HAMAMATSU
PHOTON IS OUR BUSINESS

Latest improvements of the Hamamatsu MPPCs

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Deutschland GmbH
Simon Kempf

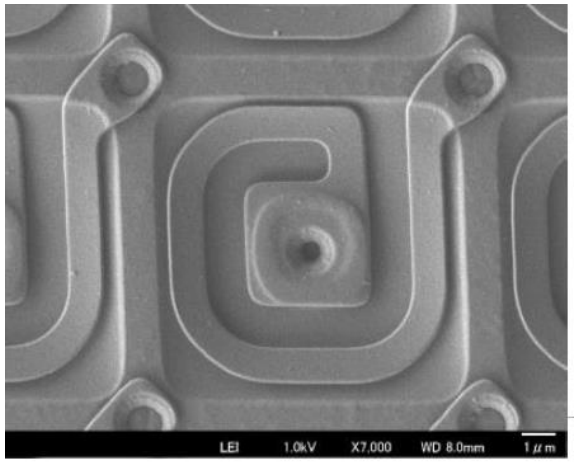
Agenda

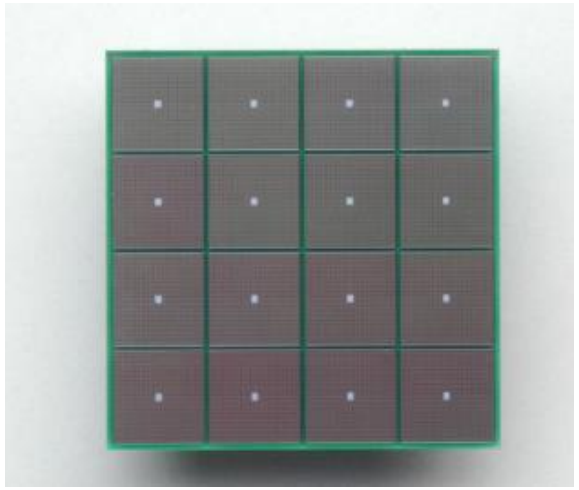
1 **Latest MPPC developments**

2 Scintillators and PET Products

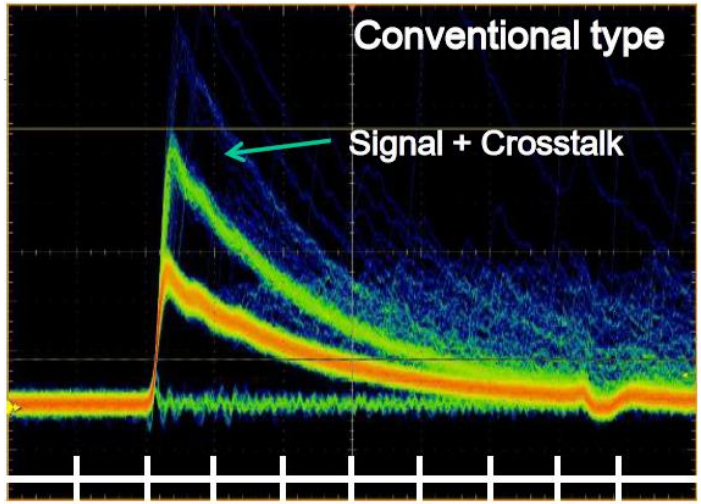
Status of the LCT4 MPPCs

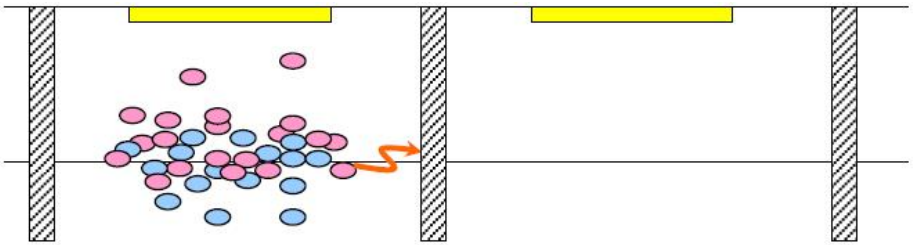
- **New material and process**
  - Lower dark counts and afterpulses
- **Thin film metal resistor**
  - Improved fillfactor
  - Low temperature coefficient
- **Trenches**
  - Lower crosstalk
- **Through Silicon Via (TSV)**
  - Minimized parasitic capacitance and resistance
  - 4 side buttable

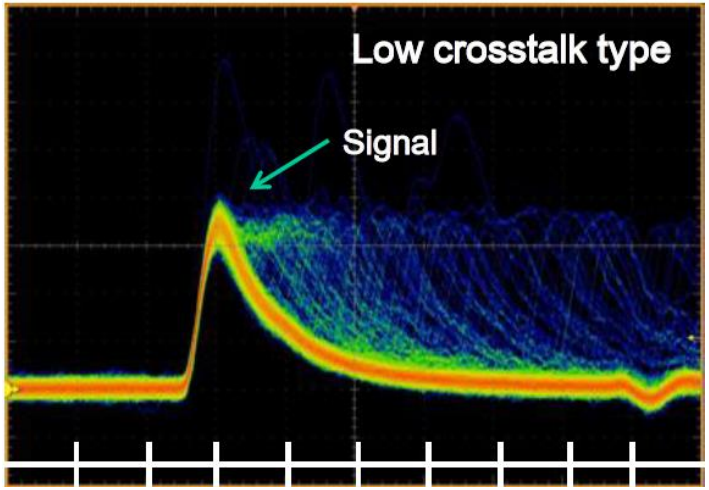


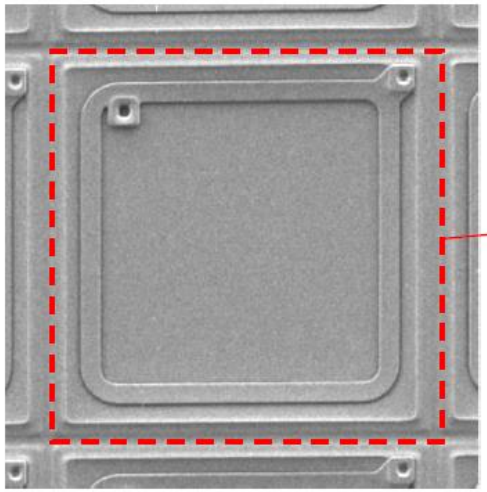


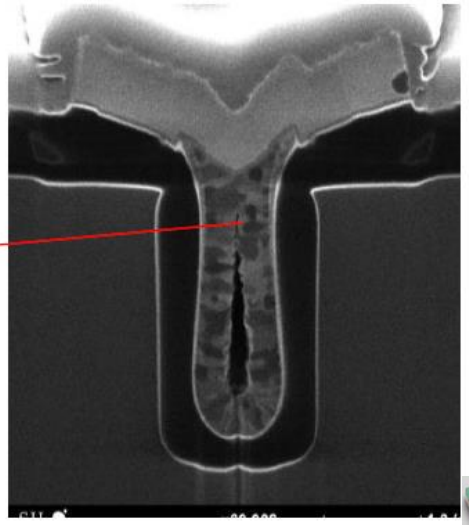
Trenches – crosstalk supression





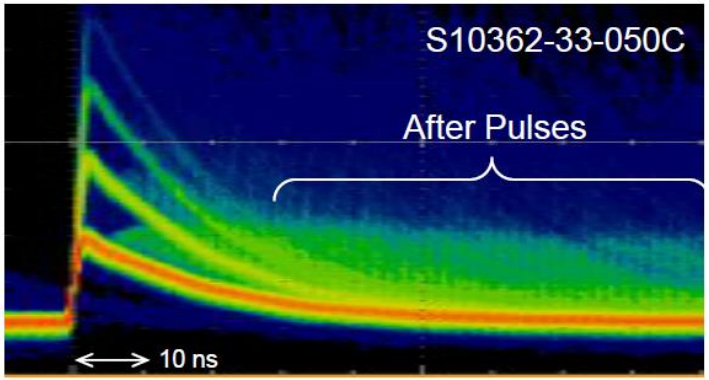


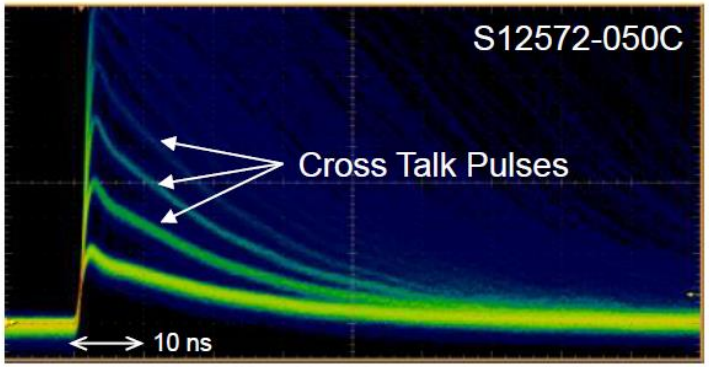


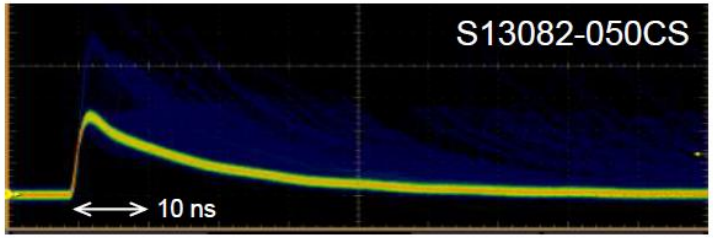


Improved signal

3x3 mm²

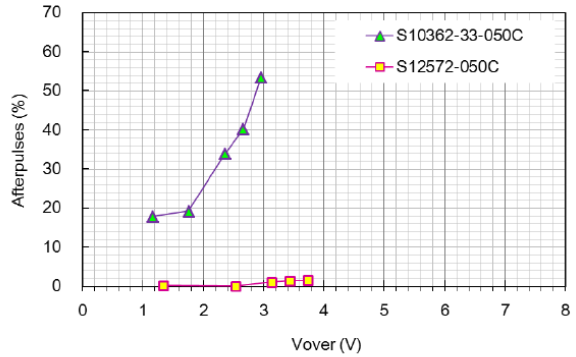


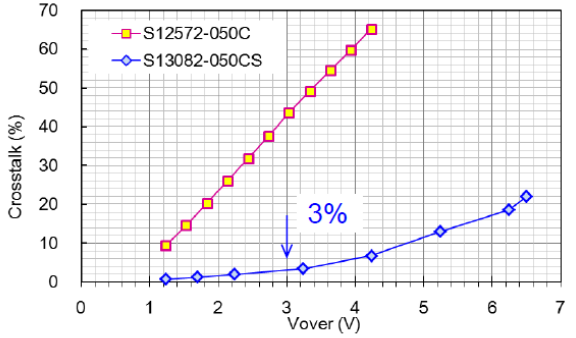


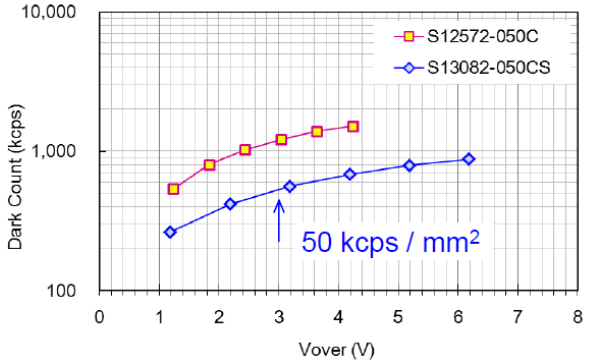


Si Wafer & Process Condition Optimized

Trench







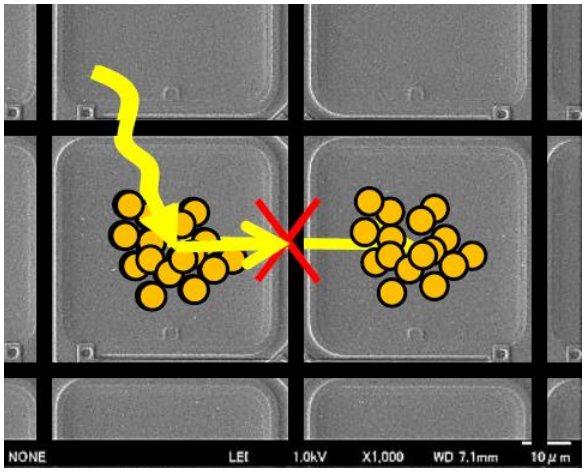
Performance comparison

3x3mm, 50umP, Vov=3V

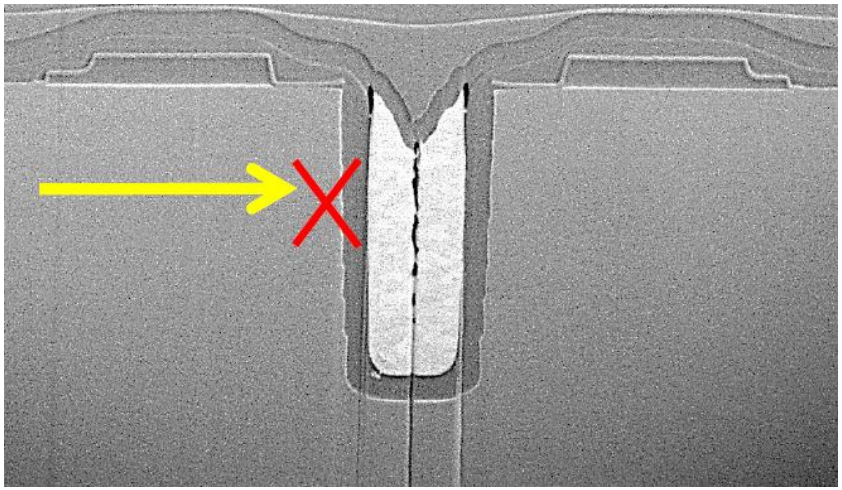
Sample	Fill Factor	PDE	After pulse	Cross talk	Dark Count
1st generation Standard	62%	> 40%	> 100%	> 70%	> 2 Mcps
2nd generation Low AP	62%	39%	< 3%	44%	1 Mcps
Latest (LCT- 4) Low AP &Low CT	61%	36%	< 3%	2%	500 kcps

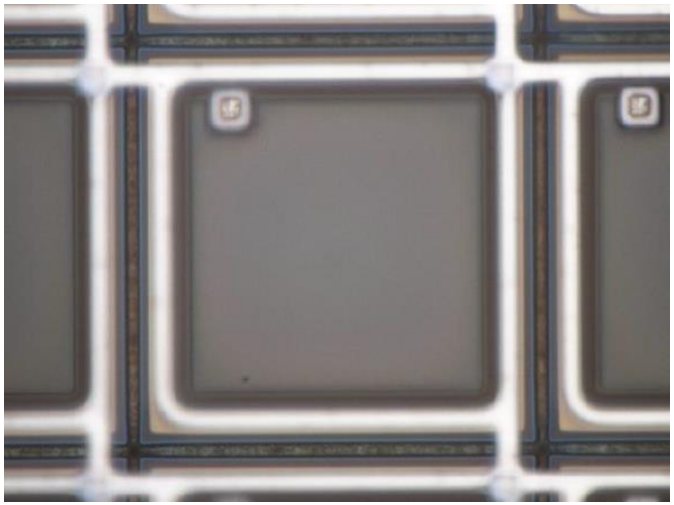
What are the newest developments? (LCT5)

Optimization of trenches and active area

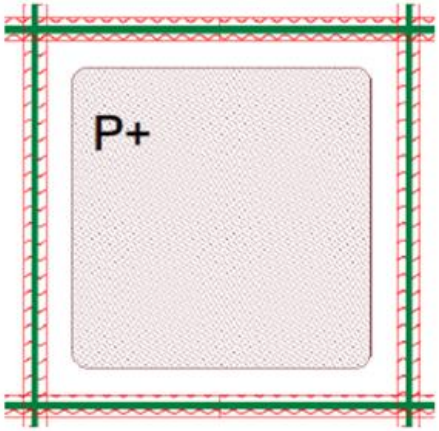


- PDE= QE x FF x AP
- Minimize the trench width
- Maximize the area

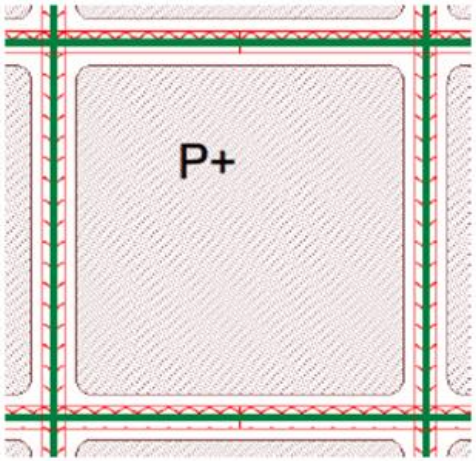




Geometrical Fillfactor

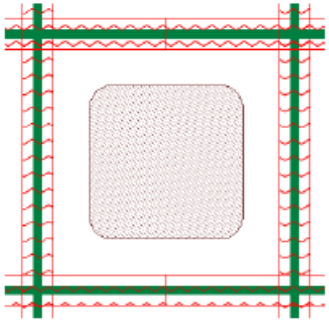


50µm LCT4 (FF 61%)

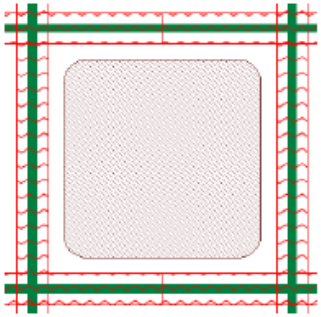


50µm LCT5 (FF 74%)

	LCT4	LCT5
100µm	79%	87%
75µm	73%	82%
50µm	61%	74%
25µm	31%	52%

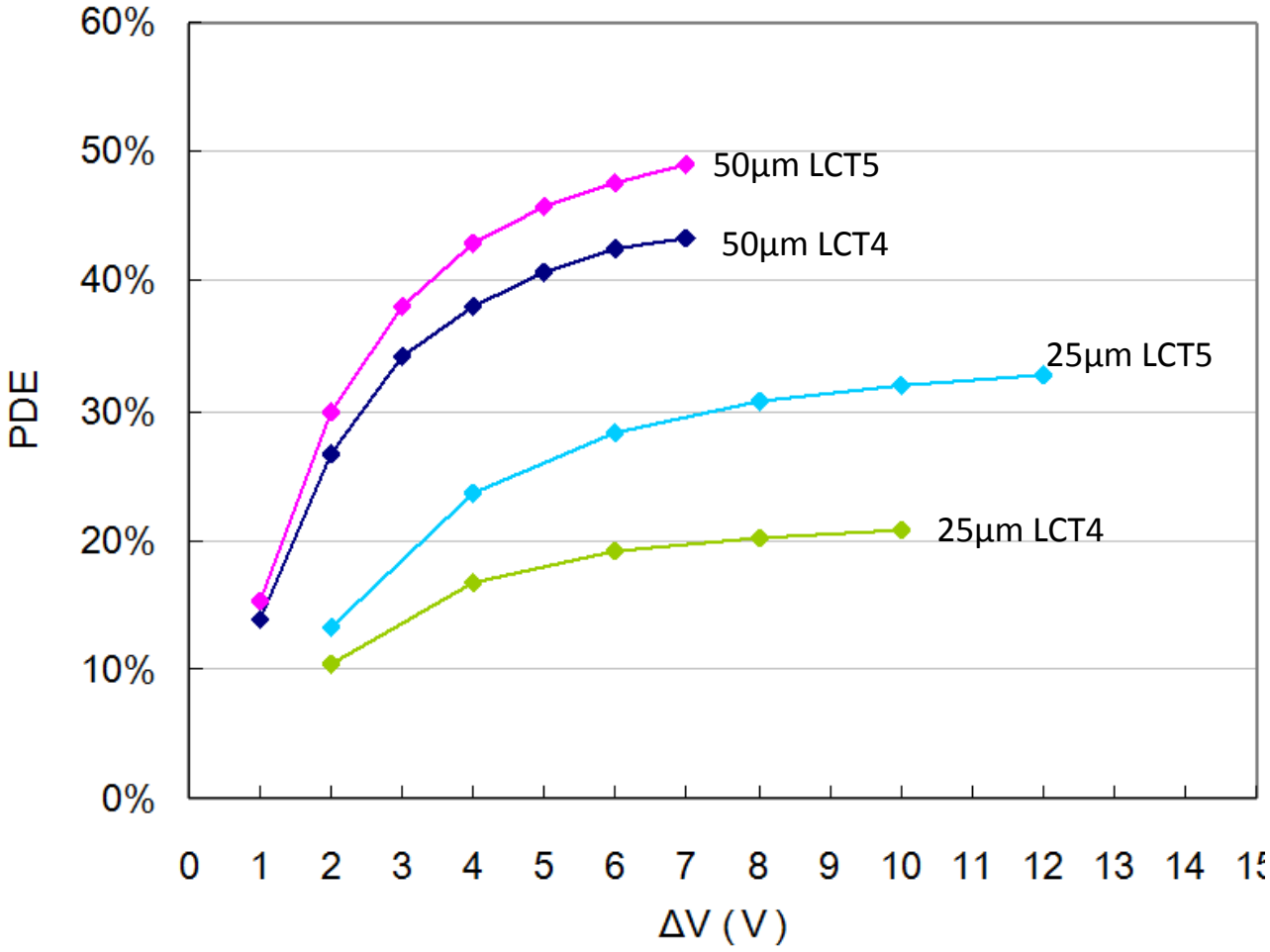


25µm LCT 4 (FF 31%)



25µm LCT 5 (FF 52%)

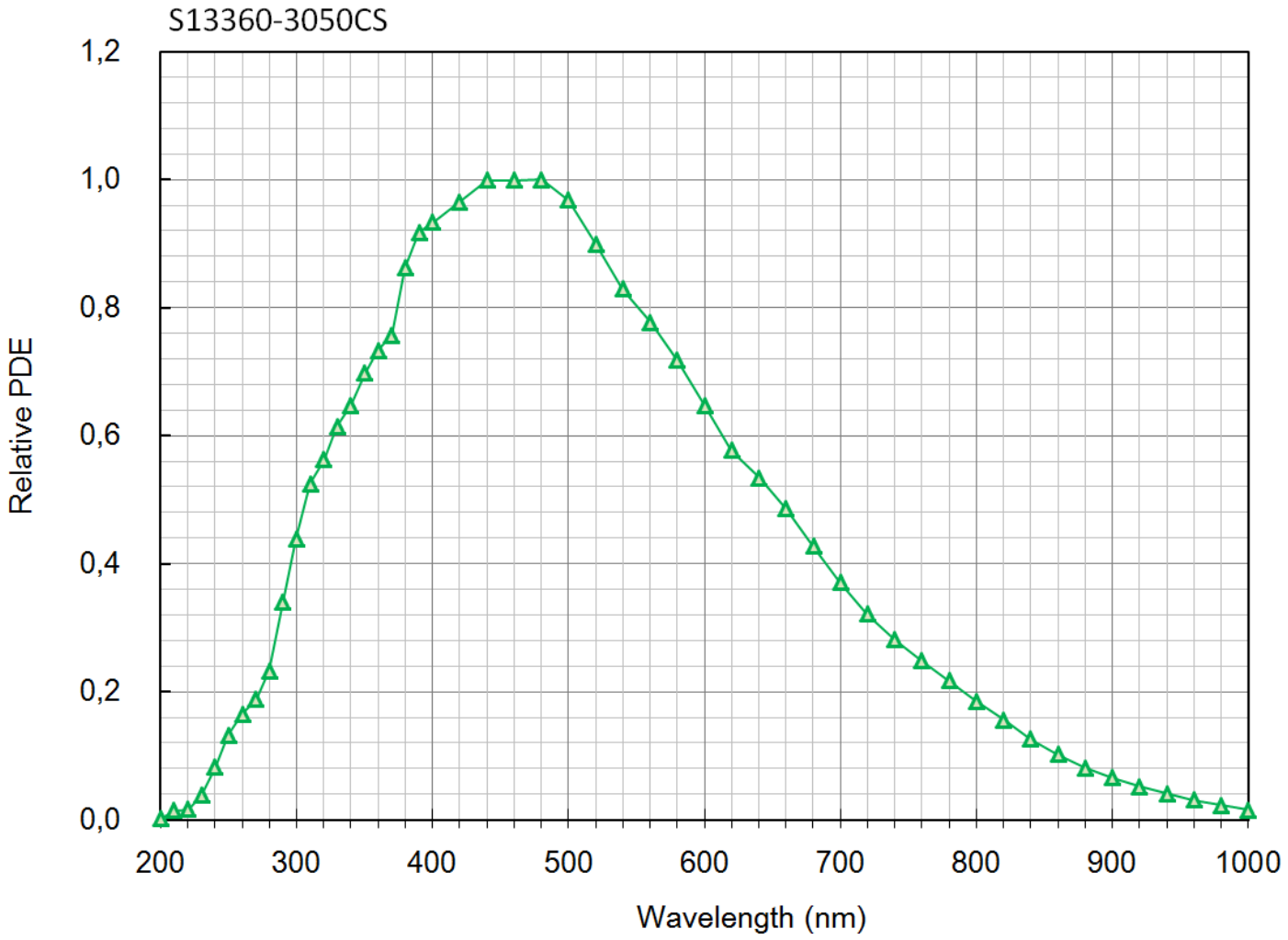
Increased PDE by higher fillfactor



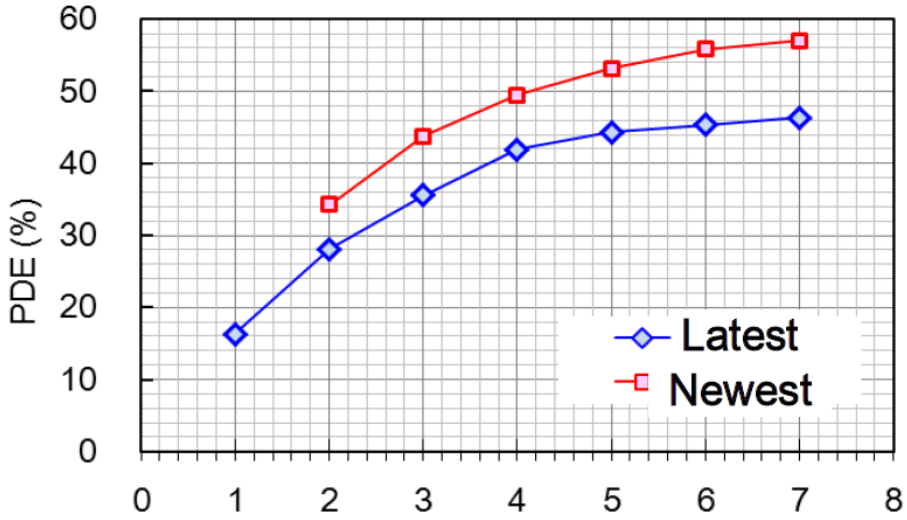
Fillfactor

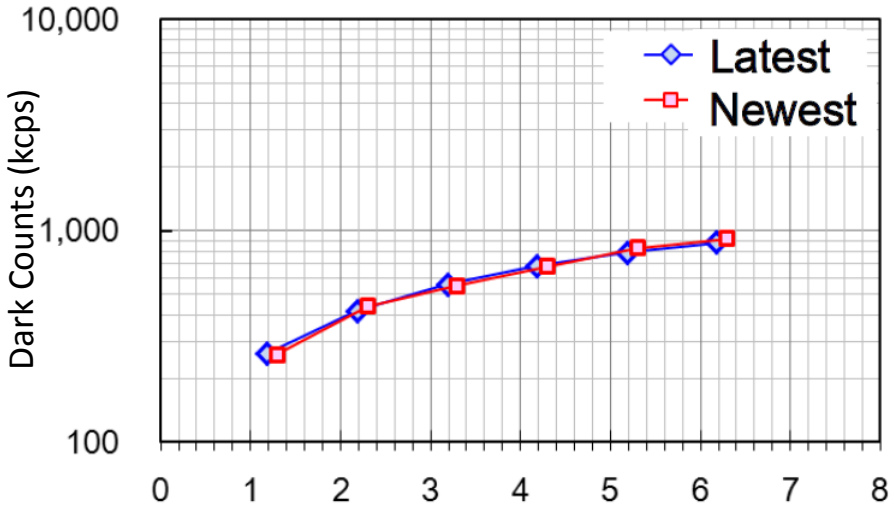
	Latest	LCT5
50µm	61%	74%
25µm	31%	52%

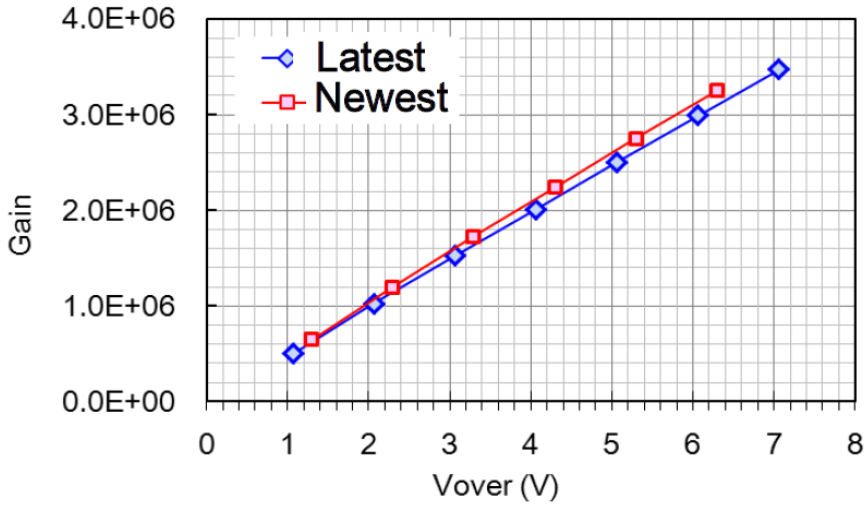
Relative PDE

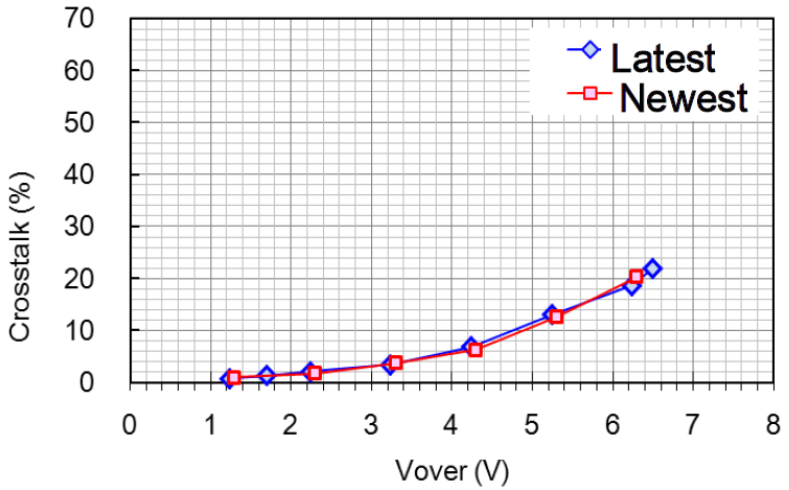


Performance comparison for 3x3mm 50µm

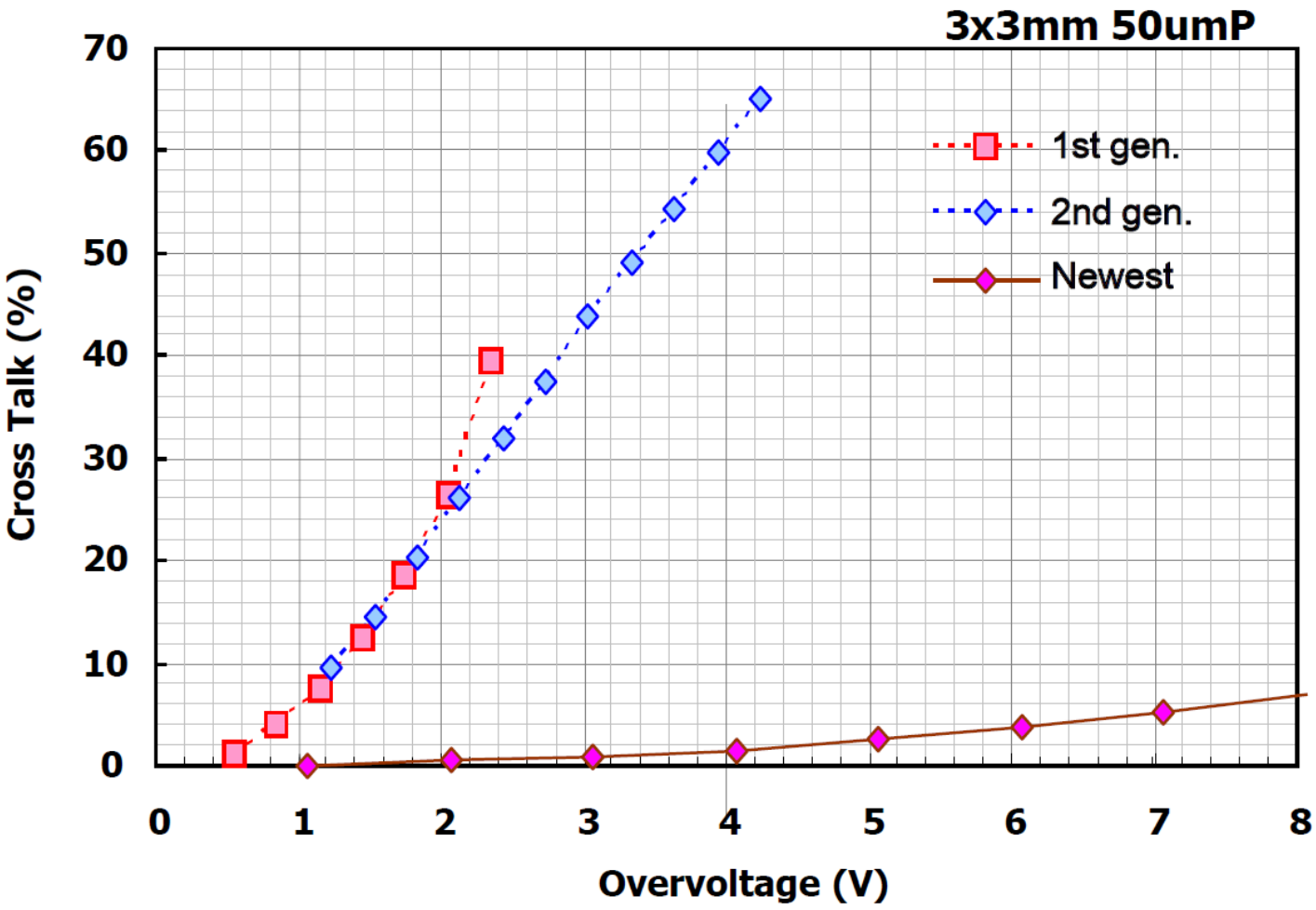




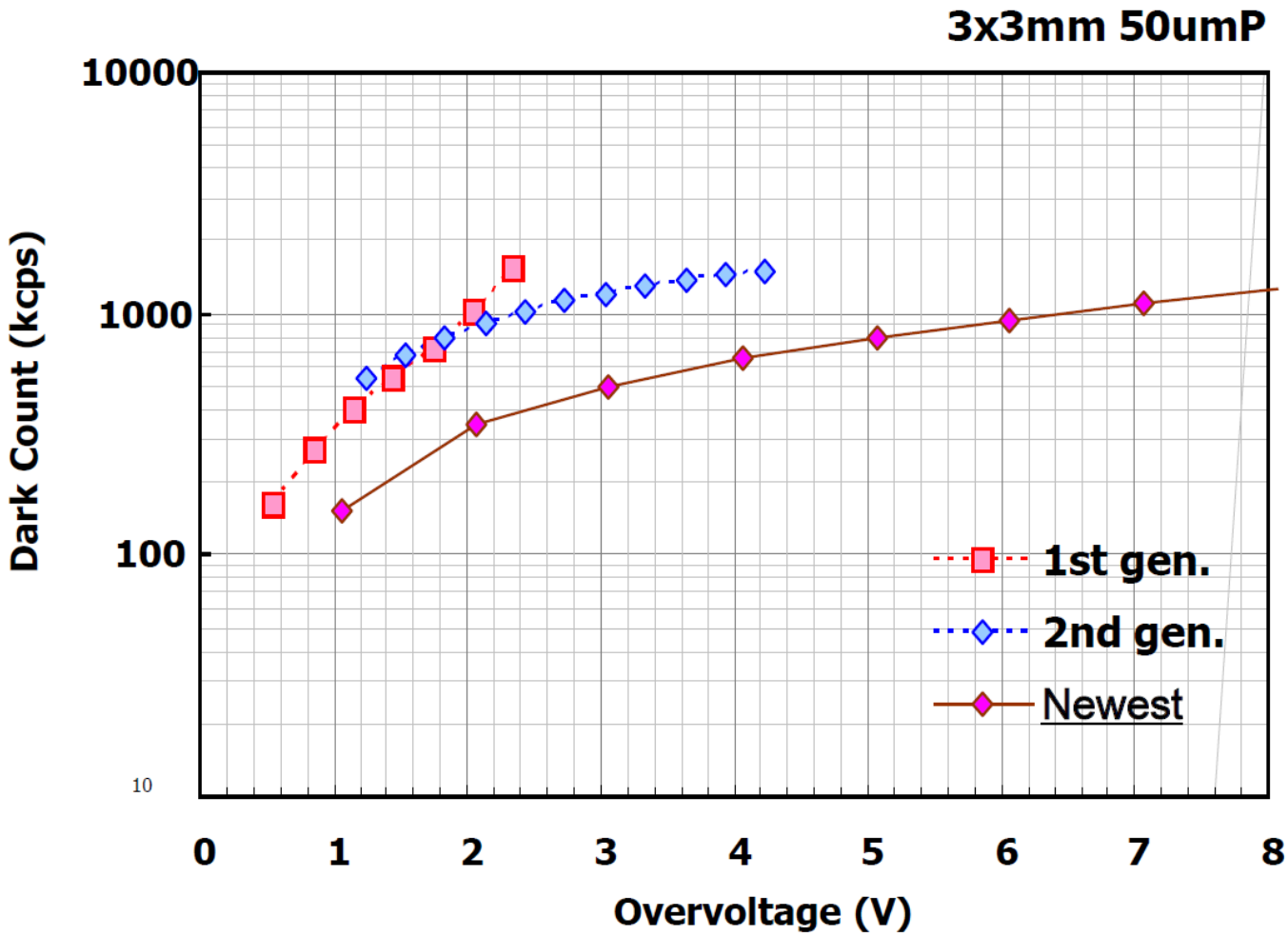




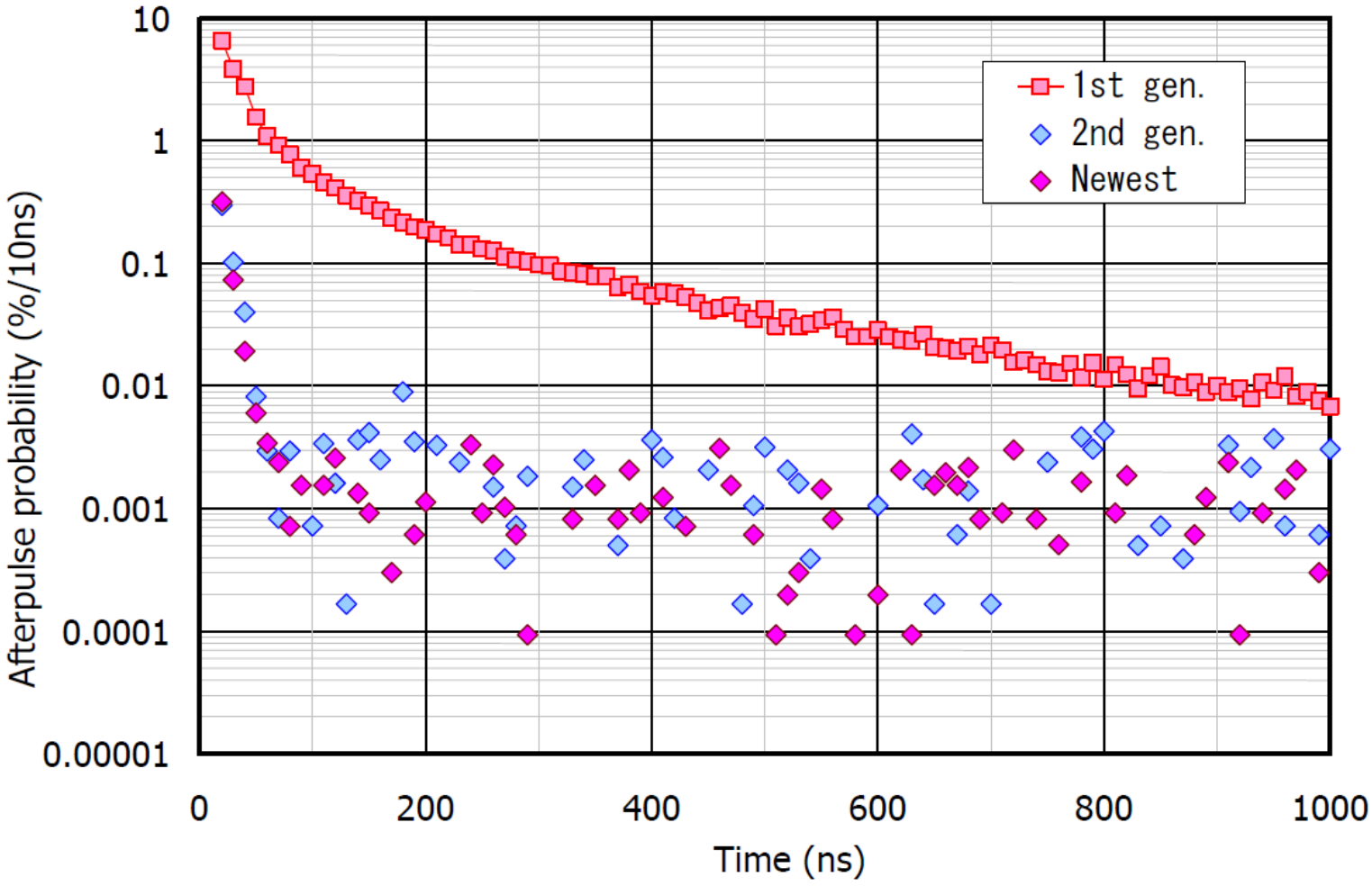
Crosstalk improvement



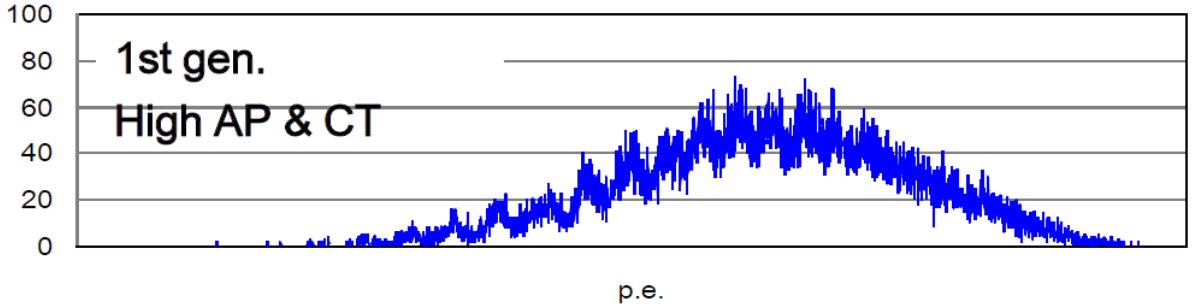
Dark count improvement

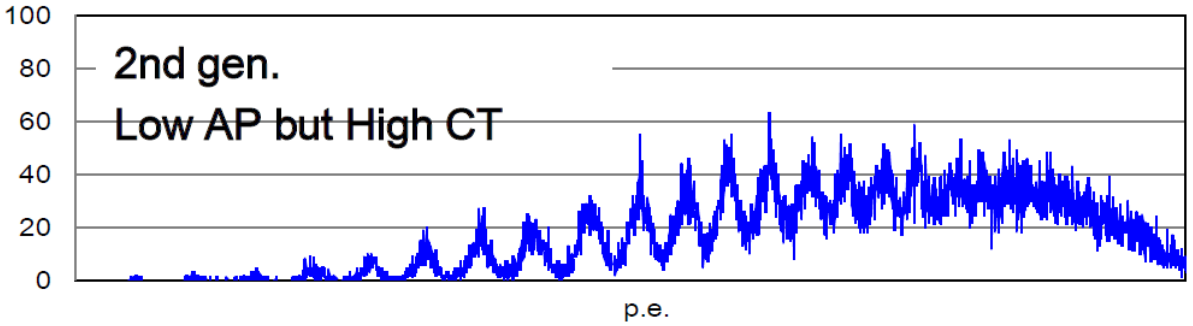


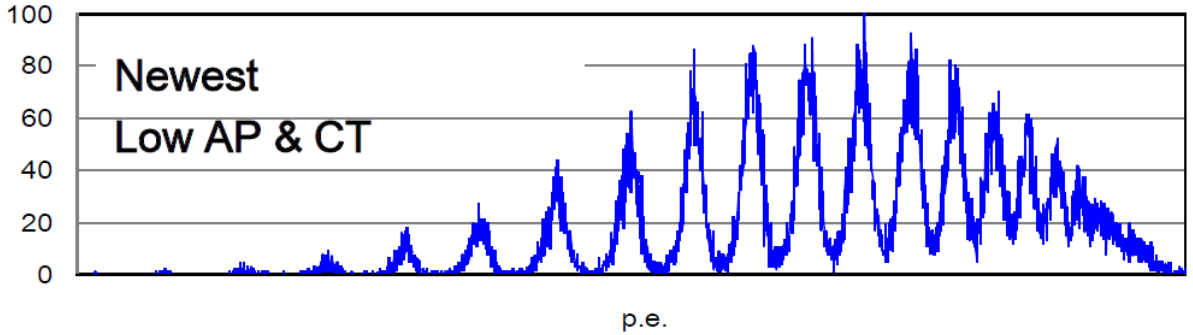
Afterpulse improvement

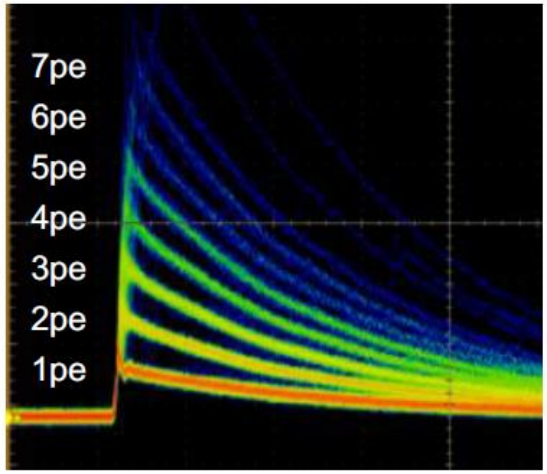


Pulse height distribution

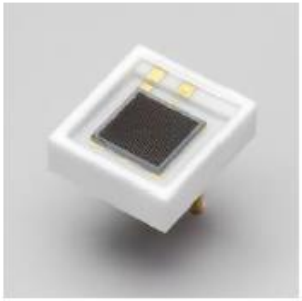


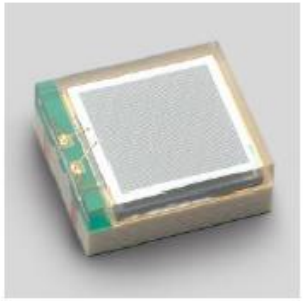






Results of the development





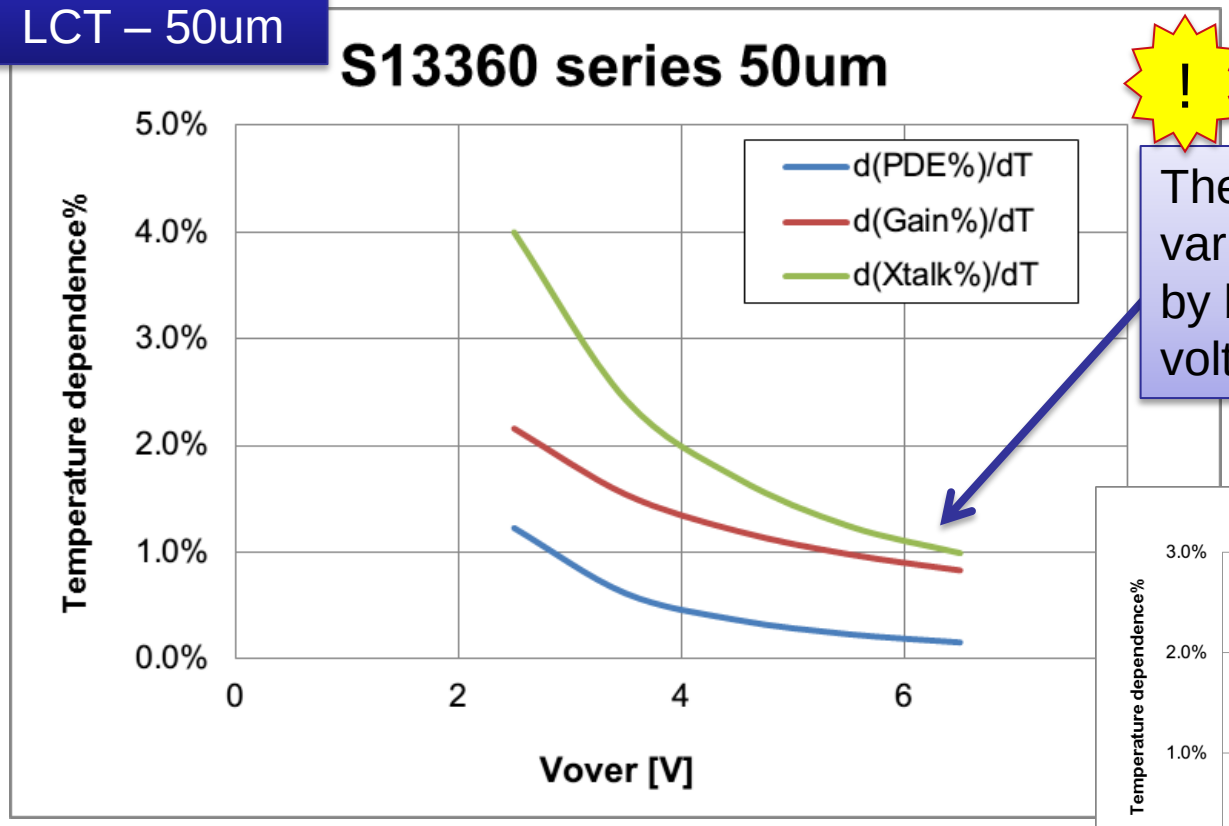
3x3mm

Type No.	Vover	Crosstalk	Dark Count	PDE	Fill Factor	Note
Latest 50um (S13082-050CS)	3V	3%	500kcps	36%	61%	LCT4
Newest 50um				**40%**	**74%**	LCT5
Latest 25um (S13082-025CS)	5V	5%	380kcps	18%	31%	LCT4
Newest 25um				**25%**	**51%**	LCT5

Characteristics of LCT-MPPC

- Stability to temperature variation at higher Vov

LCT – 50um



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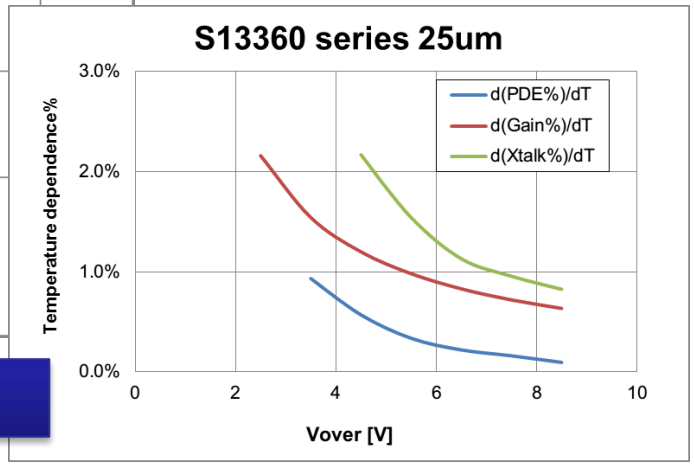
The stability to temperature variation is much improved by biasing higher over voltage.

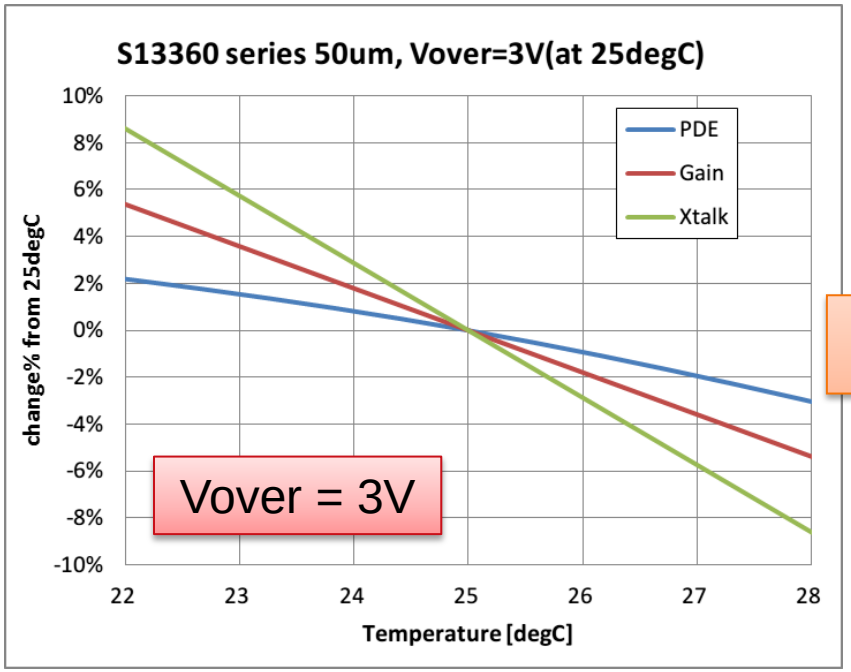


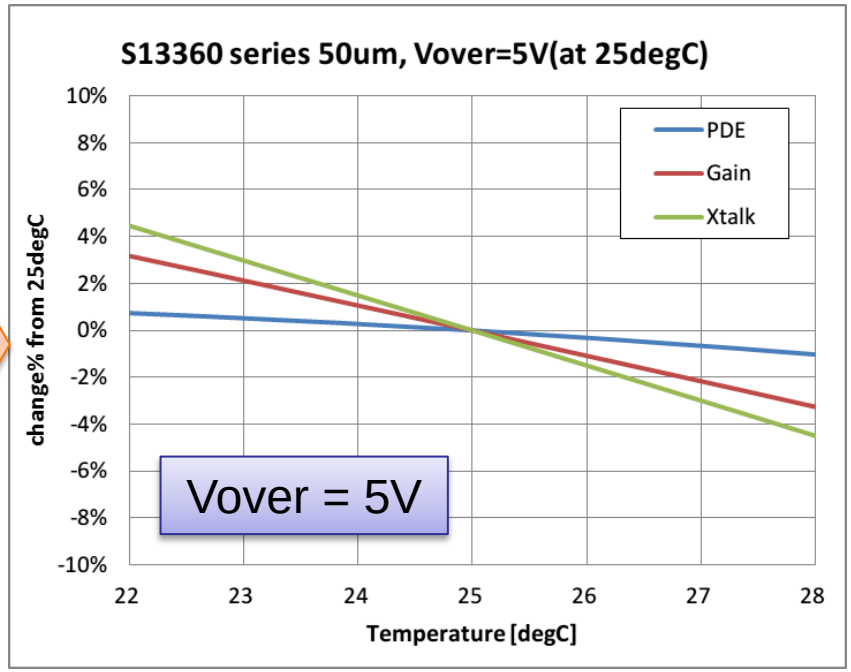
around the room temperature

LCT – 25um

Characteristics of LCT-MPPC

- Stability improvement at higher Vov
- Characteristic variation with temperature change around RT



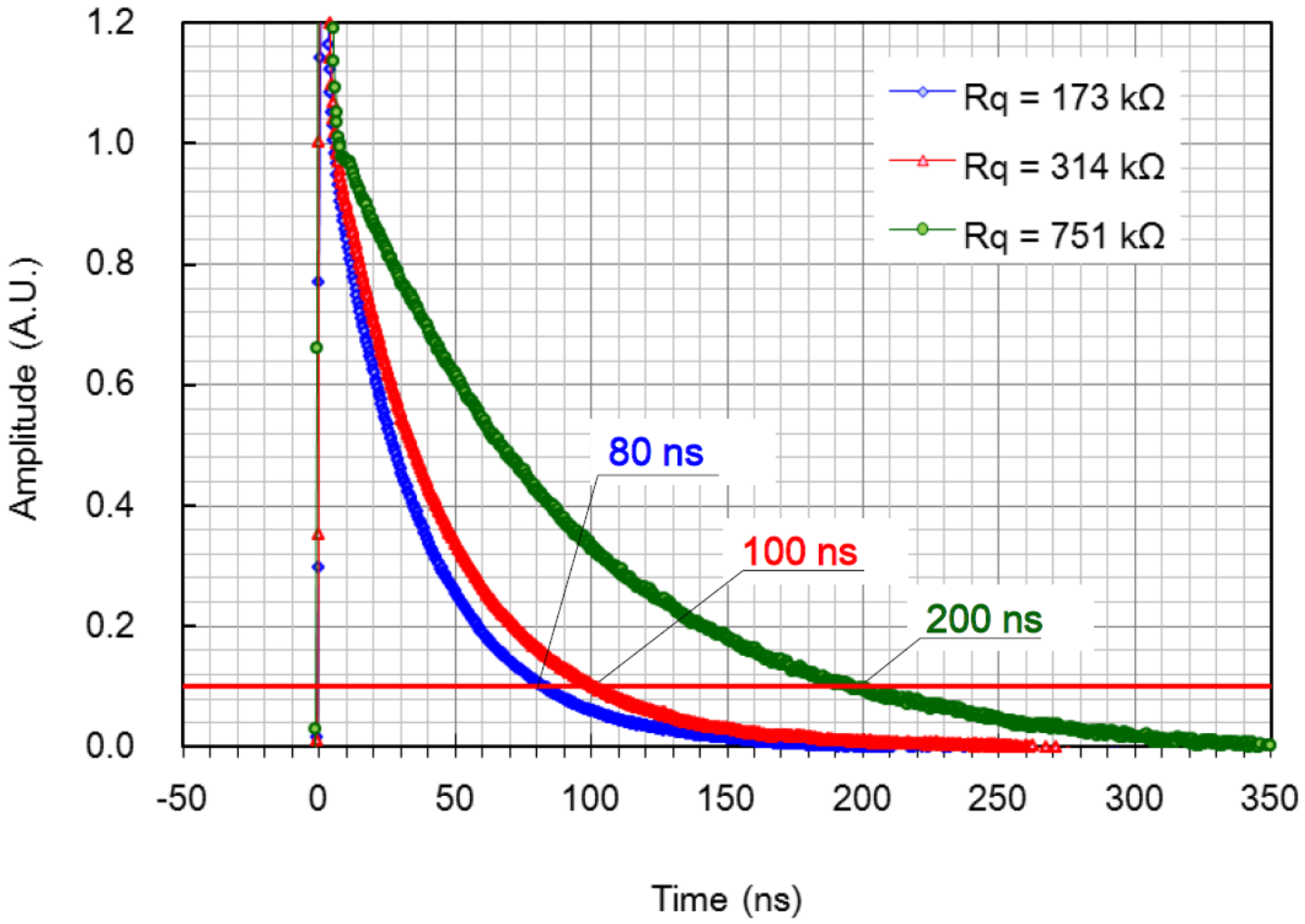


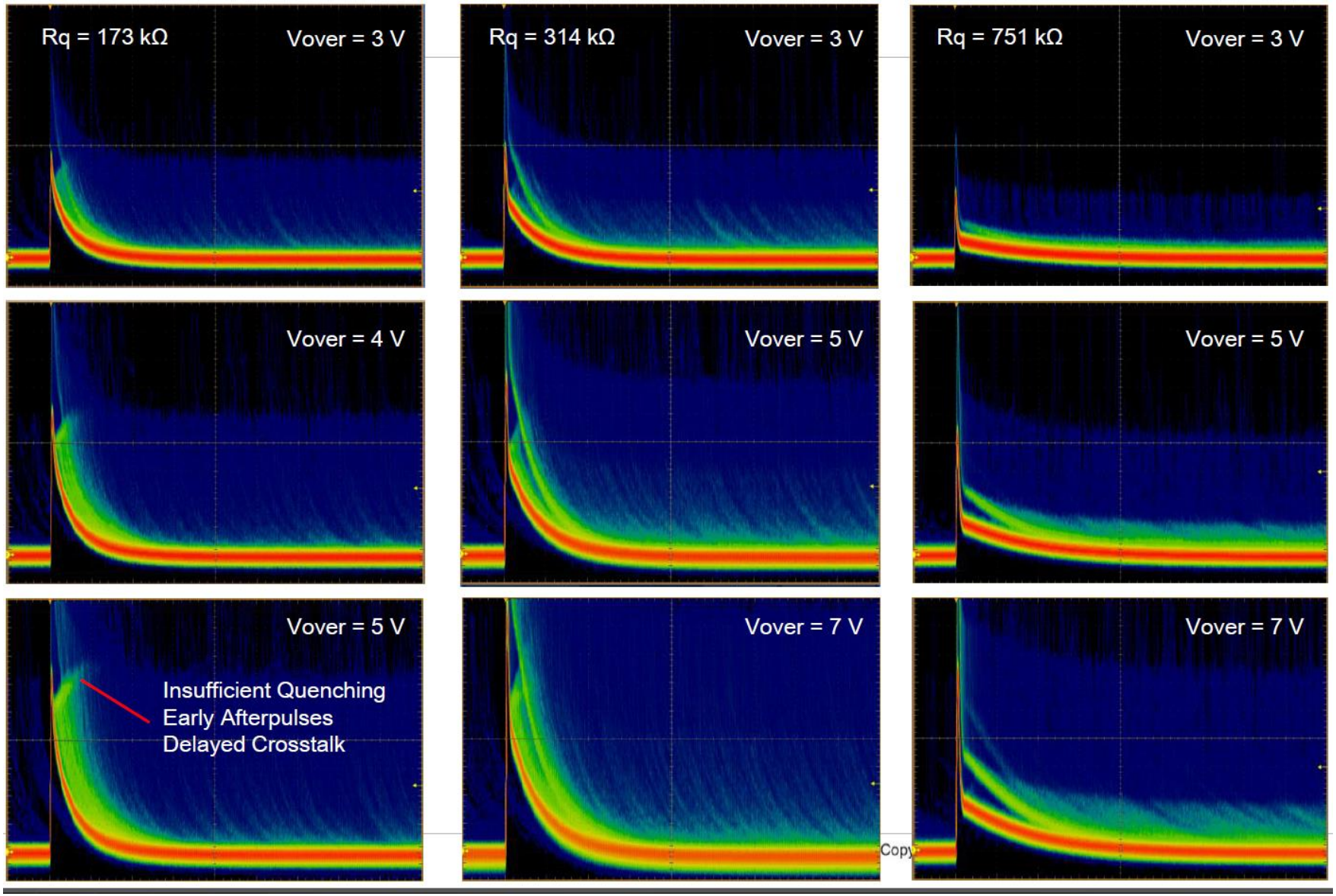
LCT – 50um

calculation data

Modification of the Metal Quenching Resistor

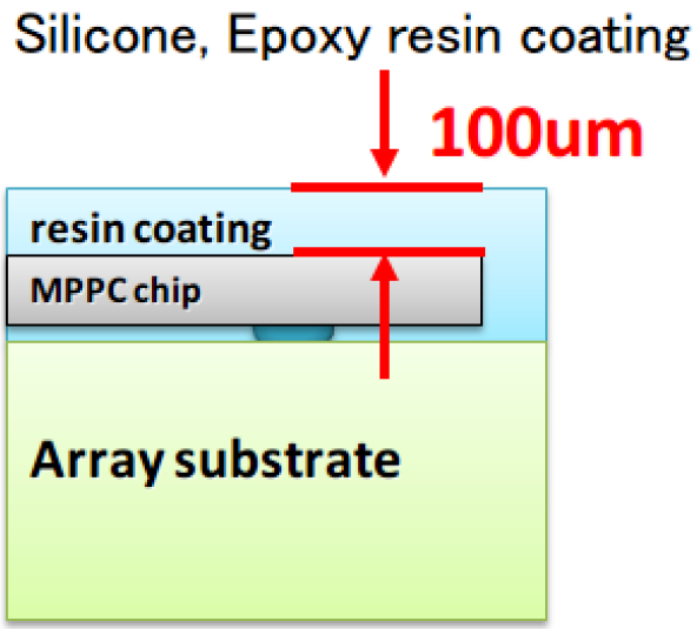
Optimization of the quenching resistor

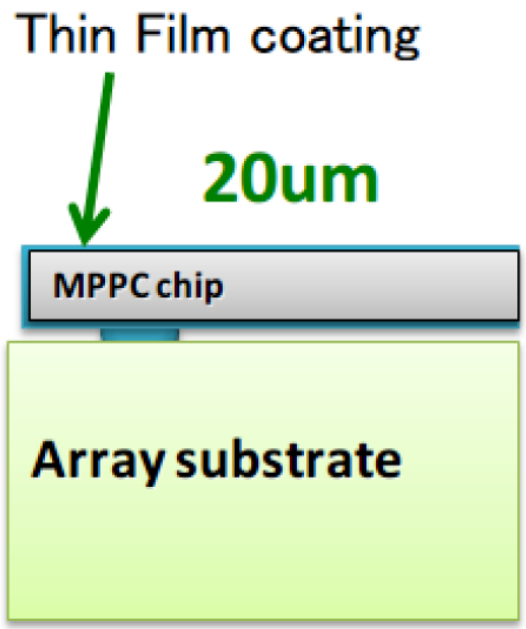



Rq = 173 kΩ
Vover = 3 V
Rq = 314 kΩ
Vover = 3 V
Rq = 751 kΩ
Vover = 3 V
Vover = 4 V
Vover = 5 V
Vover = 5 V
Vover = 5 V
Insufficient Quenching
Early Afterpulses
Delayed Crosstalk
Vover = 7 V
Vover = 7 V

Modification for Enhanced UV Sensitivity

Coating Comparison



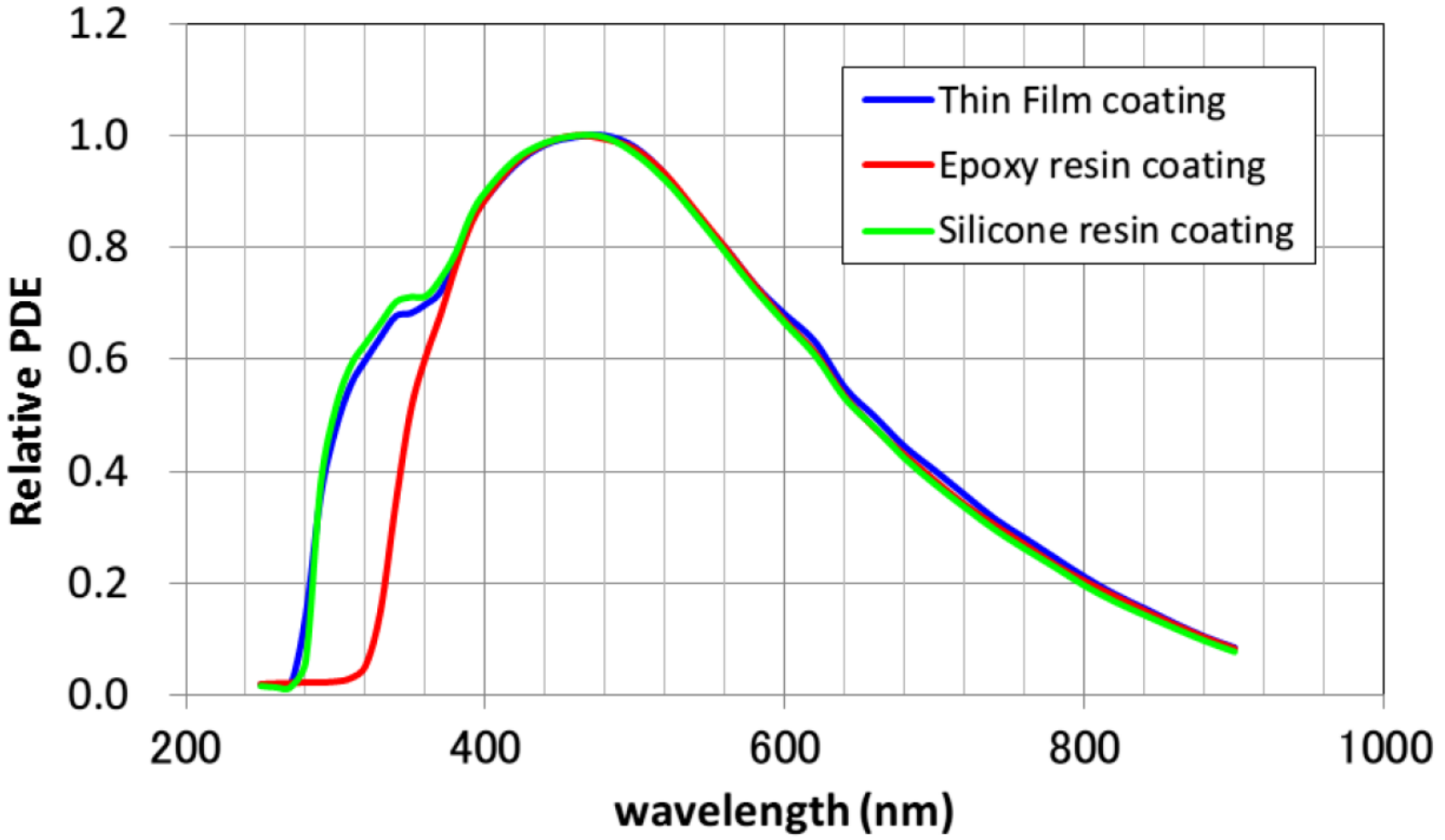


■merit
- robust to the mechanical shock
- easy handling (during assy.)
- superior transparency in UV region

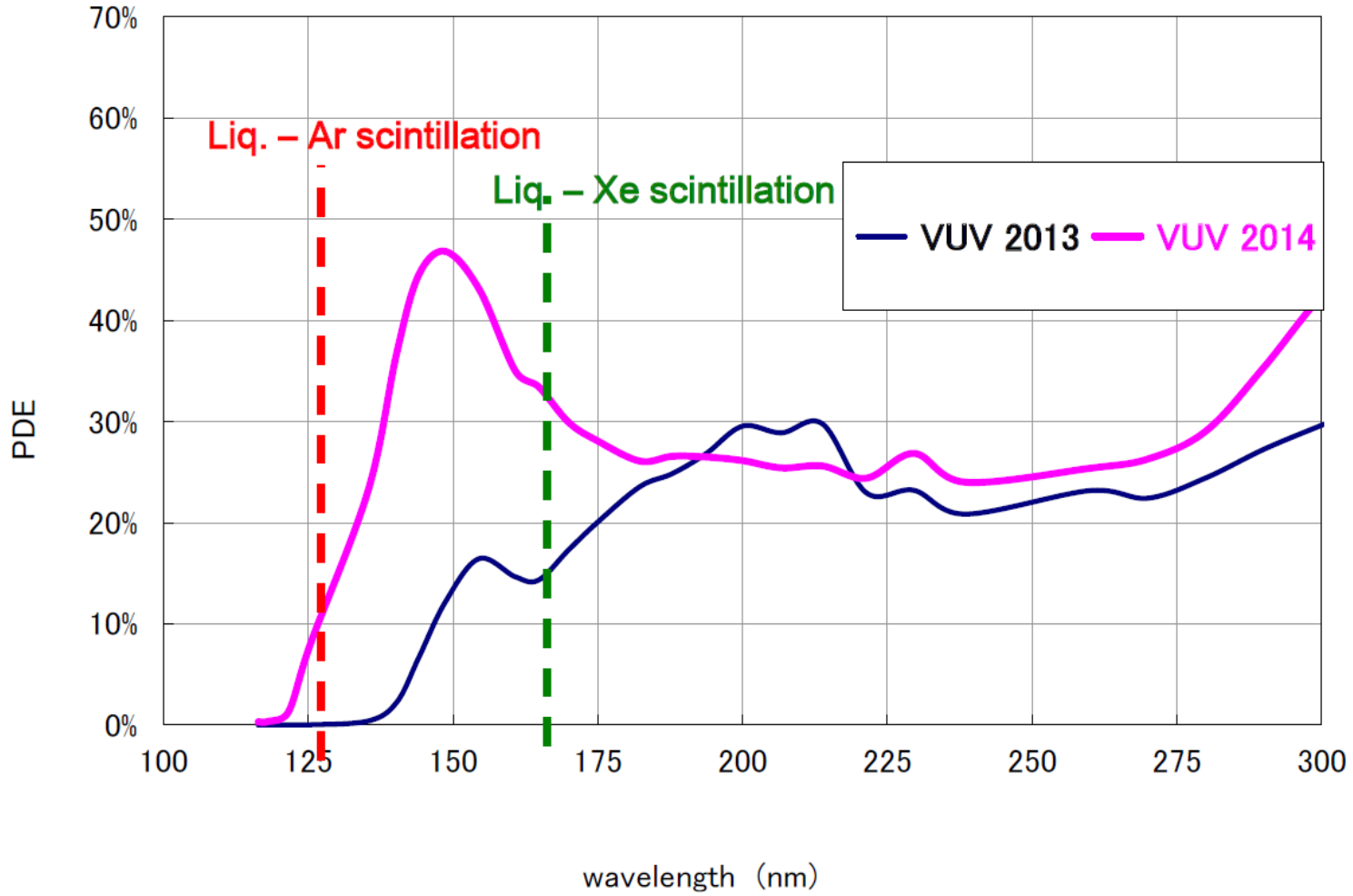
- silicone resin coating type -

■merit
- tough coating
  (mechanical shock should be avoided)
- superior transparency in UV region
- cross-talk suppression in the coating
- super flatness (minimum bending)

PDE comparison with coatings



VUV Sensitivity



Agenda

1 Latest MPPC developments

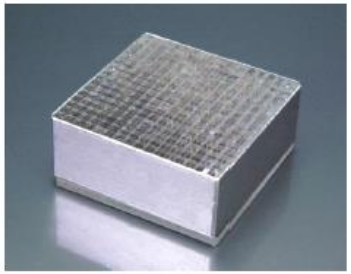
2 Scintillators and PET Products

TOF-PET

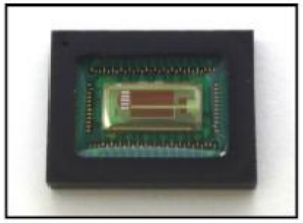
Key component of TOF-PET

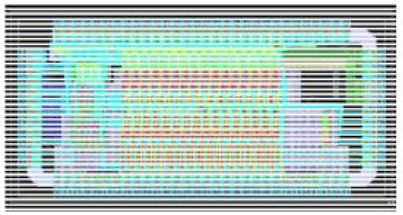
- MPPC array

- Scintillator array



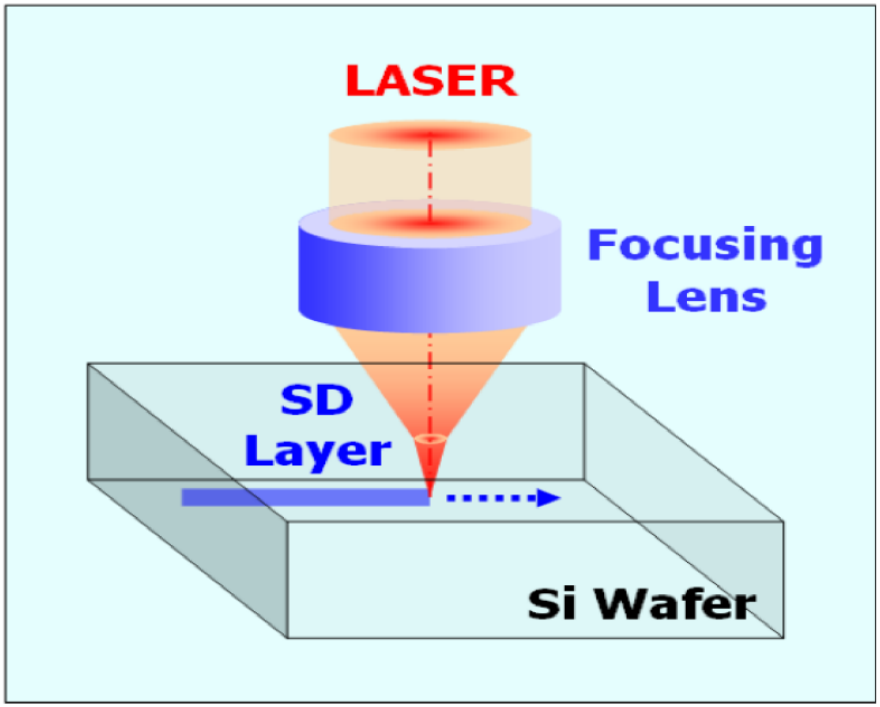
- ASIC



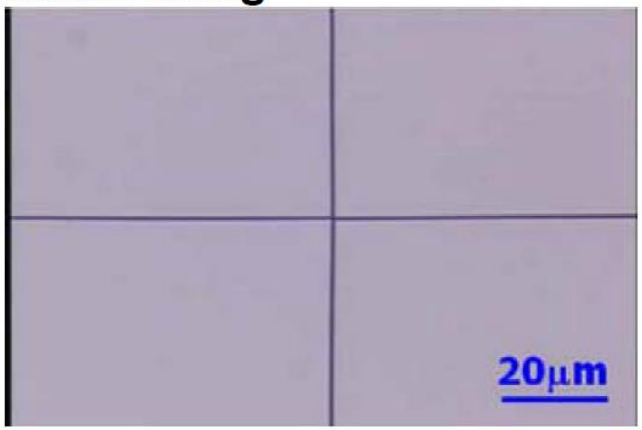


We can supply all.

Stealth Dicing Technology

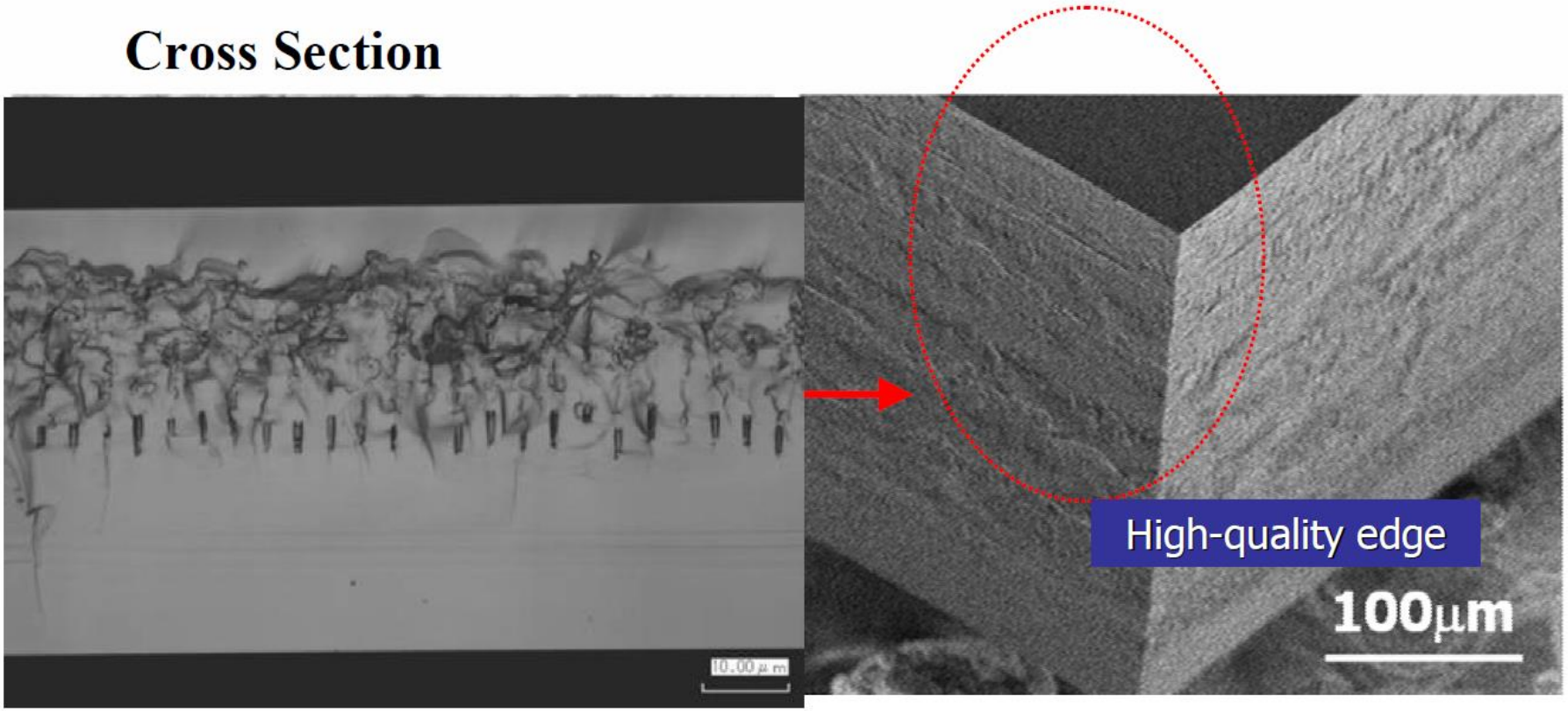


Blade Dicing

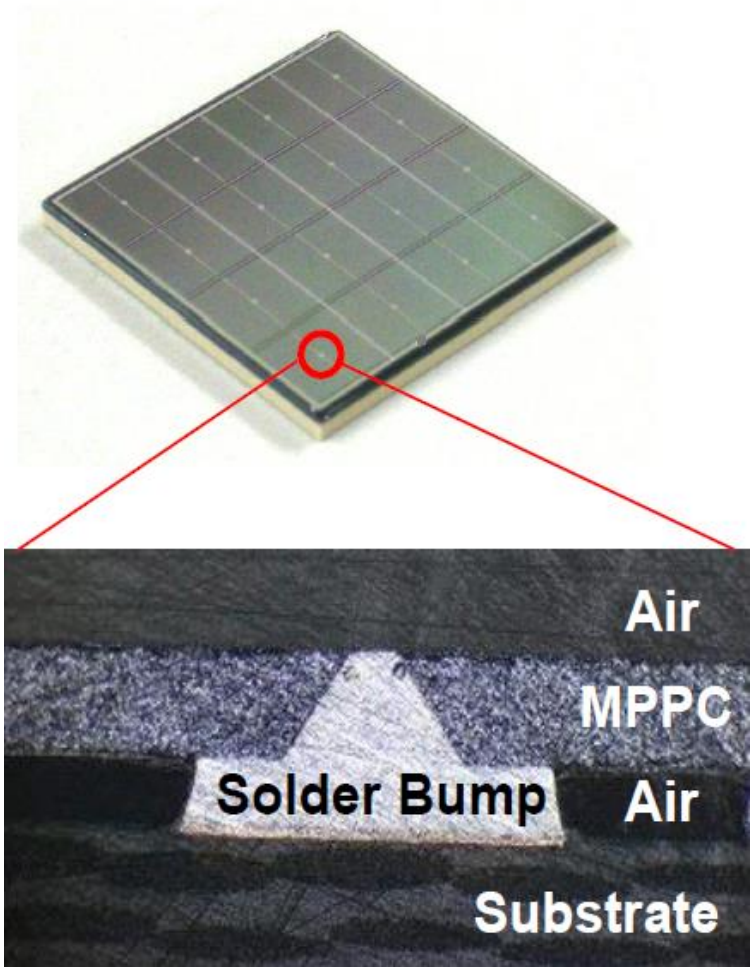


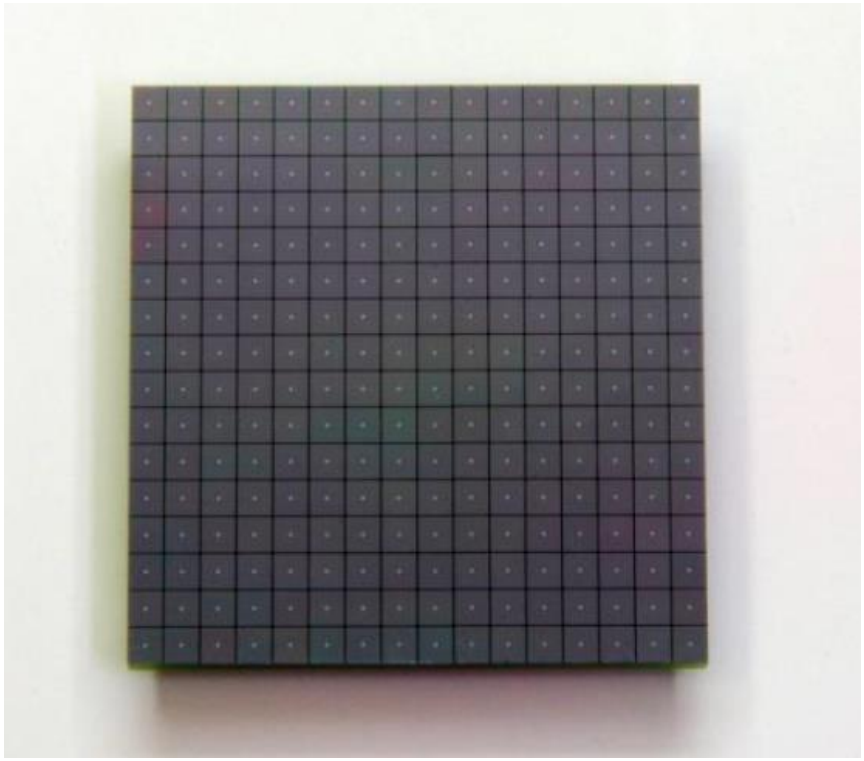
Stealth Dicing

SEM Image of the chip edge



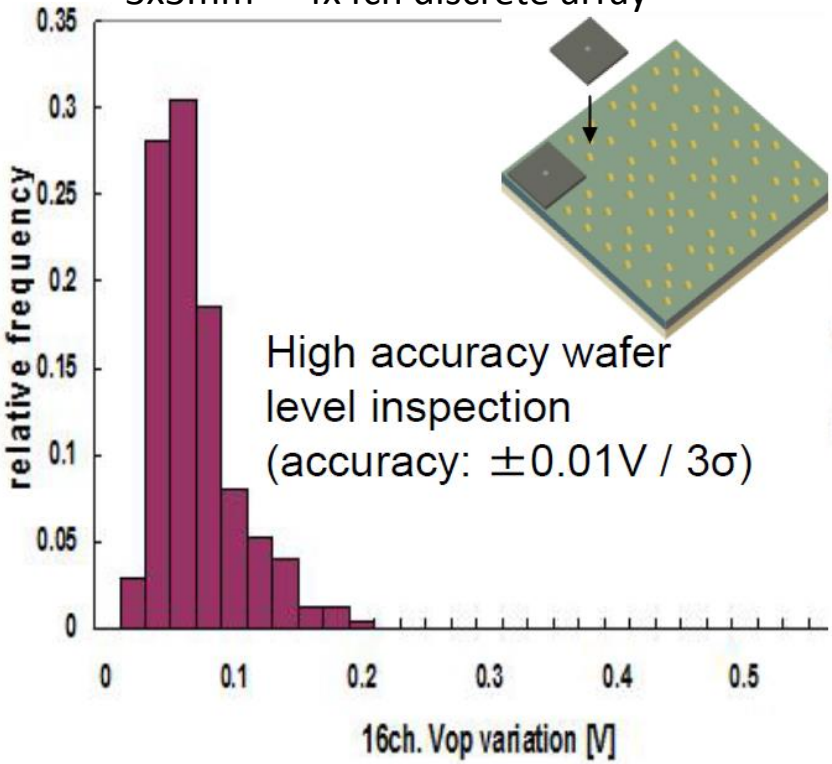
TSV Assembly Technology



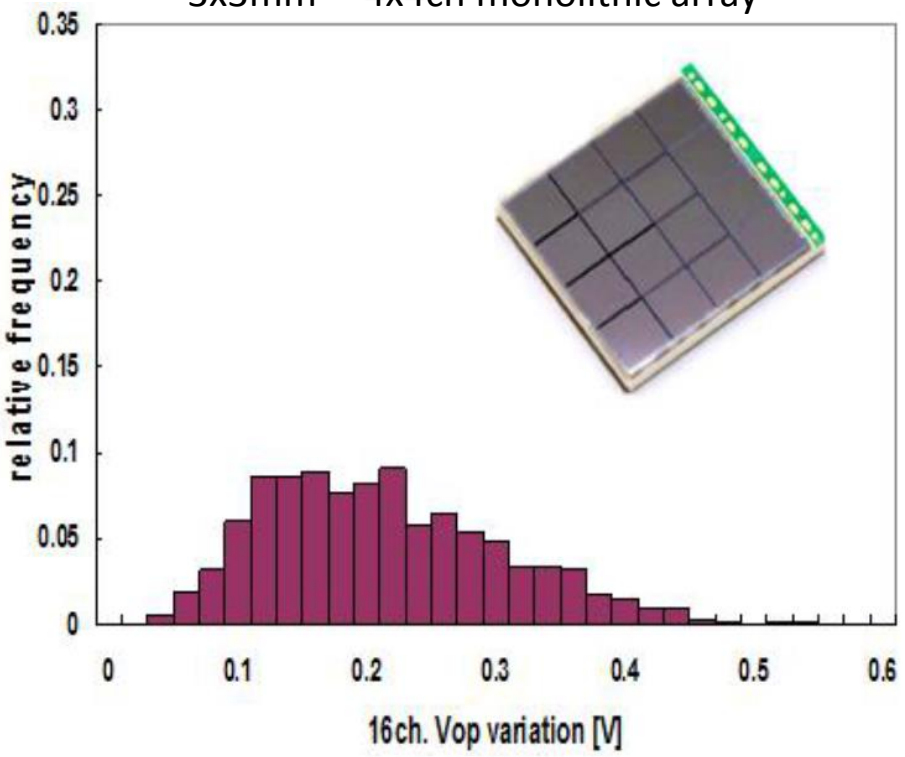


Selection of V_{op} uniformity

3x3mm² - 4x4ch discrete array

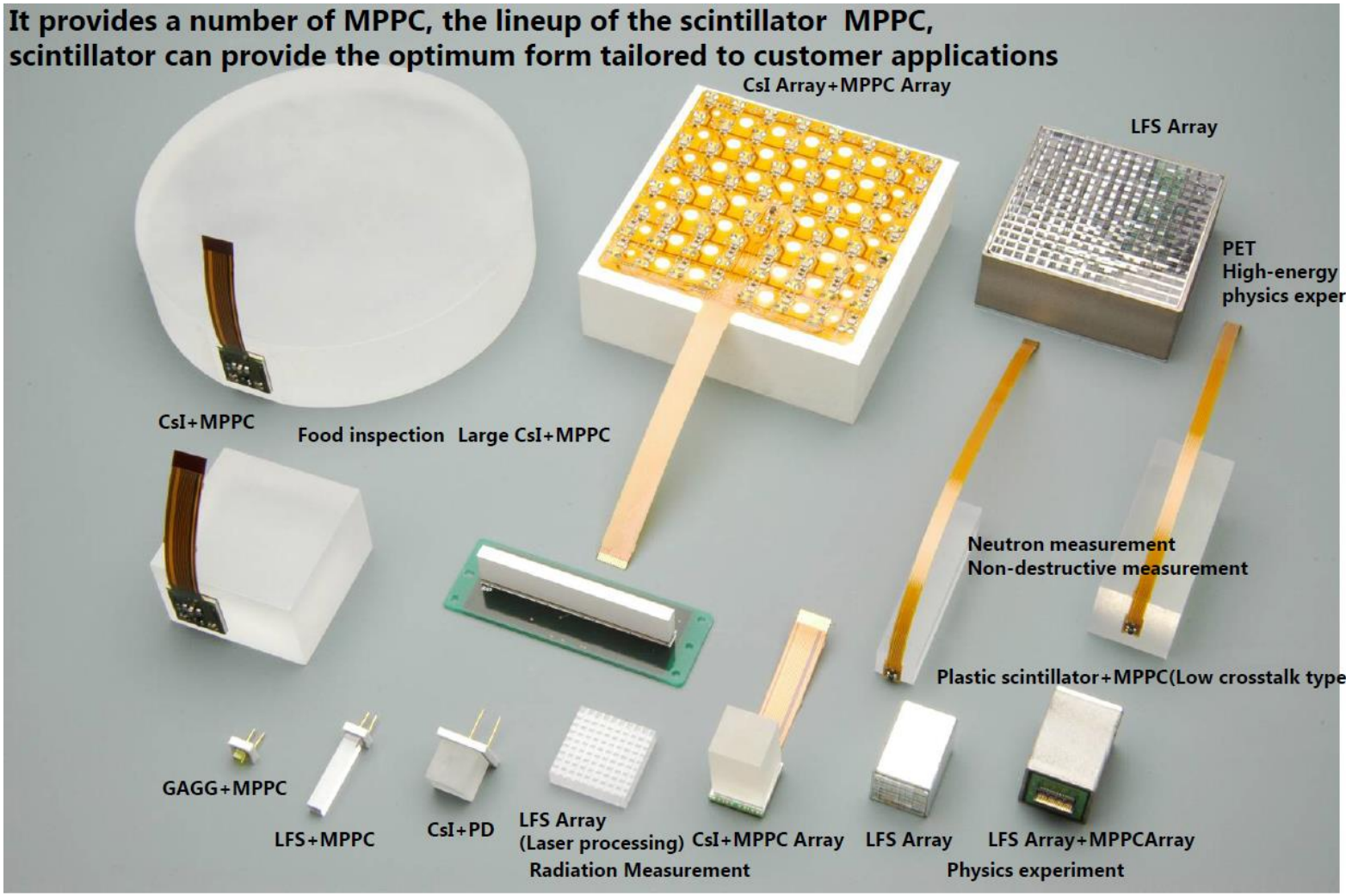


3x3mm² - 4x4ch monolithic array



We can provide a V_{op} selection of 0.1V

Scintillator Arrays



Scintillator materials

Inorganic scintillator

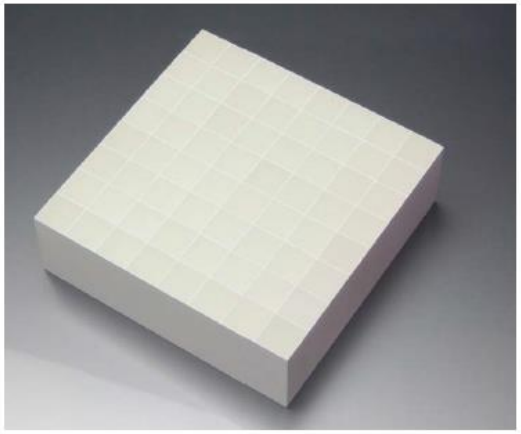
Material	Density (g/cm^3)	Light yield (NaI=100%)	Decay (ns)	Application
NaI:Tl	3.67	100	230	γ-ray, x-ray
CsI	4.53	120	1050	X-CT
CWO($CdWO_4$)	7.68	40	5000	X-CT
BGO($Bi_4Ge_3O_{12}$)	7.13	12	300	PET, HE
PWO($PbWO_4$)	8.20	1.3	10	HE
GAGG	6.63	140	88	HE
LYSO	7.25	80	41	PET, HE
LFS	7.35	85	33	PET, HE

HE: High energy physics

Different types of separation

Reflective Adhesive Type

Ex:CsI:(10x10x25㎜)x 8x8



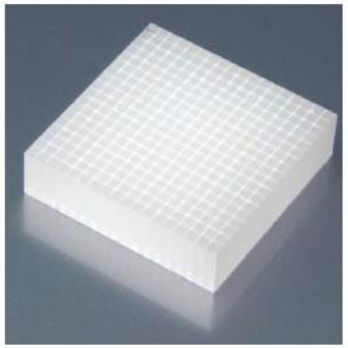
Reflective Film Type

LFS:(3.2x3.2x20㎜)x16x16

Laser Processing Type

LFS:(1.2x1.2x5㎜)x18x18

Processable LFS / LYSO

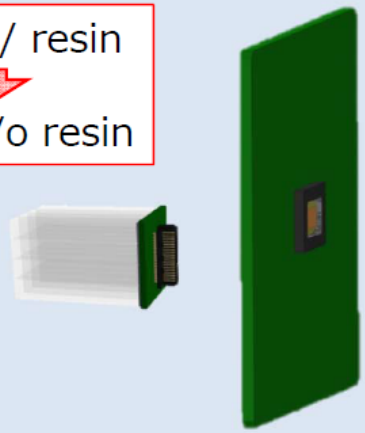


Parameters	Reflective Adhesive	Reflective Film	Laser Processing
Separation	Best	Good	Weak
Cost	High	Middle	Low
Max	No limit	No limit	Thickness 5㎜
Min	1.6㎜ pitch	1.2㎜ pitch	1.2㎜ pitch

Best selection

Detector

LCT4 w/ resin
⇩
LCT5 w/o resin

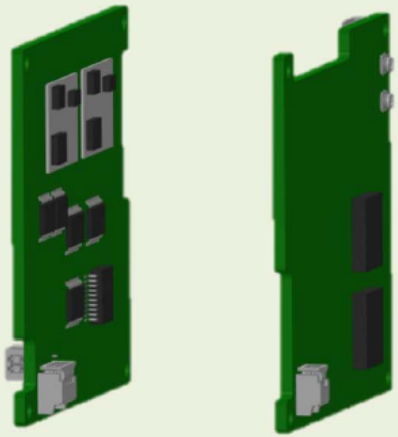


- **LCT 3mm□ 75um pitch**
- 100um resin thickness
- **3.2mm pitch LFS array**

CRT(FWHM)=

175 ps

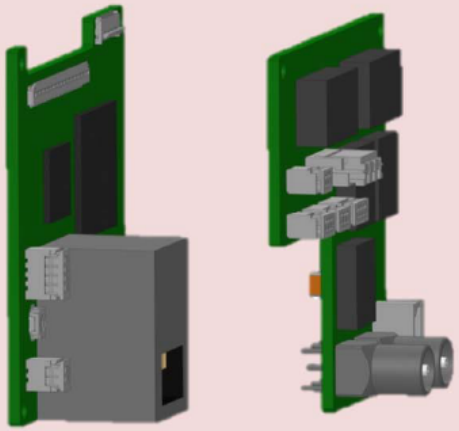
ASIC



- **New HPK-ASIC** of 0.18um-SiGe process.
- Power consumption had reduced 60%, bandwidth was more than doubled.

200 ps

Module



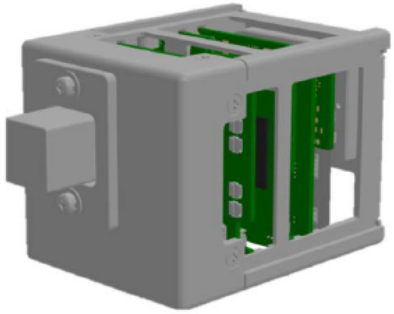
- TDC
- Gigabit Ethernet
- Local Power Supply

280 ps

Lineup

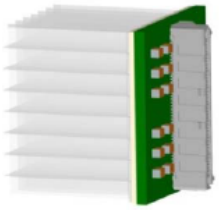
For evaluation

・4×4ch module with Ethernet I/F
(possible to replace the MPPC and the scintillator)



For system (mass production)

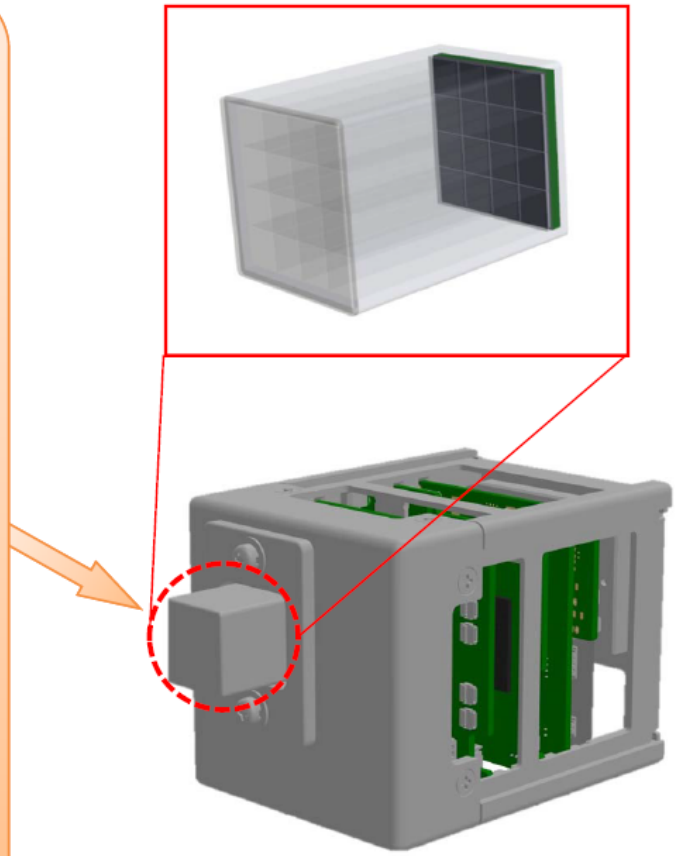
・8×8ch or 16×16ch module with High speed Serial I/F
・Full custom module for each customer
(we can respond to custom request flexibly.)



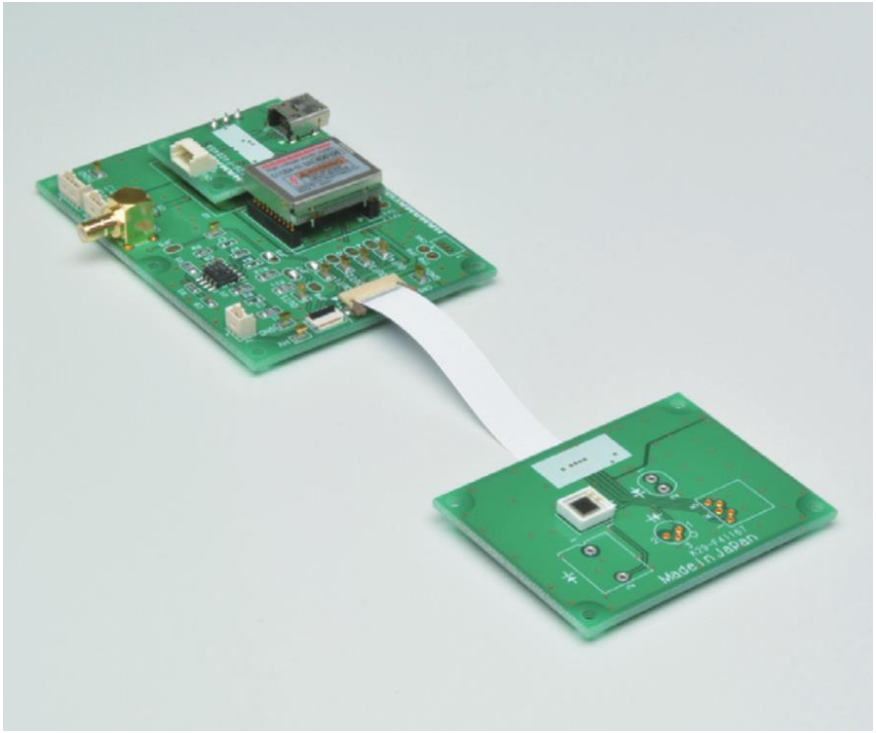
Customization possibilities

You can select and changing.

MPPC		**Scintillator**
Low Cross Talk		LFS
High Fill Factor		LYSO
1mm□		BGO
3mm□	+	1mm□
4mm□		3mm□
5mm□		4mm□
50um pixel		5mm□
75um pixel		etc
100um pixel		
etc		



Modules



Thank you very much!