Use of Hybrid Photon Detectors in scintillation studies and imaging applications

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Basic concept of Hybrid Photon Detection (HPD) is known more than 50 years but their intense use started 20 years ago with research and development of scintillators for CERN application: “New generation of electromagnetic calorimeters at LHC”

This poster has three main goals:
1. to describe Hybrid Photon Detection (HPD), especially Hybrid PhotoMultipliers (HPMT)
2. gamma spectroscopy of scintillators including measurements of scintillation using HPMT
3. to describe and characterize the newest systems as X-Ray-Sensitive Hybrid Photon Detectors or Tubes and their possible use in X- and γ-Ray detection and imaging (LHCb project, medicine, etc.)

Summary and conclusions
- HPMT are sophisticated new photon detectors characterized by easy and reliable photoelectron calibration characterized by less noise compared with classical PMT’s
- HPMT is important value, especially in imaging applications.
- HPMT consists of only vacuum-sealed photocathode – Si-PIN diode as anode
- Photoelectrons are accelerated by an electric field
- No dynodes are present
- Advantages (compared to PMT): high photoelectron resolution, good timing, less noise than PMT
- But it is necessary to amplify signal of HPMT

SCINTILLATION - SCINTILLATION DETECTION

Excitation Emission

CRystal

Radiation – photons of GeV, X- and γ-rays or ions

Characterization

- scintillation properties (response)
- light or photoelectron yield (L.Y./phMeV or Nphels/MeV)
- energy resolution (FWHM in %)
- proportionality (important for scintillation detectors) = calculated to 662 keV energy line of 137Cs
- time dependences including scintillation decay

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HYBRID PHOTON DETECTION - light conversion of scintillating photons into photoelectrons at a photocathode and their detection at Si-PIN anode

ΔX-γ- or γ-Ray optoelectronic camera

ΔX- or γ-Rays

Characterization

- Nphels, detector yield
- energy resolution – FWHM (% or FW(1/5) (%)
- proportionality

Generally, we measure Nphels photoelectron yield on thin crystal samples ~ 0.5-1 mm
From the above given Nphels results the Si-PIN detector exhibit (1 mm thickness) YAP:Ce ~ 5.32 phels/keV LYSO:Ce ~ 4.78 phels/keV (L.Y. above 20.105 phel/MeV)

Energy resolution is important value, especially in imaging applications.
The best FWHM (FW(1/5)) ~ 5 % at 662 keV energy line followed by LYSO:Ce and LuAG:Ce (FWHM ~ 10 %)

Energy resolution is important parameter, especially for scintillation detection – it is possible energy range of its using.
YAP:Ce exhibit good proportionality in the range ~ 30 – 1300 keV.
Also YAG:Ce has ~ good proportionality.

Summary and conclusions
- HPMT are sophisticated new photon detectors characterized by easy and reliable photoelectron calibration characterized by less noise compared with classical PMT’s
- The largest use of HPD’s (HPMT) is at LHCb experiment at CERN as the RICH detectors for particle identification (~ 500 HPD’s). Each of HPD contains array of 8192 Si pixels pixels details of their use at CERN at LHCb RICH detector will be given in other talks of this conference.
- Possible imaging applications of scintillators, HPMT’s or other detectors (e.g. CCD’s)
- Again, similarly as with the use of HPD (HPMT) at CERN LHCb project the HPD (HPMT) can also be used in imaging applications as well.
- Generally, (Y,Lu)Al garnets or perovskites are stable and hard crystals and it is no reason why they could be used as PMT window – especially YAP:Ce was tested as photocathode window (see [4-6]). YAP:Ce crystals are produced by Crytur Ltd., Palackeho 175, 511 01 Turnov, Czech Republic.
- OPA tube (ray optoelectronic camera) was tested ten years ago (see [4-6]). The tube consists of two principal parts: (i) YAP:Ce window (photocathode was evaporated on the inner side of the vacuum tube) and (ii) array consisting of scintillating elements (pixels – here spatial resolution depends on profile of pixels but they are ~ 1 × 1 mm² of profile) and (ii) silicon anode is an array of Si-diode pixels (array chip) alike as in HPD’s of RICH LHCb detectors.
- The use of Ce-doped inorganic scintillating crystals (Y,Lu)Al garnets, perovskites and silicates show that Lu-containing ones should be used (they are heavier than Hg(II) alone) but it is necessary to eliminate their slow decay components due to presence of shallow traps in (Lu,Lu)Al garnets, perovskites and silicates.
- Now, it seems that YAP:Ce crystal was tested and is convenient in imaging applications (y-camera, small animal PET).