Radiation Detection and engineering of radiation detectors

Part 2

Scintillation counter

A **scintillation counter** is an instrument for detecting and measuring ionizing radiation by using the excitation effect of incident radiation on a scintillating material, and detecting the resultant light pulses.

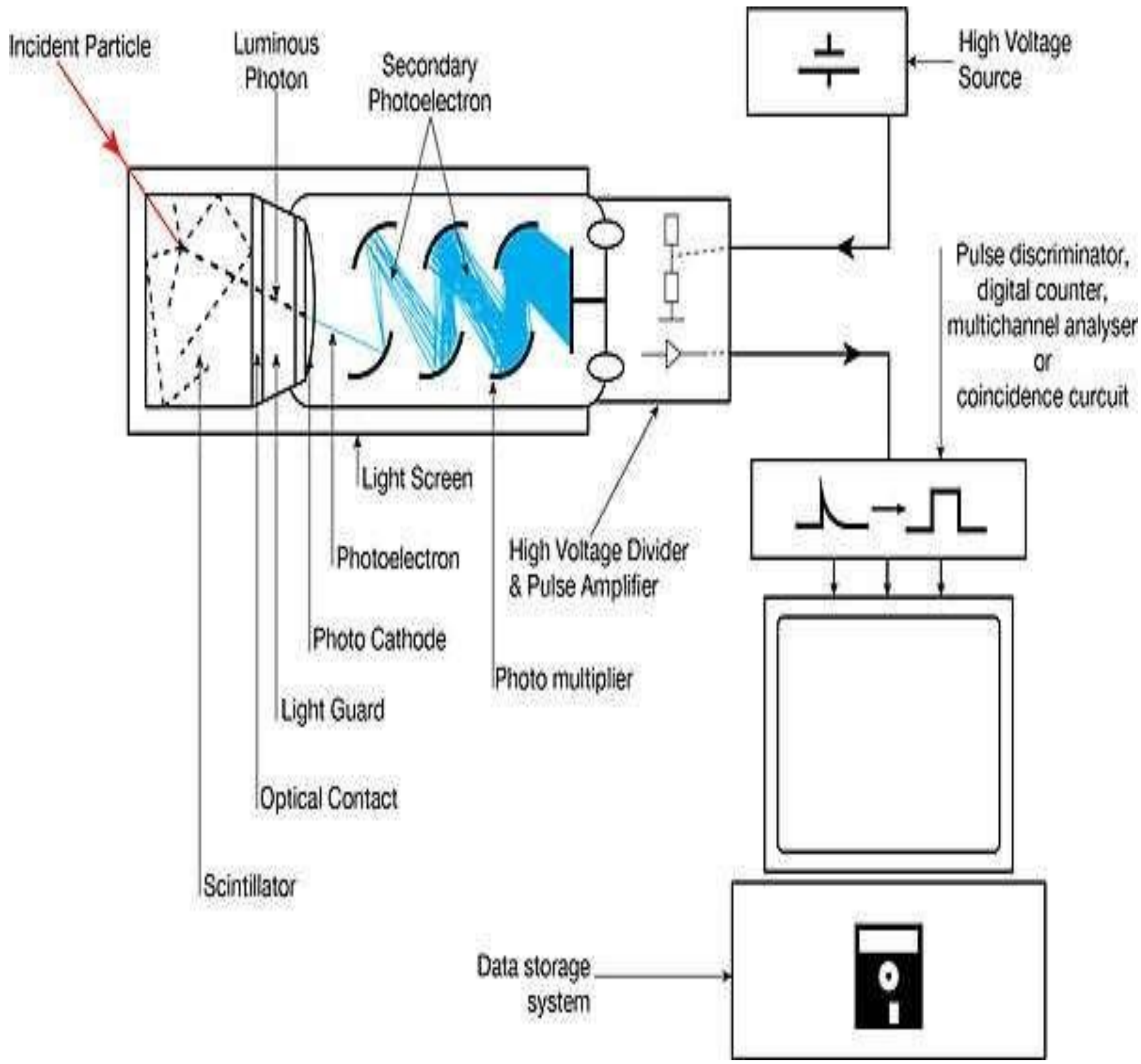


Figure (1): Schematic of a scintillation counter

The operation of scintillation counter

- When an ionizing particle passes into the scintillator material, atoms are excited along a track. For charged particles the track is the path of the particle itself.
- The scintillator produces a multitude of low-energy photons, typically near the blue end of the visible spectrum.
- The quantity is proportional to the energy deposited by the ionizing particle.
- These can be directed to the photocathode of a photomultiplier tube which emits at most one electron for each arriving photon due to the photoelectric effect.
- The low-energy photons which are then converted into photoelectrons and multiplied in the photomultiplier .

The apparatus of Sintillation counter :

1. **Scintillator**

- Scintillators are materials- solids, liquids, gases- that produce sparks or scintillations of light when ionizing radiation passes through them.
- The amount of light produced in the scintillator is very small.
- It must be amplified before it can be recorded as a pulse or in any other way.

2. **sensitive photodetector**

- The most common type is the Photomultiplier tube (PMT).
- The Photomultiplier tube (PMT) is used to amplify or multiply of the scintillator's light.
- Amplifications of the order of 10^6 are common for many commercial photo multiplier tubes.

The scintillation counter consists of the following components:

1. **scintillator** which generates photons in response to incident radiation.
2. **sensitive photodetector** (usually a photomultiplier tube (PMT), a charge- coupled device (CCD) camera, or a photodiode): which converts the light to an electrical signal.
3. **An electronic circuits** to process the electrical signal.

Photomultipliers are typically constructed with an evacuated glass housing (using an extremely tight and durable glass-to-metal seal like other vacuum tubes).

- It is containing a photocathode, several dynodes, and an anode.
- Incident photons strike the photocathode material, which is usually a thin vapor-deposited conducting layer on the inside of the entry window of the device.
- Electrons are ejected from the surface as a consequence of the photoelectric effect.
- These electrons are directed by the focusing electrode toward the electron multiplier, where electrons are multiplied by the process of secondary emission.

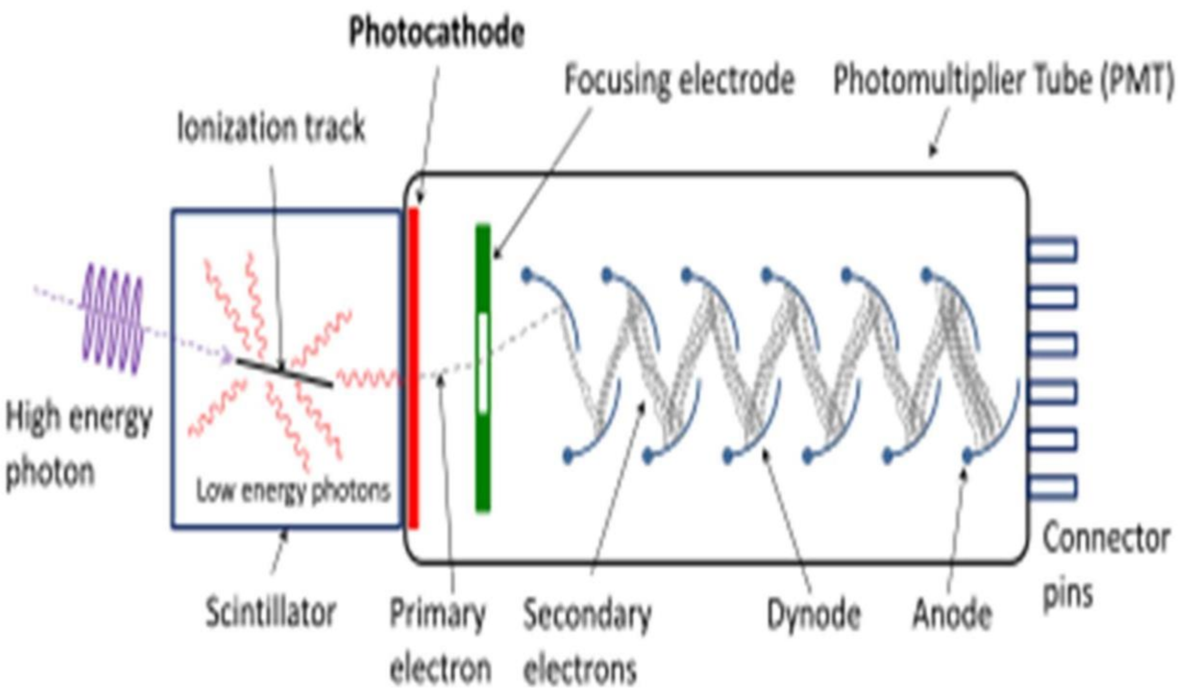
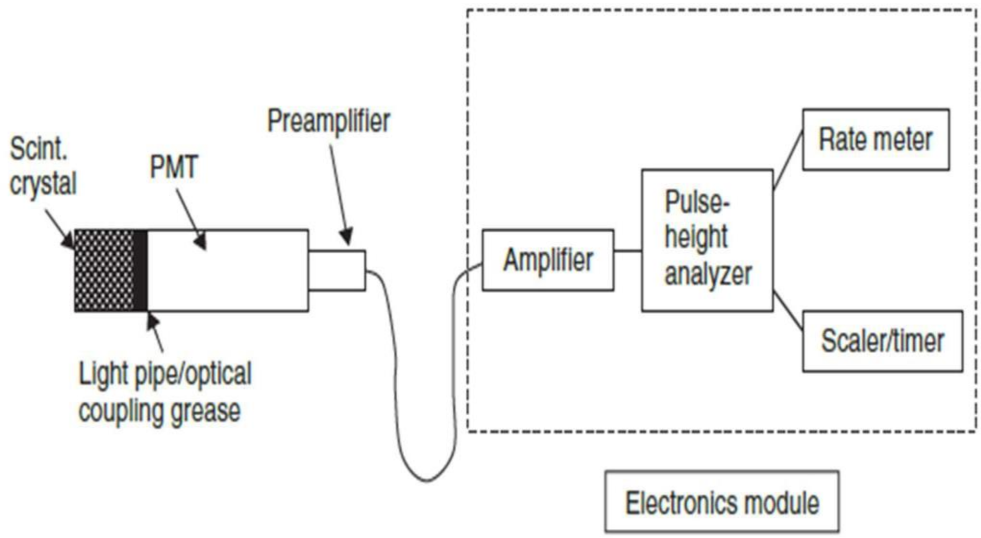


Figure (2): Schematic of a photomultiplier tube coupled to a scintillator.

This arrangement is for detection of gamma rays.

3. An electronic circuit

- **Preamplifier circuit**
- **Linear amplifier**
- **Pulse height analyzer**
- **Scaler and timer**
- **Rate meter**



Block diagram of a scintillation detector. The detector/PMT assembly is usually separated from the electronics module by a cable.

Figure (3) : The contents of the electronic circuit

Dead time of scintillation counter:

The dead time or resolving time : is the minimum time interval required between two successive events for a detector system to register them as separate events.

For a scintillation counter, this time is equal to the sum of three time intervals.

• Time it takes to produce the scintillation, essentially equal to the decay time of the scintillator (0.23 msec).

• Time it takes for electron multiplication in the photo tube, of the order of 20-40 ns.

• Time it takes to amplify the signal and record it by a scalar. The recovery time of commercial scales is of the order of 1 μs.

By adding the three above components, the resulting dead time of a scintillation counter is of the order of 1-5 μs. This is much shorter than the dead time of gas-filled counter, which is of the order of tens of hundreds of micro seconds.

Types of scintillator:

1. Inorganic crystal :
    - alkali iodide that contain small concentration of an impurity, eg. NaI, CsI.
    - High efficiency for detections of gamma rays.
    - Pulse decay time about 1 microsecond
2. Organic scintillator:
    - aromatic compound naphthalene, stilbene.
    - pulse decay time of about 10 nanoseconds.
    - detection of beta particles
3. Plastic scintillator
    - Scintillation chemicals in plastic matrix
    - Pulse decay time 1-2 nanosecond
    - Contain hydrogen (detection of fast neutron)
    - Can be machined into almost ant desirable shape and size ranging from thin fibers to thin sheets. They are inert to water air, and many chemicals, and for this reason they can be used in direct contact with the radioactive sample.
4. Gaseous scintillator
    - Mixtures of noble gases
    - The scintillations are produced as a results of atomic transition, since the light emitted by noble gases belongs to the ultraviolet region, other gases such as nitrogen, are added to the main gas to act as wavelength shifters. Thin layers of fluorescent materials used for coating the inner walls of gas container to achieve the effect of converting invisible ultraviolet (UV) radiation into visible light.

Q : Thin layers of fluorescent materials used for coating the inner walls of gas container.

Solution : **(تعليل)**

To achieve the effect of converting invisible ultraviolet (UV) radiation into visible light.