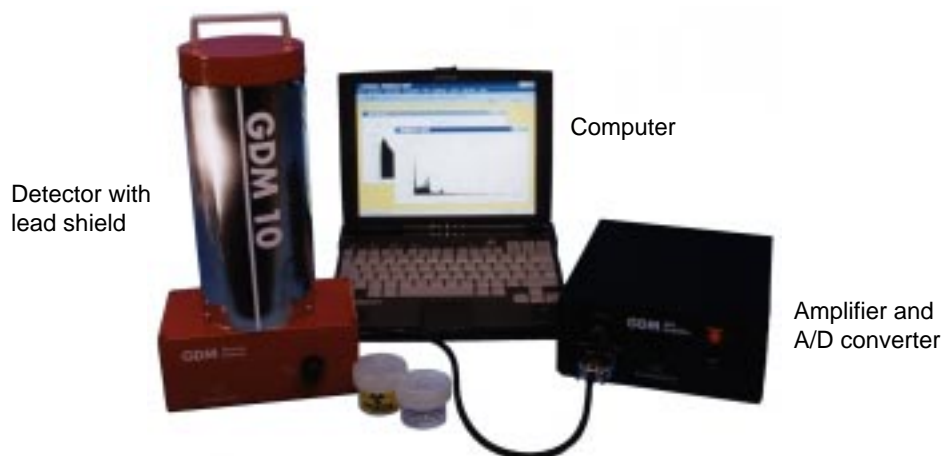


Figure 1.

The detector and the amplifier box are connected via an interface to an IBM compatible computer. The computer can be a single computer or form part of a network of several computers. The installation is described in Chapter 2.

The detection of the gamma radiation, the subsequent data processing and the presentation in the form of a spectrum is performed by the software of the system.

The spectra can be stored on a floppy disc or a hard disc for later analysis and distribution to the other computers of the laboratory class. The spectra can thus be analysed by all students in the laboratory class.

Part of or the whole spectrum can be plotted on a matrix printer or printed out channel by channel.

The GDM 10 is supplied with a Teacher's Handbook, which contains detailed comments on a selection of laboratory instructions, mainly for teaching in physics and biology. The Teacher's Handbook, together with the GDM 10 Manual, provides important hints for planning and preparing the laboratory work.

2 Installation

2.1 GDM 10 consists of the following parts:

1. Detector box with a built-in high-voltage module. The NaI detector and its photo multiplier (PM) tube are mounted on the box. The detector is surrounded by a cylinder containing lead shot for shielding the detector from background radiation. A signal cable and a voltage supply cable are connected to the detector box. On the front of the box is a 10-turn knob for adjustment of the high voltage (0 -1500 V) for the PM tube. This is used for adjustment of the signal gain.
2. Amplifier box containing low-voltage power supply, amplifier and A/D-converter (the circuit that converts the analog signal to digital information). The connectors for the signal cables and the voltage cables from the detector box are situated on one of the short sides of the box. At the opposite short side of the box are the mains cable and connector for the cable from the interface. Electronic noise as well as signals from the lowest-energy gamma quanta can be discriminated (removed) by means of the 10-turn knob.
3. RS-232 cable to be installed between the 25 pin RS-232 contact at the back panel of the Amplifier box and one of the serial ports of your computer.
4. Floppy disc with the code WinDAS in the form of an object code.
5. Five plastic jars for samples. The standard jars are matched in size to the opening above the detector.
6. GDM 10 User's Guide.
7. Teacher's Handbook.
8. Student Instructions include detailed instructions for the laboratory experiments.
9. Test jar with a solution of ^{152}Eu activity for energy and efficiency calibration (non-US version).
10. Test jars with solution of ^{134}Cs and ^{137}Cs (non-US version).

2.2 Installation of the hardware

Several different peripheral units can be connected to a PC. In order for the central unit to keep track of the peripheral units, each unit has a unique address. Thus there must only be one unit for each given address. Our Amplifier Box use RS-232 interface to communicate with the computer. The addresses for the serial ports of the computer is already determined by the manufacturer of the computer. You are free to choose the available serial port of your computer. Within the menu **Settings System setup**, you can chose the serial port number. When we deliver the system our default setting is serial port number one.

Check that the computer is switched off. Take the RS-232 cable and connect it to the 25 pin RS-232 contact on the back panel of the Amplifier box and to an available serial port of your computer.

2.2.1 Connection of detector and amplifier box

Put the detector and amplifier box close to the computer. The RS-232 cable is connected at the back of the computer to the amplifier box (see figure 3). This connection must always be done with the computer switched off.

Then connect the mains cable of the amplifier box to the mains voltage. Now connect the cable from the detector box to the amplifier box. Switch on the main power on the rear of the amplifier box. The detector system is now ready for use! Figure 3 shows a schematic sketch of the system.

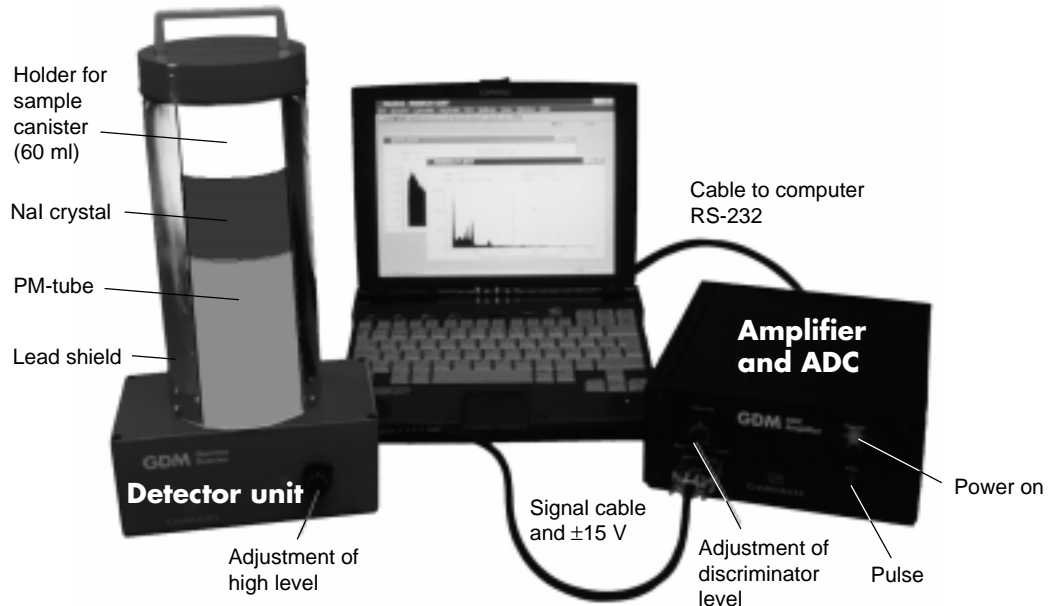


Figure 3.

3 Description of the Detector System

3.1 The detector

The sensitive part of the detector is a scintillator, which consists of a cylindrical NaI crystal with a diameter of 5 cm. The incoming gamma quanta deposit all their energy, or part of it, to the electrons in the crystal due to collisions (Compton effect) or photo-electric effect. The resulting fast electrons collide with the atoms of the crystal, which are excited and subsequently deexcited by emitting photons with a wave length in the region of visible light. The photons reach the photo cathode of a photo multiplier tube (PM tube), which is optically coupled to the crystal. Here the photons will cause the emission of electrons through the photo-electric effect. The number of electrons emitted from the photo cathode is proportional to the energy of the gamma radiation. The electrons are accelerated in the PM tube towards a structure of metal plates (dynodes). At the first dynode the electrons emit more electrons (see figure 4). The shower of electrons is amplified at each dynode (in total 10). The potential difference between each consecutive dynode is about 75 V. The resulting shower of electrons gives rise to an electric pulse, whose amplitude is directly proportional to the amount of light collected on the photo cathode, and thus directly proportional to the energy of the gamma radiation. By measuring the amplitude, the energy of the corresponding gamma quantum can be determined.

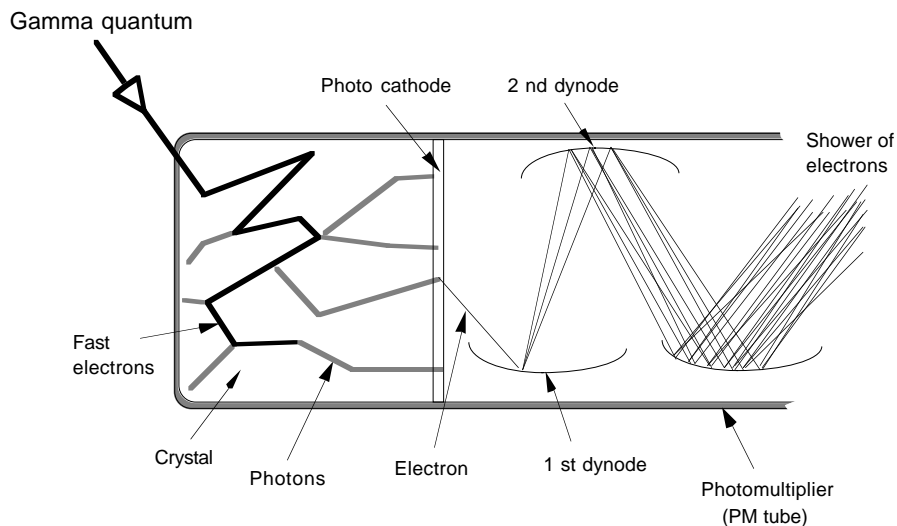


Figure 4.

3.2 How is a spectrum created?

The electric pulses from the PM tube are amplified in the amplifier and then registered by the computer and sorted into a histogram according to their amplitude. Since the amplitude is proportional to the gamma energy, the histogram reproduces the energy distribution of the detected gamma quanta.

The analogue information (the amplitude) must be converted to suitable digital information (binary number) for the computer. The electronic circuit which carries out the conversion is called an A/D converter (Analog-to-Digital converter). The process is illustrated in the simplified drawing of figure 5.

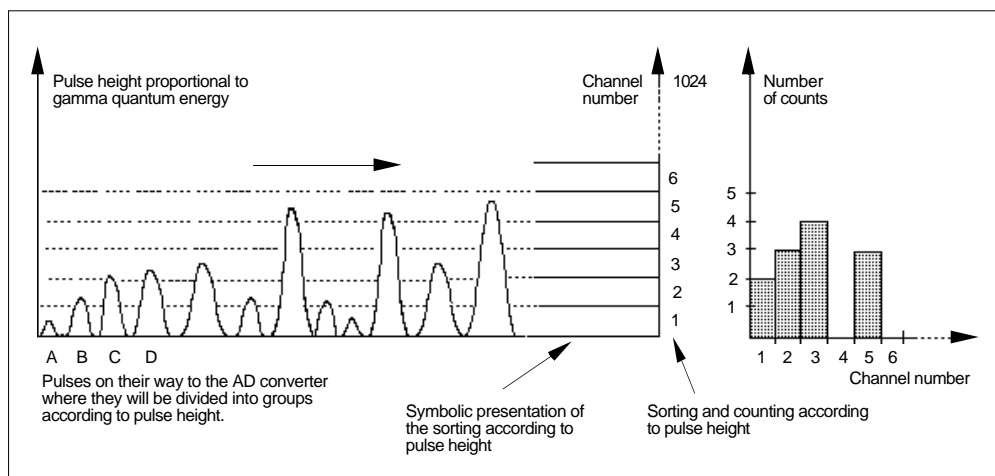


Figure 5.

The incoming pulses are read by the A/D converter, which makes a classification, i.e. sorts the pulses into different boxes ('channels') according to their pulse height. The GDM 10 detector system uses an A/D converter with 1024 channels. The channels are numbered according to increasing pulse height, and the channel number is thus proportional to the gamma energy.

For example, pulse **A** is put into channel number 1, pulse **B** into channel number 2, pulse **C** and **D** into number 3, and so on.

One thus obtains a histogram of the pulse height distribution for all detected gamma quanta. Since the pulse height is proportional to the gamma energy, the histogram reproduces the distribution of the corresponding gamma energies. The histogram is usually referred to as an energy spectrum.

In order to find out which channel number corresponds to which energy, it is necessary to make an energy calibration, which is obtained by using radioactive sources which emit gamma quanta with known energies.

3.3 What characterises a spectrum?

Figure 9 shows the pulse height distribution or spectrum of a scintillation detector that is exposed to gamma radiation of one single energy (monochromatic radiation). A large fraction of the incoming gamma quanta deposit all their energy in the crystal by photoelectric effect or multiple scattering, which gives rise to the peak ('photopeak') in the spectrum. The peak has a certain width, due to the statistical response of mainly the PM tube. The width of the peak depends on the energy of the radiation, and is typically between 5 and 10 % of the channel number which represents the center of the peak. This measure is called the resolution of the detector, and is obtained by dividing the width of the peak (in channels or MeV) at half of the peak height with the channel number of the peak or its energy. For the 0.66 MeV peak in the spectrum of Cesium the resolution is typically about 7 % (see figure 6).

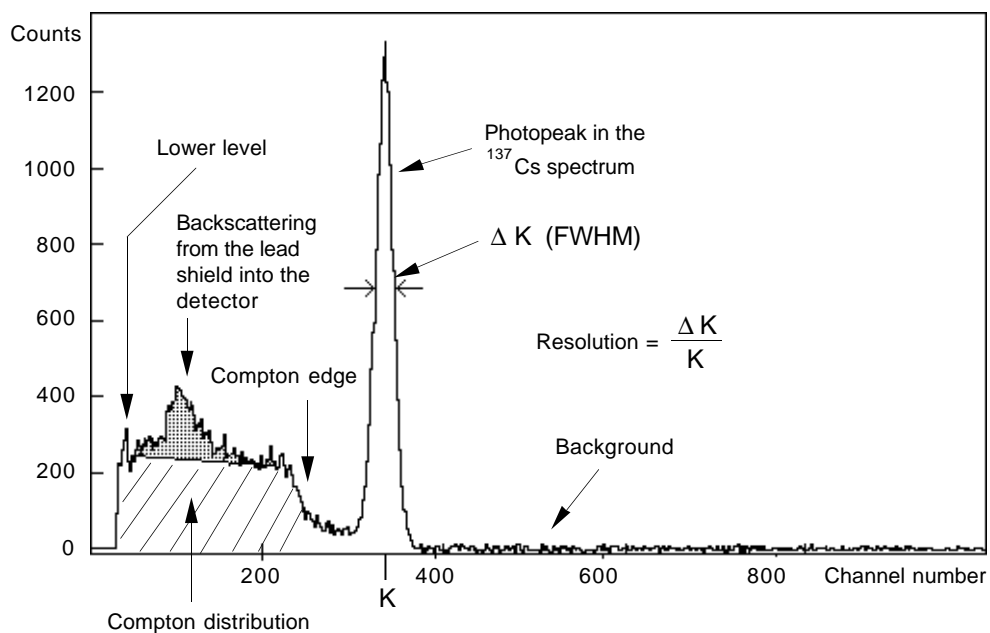


Figure 6.

The energy distribution to the left of the photo peak is called the Compton distribution and originates from processes where the gamma energy is only partly absorbed in the NaI detector (Compton scattering). Two such processes are possible (see fig 7):

- 1) The incoming gamma quantum is scattered from (collides with) an electron in the NaI crystal, loses part of its energy, and leaves the crystal without being completely absorbed. This process gives rise to most of the pulses to the left of the Compton edge except the shadowed region.
- 2) The incoming gamma quantum first collides with an electron in the surrounding lead shield, scatters and loses part of its energy before finally being detected in the NaI crystal (gives up its remaining energy). This process gives rise to the shadowed region in figure 6.

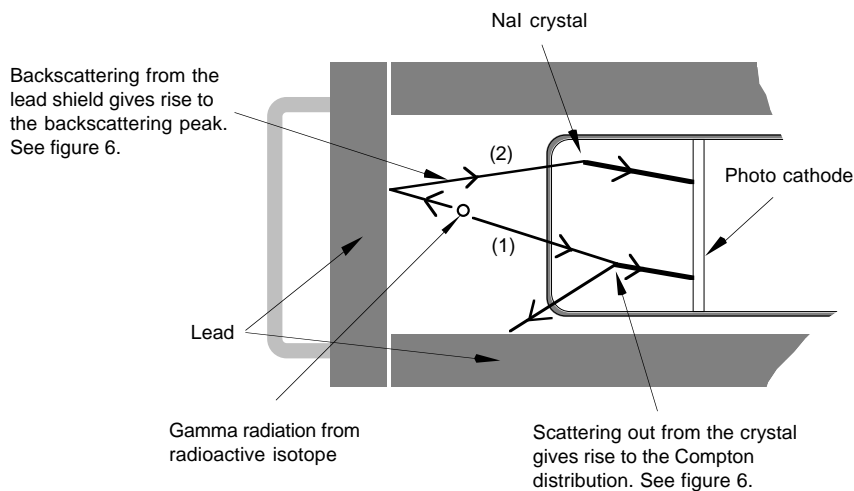


Figure 7.

4 Technical Specifications

Detector Unit

- **Detector**
NaI (2" x 2") with PM-tube
- **Energy resolution**
< 7.0 % full width half maximum at 661 keV
- **Cylindrical lead shielding**
Filling: removable lead pellets
Sample container: 60 ml
- **High-voltage supply**
10-1500 V
Continuously adjustable by a 10-turn potentiometer
Stability 100 ppm/°C, 0 to 50°C
- **Dimensions**
Height: 40 cm (16")
Diameter: 12 cm (5")
Weight: 2 kg + 18 kg lead (4.4 lbs + 40 lbs)

Electronic Unit

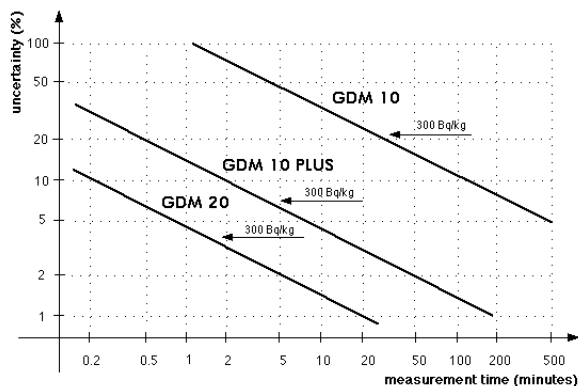
- **Amplifier time**
Constant: 2 μ s.
- **Discriminator**
Adjustable up to 100 % of full range by 10-turn potentiometer.
- **Analog/Digital Converter**
1024 channels,
50 MHz clock frequency
Integral non-linearity:
 ± 0.2 % over 98 % of full range
Differential non-linearity:
 ± 2 % deviation from average channel width over 98 % of full range
- **Power supply**
Input: 200 VAC, 50/60 Hz, 73 mA
Output: ± 15 V, 200 mA, supports detector unit

Computer Interface

Connects to PC, RS-232 interface

Sensitivity

For cesium samples according to the following diagram:



Miscellaneous

Instruction manual, calibration sources and sample containers are provided.

Options

- **GDM 10 PLUS upgrade**

Equipment for measurement of low activities consisting of a sample holder (0.5 l) of Marinelli type and a thicker lead shield. This will increase the sensitivity of the detector system by a factor of 7.

- **Particle detector**

Equipment for measurement of alpha and beta activities consisting of a semiconductor detector made of silicon with a signal preamplifier and power supply.

- **GDM 15 upgrade**

Equipment for upgrading GDM 10 to a highly sensitive measuring system of professional type. Suitable for environmental studies by e.g. the Municipal Department of Environment. The equipment consists of a 3" x 3" NaI detector enclosed in a special lead shield and software for automatic computer analysis (determination of activity).

- **GDM 20 upgrade**

Equipment for upgrading GDM 10 to a very highly sensitive measuring system of professional type. The equipment consists of a 3" x 3" NaI detector enclosed in a special container with 10 cm thick walls containing 315 kg lead pallets and software for automatic computer analysis (determination of activity).

- **Charcoal canisters**

Charcoal canisters for determination of the amount of radon gas in air.

5 Radiation Safety Recommendations

(non-US version)

The source kit to the GDM systems consists of three calibration sources in the form of radioactive water solutions contained in plastic jars. The plastic jars consist of rigid plastic with a permanently sealed lid. Each jar is provided with a warning sign for ionising radiation, strength of the activity, the nuclide and the year of manufacture together with the text 'Radioactive Material'.

The three calibration sources are:

1 jar with at the most 2 kBq ^{152}Eu in 60 ml of water
(For energy and efficiency calibration)

2 jars with a mixture of at the most 0.5 kBq ^{134}Cs and ^{137}Cs in 60 ml of water
(The 'Chernobyl mixture' which contains activity after the fallout of the Chernobyl accident.)

The activity in these solutions is so low that it will not give rise to any radiation of importance from a radiation safety point of view. The plastic jars are so well sealed that the radioactive solution cannot leak out without external damage to the jars.

The following recommendations should be followed:

1. When the radiation sources are not used, they should be stored together with the other radiation sources of the school.
2. Don't make any external damage to the plastic jars.
3. The radiation sources can be used for demonstration purposes or in laboratory work, provided the students are aware of the present recommendations.
4. When a radiation source is damaged or for any other reason is not to be used any longer, it should be poured down the sink and the plastic jar thrown away as normal waste after removal of the warning sign.
5. If a jar has been damaged so that the radioactive solution can be or has been released, the remaining solution should be poured down the sink. All spilled solution should be dried up with paper towels and the place be cleaned with water. The decontamination should be carried out with plastic gloves, which should be, together with the plastic jar and the plastic bag, thrown into the rubbish.

Gammadata will on request provide more information concerning the radiation sources.