Gaseous photomultiplier with a 25-picosecond single-photon time resolution

Ryogo Okubo[a], Kodai Matsuoka[abc], Yuya Adachi[a]

[a]Nagoya University, [b]High Energy Accelerator Research Organization (KEK), [c]The Graduate University for Advanced Studies (SOKENDAI)

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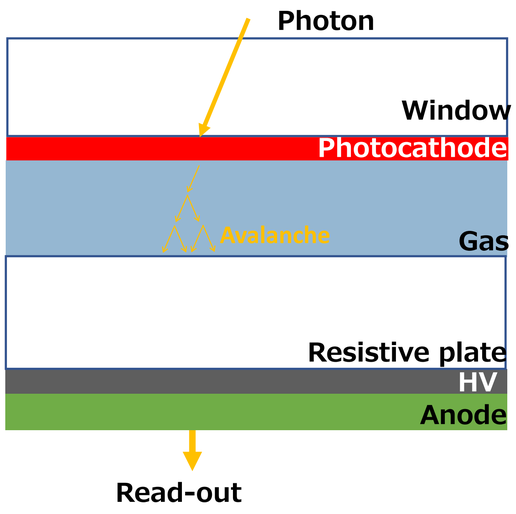
Introduction

To improve the performance of particle detectors that detect Cherenkov or scintillation light, Photodetectors with high efficiency, extensive coverage, and high time resolution are required. Conventional photodetectors can satisfy a part of them, but not all simultaneously.



GasPM:

Gaseous **P**hoto **M**ultiplier

Advantages

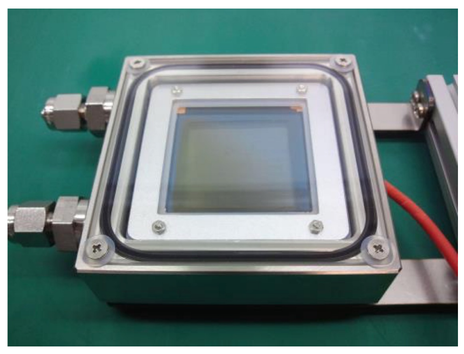
- **High time resolution**
  Fast avalanche in the narrow $O(100\mu m)$ gap
- **Large Photo coverage**
  Can be enlarged without reducing time resolution by uniform structure
  Easy to enlarge because of the atmospheric pressure of the gas
- **Lower-cost**
  The structure is simple, and no expensive materials are used

Time resolution measurement

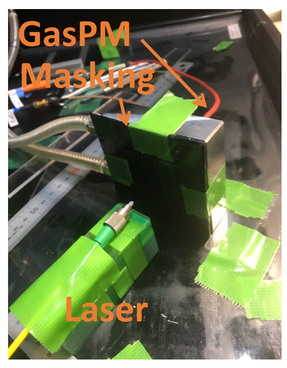
The first target of the development is to demonstrate that GasPM has a great time resolution. The first prototype was developed for it.

It has a LaB_6 photocathode that can be handled in the air to make assembly easier and uses TEMPAX Float ® glass that has a high resistivity for a resistive plate to reduce the risk of breakdown. A laser was spotted through an optical fiber on a $6\times6\ \mathrm{mm}^2$ active area around the center of the photocathode, and signals were recorded by a digitizer.

GasPM 1st Prototype



Setup of the measurement



Laser

Wavelength: 375 nm
Repetition rate : 100MHz
Average Power: 1 mW

Read-out

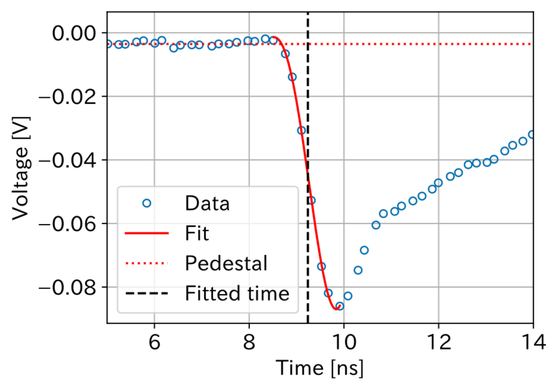
DRS4 evaluation board

- Sampling rate: 5 G samples / sec
- Analog bandwidth: 700 MHz
- Time resolution: 14.0 ± 0.3 ps

Results

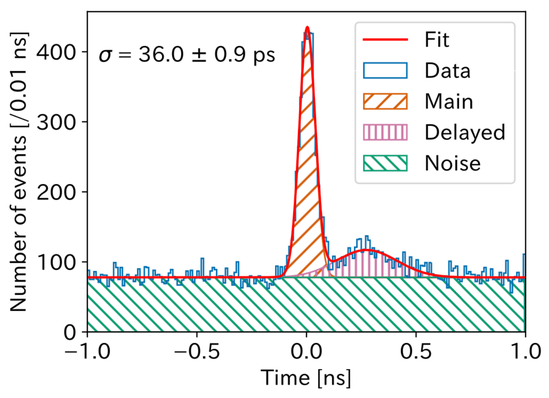
Waveform fitting

Performed waveform fitting for good time resolution



- Subtracted pedestal from baseline fitting
- Extract only the rising edge → Polynomial fitting
- Signal detection time: time at half of the pulse height

Time resolution



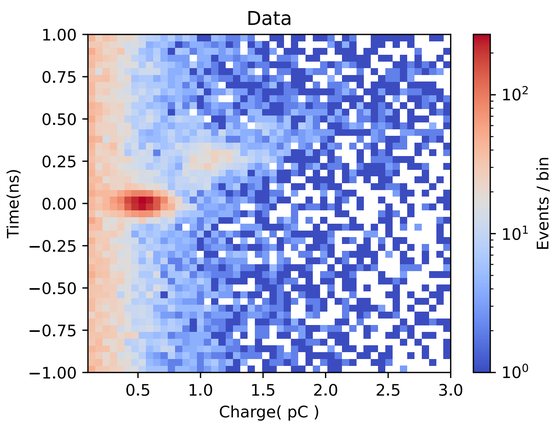
Double gaussian fitting to separate “delayed” signals

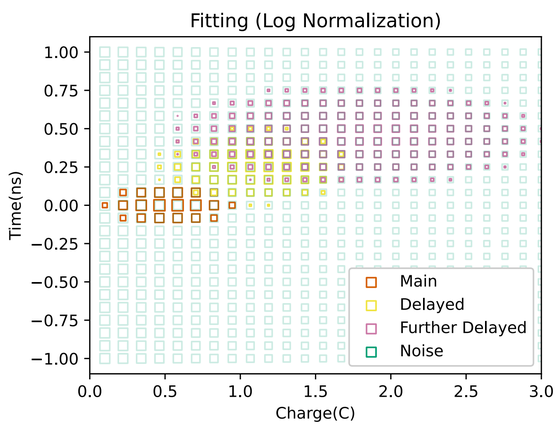
$\sigma = 36.0 \pm 0.9$ ps
→ **σ =25.0 ± 1.ps**
(w/o Laser width or read-out resolution)

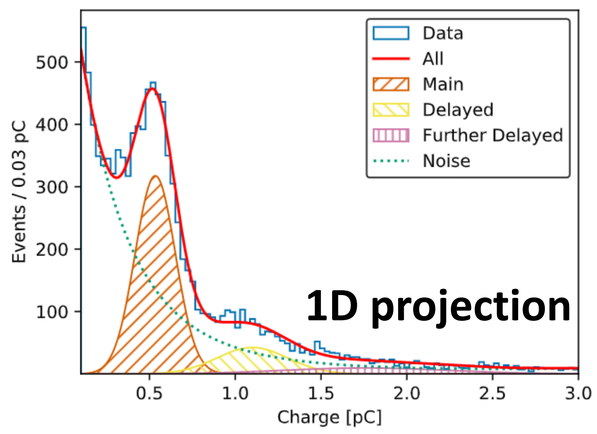
Better performance than that of MCP-PMT!

Delayed signals

To extract the signal yields, 2D fitting for the timing and the charge was performed. As a result, laser timing signals have three components, main, delayed, and further delayed.



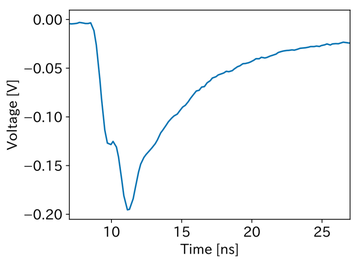


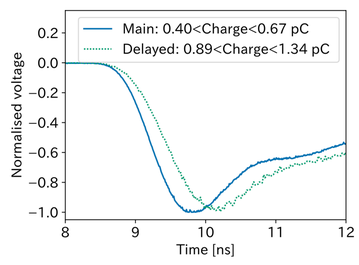


	Yield	Ratio of the signal component
Main	3224 ± 64	1
delayed	752 ± 48	0.23 ± 0.02
Further-delayed	394 ± 47	0.30 ± 0.02

The cause of the delayed signals

Observed multi-pulse in delayed signals
Averaged waveform shape was different
→ Multi-pulse made large-gain and distorted shape signals

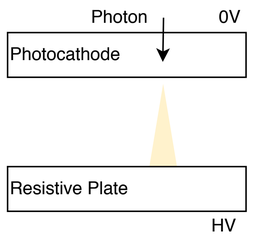




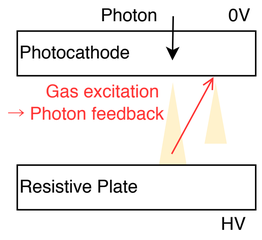
Photon-feedback

- Excited Gas by avalanche → UV light when de-excitation → Secondary Avalanche
- Using the ratio of the signal component, photon feedback occurrence under the assumption of a Poisson model is estimated to be 0.30 ± 0.02. The signal ratio shows good agreement with this assumption.
- The pulse shape of the Delayed signals shows good agreement with the sum of the Main and 530 ps (electron drift time in the gap) shifted Main waveforms. The signal time difference agrees with this assumption.

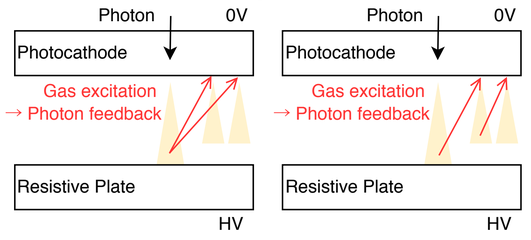
Main

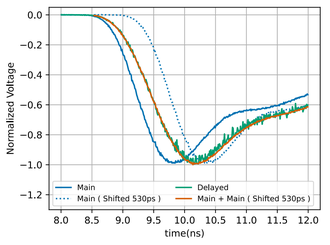


Delayed



Further Delayed





Conclusion

We developed a gaseous photodetector, GasPM that could have a large coverage and high time resolution at a low cost. We demonstrated the high time resolution of 25.0 ps using the first prototype. Some delayed signals were observed, and they are caused by photon feedback. It would be a major challenge for GasPM in our future development.

Acknowledgments

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