



Innovating Photon Detection: Latest Developments in RayQuant's CMOS SiPM

Hui Lao

RayQuant Technology Co. Ltd.

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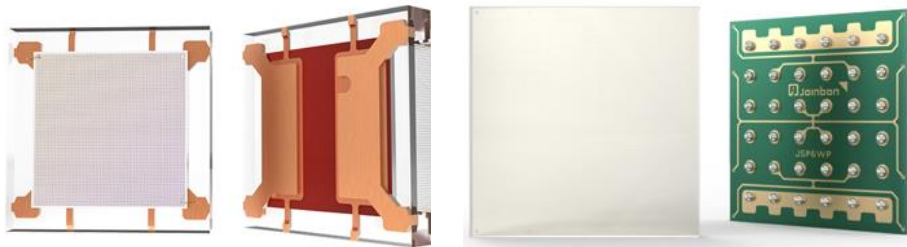
03 Application Cases

RayQuant's Products Outline

Specializing in SiPM implementation using standard CMOS technology, with developed series of chip products, application modules, and comprehensive solutions.

SiPM Chips

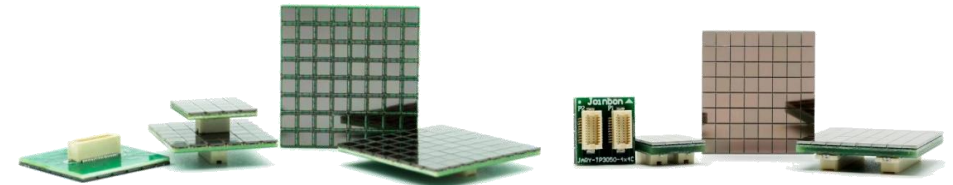
TN x050 Series SiPM TP x050 Series SiPM



SiPM Array

JARY-TP30xx Series

JARY-TN30xx Series

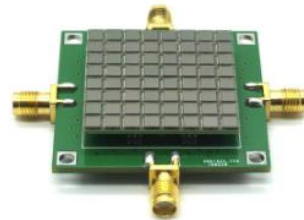


Customized SiPM modules & Application resolution

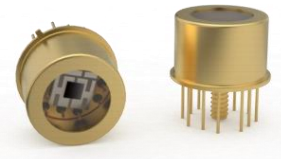
Single Photon Counter



High SNR SiPM Array Summation Readout Evaluation Board



Cryogenic SiPM



SiPM Evaluation Board



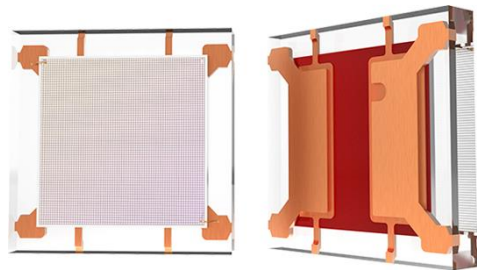
Power Supply Module with Temperature Compensation



RayQuant's Products Outline

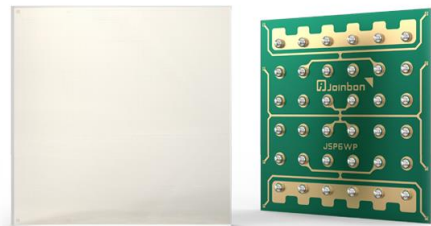
Following three rounds of technological iterations, two generations of SiPM products have been launched and mass-produced.

First Generation TN x050Series SiPM



Second Generation TP x050Series SiPM

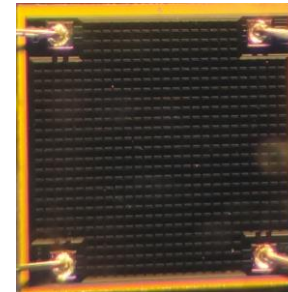
PDE:35%
SPTR:75ps



More compact and reliable "dead zone"
size <0.05mm

Third Generation RQLx035series SiPM

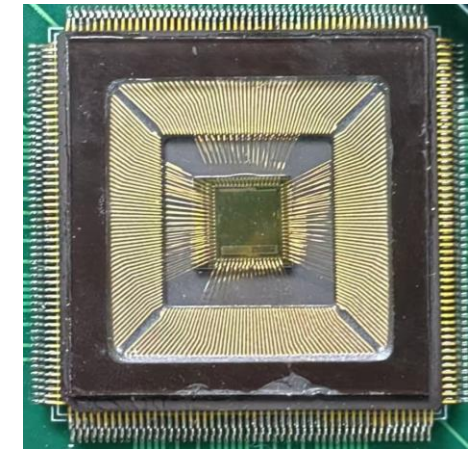
PDE over 60%
SPTR better than 50ps



New device structure with enhanced blue-
light performance and higher PDE in
red/near-infrared wavelengths, targeting
applications in TOF-PET, LiDAR, and
related fields.

Digital: MT SiPM

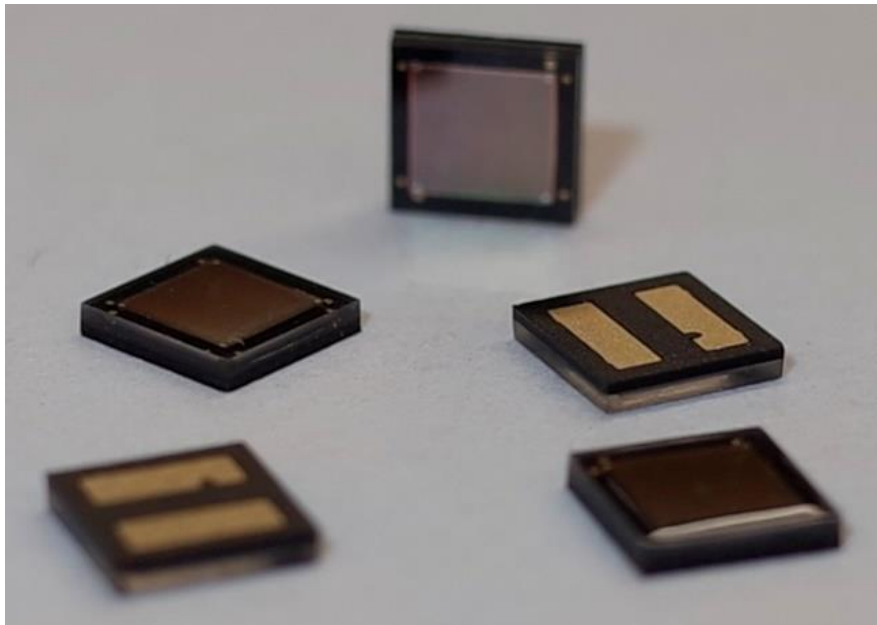
CMOS transistor quenching
integrated multi-threshold all-digital
sampling circuit



Nearly 500,000 CMOS SiPM chips have been delivered so far.

RQLx035 Series SiPM

Typ. no.	Active area	Microcell pitch	Number of microcell	Fill Factor
RQL1035	0.98 mm*0.98 mm	35 μ m	596	78%
RQL3035	2.98 mm*2.98mm		6501	



Features

- High Fill factor (78%)
- High PDE (61% at 420 nm, $V_{ov}=3V$)
- High gain (10^6 order)
- Excellent breakdown voltage uniformity
- Picosecond-level photon response
- Low crosstalk and afterpulsing
- Excellent magnetic field compatibility
- Compact optical package

Breakdown voltage

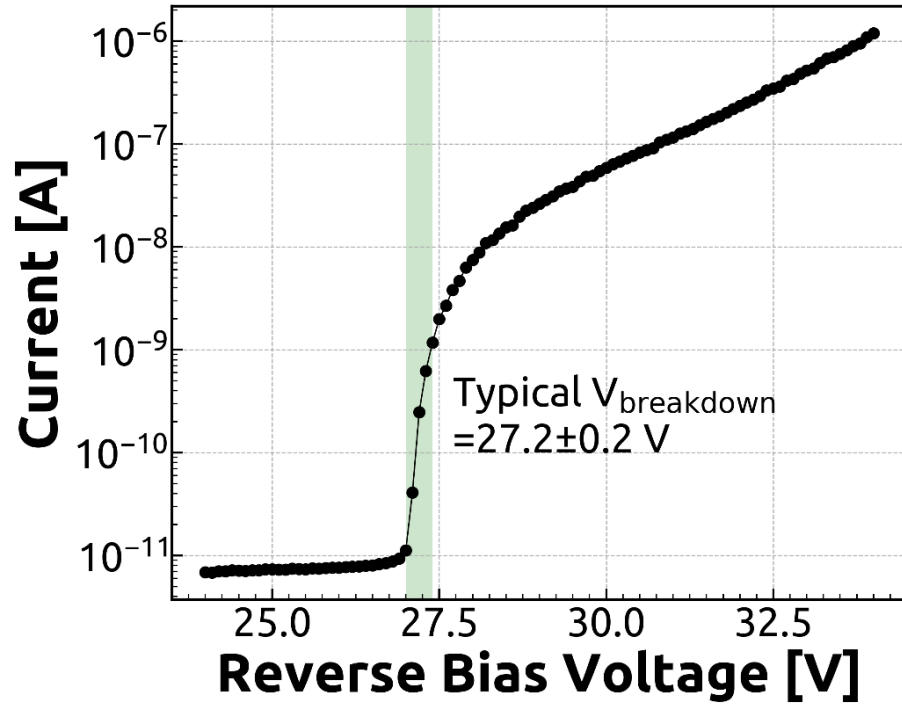


Fig.1. Current [mm⁻²] vs V_{bias}

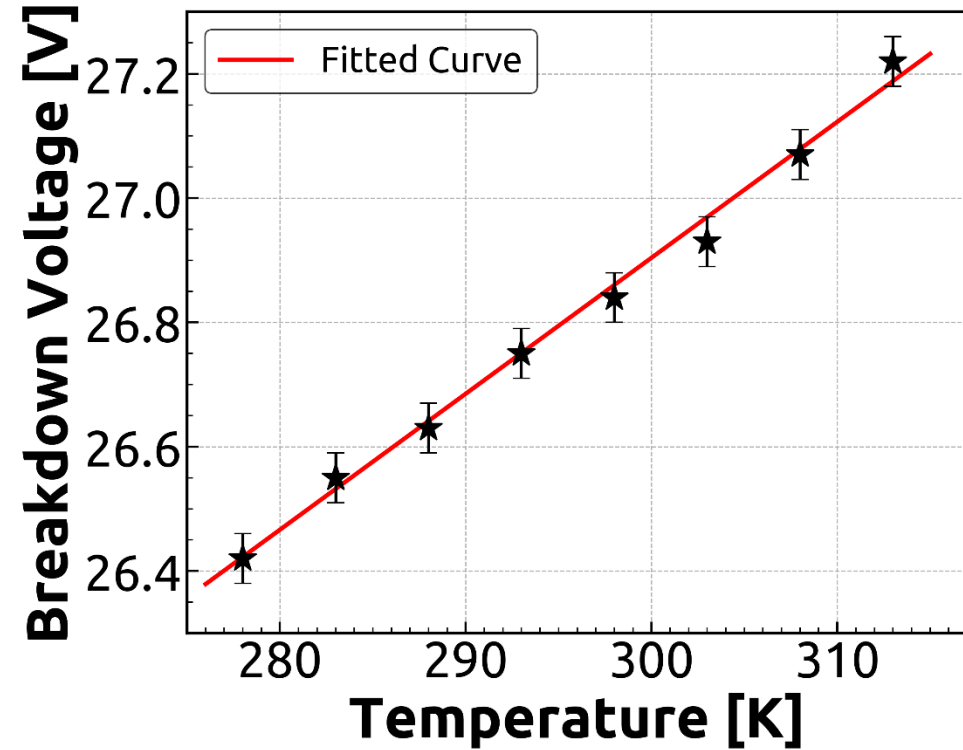


Fig.2. Temperature dependence of breakdown voltage

22mV/K temperature dependence

RQLx035 Product Performance

Gain

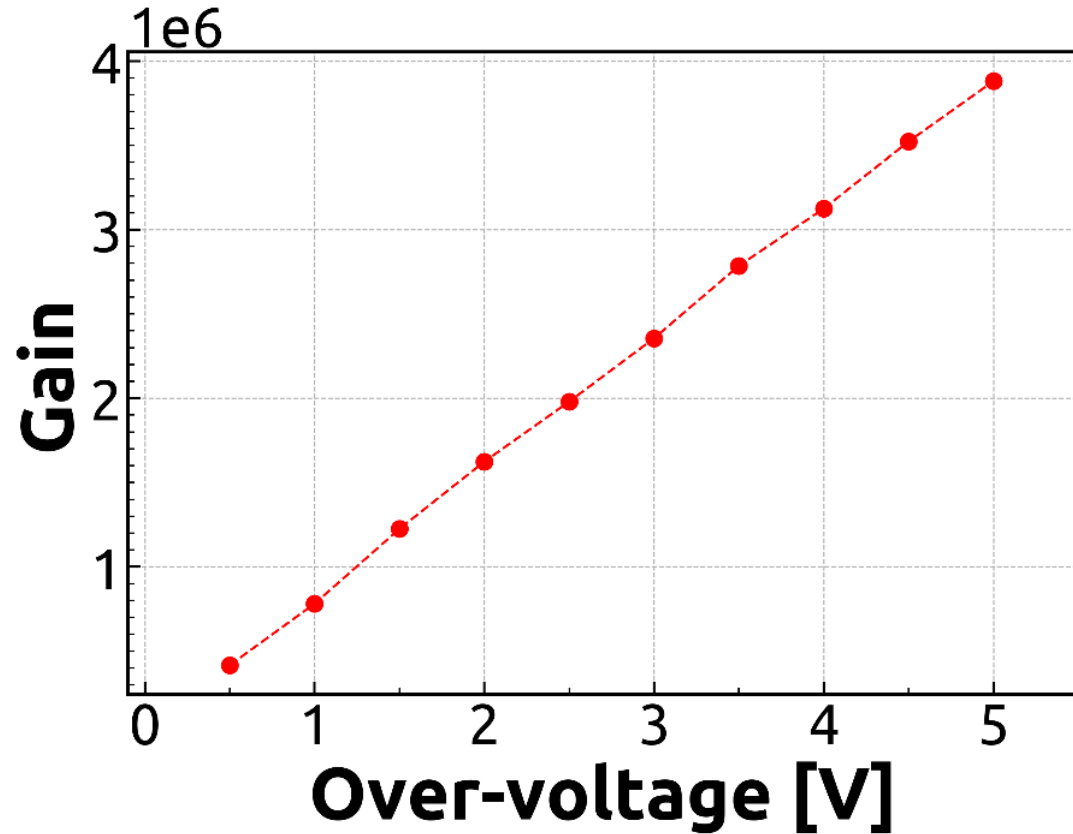


Fig.1. Gain vs. overvoltage

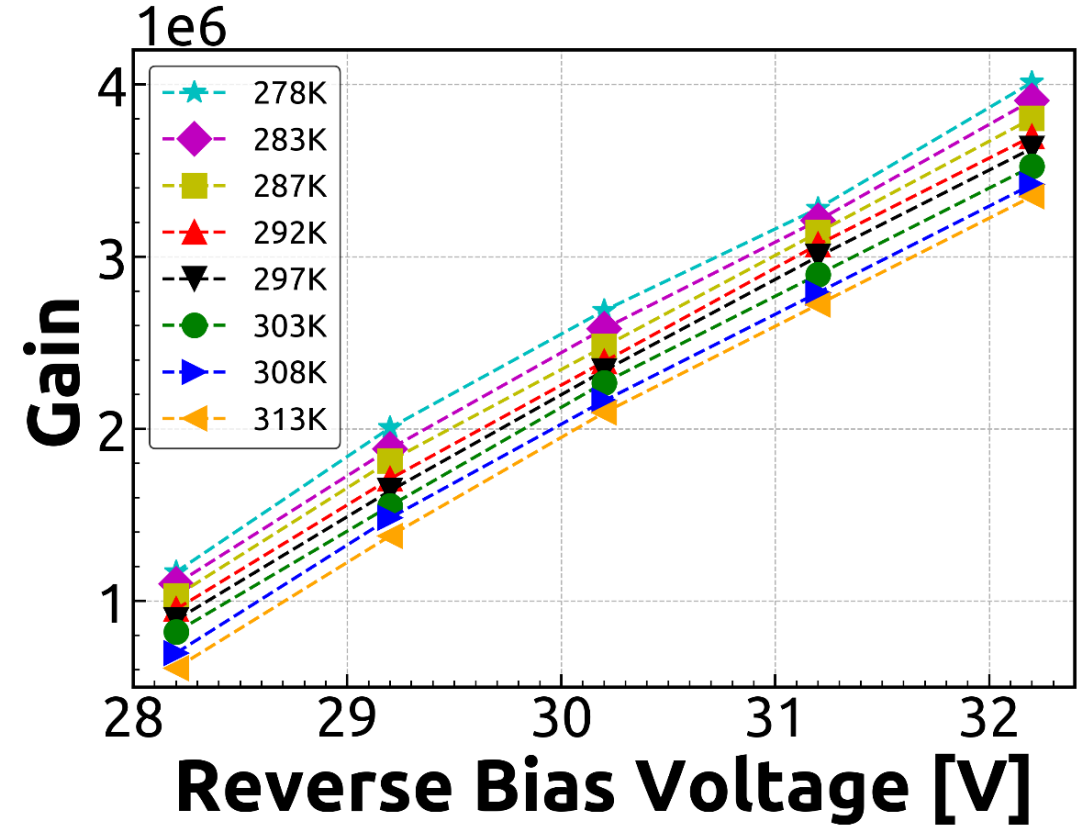


Fig.2. Gain vs. V_{bias} at various temperature

RQLx035 Product Performance

Dark count rate (DCR) [mm⁻²] and crosstalk

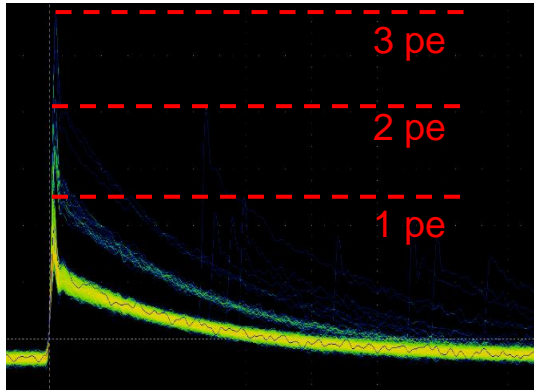


Fig.1. SiPM behavior in dark condition

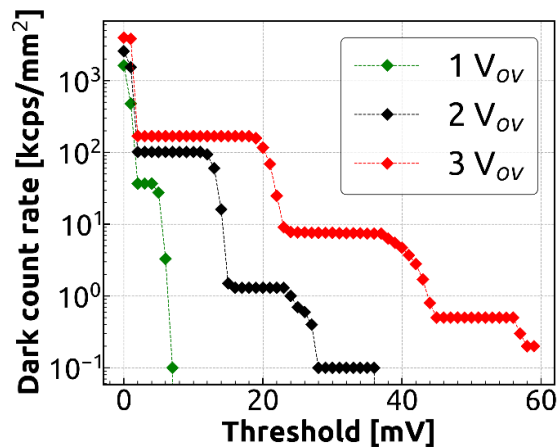


Fig.2. Statistical characteristics

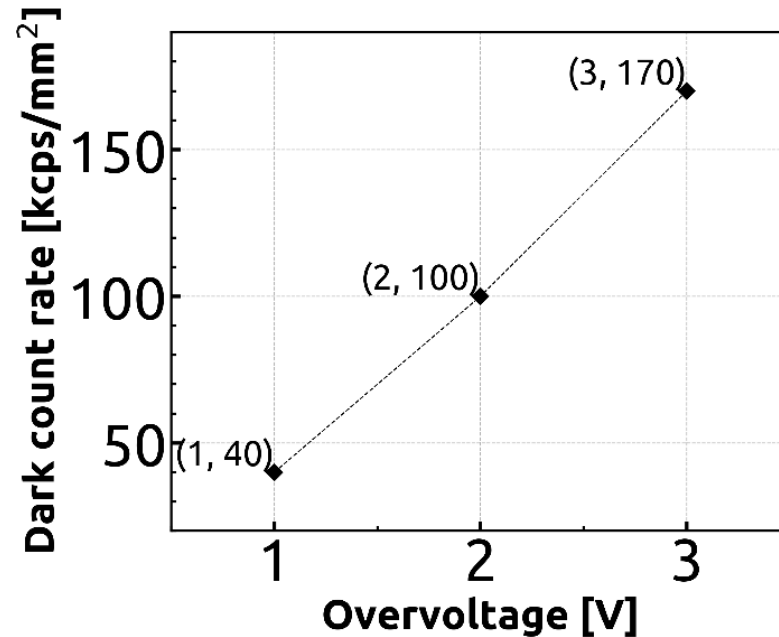


Fig.3. Dark count rate (DCR) [mm⁻²] vs V_{bias}

DCR : 40 kcps/mm² @ V_{ov}=1V

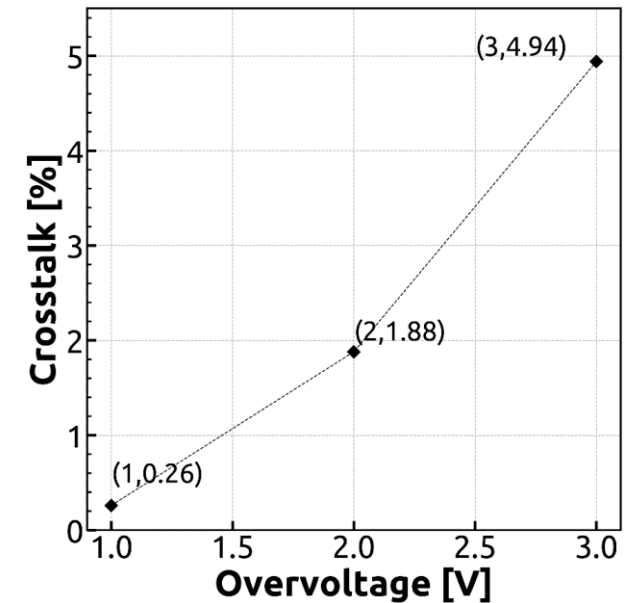


Fig.4. Crosstalk vs V_{bias}

Crosstalk : 0.26% @ V_{ov}=1V

RQLx035 Product Performance

Photon detection efficiency

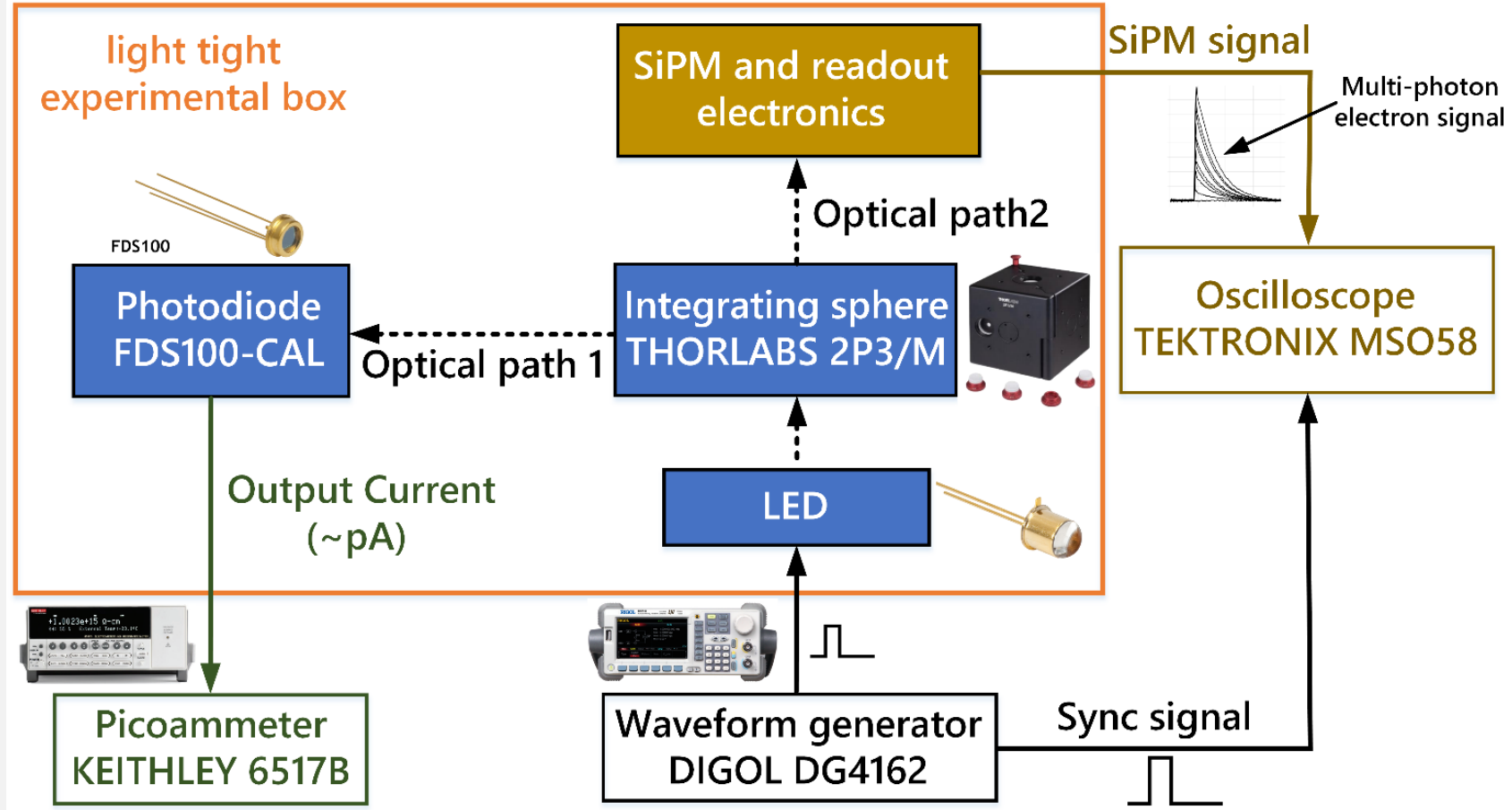


Fig.1. Diagram of PDE measurement setup

RQLx035 Product Performance

Photon detection efficiency

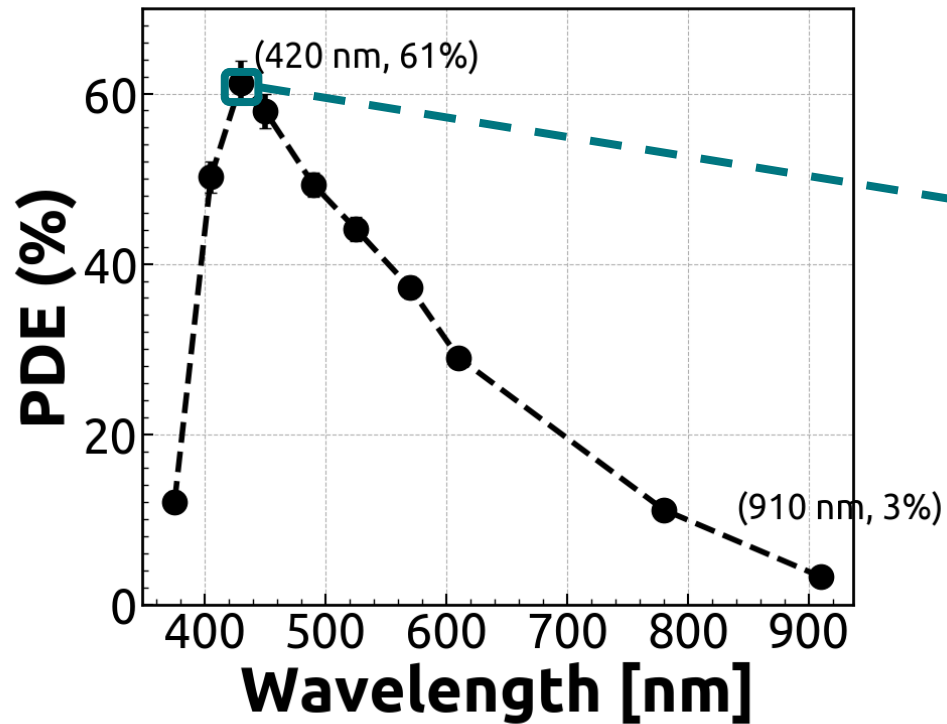


Fig.1. PDE($V_{ov}=3V$) vs. wavelength

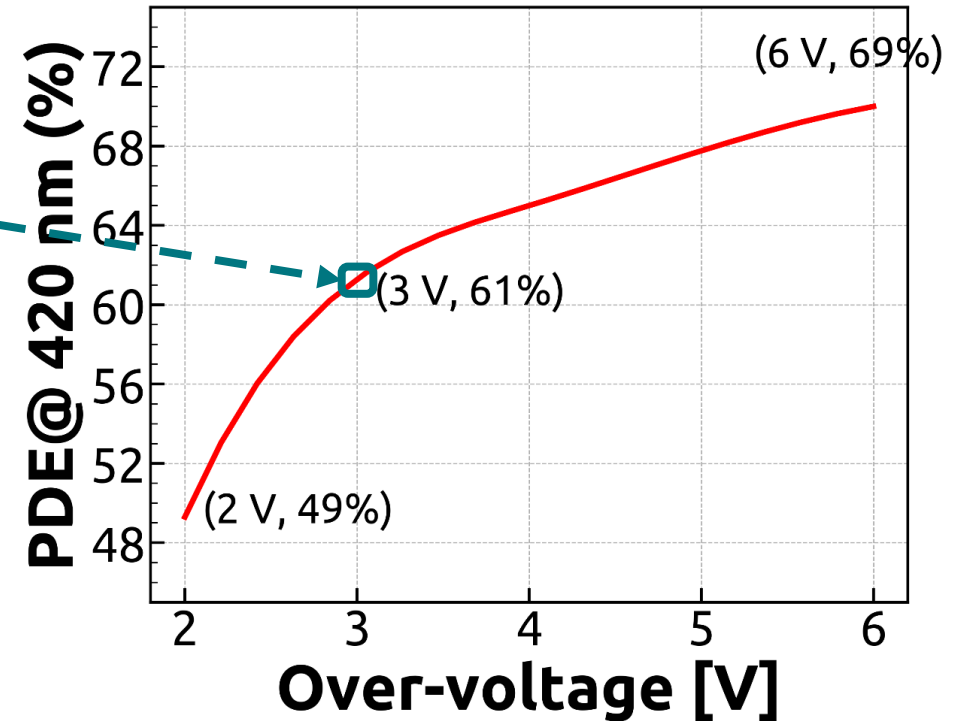


Fig.2. Peak PDE at 420 nm vs. overvoltage

PDE: 69% @ $V_{ov}=6V$

RQLx035 Product Performance

Single photon time resolution (SPTR)

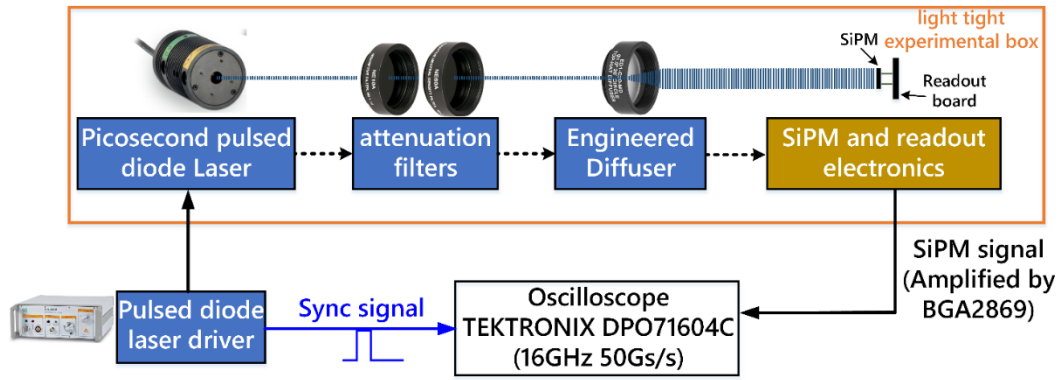


Fig.1. Diagram of SPTR measurement setup

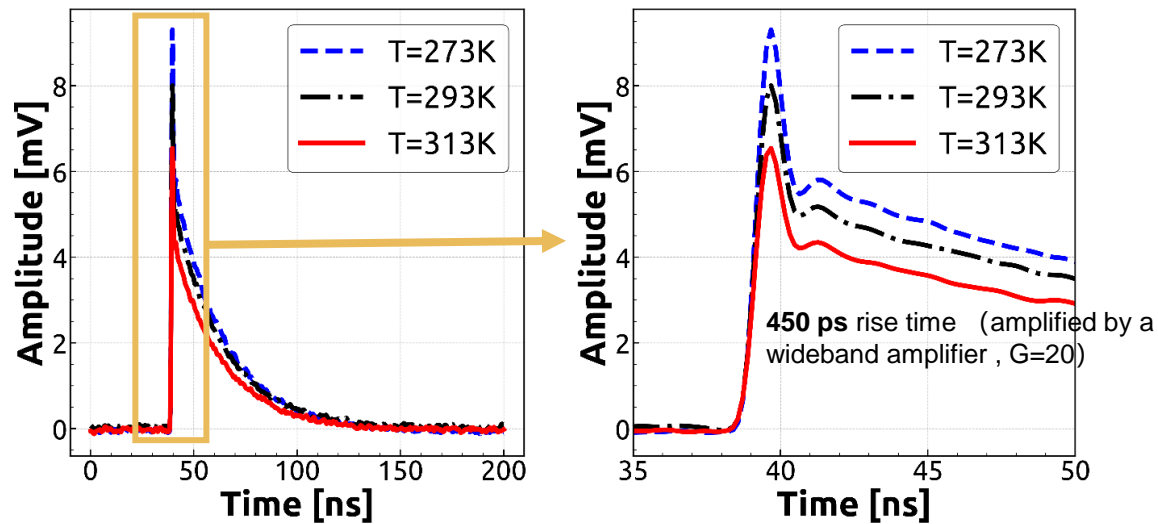


Fig.3. Single-photon pulses of SiPM at different temperatures (left) and zoomed-in view (right)

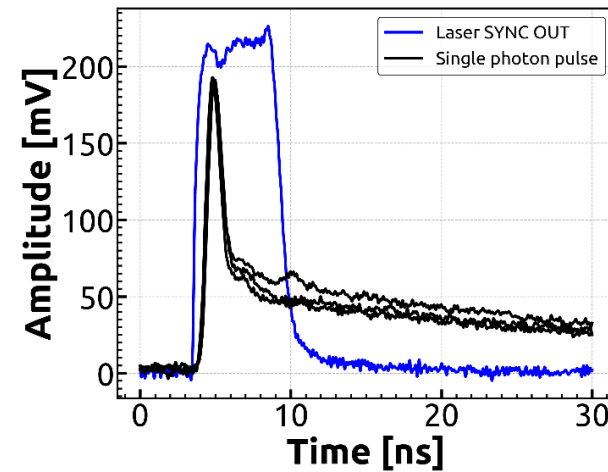


Fig.2. Single-photon response signal of SiPM

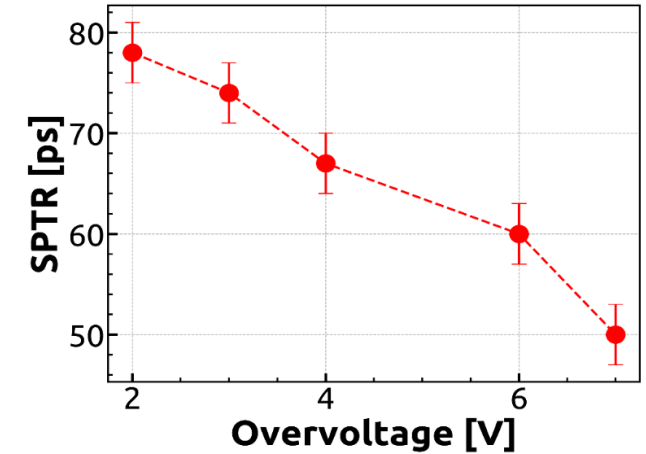


Fig.4. Single photon time resolution (SPTR) vs. Overvoltage at 440 nm

SPTR: 50ps @ $V_{ov}=7V$

Performance Summary

	TN series	RQL series
$V_{\text{breakdown}}$ [V]	25.2 ±0.2V	27.2 ±0.2V
Temperature coefficient of $V_{\text{breakdown}}$ [mV/K]	34.4	22.0
Pixel pitch [μm]	50	35
Fill factor	70.6%	78%
C_{pixel} [fF]	165	123
Gain	2.5×10^6	1.6×10^6
Dark current [nA]	90	35
Dark count rate [kcps/mm ²]	120	100
Optical crosstalk	3.5%	1.88%
Afterpulsing	2.0%	<1%
PDE @420 nm	35%	49%

(T=25 °C, $V_{\text{ov}}=2$ V)

An excellent CMOS SiPM has been developed at a new generation process:

- More stable temperature characteristics
- Higher fill factor
- Lower dark noise
- Higher PDE

Measured energy resolution (ER)

Results of Energy Resolution

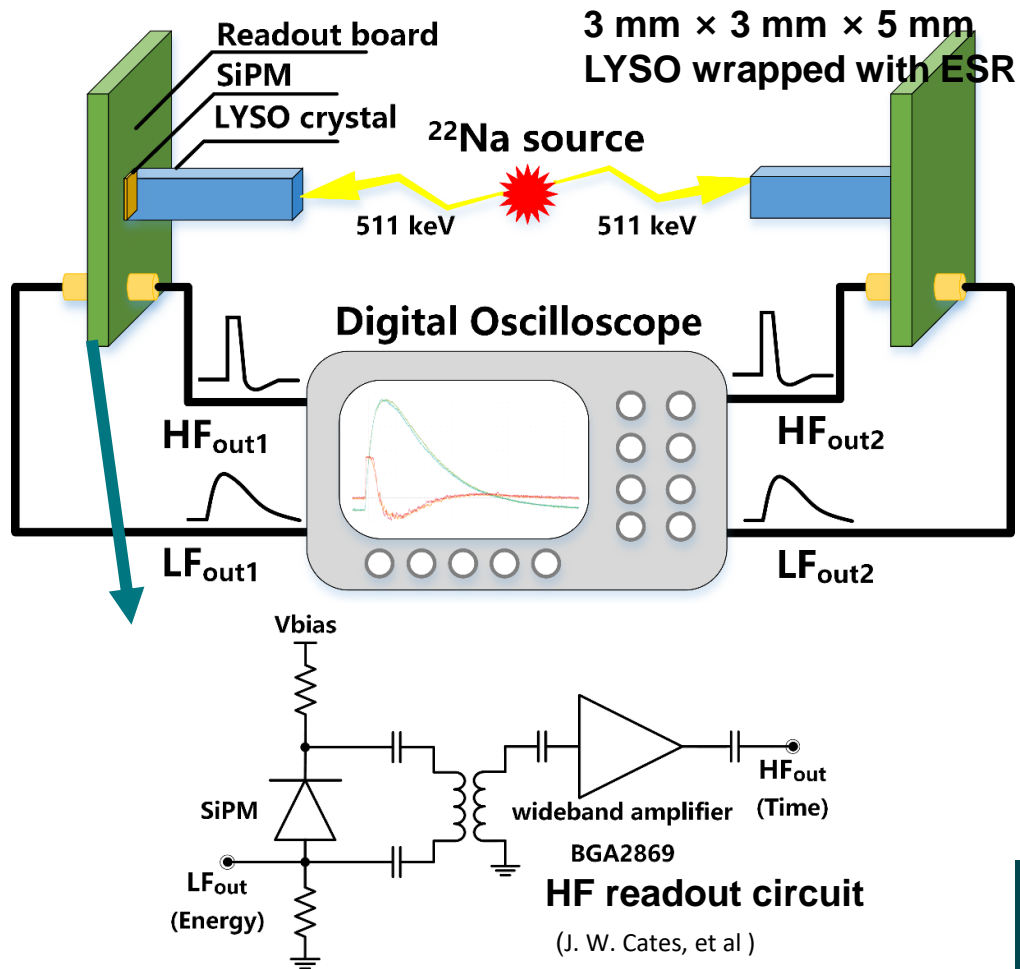


Fig.1. Measurement setup and readout circuit for SiPM

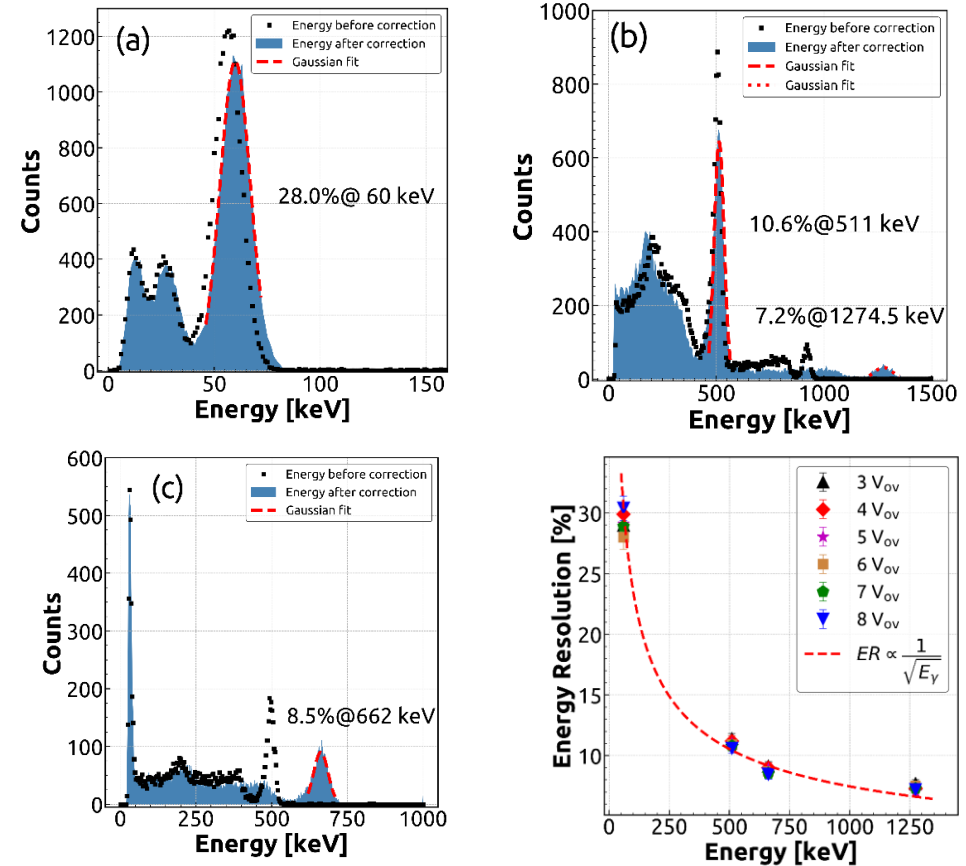


Fig.2. Results of Energy resolution

Energy resolution of **10.6% @ 511 keV** and **28% @ 60 keV** after saturation correction are achieved.

Measured coincidence time resolution (CTR)

Measurement setup and results of CTR

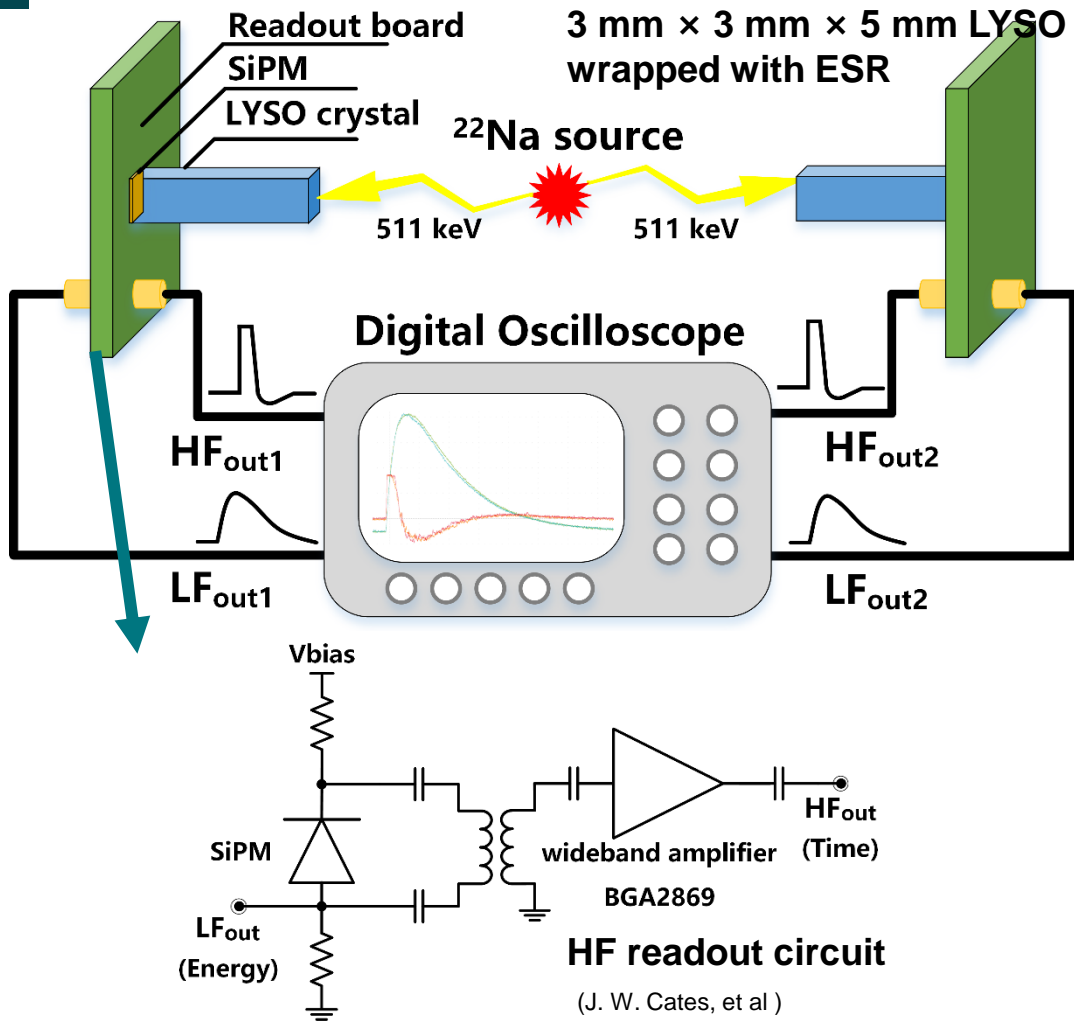


Fig.1. Measurement setup and readout circuit for SiPM

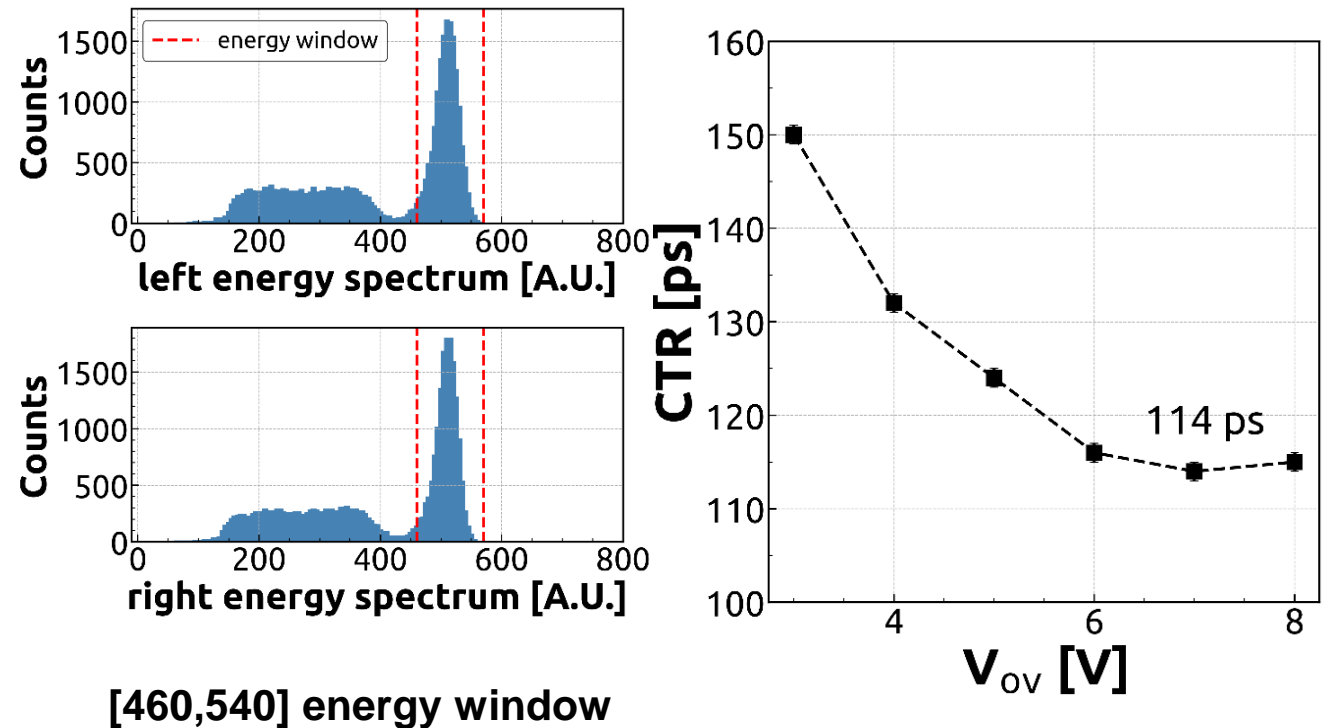


Fig.2. Results of CTR

CTR of 114 ps is achieved

Application Case: All-digital clinical PET-CT



PET is the most advanced medical imaging equipment.

- The most advanced medical imaging technology.
- A molecular imaging technology with extremely high biochemical sensitivity.
- The most comprehensive medical imaging device for localization, qualification, quantification, and monitoring.

**TOF (Time of Flight)-
based PET systems have
become feasible.**

**Significant improvements in
spatial resolution,
sensitivity, and performance.**

**Strong magnetic
field compatibility
(PET-MRI).**

System Sensitivity	17 kcps/MBq
Radial Resolution	1.9 mm(3D-OSEM)
Axial Resolution	1.7 mm(3D-OSEM)
Time Resolution	249ps
Energy Resolutions	10% @511 keV

<https://www.raysolution.com/>

Image courtesy of RAYSOLUTION Healthcare All-digital PET-CT: DigitMI 930

SiPM-based Photon Counting Security CT Detector

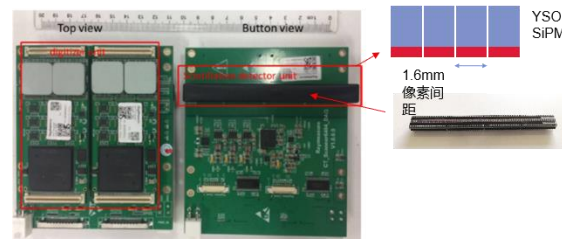
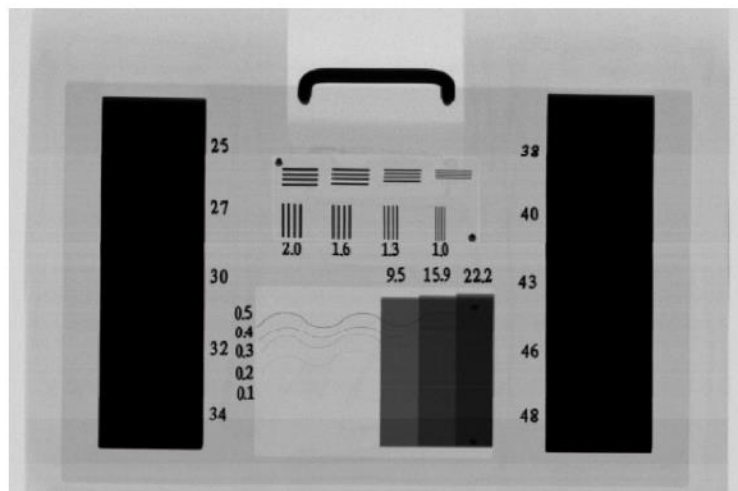
- Single-Photon Sensitivity
- Excellent photon counting capability.
- Reduces X-ray dosage.

High gain, high detection efficiency, wide dynamic range, and excellent X-ray energy resolution, enabling spectroscopic imaging.

Fast response speed, improving counting rate.

Scanned Images

1. Spatial resolution better than 1mm
2. Linear resolution better than 0.2mm



Application Case: Dental CR imaging



High Sensitivity

High Speed Response

Compact and Miniaturized

Simplify the system
Reduce costs



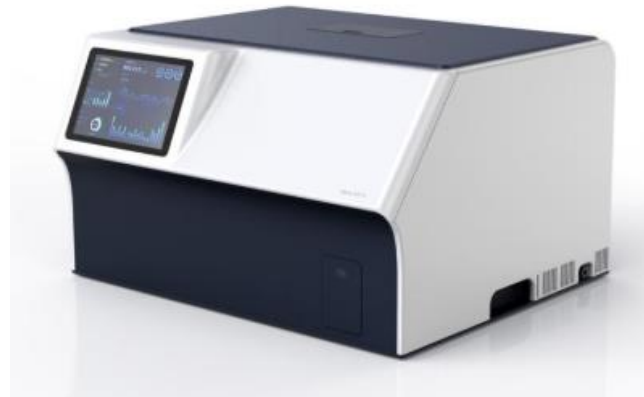
spatial resolution : 17 lp/mm;
imaging time <6s

Radiation Dose Meter



- Well-matched spectral response range
- High response speed
- High gain and sensitivity
- Compact and small, adding value to the product
- Simplifies systems and reduces costs

Fluorescent PCR instrument



- Single photon sensitivity with excellent photon counting capability
- Fast response time, dramatically increasing processing speed
- Compact design to meet high channel density requirements.

β -ray method airborne particulate matter and dust monitor



- High sensitivity (high detection efficiency)
- 6mm x 6mm detection area, wide dynamic range
- Compact and miniaturized
- High reliability for outdoor work



Thanks !

Hui Lao
RayQuant Technology Co. Ltd.
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