Development of a new type of hybrid photo-detector involving photocathode, scintillator and silicon photomultiplier: SiPMT

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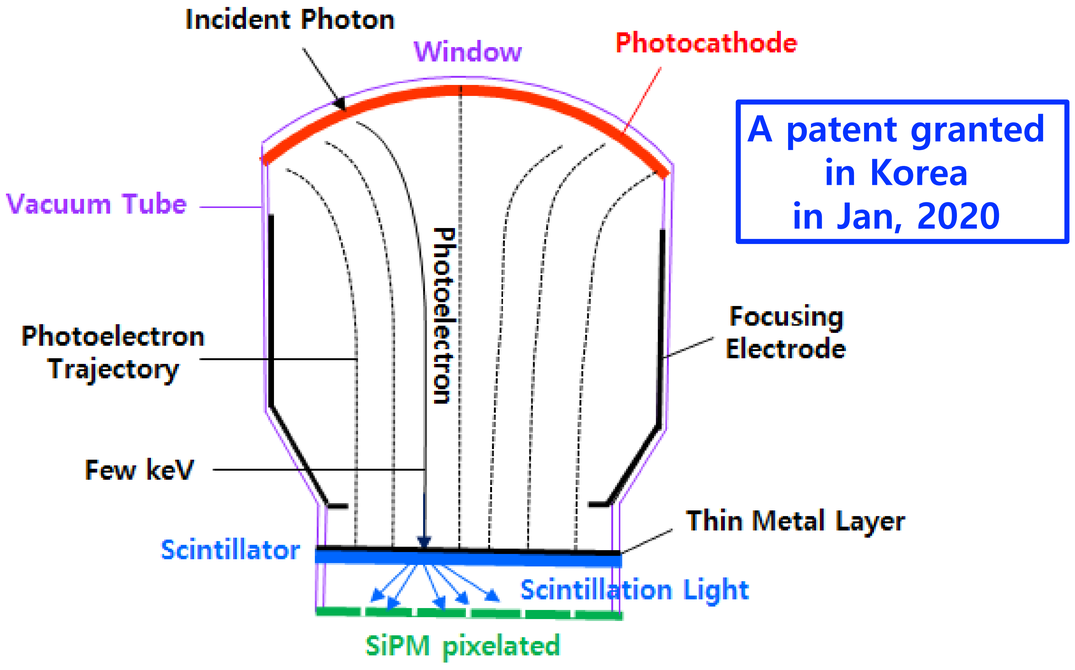
Abstract

We proposed a new type of hybrid photo-detector that consists of photocathode, electrode, scintillator, and silicon photomultiplier in vacuum tube. This type of photo-detector with a large area of photocathode could be utilized in photo-detector array for neutrino detection. Photons incident onto the photocathode are converted to photo-electrons. Due to the electric field, the photo-electrons accelerates toward the scintillator to produce scintillation lights. The scintillation lights, then, enters to the silicon photomultiplier SiPM to be converted to an electrical signal. The advantage of this type of photon-detector is that the scintillation lights contributes an extra gain in the order of tens to the total gain in addition to the base gain of at least 10^6 given from the silicon photomultiplier. We present the test result obtained with a demonstrator built to prove the principle of this type of photo-detector. We also present the design of experimental setup for fabrication of this type of detector.

SiPMT

Concept



A patent granted in Korea in Jan, 2020

Photo-detector Comparison

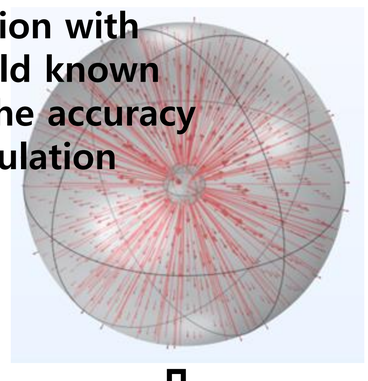
	S	M Gain	B Gain	γ Gain	Gain	Voltage	Type	Comment
PMT	1	~10^6			~10^6	~2 kV	Vacuum Tube	Complex
PD	~100	1			1	~50 V	Semiconductor	
APD	~10	~100			~100	~200 V	Semiconductor	
SiPM	1	~10^6			~10^6	~50 V	Semiconductor	
HPD	1	1	~10^4		~10^4	~10 kV (~50 V)	Vacuum Tube + Semiconductor	~10 kV
HAPD	1	~100	~10^4		~10^6	~10 kV (~200 V)	Vacuum Tube + Semiconductor	~10 kV
SiPMT	1	~10^6		≥ 20	~2 x10^7	~few kV (~ 50 V)	Vacuum Tube + Scintillator + Semiconductor	few kV

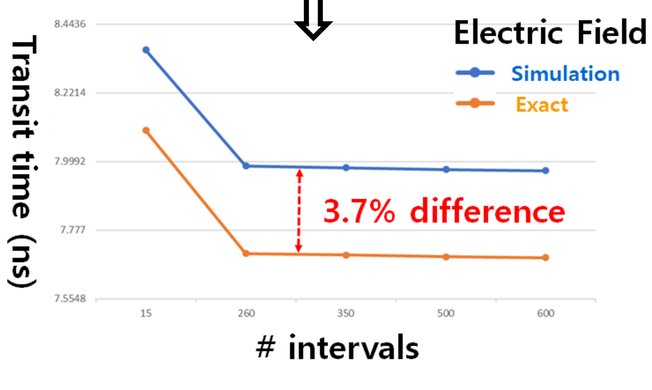
HPD: Hybrid Photo-Diode
HAPD: Hybrid APD

Voltage in (): Applied to silicon senor

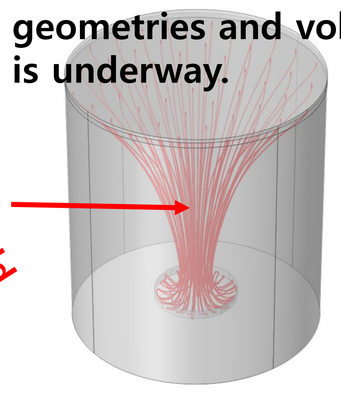
Electro-Static Simulation

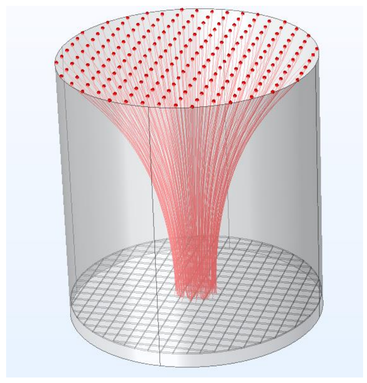
Two spherical-shell configuration with electric field known to check the accuracy of the simulation





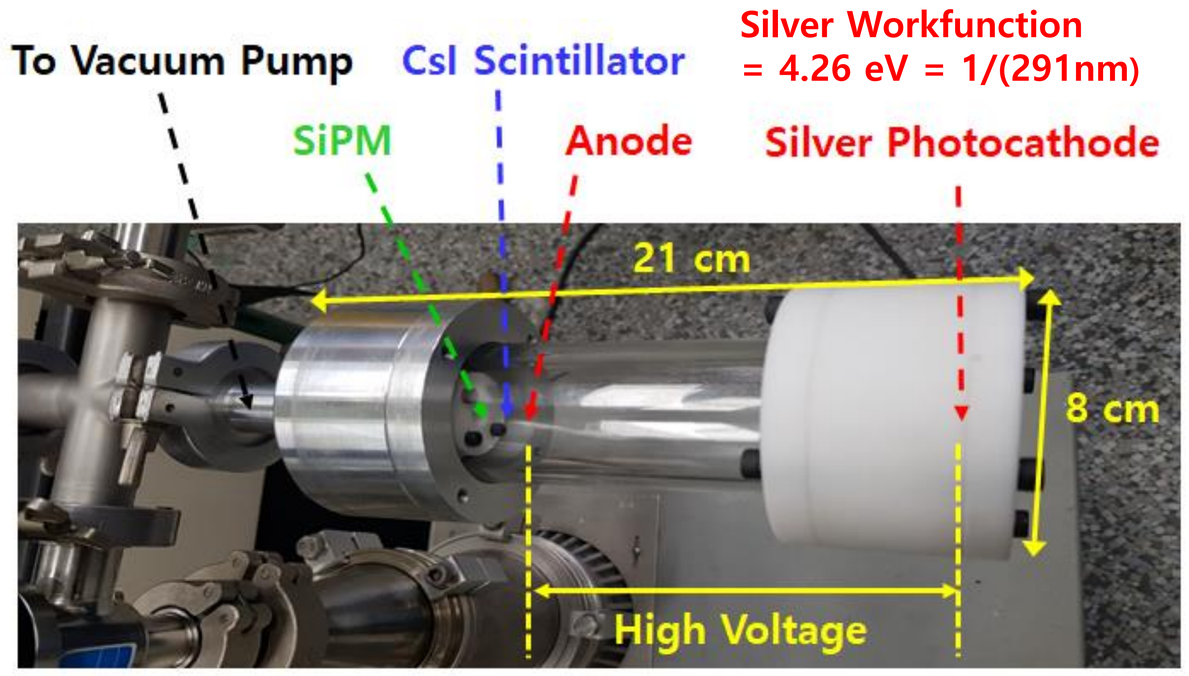
Simulation for various geometries and voltages is underway.





Demonstrator

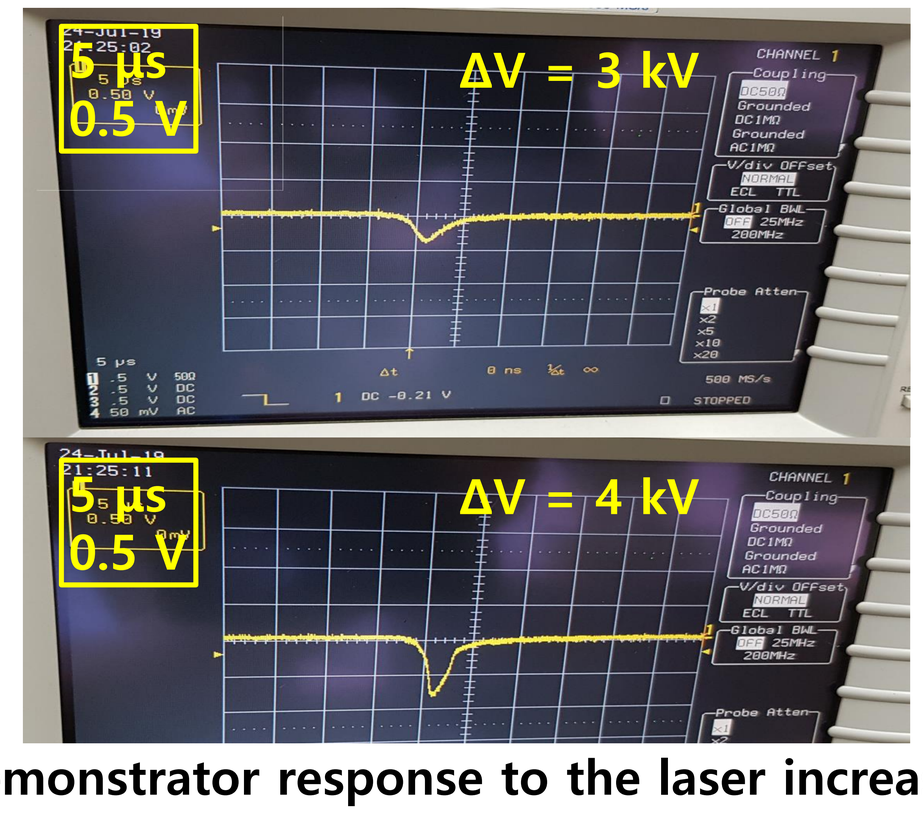
Setup



Result

- Vacuum ~ 10^{-3} Torr
- UV laser of 266 nm wavelength on silver photocathode
- High voltage ΔV applied to CsI+SiPM+preamp relative to silver photocathode

Preliminary (need to confirm)!



Demonstrator response to the laser increases as ΔV increases!

Summary

- We proposed a novel hybrid photo-detector called SiPMT which consists of photocathode, scintillator and SiPM.
- We applied for the patent regarding SiPMT and it was granted in Korea in Jan, 2020.
- SiPMT with a large area of photocathode could be utilized in a photo-detector array for neutrino detection
- Electro-static simulation for various configurations of SiPMT is underway.
- We built a demonstrator for the principle proof of SiPMT. We observed the response of SiPMT to a UV laser increases as the high voltage applied to SiPMT increases.
- Experimental setup to manufacture SiPMT is being assembled.