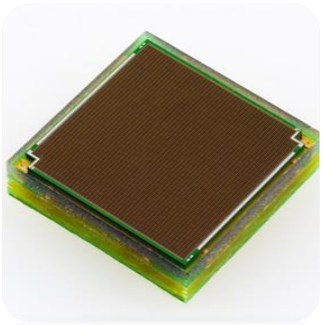
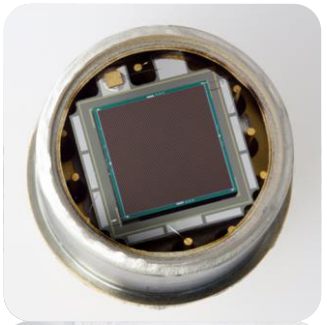
SiPM





Silicon Photomultipliers

KETEK SiPM Solutions

FAST Workshop

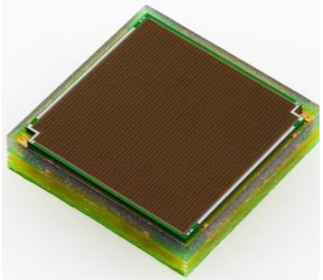
Aachen, September 2015

SiPM solutions realized by KETEK

- KETEK company profile
- KETEK SiPM off-the-shelf devices - status and developments
- KETEK customized solutions
- KETEK production setup
- KETEK CMOS integration
- Summary and outlook

KETEK at a glance

SiPM



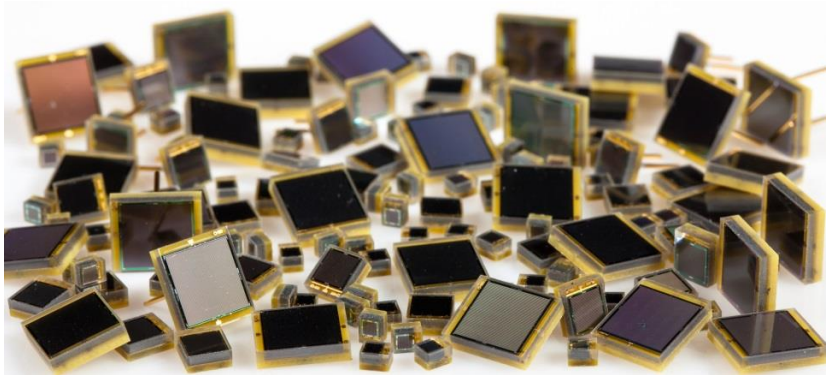
- Midsize, family-owned enterprise, formation 1989 by Dr. Josef Kemmer
- Number of employees: 81
- Managing directors: Silvia Wallner, Dr. Reinhard Fojt
- Major product lines:

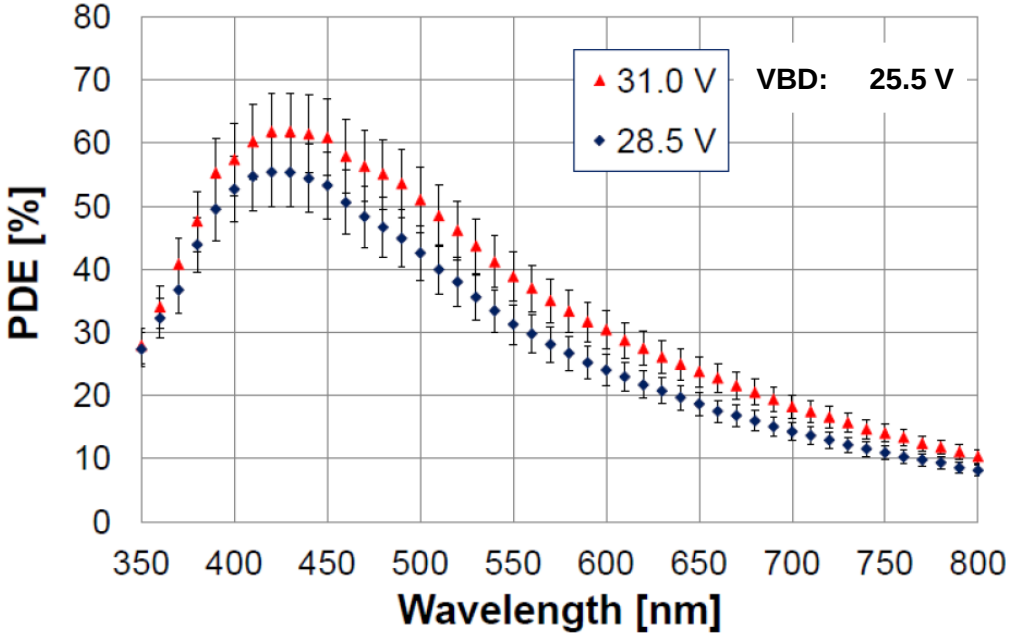
  SDD modules, detector electronics and complete systems

  Silicon Photo Multiplier Modules (SiPM)

Key Features of KETEK´s SiPM Sensors

- Very high PDE
  - up to 60% for 50µm cell type @420 nm
  - up to 37% for 15µm cell type @420 nm
- High gain
  - min. 10^6
- Optimized for blue light sensitivity
  - 420nm peak sensitivity
- Low dark rate and excess noise
  - DR down to 100kHz/mm^2
  - XT down to below 5% at 20% Overvoltage
  - DR and XT dep. on cell- and device type
- Huge bias voltage range of stable operation
  - up to 40% overvoltage
- Extremely low temperature coefficient
  - below 1% above 10% overvoltage





PM1150: *Measurements performed by CERN / Iouri Musienko*
(1.0 mm^2 active area, 50 µm cell pitch, 70% GE, no trench)

Key Features of KETEK´s SiPM Sensors

- Very high PDE
  - up to 60% for 50µm cell type @420 nm
  - up to 37% for 15µm cell type @420 nm
- High gain
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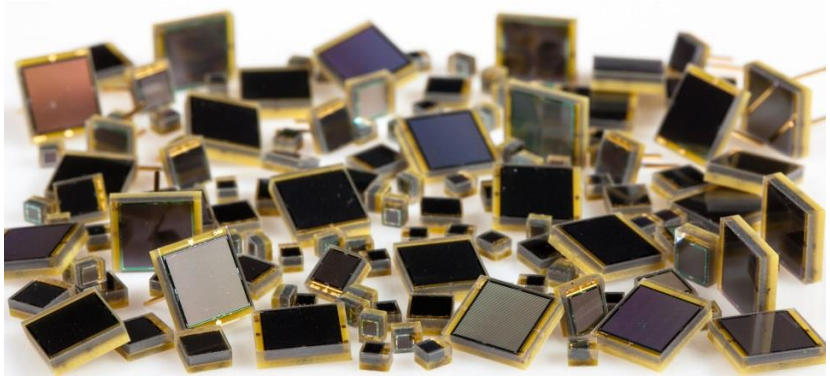
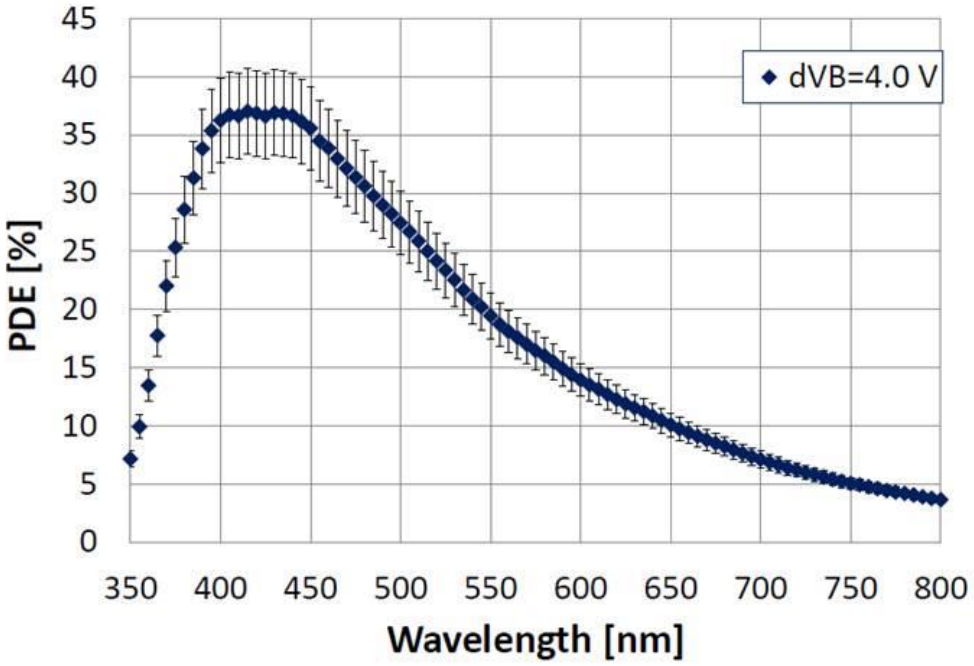
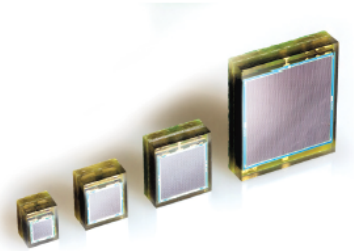




CERN06: *Measurements performed by CERN / Iouri Musienko (15µm cell pitch, 37% PDE max)*

KETEK SiPM Portfolio

SiPM



PRODUCT PORTFOLIO

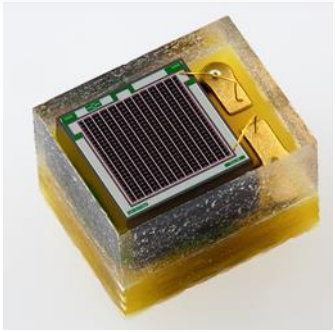
KETEK SiPM Modules
Standard

Type	Active Area (mm²)	Cell Pitch (µm)	Geometrical Efficiency (%)	PDE @ 420 nm (%)	Package Size	Connection	Order Code
PM11	1.2 x 1.2	25	48	≥ 30	2.0 x 2.5	SMD	PM1125NS-SB0
	1.2 x 1.2	50	70	≥ 53	2.0 x 2.5	SMD	PM1150NS-SB0
PM22	2.0 x 2.0	50	70	≥ 48	2.8 x 3.3	SMD	PM2250NS-SB0
PM33	3.0 x 3.0	25	48	≥ 30	3.8 x 4.3	SMD Pin	PM3325NS-SB0 PM3325NP-SB0
	3.0 x 3.0	50	70	≥ 48	3.8 x 4.3	SMD Pin	PM3350NS-SB0 PM3350NP-SB0
PM66	6.0 x 6.0	25	48	≥ 30	6.8 x 7.8	SMD[1] Pin[1]	PM6625TS-SB0 PM6625TP-SB0

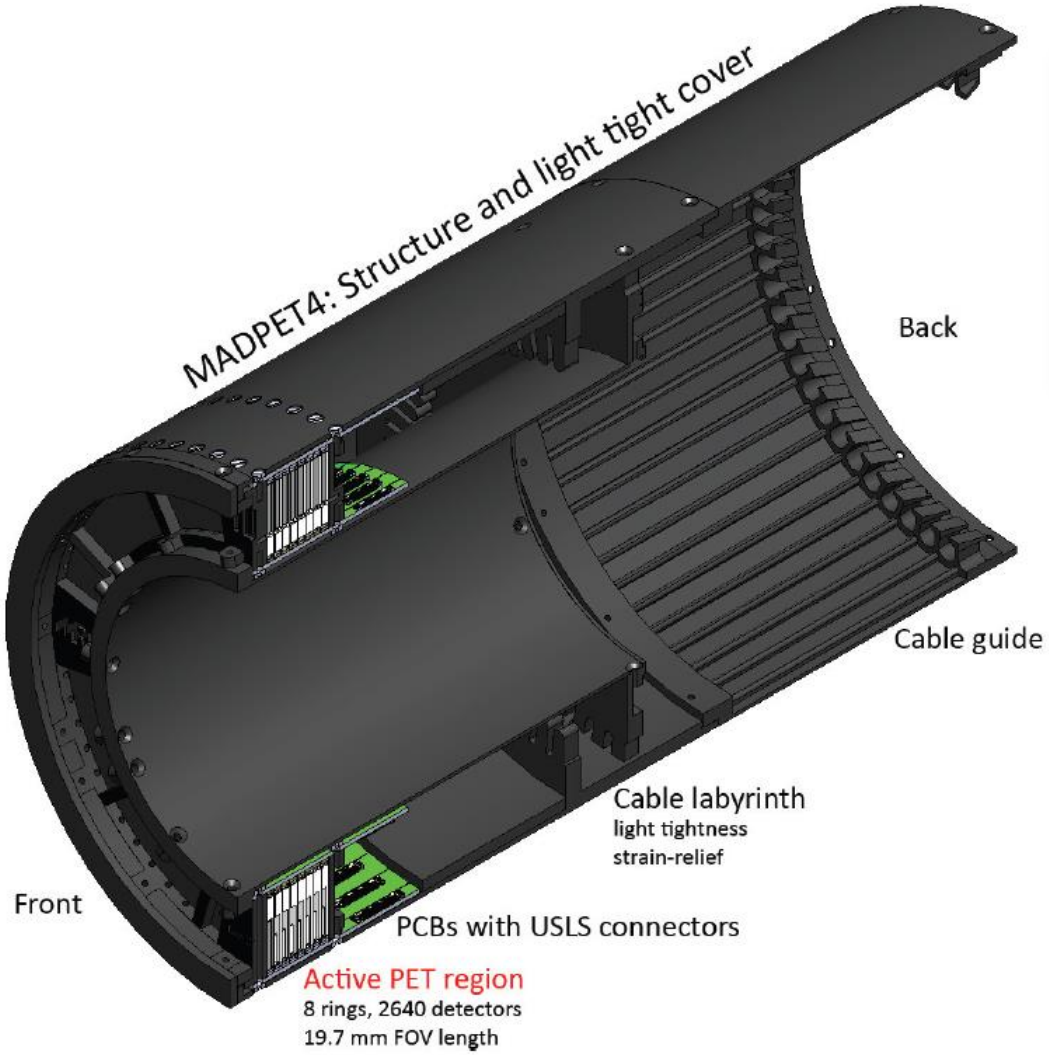
KETEK SiPM Modules
with Optical Trench Isolation

Type	Active Area (mm²)	Cell Pitch (µm)	Geometrical Efficiency (%)	PDE @ 420 nm (%)	Package Size	Connection	Order Code
PM11	1.2 x 1.2	50	63	≥ 48	2.0 x 2.5	SMD	PM1150TS-SB0
	1.2 x 1.2	75	72	≥ 50	2.0 x 2.5	SMD	PM1175TS-SB0
	1.2 x 1.2	100	80	≥ 56	2.0 x 2.5	SMD	PM11100TS-SB0
PM22	2.0 x 2.0	50	63	≥ 42	2.8 x 3.3	SMD	PM2250TS-SB0
	2.0 x 2.0	100	81	≥ 56	2.8 x 3.3	SMD	PM22100TS-SB0
PM33	3.0 x 3.0	50	63	≥ 42	3.8 x 4.3	SMD Pin	PM3350TS-SB0 PM3350TP-SB0
	3.0 x 3.0	60	66	≥ 45	3.8 x 4.3	SMD Pin	PM3360TS-SB0 PM3360TP-SB0
	3.0 x 3.0	75	72	≥ 50	3.8 x 4.3	SMD Pin	PM3375TS-SB0 PM3375TP-SB0
PM 66	6.0 x 6.0	50	63	≥ 42	6.8 x 7.8	SMD[1] Pin[1]	PM6650TS-SB0 PM6650TP-SB0
	6.0 x 6.0	60	66	≥ 45	6.8 x 7.8	SMD Pin	PM6660TS-SB0 PM6660TP-SB0

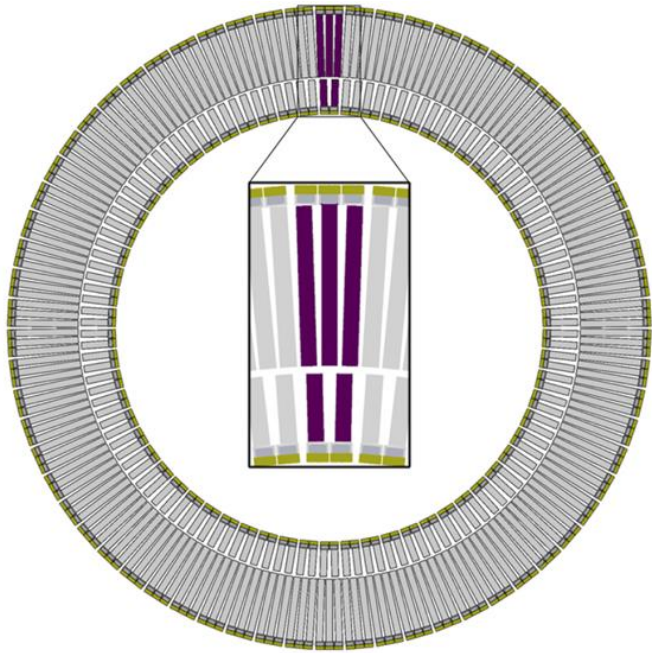
PM1150NS



KETEK SiPM PM1150NS in MADPET4

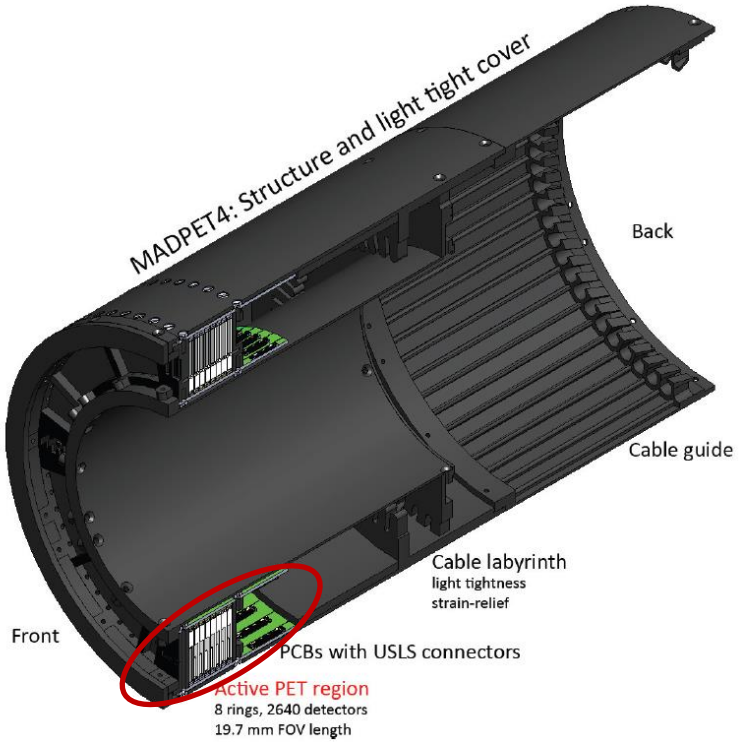


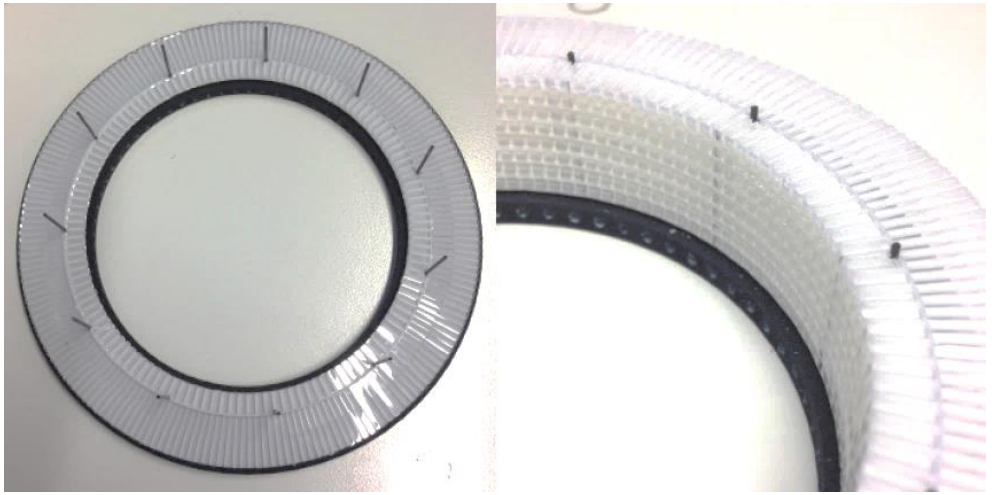
MADPET4
(Munich Avalanche Photo-Diode PET) is the first preclinical PET insert for simultaneous PET/MRI which is based on SiPMs and working in a 7 T MRI scanner.



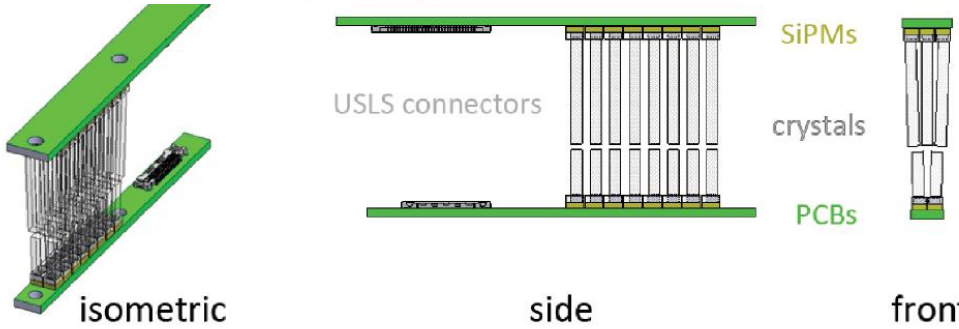
F. Schneider, TUM

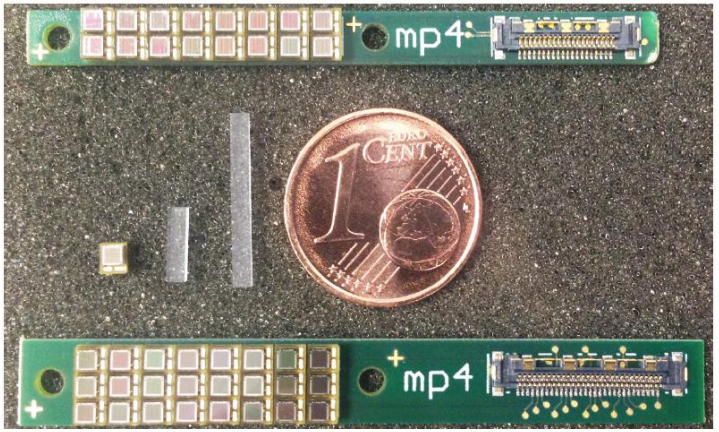
KETEK SiPM PM1150NS in MADPET4





Left: Single ring element with 330 crystals in the 3D printed structure (white).
Right: Assembly of the 8 rings with all 2640 crystals



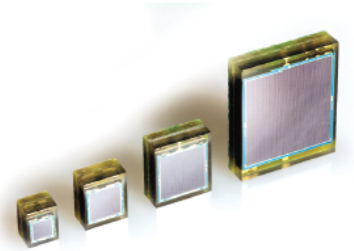


Schematic views of a single module with in total 40 detector channels.
Pitch between the rings in axial direction is 2.6mm, covering an axial FOV of 19.7mm

F. Schneider, TUM

KETEK SiPM Portfolio

SiPM



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	1.2 x 1.2	50	70	≥ 53	2.0 x 2.5	SMD	PM1150NS-SB0
PM22	2.0 x 2.0	50	70	≥ 48	2.8 x 3.3	SMD	PM2250NS-SB0
PM33	3.0 x 3.0	25	48	≥ 30	3.8 x 4.3	SMD Pin	PM3325NS-SB0 PM3325NP-SB0
	3.0 x 3.0	50	70	≥ 48	3.8 x 4.3	SMD Pin	PM3350NS-SB0 PM3350NP-SB0
PM66	6.0 x 6.0	25	48	≥ 30	6.8 x 7.8	SMD[1] Pin[1]	PM6625TS-SB0 PM6625TP-SB0

KETEK SiPM Modules
with Optical Trench Isolation

Type	Active Area (mm²)	Cell Pitch (µm)	Geometrical Efficiency (%)	PDE @ 420 nm (%)	Package Size	Connection	Order Code
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	1.2 x 1.2	75	72	≥ 50	2.0 x 2.5	SMD	PM1175TS-SB0
	1.2 x 1.2	100	80	≥ 56	2.0 x 2.5	SMD	PM11100TS-SB0
PM22	2.0 x 2.0	50	63	≥ 42	2.8 x 3.3	SMD	PM2250TS-SB0
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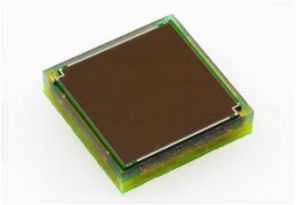
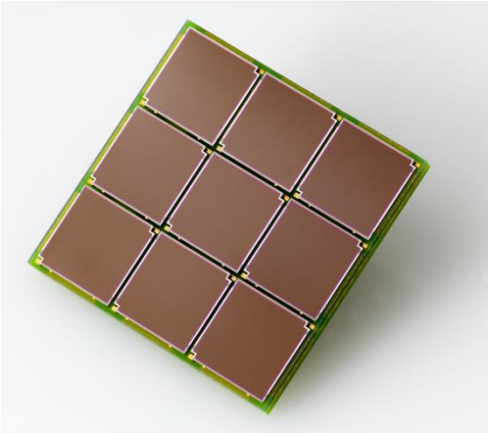
	3.0 x 3.0	60	66	≥ 45	3.8 x 4.3	SMD Pin	PM3360TS-SB0 PM3360TP-SB0
	3.0 x 3.0	75	72	≥ 50	3.8 x 4.3	SMD Pin	PM3375TS-SB0 PM3375TP-SB0
PM 66	6.0 x 6.0	50	63	≥ 42	6.8 x 7.8	SMD[1] Pin[1]	PM6650TS-SB0 PM6650TP-SB0
	6.0 x 6.0	60	66	≥ 45	6.8 x 7.8	SMD Pin	PM6660TS-SB0 PM6660TP-SB0

NEW Package 2.0



NEW SiPM Array

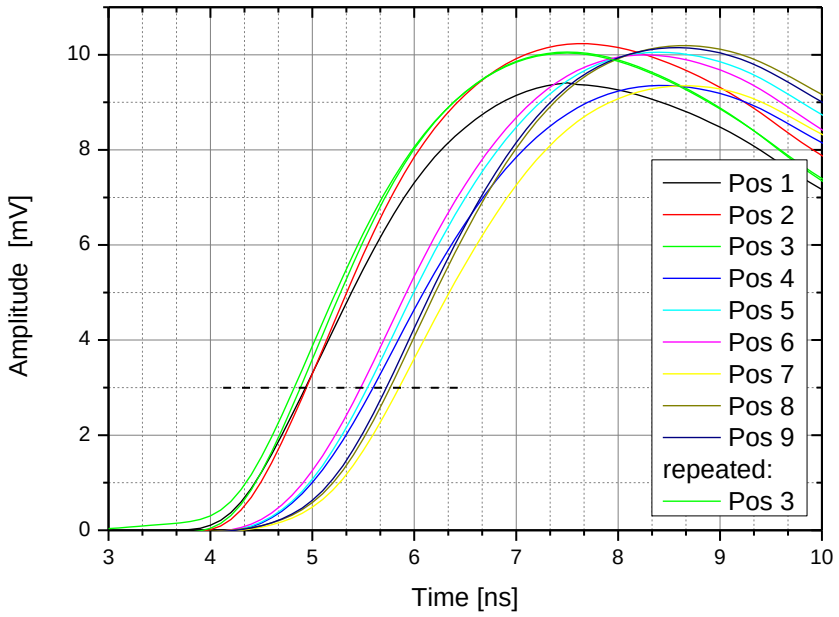


Motivation for SPTR- and TTD-studies

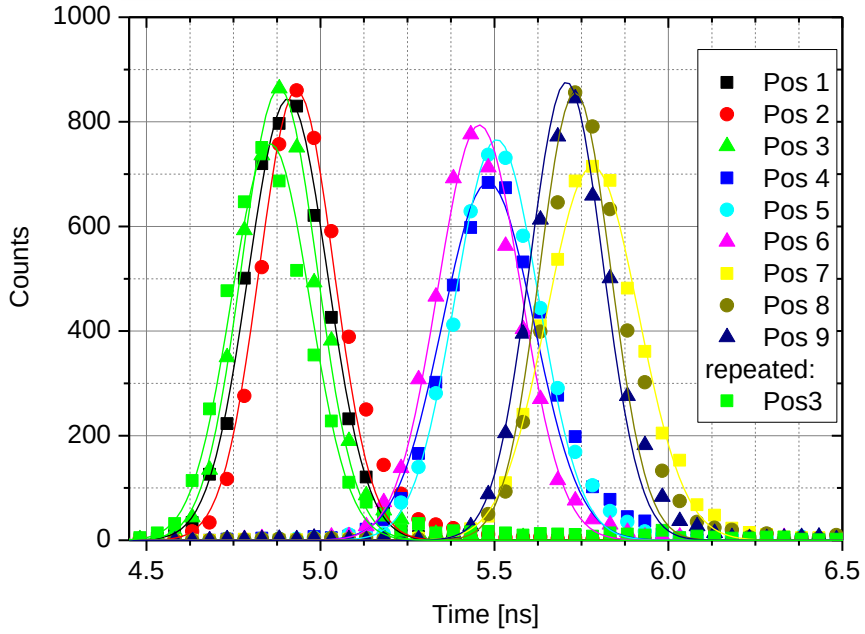
- Transit-Time-Delay (TTD) leads to asymmetrical SPTR distribution
- TTD is dominating factor for SPTR
- Improvement of TTD will help to achieve better SPTR

KETEK

Averaged waveforms



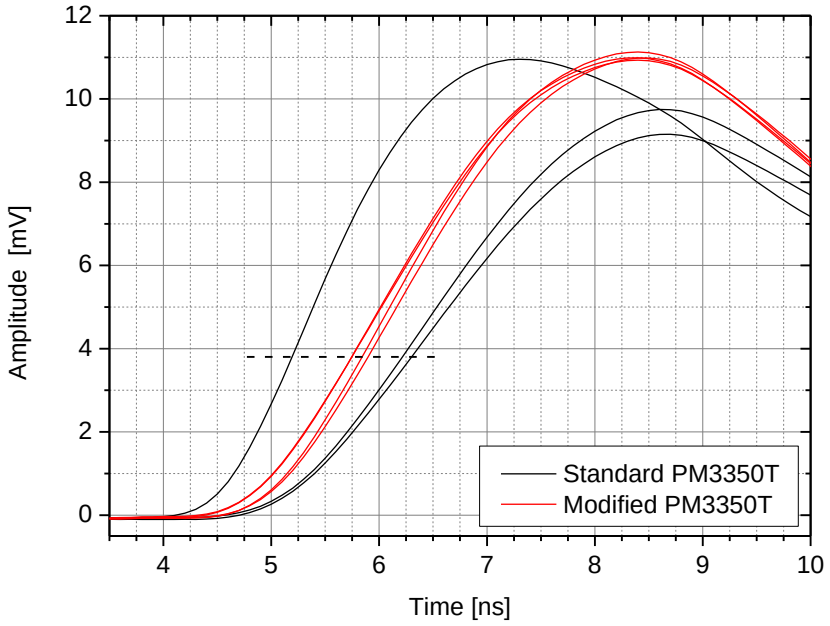
Localized SPTR measurements



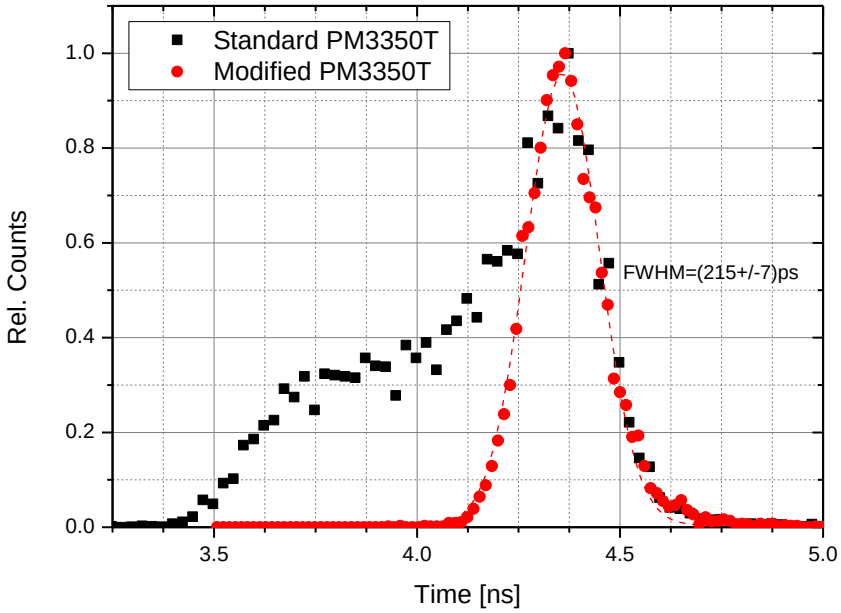
Comparison of Transit-Time-Delay and SPTR

- Significant decrease of TTD (900 ps -> 170 ps)
- Better amplitude stability
- Symmetrical SPTR distribution with 215±7 ps

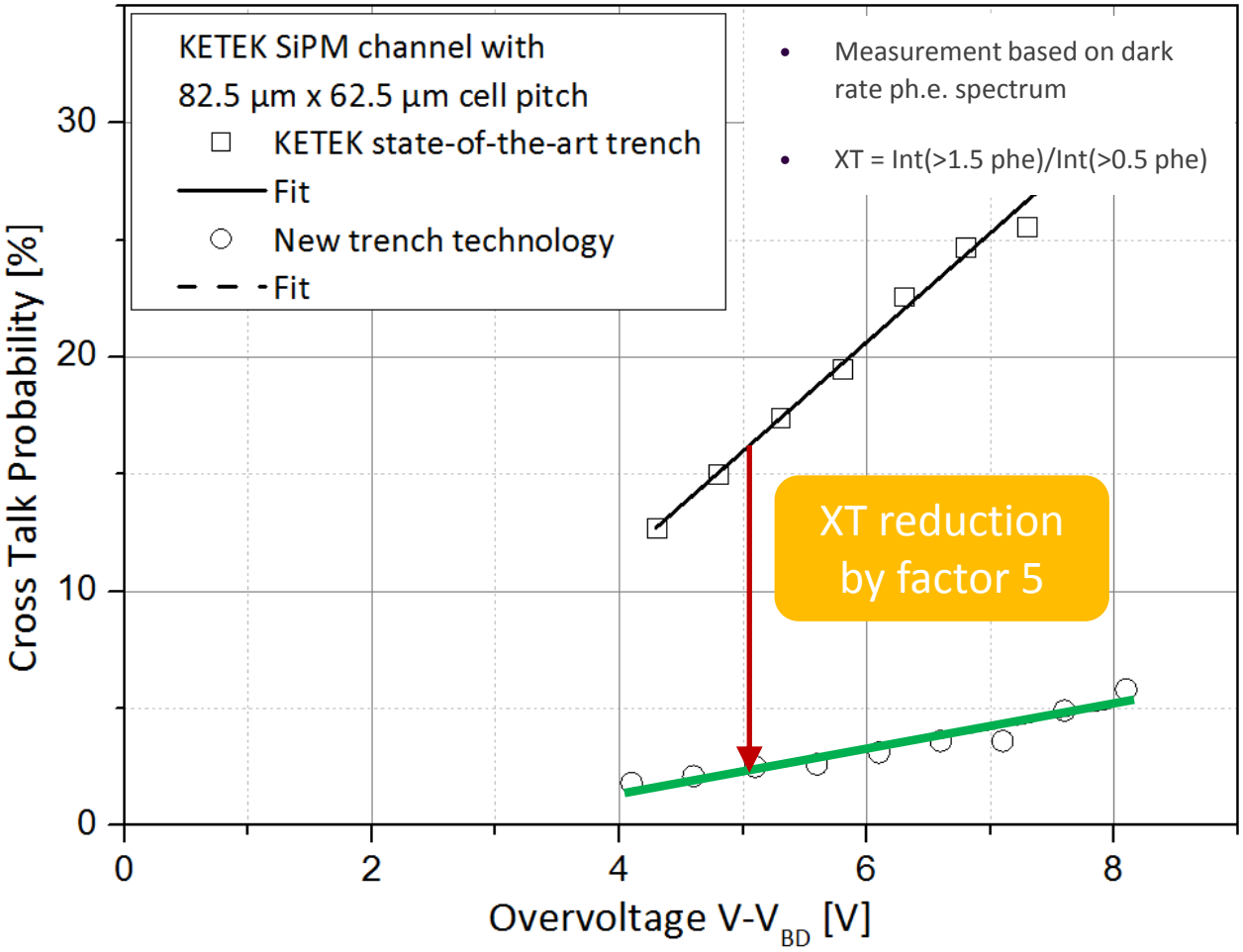
Averaged waveforms



SPTR measurements



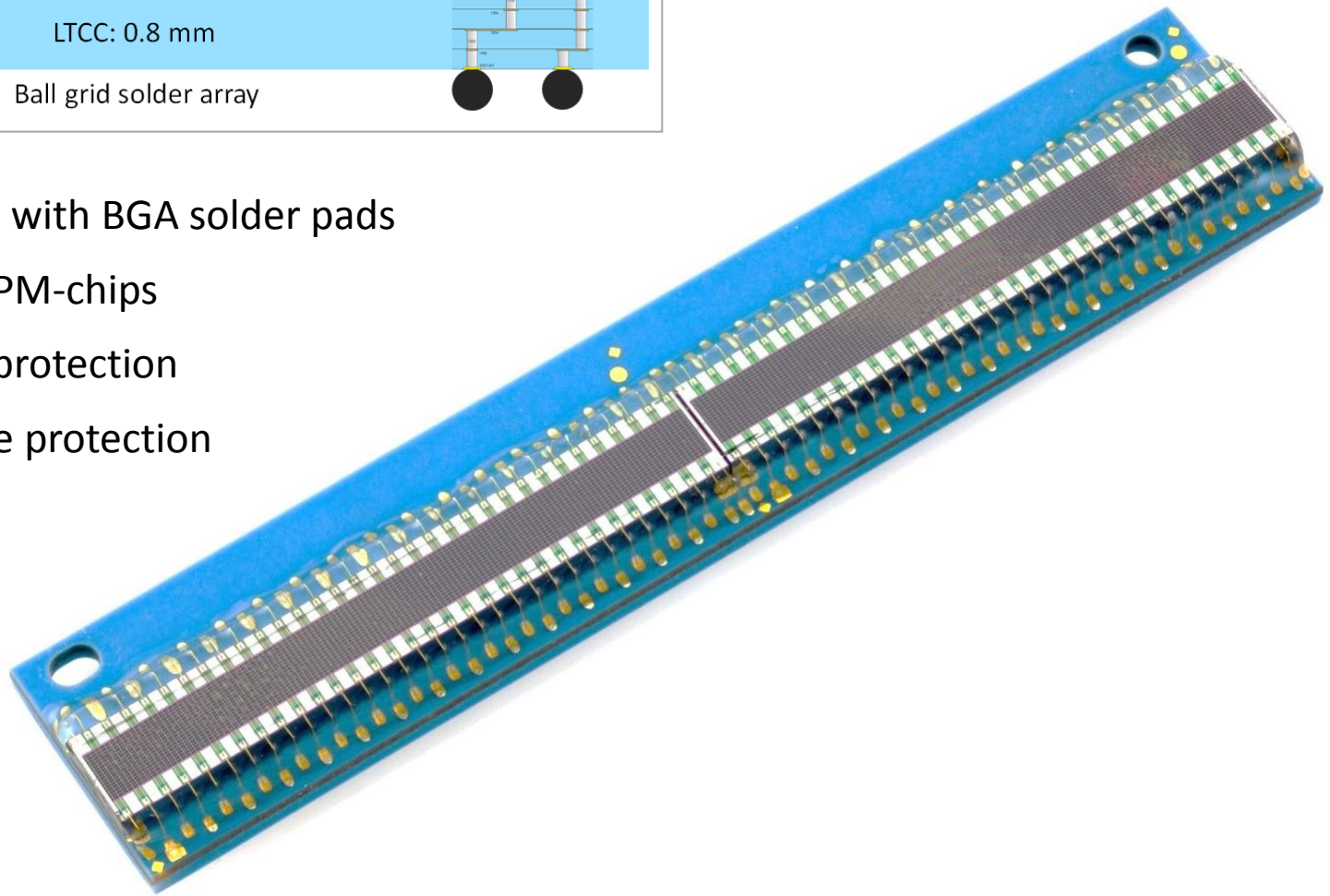
Enhanced optical cross-talk suppression



At 5 V overvoltage (typical operation condition):
Reduction from 17 % down to < 3 % (factor 5)

Customized SiPM solutions

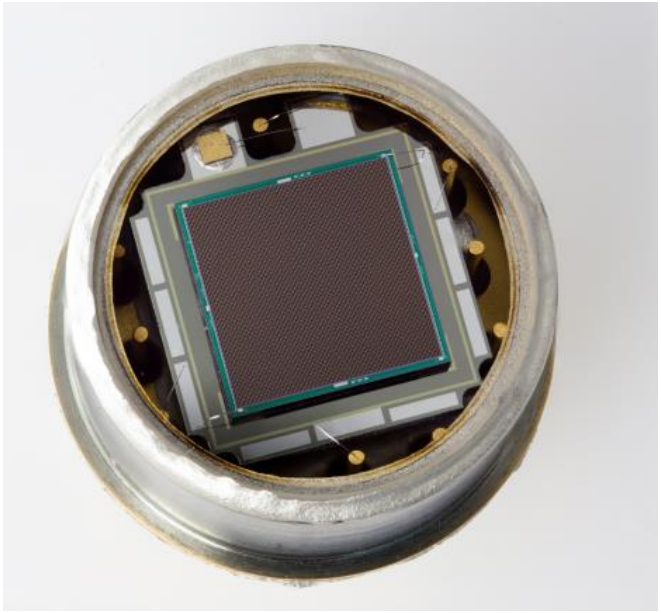
- LTCC support plate with BGA solder pads
- Two 64-channel SiPM-chips
- Thin glass lid chip protection
- Glop top bond wire protection



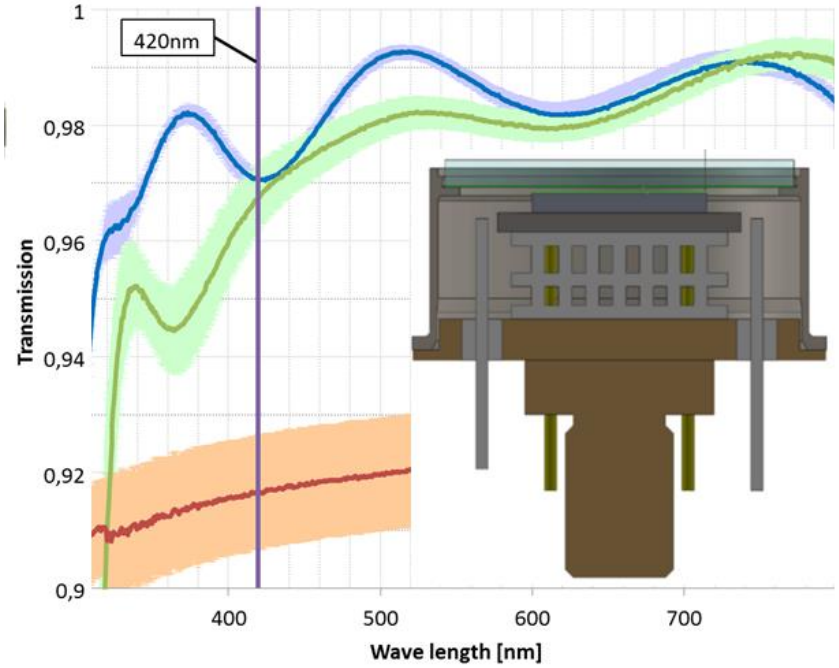
Customized packaging

- Lower noise at lower temperatures
- Different SiPMs up to 36mm²
- Quartz-Window with double-sided ARC

KETEK Ultra Low Noise SiPM: Flexible technology for customized packaging solutions



TO8-package incl. cooling for extremely low DR

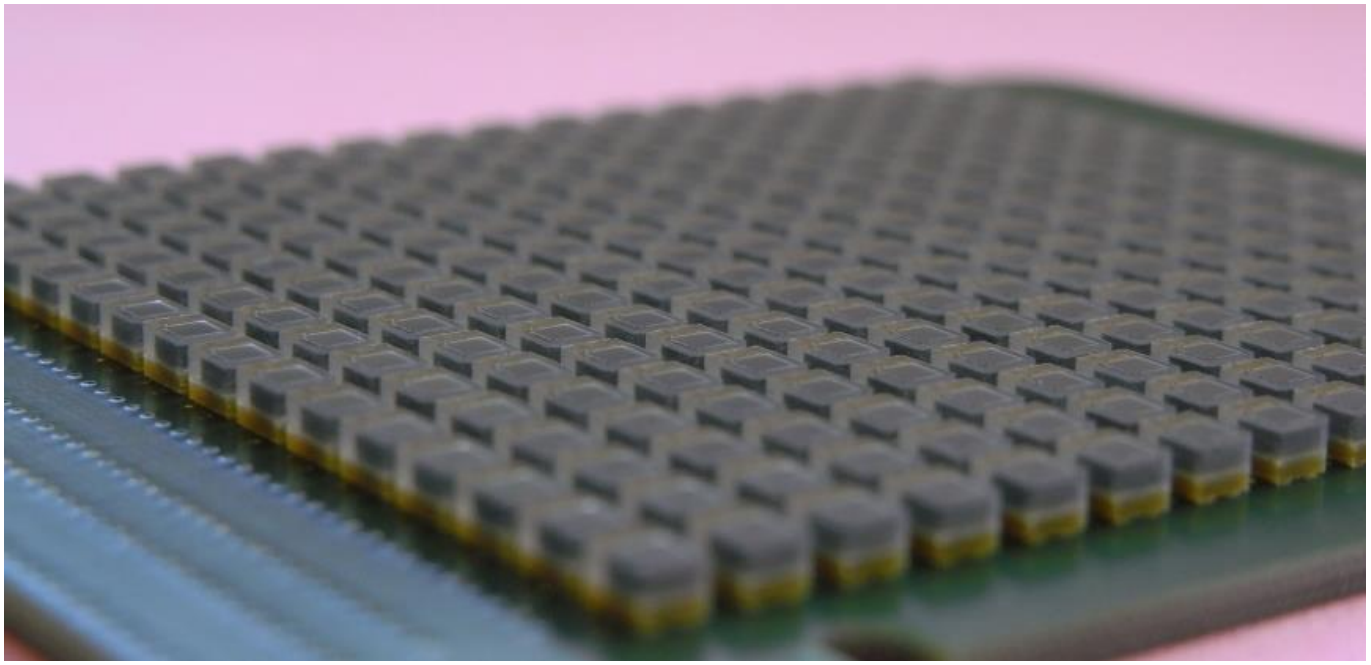


Customized packaging

- Array solution with SMD devices
- Different sensor boards
- Large area detection systems

KETEK Sensor Arrays: Flexible technology for customized array solutions

Customized Arrays

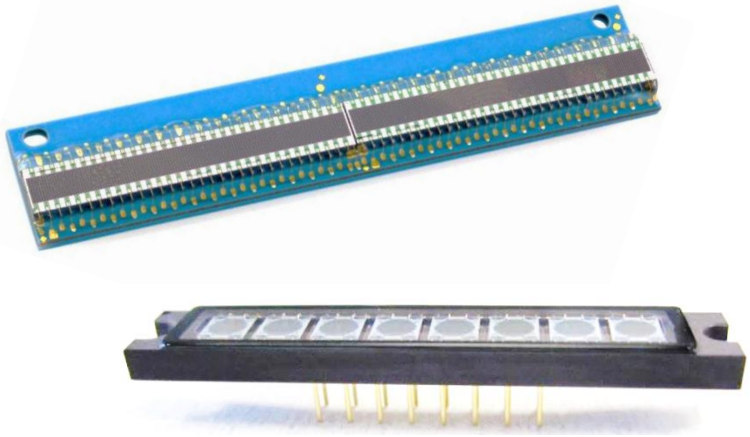


256 channel array build with PM11

SiPM production setup – two facilities

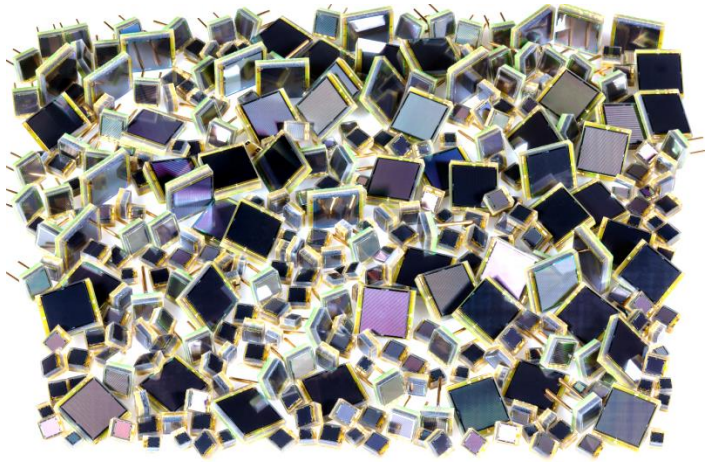
KETEK inhouse production

- Technology development
- Prototyping
- Customized products
- Variable packaging options



KETEK foundry production

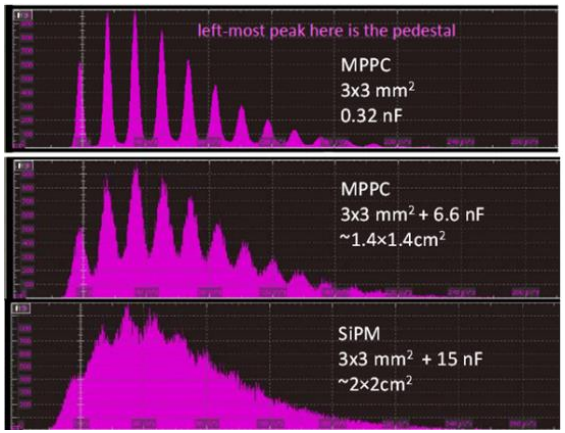
- High volume production
- Fast throughput time
- Low cost
- Electronics integration



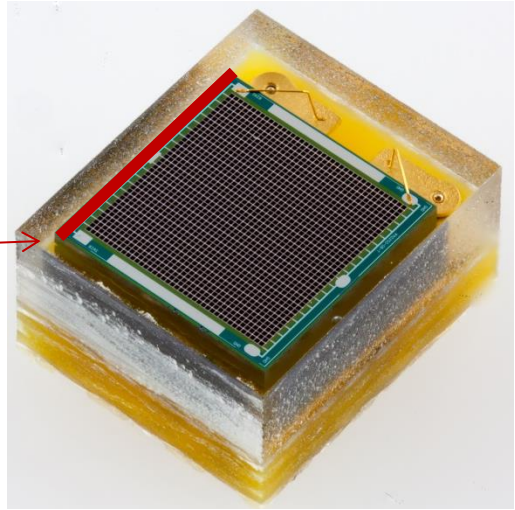
Excellent setup for cost effective innovations

SiPM – CMOS-integration

- R&D activity together with MEPHI
- Target: SiPM readout for large area SiPM
- Problem: Signal degradation with scaling of the active area due to increase of the parasitic capacitance
- Approach:
  - signal of small micro pixel sub-groups is amplified on chip level
  - sub-group signals are capacitive decoupled from each other
  - CMOS only outside of active area to keep GE (PDE) as high as possible
  - separation of CMOS- and sensor part minimizes electro-optical crosstalk of the active elements



G. Visser (Indiana Univ.)



Summary and Outlook

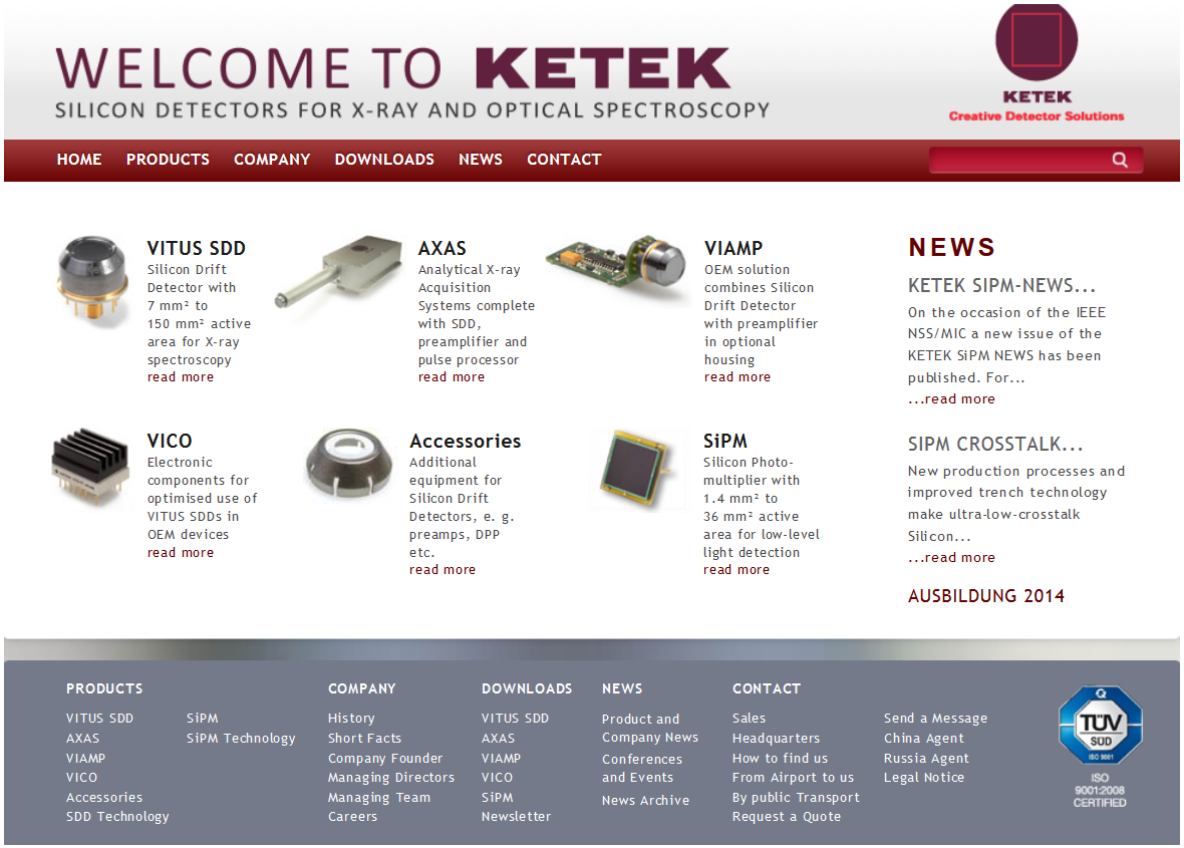
- KETEK present SiPM devices feature
  - high PDE
  - excellent gain and temperature stability
  - low excess noise

- KETEK SiPM technology and setup supports customized
  - chip design
  - packaging solutions

- KETEK new standard *Package 2.0* introduces
  - 4-side-tileability
  - improved TTD / SPTR
  - reduced XT

- Present focus
  - Further improvement of the basic SiPM parameters PDE, DR and recovery time
  - enhanced GE

- Outlook
  - Together with MEPHI RnD on integration of electronics on chip-level



Website
www.ketek.biz

26 YEARS

1989 - 2015

THANK YOU