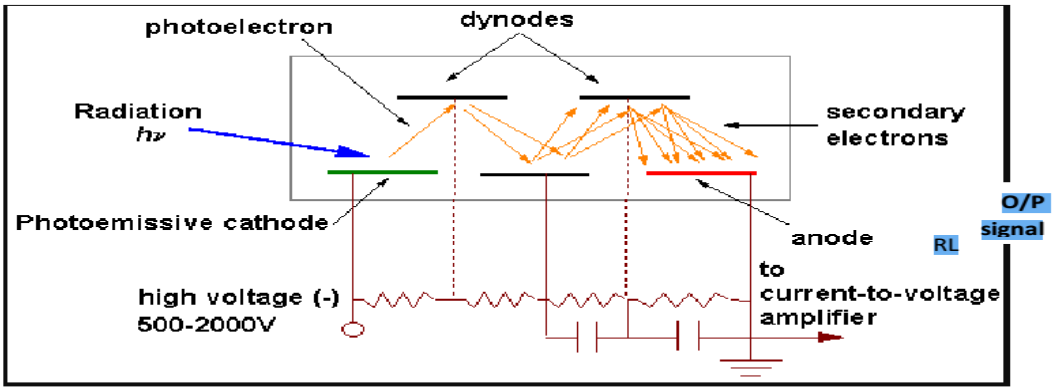
The Photomultiplier:

A photomultiplier tube (PMT) is a combination of a vacuum photodiode and an electron multiplier tube (PMT) is a combination of a vacuum photodiode and an electron multiplier. This multiplier amplifies the photocurrent by secondary emission.



Figure(2): Photocathode+ Electron Multiplier (Structure of the Photomultiplier Tube).

A PMT consists of an evacuated glass tube with a semitransparent photocath at its entarance and several dynodes (8-15 dynodes) in the interior.

Strikes it are guided from the photocathode when light strikes it are guided, using an electric field, toward the 1 st dynode which is coated with a substance that emits secondary electrons if electrons impinge upon dynode from this towards the 3rd , and so on. The voltage difference between two successive dynodes is about 80-120 V.

The photocathode material is mostly a compound of Cs-Sb while the material used to coat the dynodes is either Cs-sb or Ag-Mg. the average number of secondary electrons emitted for each incident electron is known as "secondary emission ratio δ".

δ depends on the dynode material and the interdynode voltage. The dependence of δ on voltage has the form:

$\delta = a V_S^b$ a,b are constants, V is the interdynode voltage (i.e. potential difference between two successive dynodes).

$\delta = 0.2V_s^{0.7}$ for Cs-sb dynodes, $\delta = 0.025\ V_s$ for Ag Mgo dynodes, the electron multiplication (M) of the PMT (i.e., the total no. of secondary electrons per initial photoelectron" is:

$M=\delta^n$ where n is the no. of dynodes

Hence $M= (a\ V_s^b) = k\ V_s^{bn}$ K: constant = a^n

Ex: For δ=4 and n=10 dynodes; then:

$M= 4^{10} \approx 10^6$

Therefore, a cloud of secondary electrons is finally collected on the last electrode (the anode), where it produced a voltage pulse of magnitude:

$V = M\frac{e}{c}$ Where c is the effective capacity of the anode. With C=20 pF, then V≈0.01 volt, thus giving a pulse that can easily be further amplified and detected by conventional circuit.

A very important parameter of a PMT is the spectral sensitivity of its photocathode. The Cs-Sb surface has a max. sensitivity at 440 nm. Such a response called S-11. Other responses are known as S-13, S-20 etc. The quantum efficiency reachs 20-30 % from practical photocathodes.

Ordinary glass or pyrex can absorb photons of $\lambda \leq 350$ nm, hence the PMTs window (radiation entrance) is usually made of quartz when they are used to detect UV photons. The PMTs are therefore, more sensitive than any other detector in the near UV and Vissible regions.

The dark current (electrons emitted from the photocathode in absence of radiation due to thermoionic emission) increases with photocathode area. A 50 mm diameter photocathode may release in the dark as many as 10^5 electron/s at room temperature. Cooling of the photocathode reduces this source of noise by a factor of 10 (for Cs-Sb) when the temperature is reduced from R.T. to 0 ^{0}c.In similar condition, the reduction of 16 times can be obtained for trialkali photocathodes.

PMT general characteristics:

1. High sensitivity (~ 100kA/W); the minimum detectable power is 10^{-15} W.
2. Linearity; the produced current is proportional to the incident power.
3. Fast response; (1-100 ns).

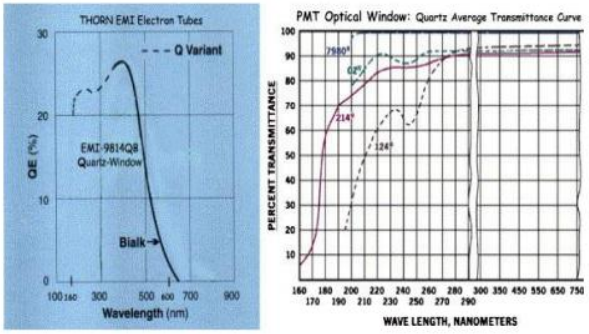
Environmental limitation:

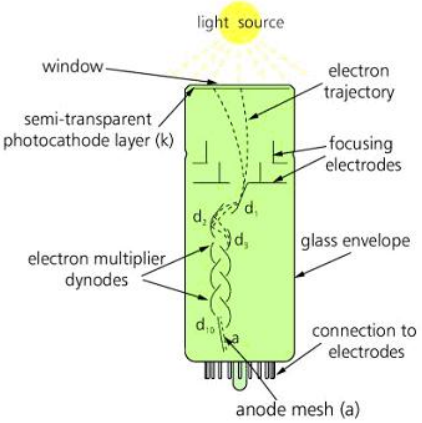
1. Sensitive to magnetic and electrostatic fields ⟶ μ-metal shield (Fe-Ni alloy).
2. Temperture limitations ⟶ Cooling.
3. Radiation sources ⟶ Shielding.
4. Intense light must be avoided.

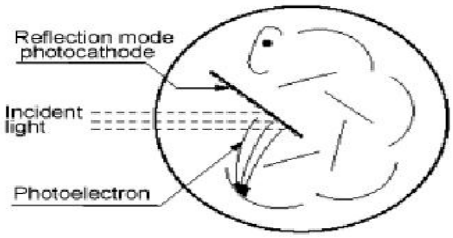
Email (alaa.hussein.ali@uomus.edu.iq)

Al-Mustaqbal University
Department (الاجهزة الطبية)
Class (الرابعة)
Subject (نظم الليزرالطبية)
Lecturer (أ.د علاء حسين علي)

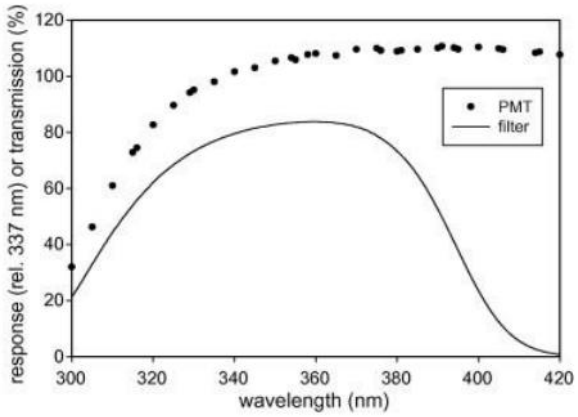
2nd term – Lect. (**Photomultiplier**)

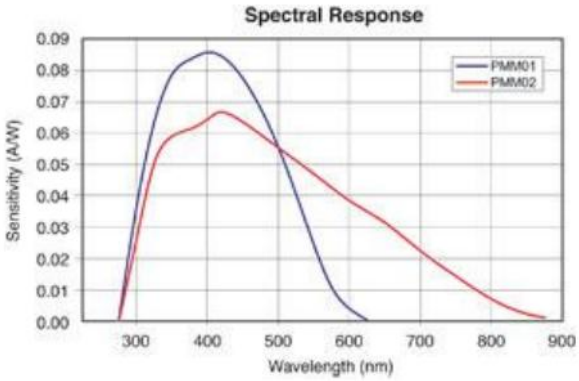






Email (alaa.hussein.ali@uomus.edu.iq)


response (rel. 337 nm) or transmission (%)
wavelength (nm)
PMT
filter


Spectral Response
Sensitivity (A/W)
Wavelength (nm)
PMM01
PMM02