JOINT INSTITUTE FOR NUCLEAR RESEARCH

Dzhelepov Laboratory of Nuclear Problems

Radiation Protection and safety of radiation sources

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Aim of the project

- Information about radiation protection and safety from radiation sources.
- Studying information radioactive sources and spectrum energy and different types of detectors.
- Recognize data acquisition system DRS digital oscilloscope.
- Some information about x-ray tube .
- More detailed study of CdTe detector (calibration, resolution and efficiency).
- Using CdTe detector for identification different types of material using attenuation coefficient formula.
- Comparison and identification of Iodine using different detectors types (Pixel detector and CdTe) .

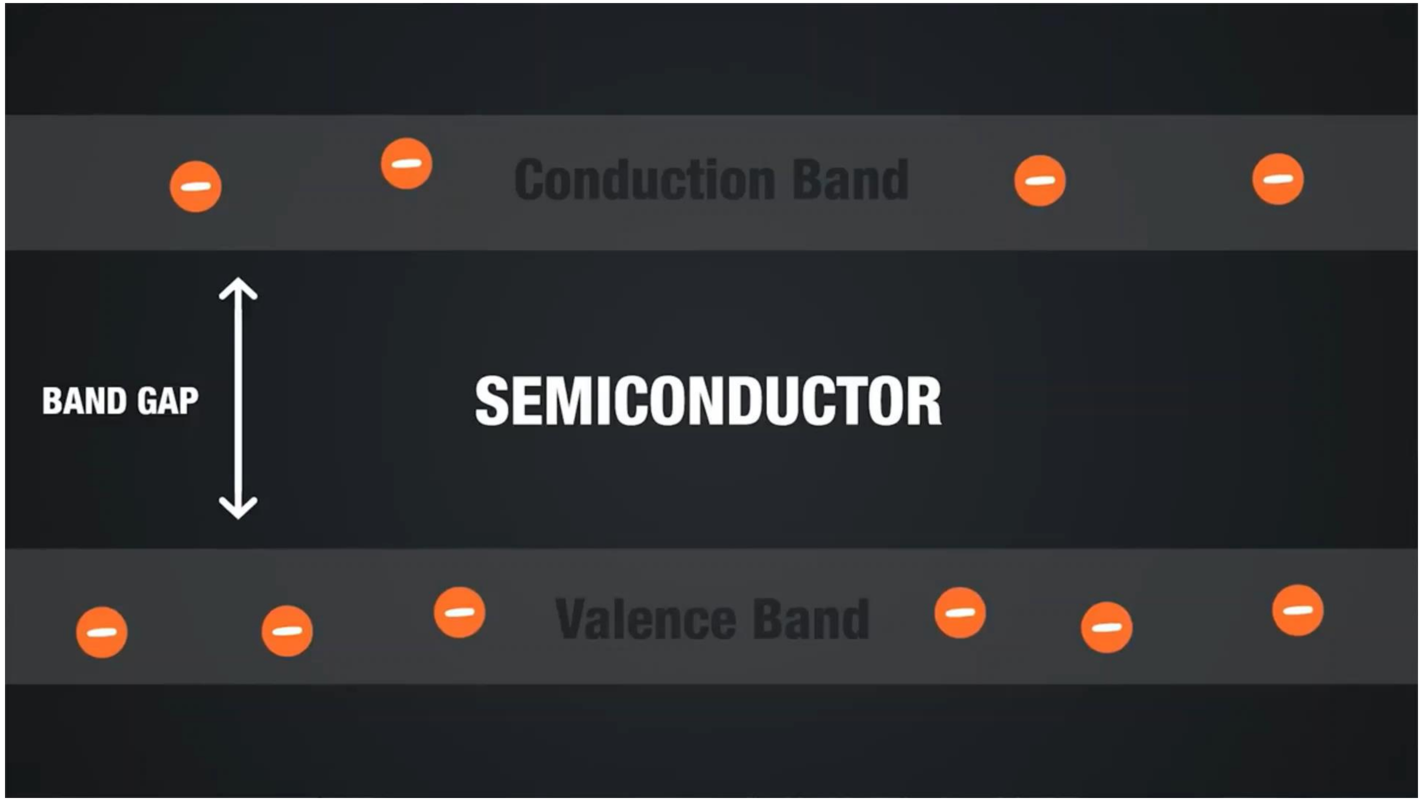
Detector

It is the device which converts the amount of radiation into measurable phenomenon.

Types of detector

- Gas detector
- Scintillator detector
- Semiconductor detector
- pixel detector

In semiconductor detectors the energy levels called bands, there are two types of bands lower band(Valence) and upper band (Conduction).
As the applied voltage increase the band gap decrease, free charge carriers (**electron-hole pairs**) are created by the excitation of an electron from the valence band to the conduction band. This excitation left a hole in the valence band, which behaves as a positive charge, and an electron-hole pair is created. Holes can sometimes be confusing as they are not physical particles in the way that electrons are. Rather they are the absence of an electron in an atom. **Holes can move from atom to atom** in semiconducting materials as electrons leave their positions.
The free charge carriers are **electrons** and **electron holes** (electron-hole pairs). Electrons and holes are created by the **excitation of an electron** from the valence band to the conduction band.



Semiconductor	The Band Gap Energy (eV)	The energy required for e hole-pair
Si	1.12 eV	3.65 eV
GaAs	1.42 eV	4.2 eV
CdTe	1.5 eV	4.5 eV

Table: Energy Bands and the Average energy to produce an electron-hole pair for Si, Gallium Arsenide and Cadmium tellurite at room temperature 300K

Cadmium Telluride (CdTe) Detector

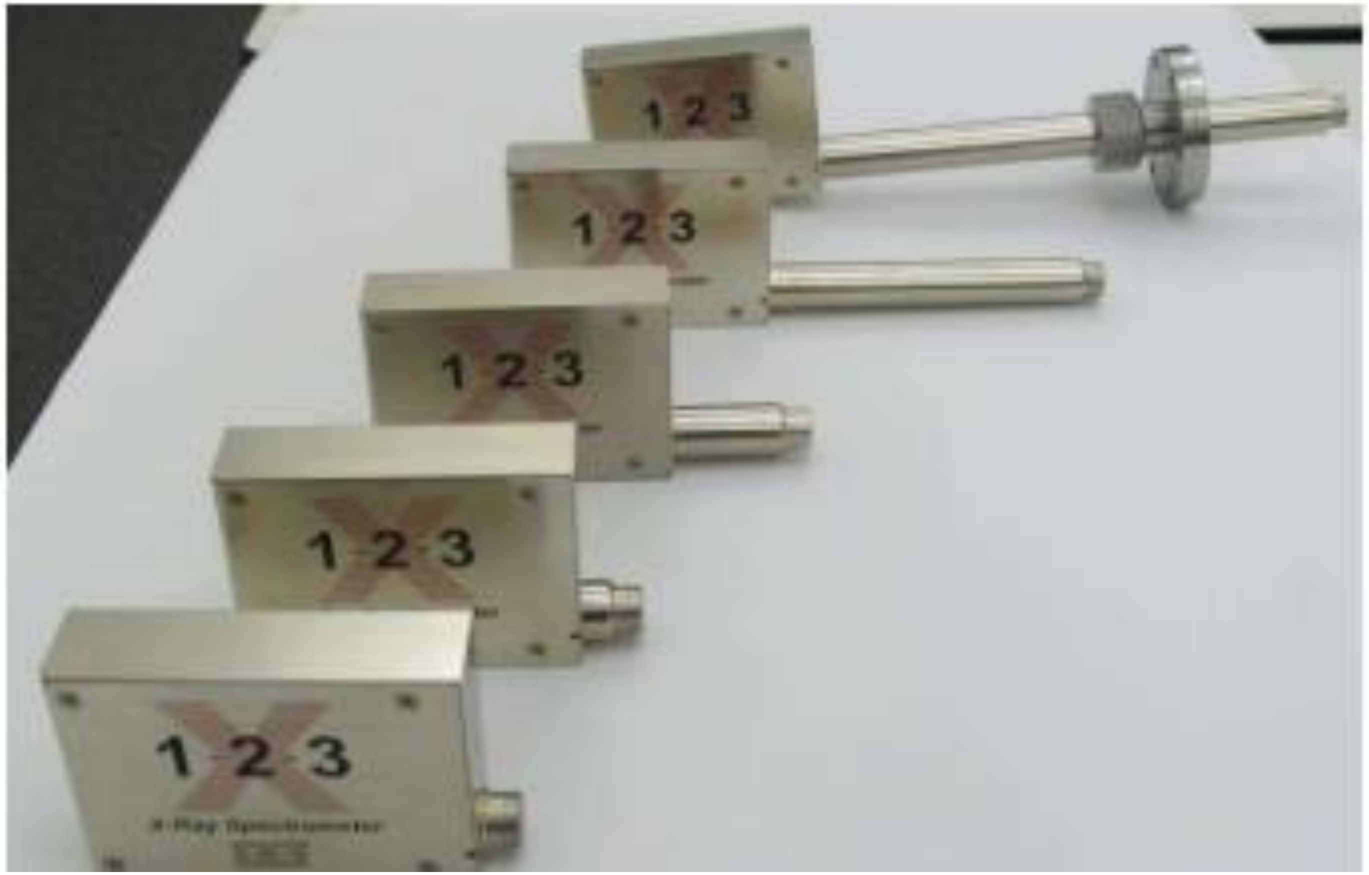
The X-123-CdTe is recommended for higher energy X-rays, above 30 keV or so. The 0.5 mm silicon used in the other detectors loses sensitivity above 15 keV, while the CdTe detector remains near 100% efficient for all characteristic X-rays, to 100 keV. It is often used in characterizing X-ray tubes as well as XRF for rare earth metals, lead, mercury, and other higher Z materials.

The energy resolution (Re) of a detector

measures its ability to distinguish gamma-rays with close energies.

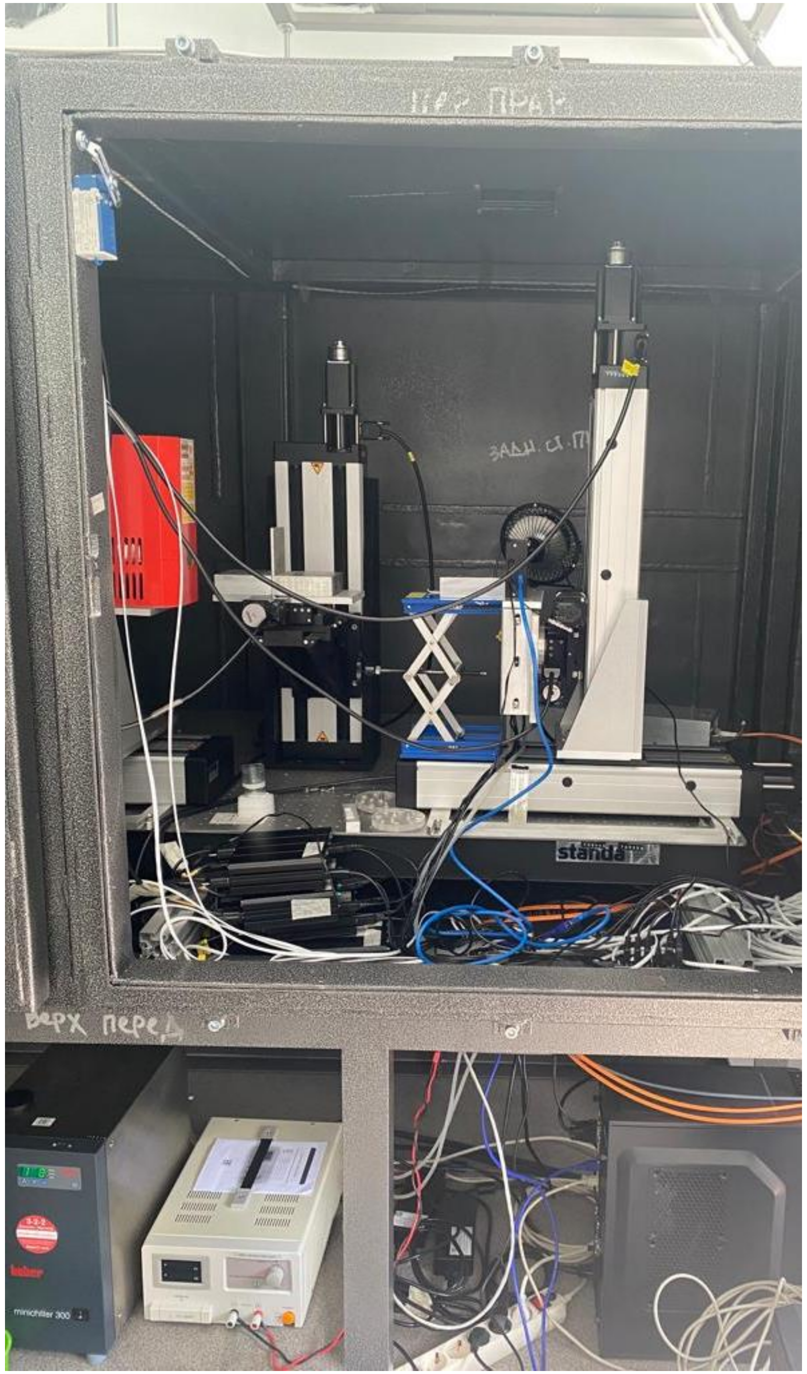
CdTe has Thickness 1 mm and area 25 mm^{2}, Resolution at 122KeV about 1.2KeV around 1%.

Germanium Detector has a lower resolution, but it function only in low temperature.



Amptek

- it is a high technology company and a recognized world leader in the design and manufacture of state-of-the-art nuclear instrumentation for the satellite, x-ray and gamma ray detection, laboratory, analytical, and portable instrumentation industries.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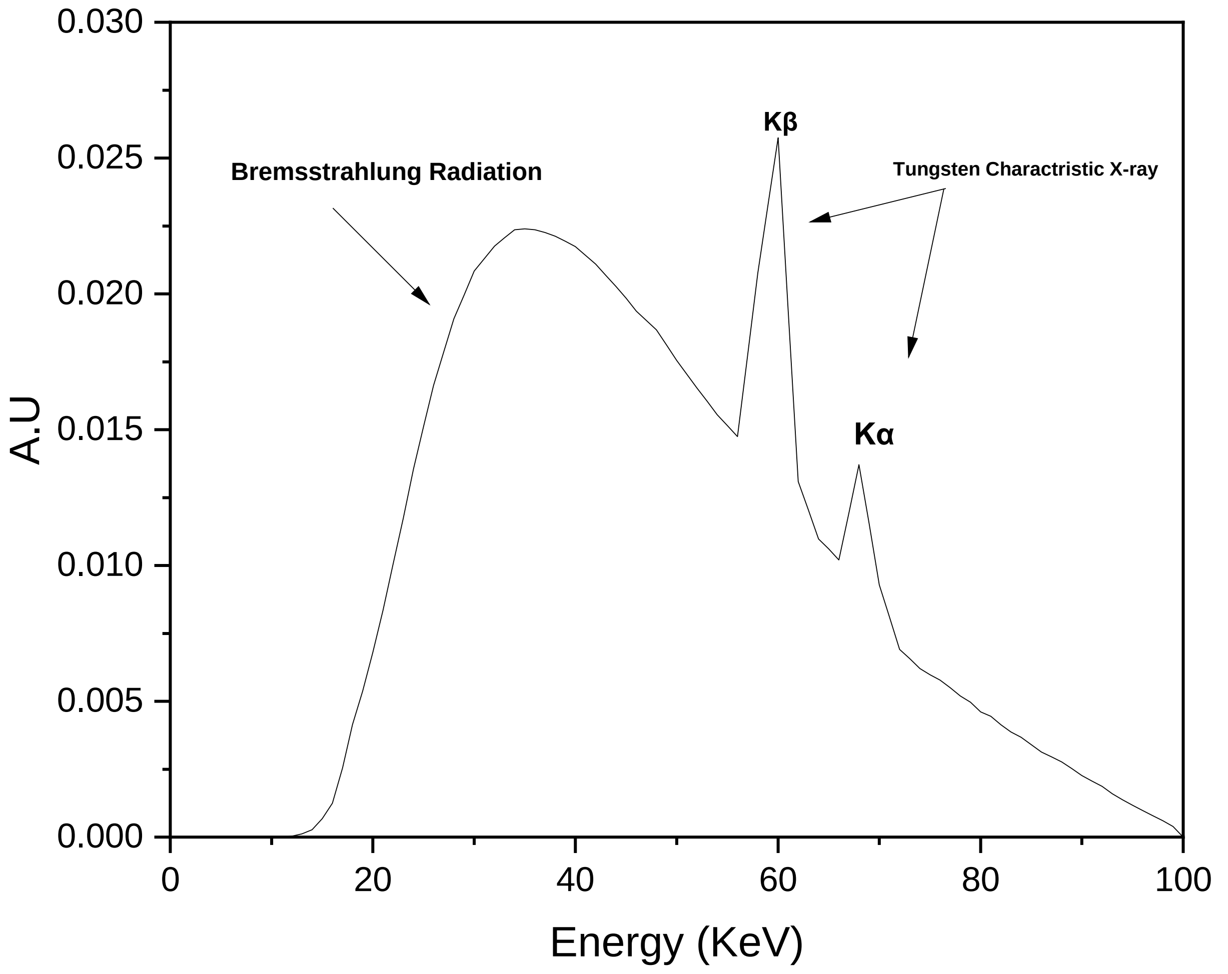
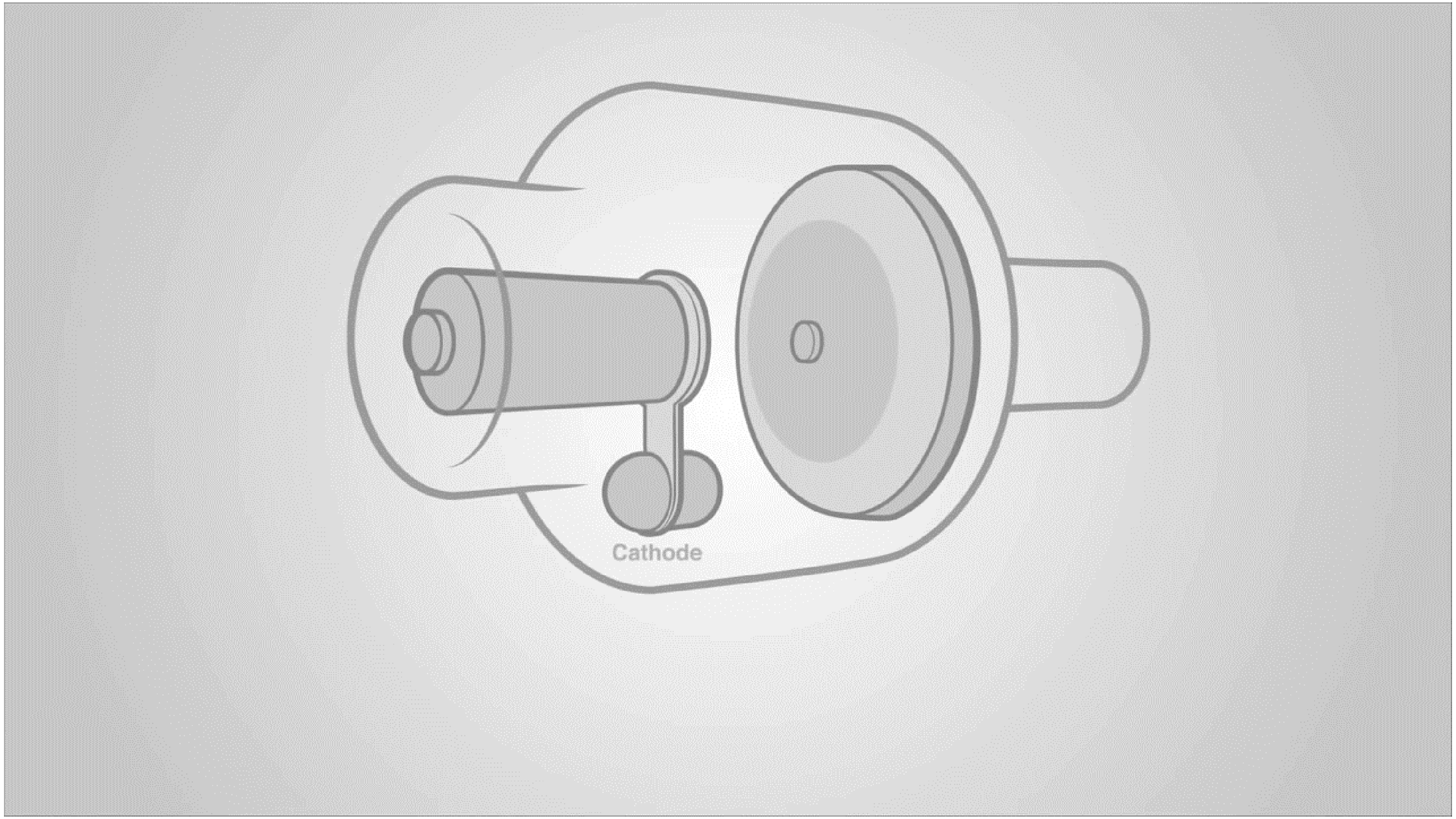
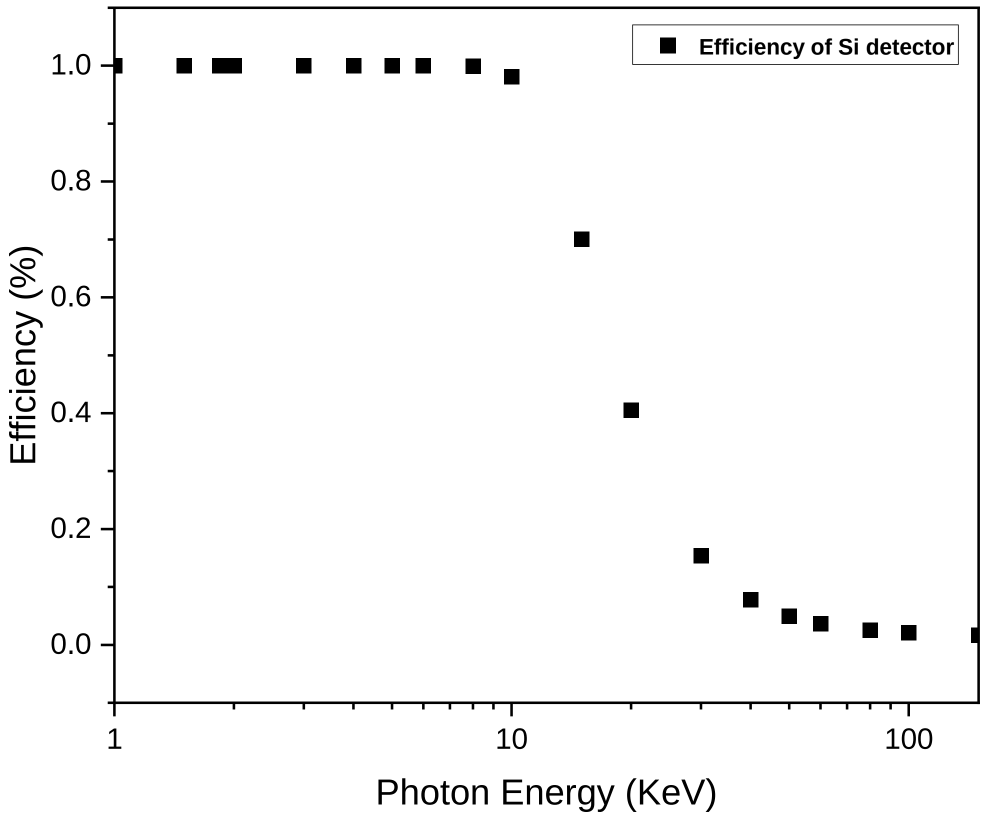


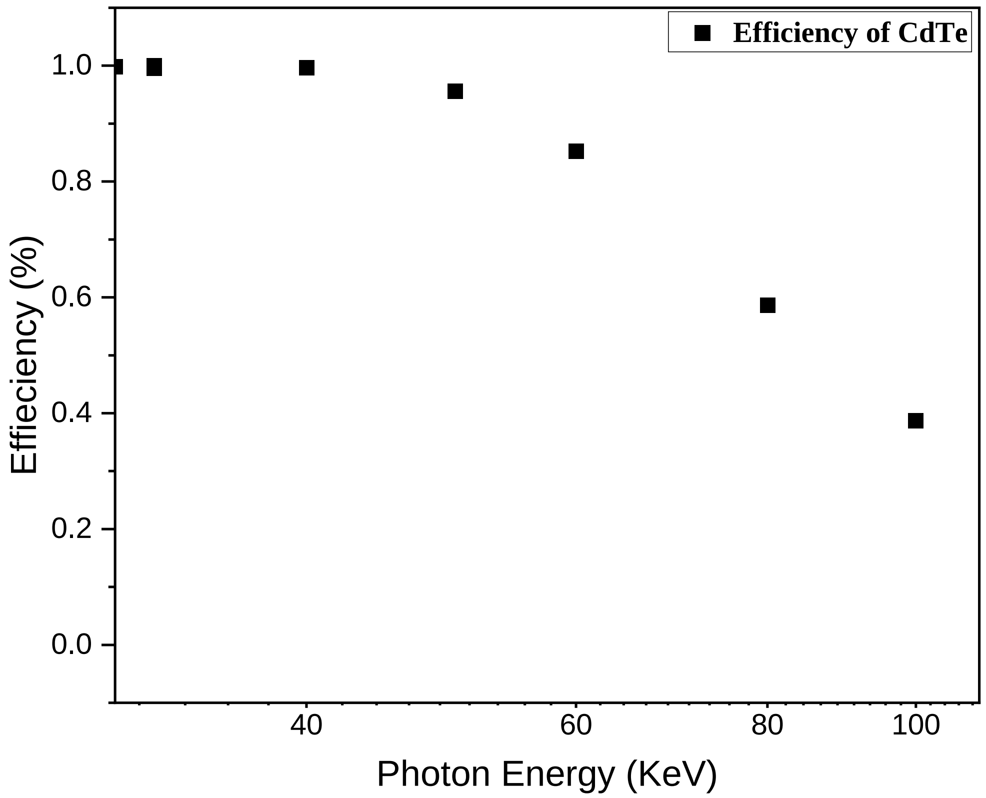
Fig(1) Calculated spectrum of X-ray tube (Hamamatsu)


Cathode

Comparison between registration efficiency of **CdTe** and **Si** detector at thickness 500μm



Figure(2)



Figure(3)

Efficiency of detector

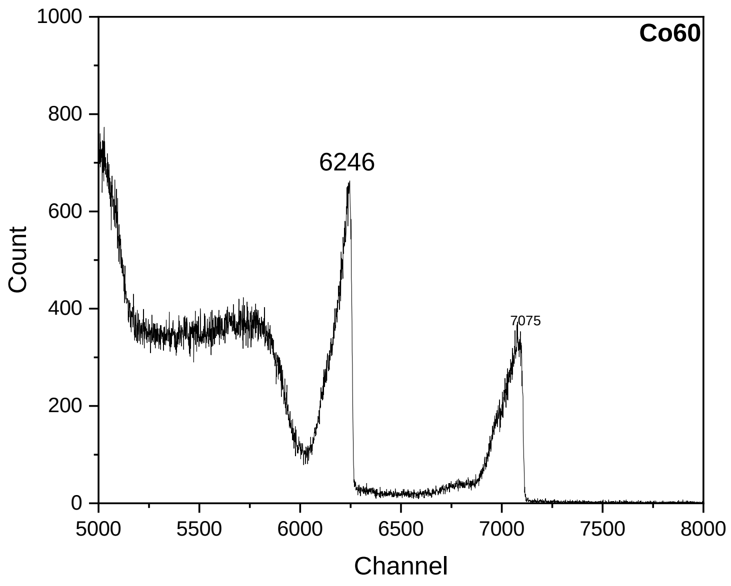
Defined as the ratio of the output signals to incident electrons, X-rays or photons to a detector (input signals) and Its ability to registration to whole number of incident photons.

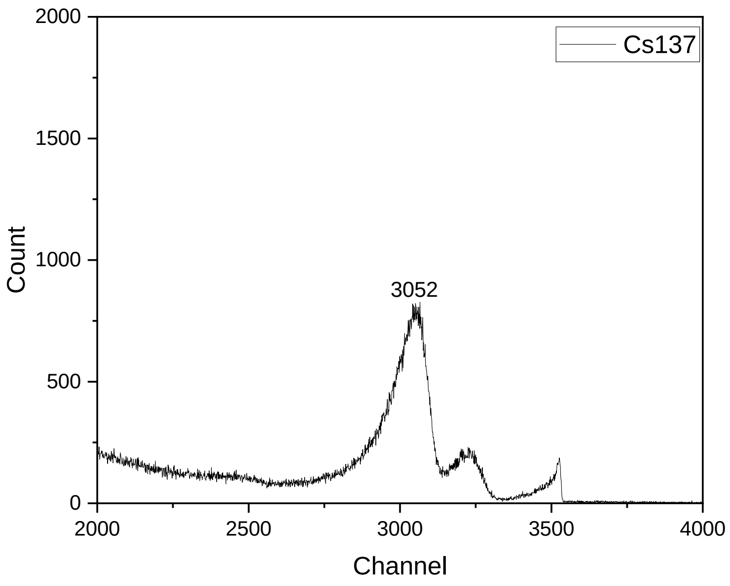
From the previous figures we can see that the most tomography used practically silicon pixel detector, the figures shows that the registration efficiency in Si detector at energy 50 KeV up to 60 KeV at thickness 500μ about 10% while in case of CdTe detector at the same thickness the registration efficiency about 90% so CdTe has more advantage than silicon

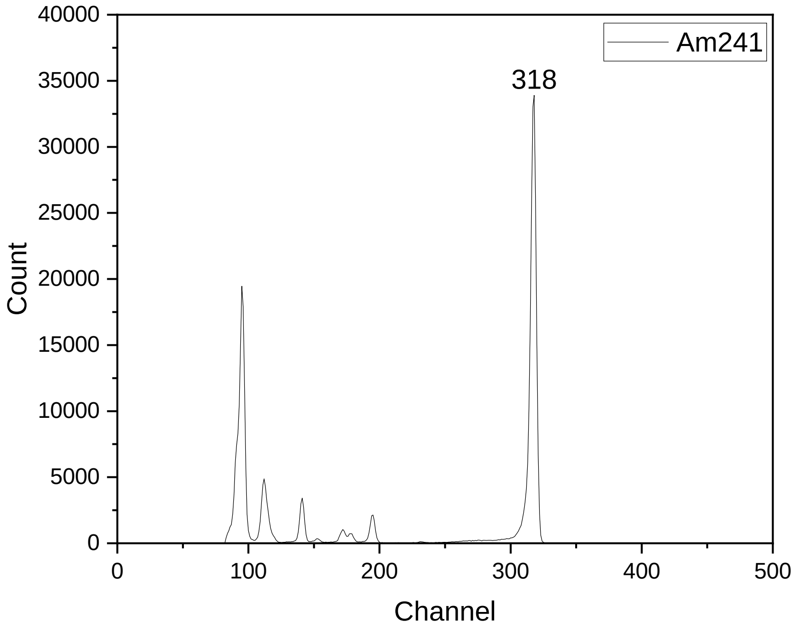
That mean the incident photons on object in case of CdTe will be registed about 90% and make the most advantage giving information data.

In that case when the patient exposed to 100 photons in case of Si detector registration efficiency of photons will be only 10 photons but in case of CdTe detector it will registed to 50 photons, so CdTe has more advantage and is better to use in tomography and detecting gamma rays

In Figures (4.a)(4.b)(4.c) the relation between channel and count for Co60, Cs137 and Am241 before calibration, respectively.





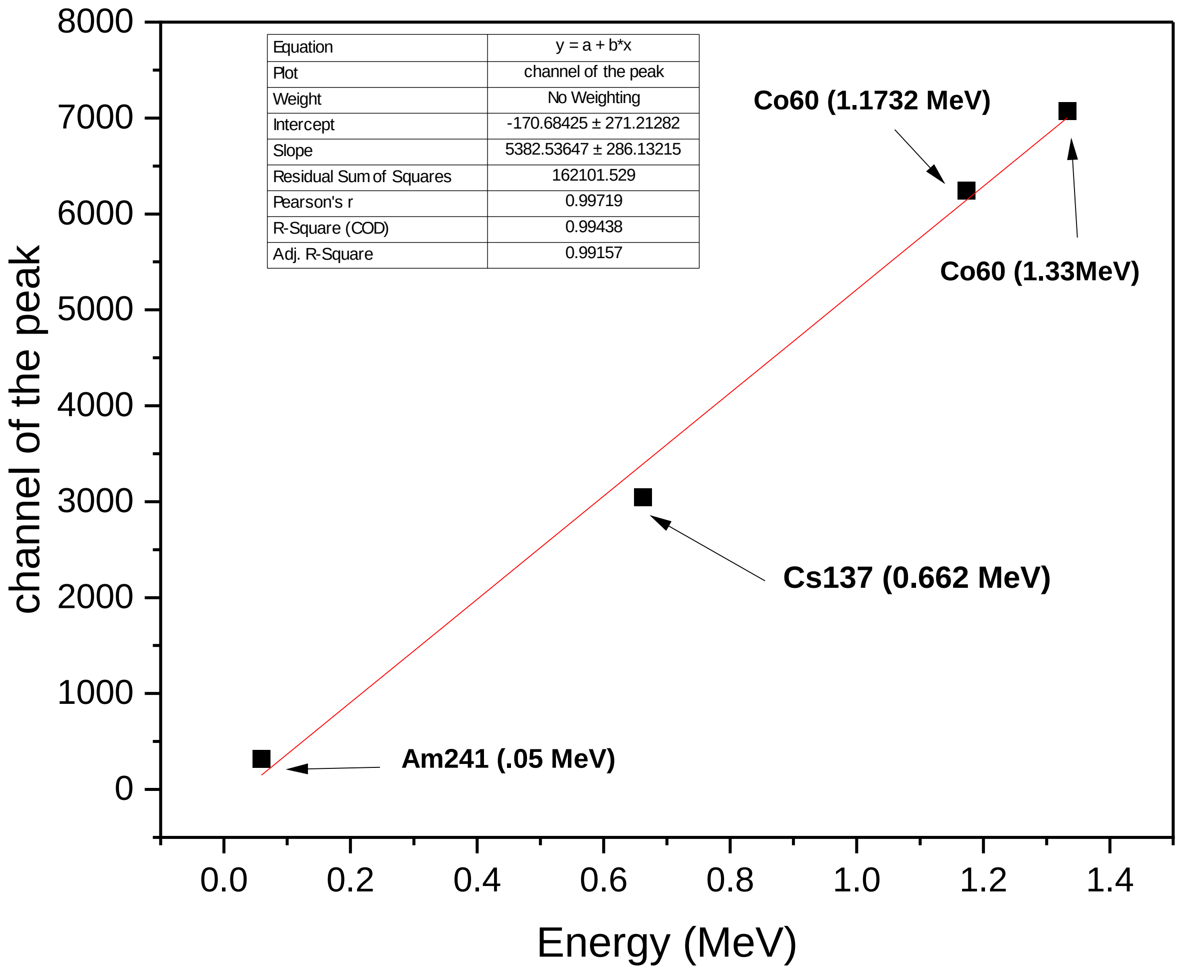


Figure(4.a)

Figure(4.b)

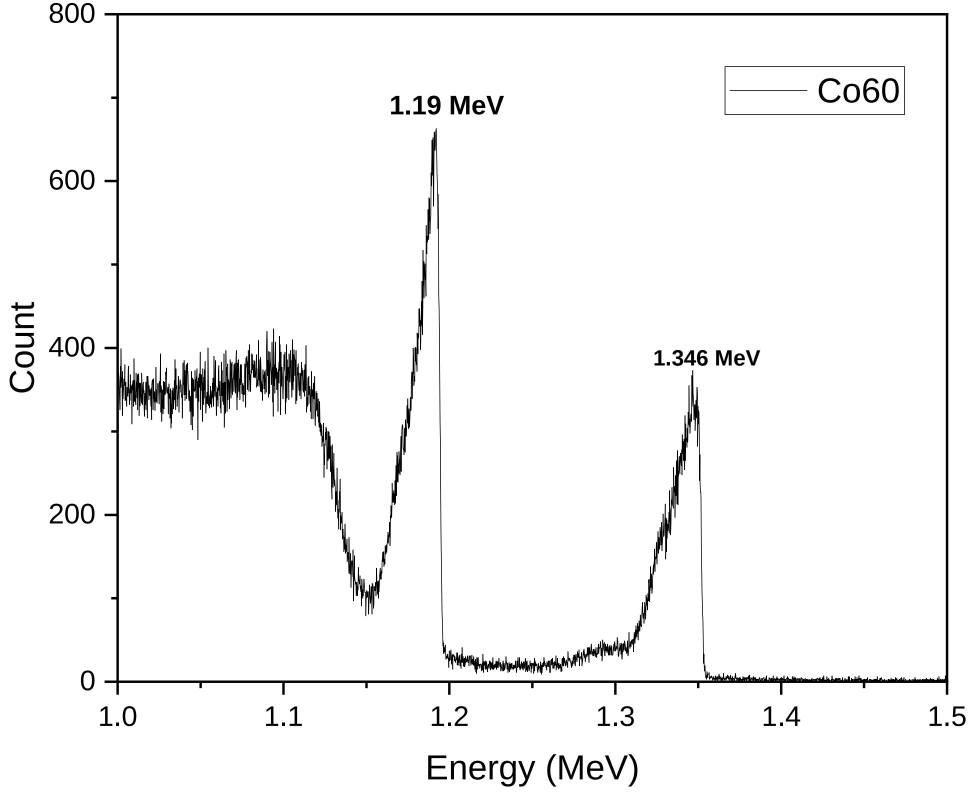
Figure(4.c)

- **Cadmium Tellurite detector (CdTe) for calibration energy by using three types of radioactive sources Am241, Co60 and Cs137.**

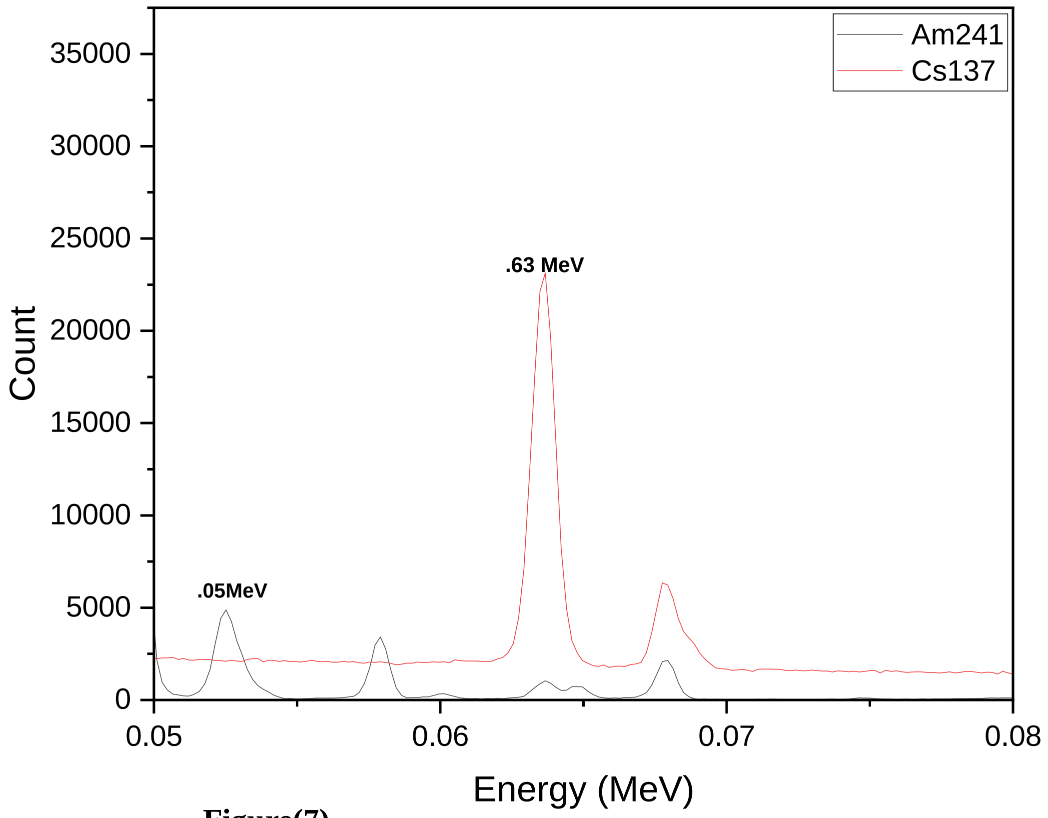


Figure(5)

The Energy Calibration Spectrums for different isotopes



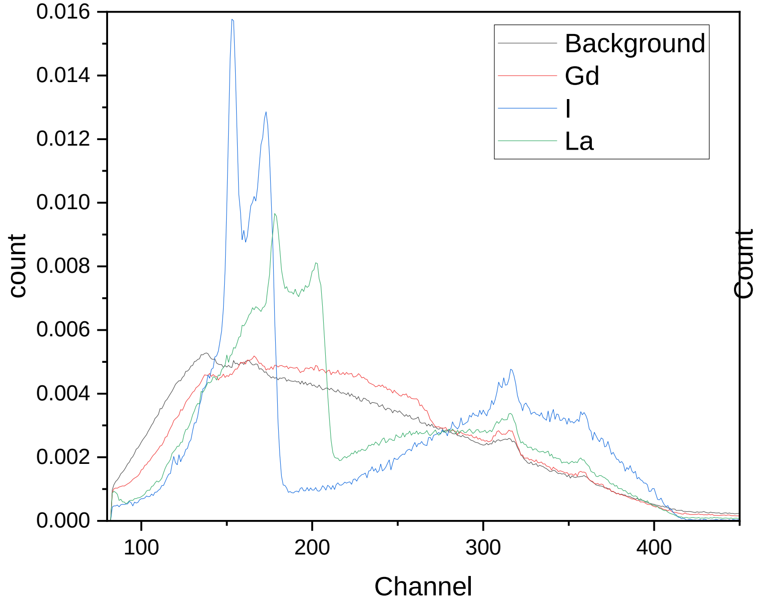
Figure(6)



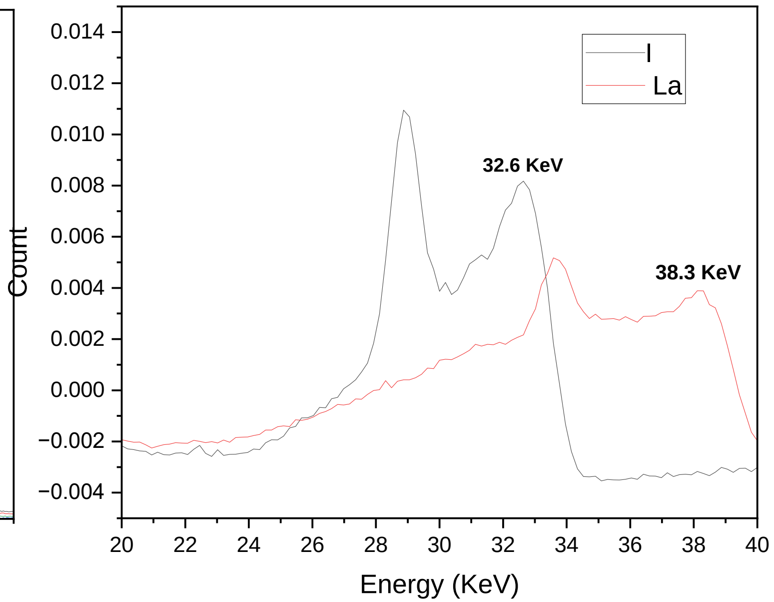
Figure(7)

Separating elements using CdTe

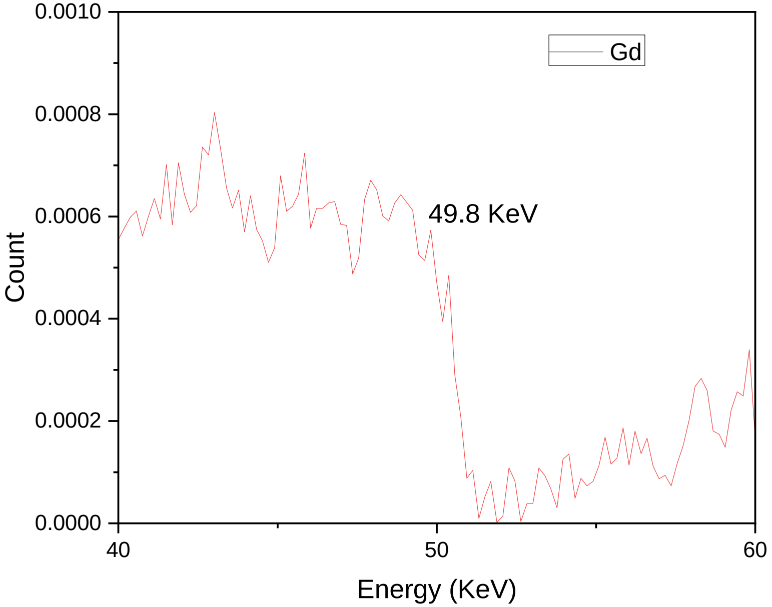
(Iodine, Gd and La)



Figure(8)



Figure(9.a)

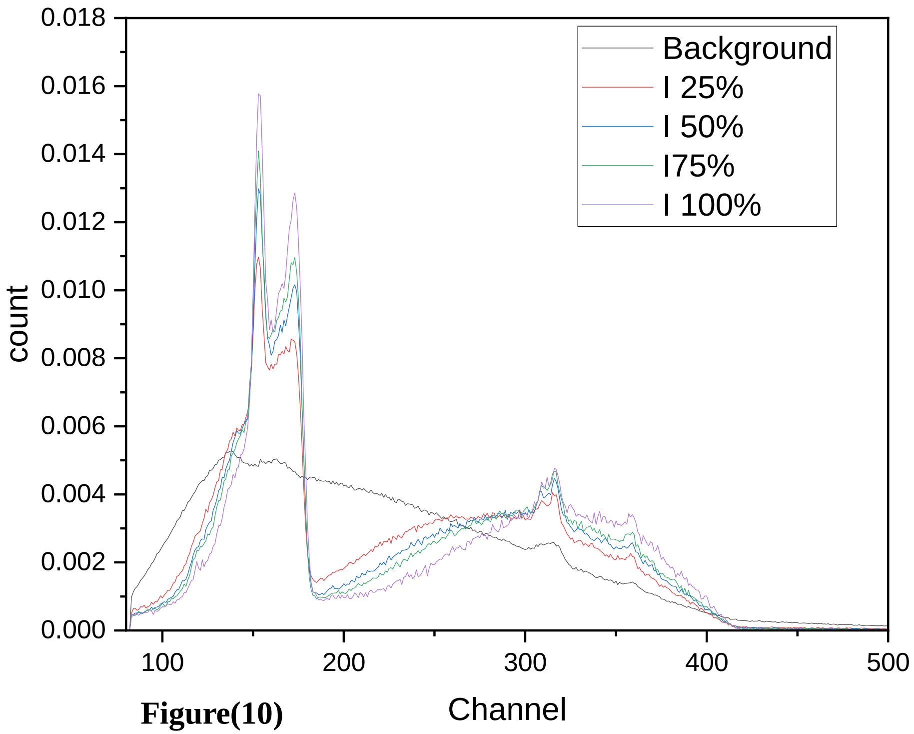


Figure(9.b)

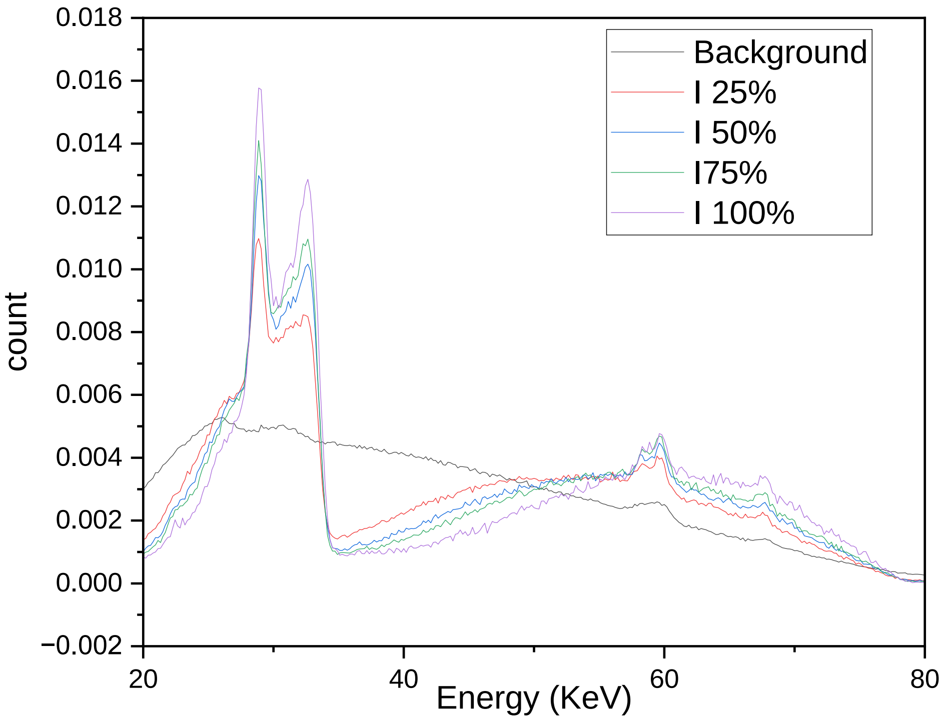
In Figures (8)(the relation between channel and count for Gd, La and Iodine before calibration.

In Figures (9.a)(9.b) respectively the spectrum of energy after calibration for Iodine and La , and for Gd.

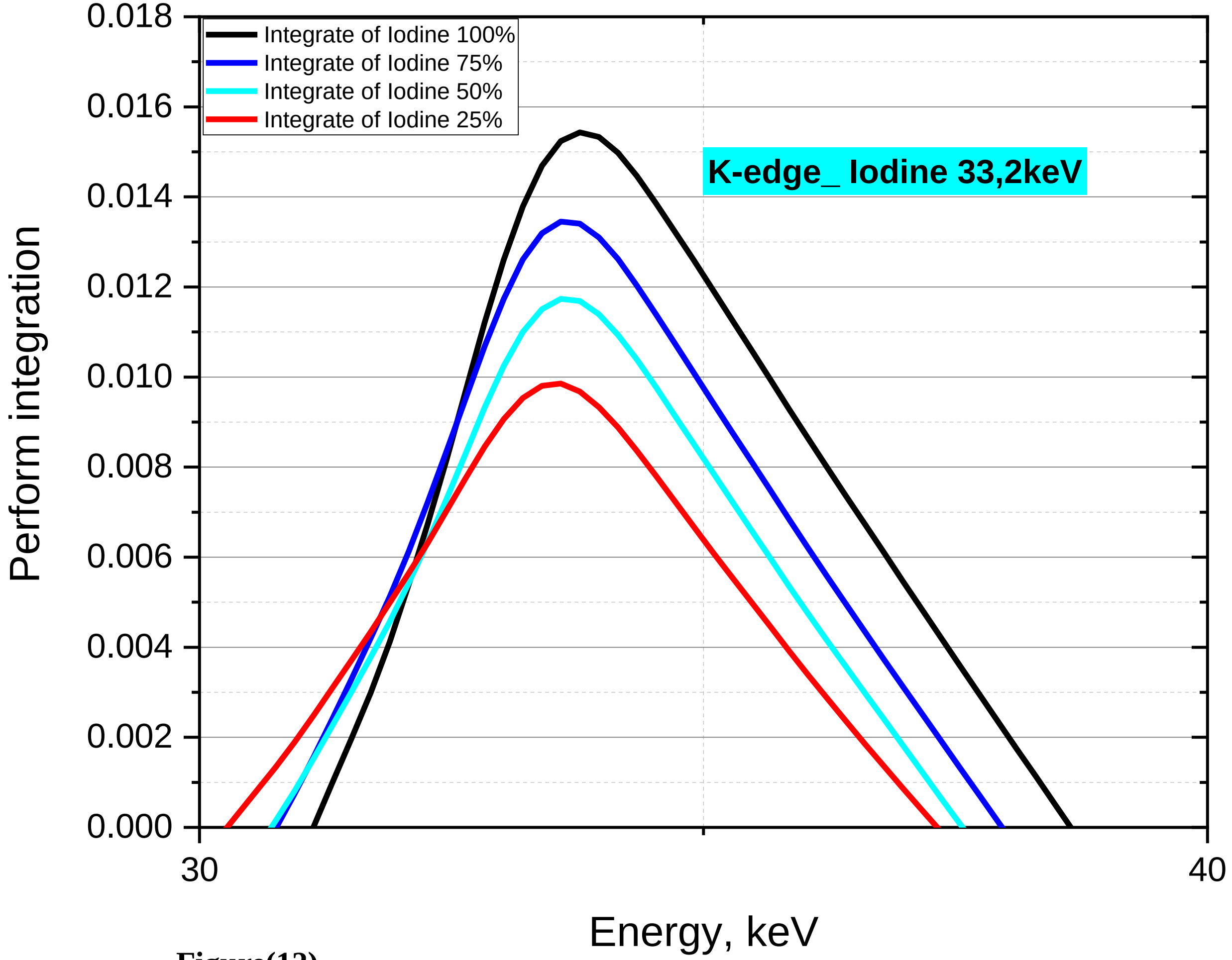
Using CdTe detector to separate iodine with different concentrations at 25%,50%,75% and 100%



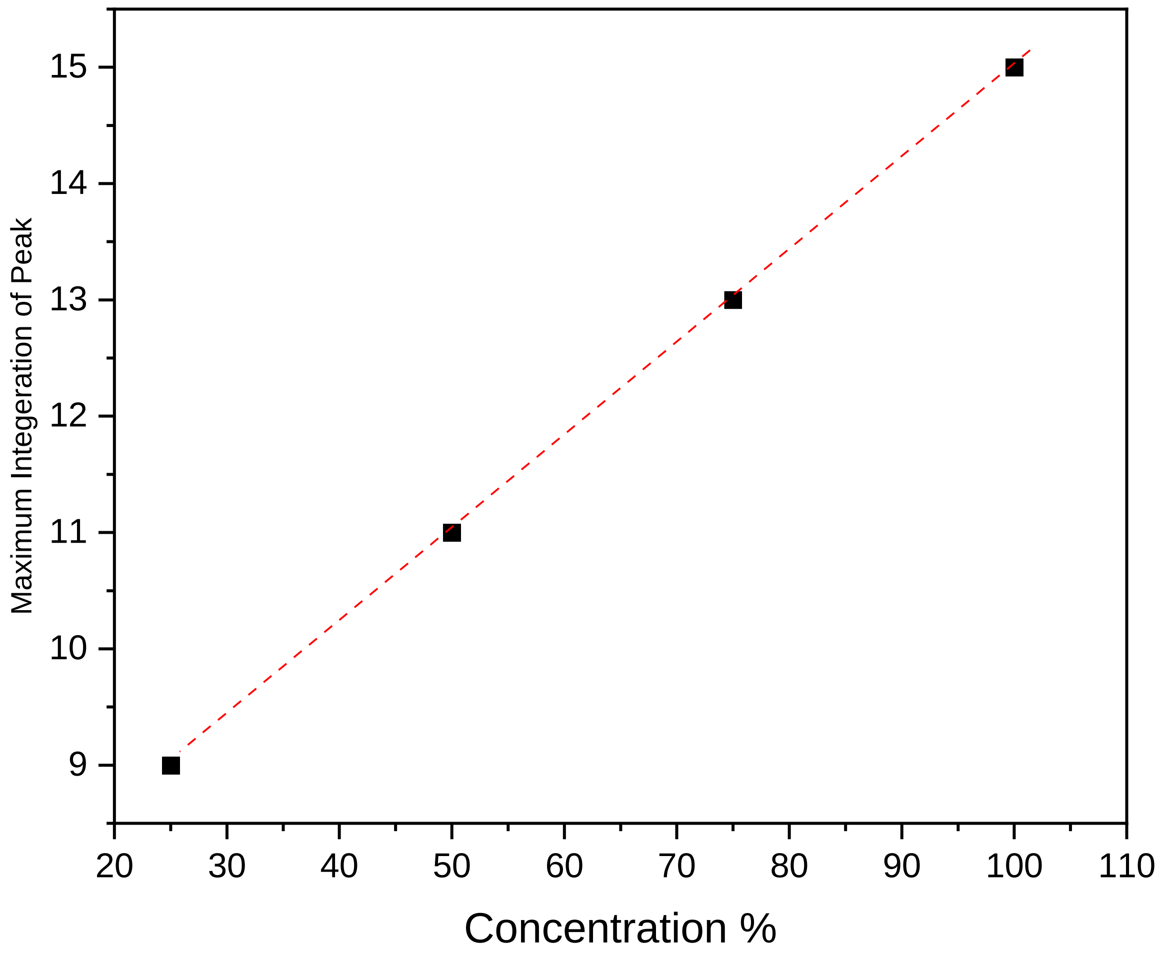
Figure(10)



Figure(11) Energy Callibration Spectrum



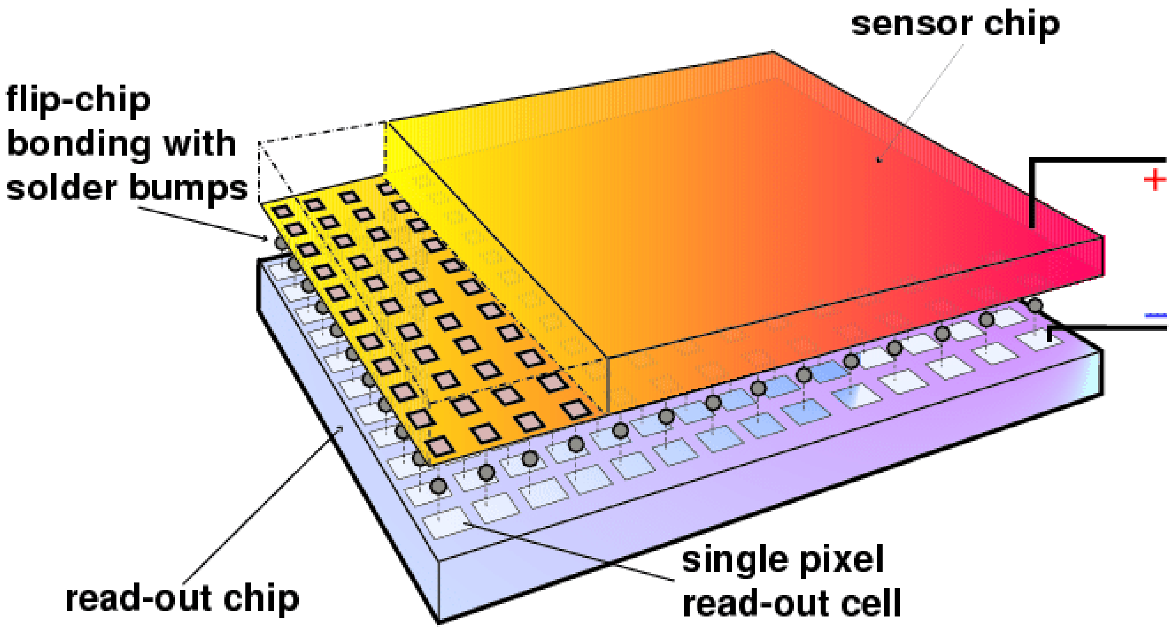
Figure(12)

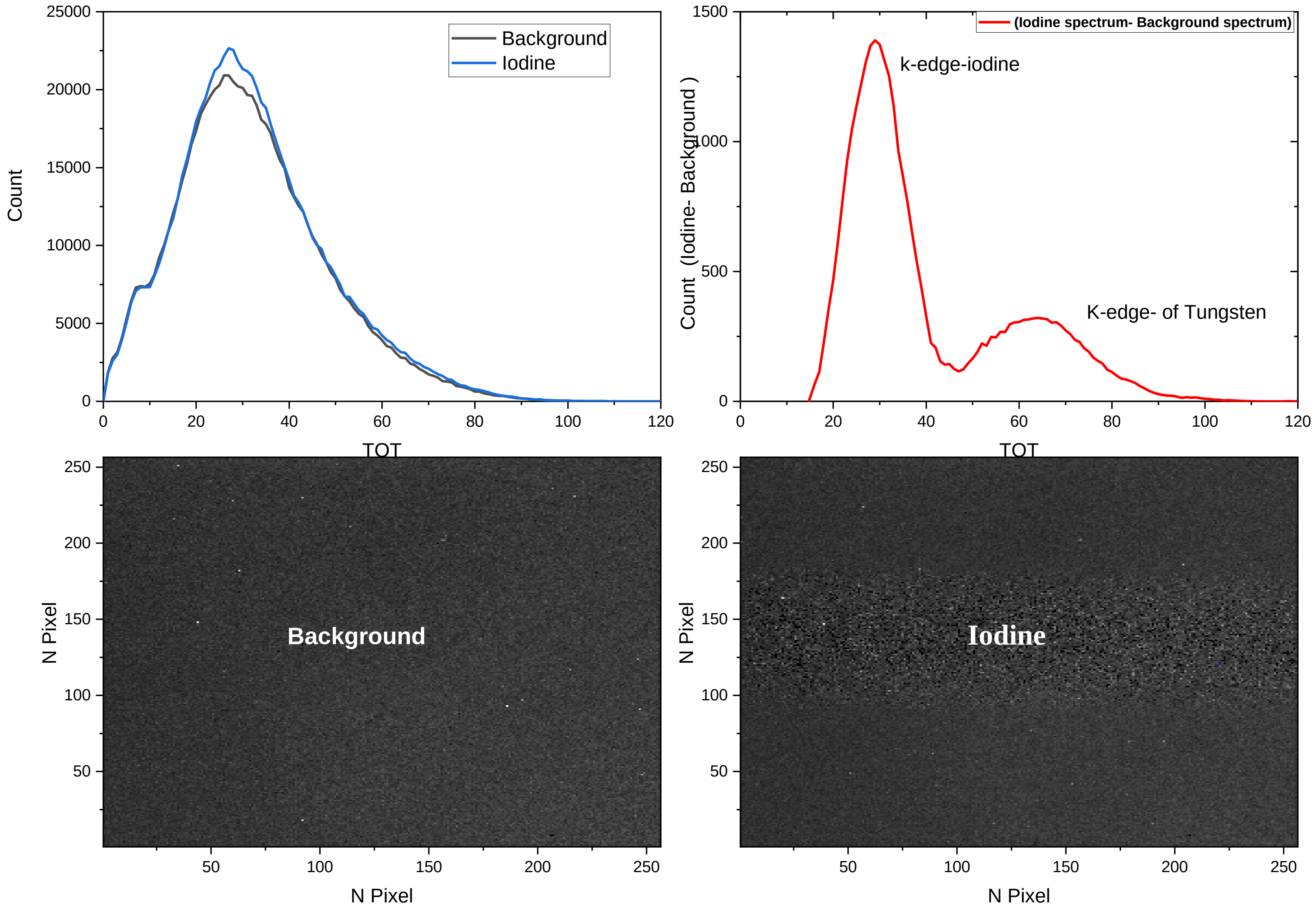


Figure(13)

Pixel Detector

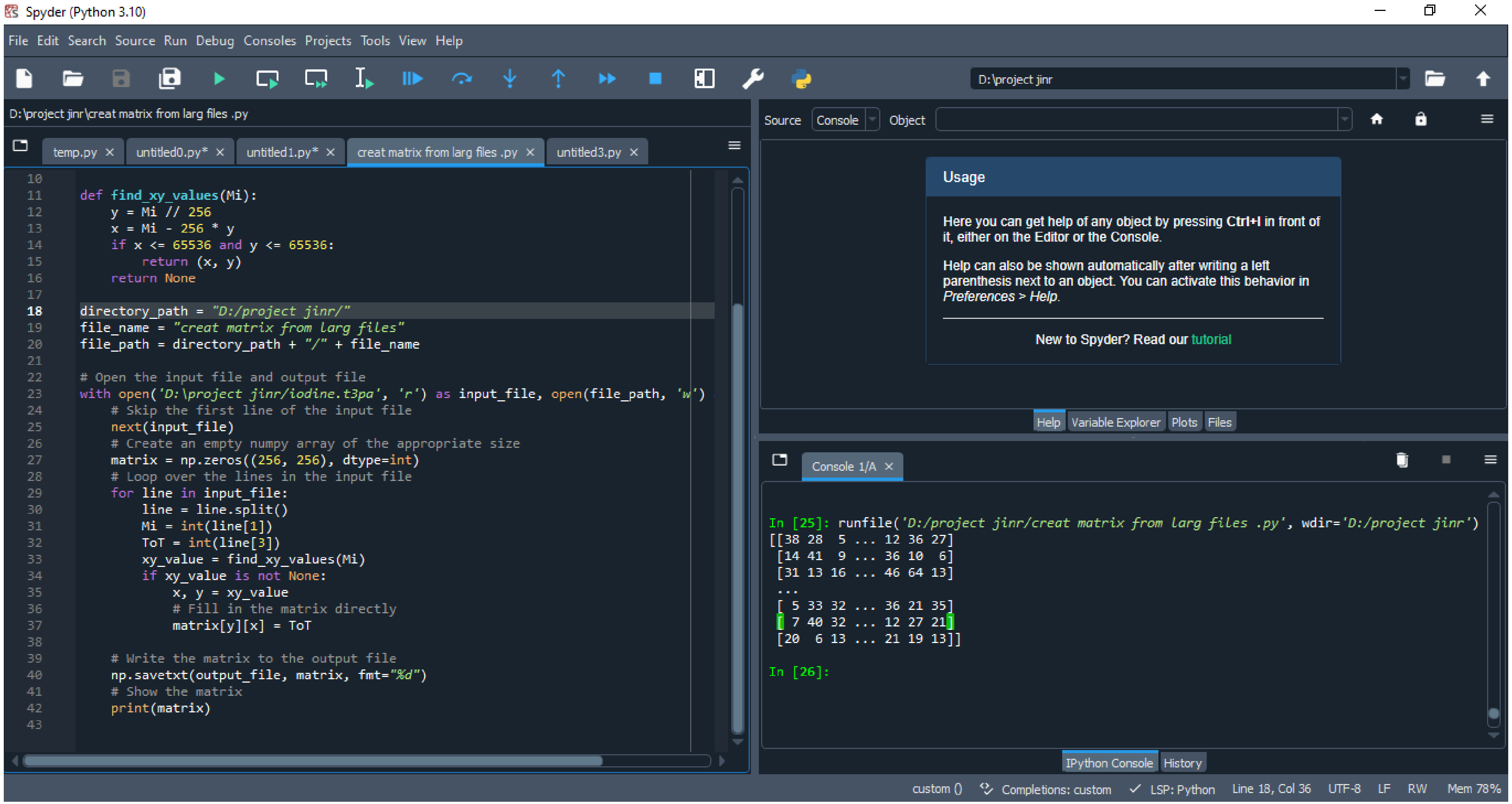
Pixel detector consists of two chips. The first chip/sensor chip is a semiconductor diode with one pixelated contact and one common backside coated by thin layer of nickel, while the second chip is composed of read-out electronics for every pixel. Bump-bonding technique is used to connect both chips. Pixel sizes range from 100 to 400 μm.





Figure(14)

Using pixel detector for identification iodine element.


Spyder (Python 3.10)
File Edit Search Source Run Debug Consoles Projects Tools View Help
D:\project jinr
D:\project jinr\creat matrix from larg files .py
temp.py
untitled0.py*
untitled1.py*
creat matrix from larg files .py
untitled3.py
def find_xy_values(Mi):
    y = Mi // 256
    x = Mi - 256 * y
    if x <= 65536 and y <= 65536:
        return (x, y)
    return None
directory_path = "D:/project jinr/"
file_name = "creat matrix from larg files"
file_path = directory_path + "/" + file_name
# Open the input file and output file
with open('D:\project jinr/iodine.t3pa', 'r') as input_file, open(file_path, 'w')
    # Skip the first line of the input file
    next(input_file)
    # Create an empty numpy array of the appropriate size
    matrix = np.zeros((256, 256), dtype=int)
    # Loop over the lines in the input file
    for line in input_file:
        line = line.split()
        Mi = int(line[1])
        ToT = int(line[3])
        xy_value = find_xy_values(Mi)
        if xy_value is not None:
            x, y = xy_value
            # Fill in the matrix directly
            matrix[y][x] = ToT
    # Write the matrix to the output file
    np.savetxt(output_file, matrix, fmt="%d")
    # Show the matrix
    print(matrix)
Source
Console
Object
Usage
Here you can get help of any object by pressing Ctrl+I in front of it, either on the Editor or the Console.
Help can also be shown automatically after writing a left parenthesis next to an object. You can activate this behavior in Preferences > Help.
New to Spyder? Read our tutorial
Help
Variable Explorer
Plots
Files
Console 1/A
In [25]: runfile('D:/project jinr/creat matrix from larg files .py', wdir='D:/project jinr')
[[38 28 5 ... 12 36 27]
 [14 41 9 ... 36 10 6]
 [31 13 16 ... 46 64 13]
 ...
 [5 33 32 ... 36 21 35]
 [7 40 32 ... 12 27 21]
 [20 6 13 ... 21 19 13]]
In [26]:
IPython Console
History
custom ()
Completions: custom
LSP: Python
Line 18, Col 36
UTF-8
LF
RW
Mem 78%

Conclusion

CdTe of 500 µm thickness expands the usable energy range for detector systems from about 25 keV (with a 500 µm silicon sensor) to about 150 keV (with a 500 µm CdTe sensor), with >90% Registration efficiency to about 65 keV .Our characterization of CdTe sensors bonded to our detectors has led us to the conclusion that the material is suitable for use in a broad range of experimental applications.

Additionally, the CdTe proved good resolution in low energy for identification different elements.

Pixel detector has ability to separate different types of elements like GaAs silicon with high efficiency and technique resulting Matrix of the element. The square pixel (55x55µm) results equal spatial precession in both directions removing the need for double sided modules and saving factor 2 in material.

Pixel detector is very economic way in power and space as its size is tiny compared to other detectors.

Acknowledgment

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Thank You