SensL

THE LOW LIGHT SENSING COMPANY

SPM Manufacture for Large Area Detection

Pádraig Hughes, SPM Product Manager

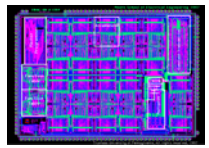
LIGHT07, Sept. 2007

Motivation

Solid State

Vacuum Tube

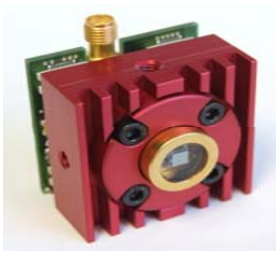
Plasma tv
(Bitzer/Gene Slottow)



CMOS chip (174,569 transistors)

Silicon Transistor
(Texas Inst.)

LED (Holonyak)



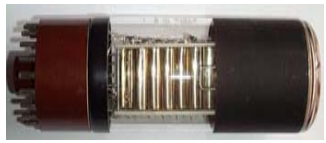
SPM

1875 1900 1925 1950 1975 2000

LightBulb
(Edison)

CRT
(Ferdinand Braun)

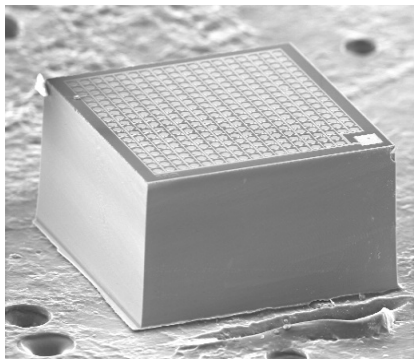
Vacuum Tube Diode
(Fleming)

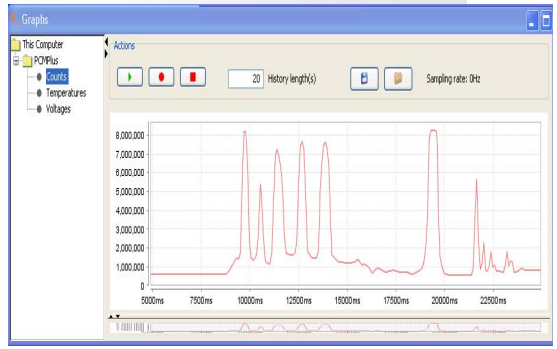


Photomultiplier Tube (RCA)

ENIAC (17,468 Tubes)

…… Low Light Sensors, Modules and Imaging Arrays.

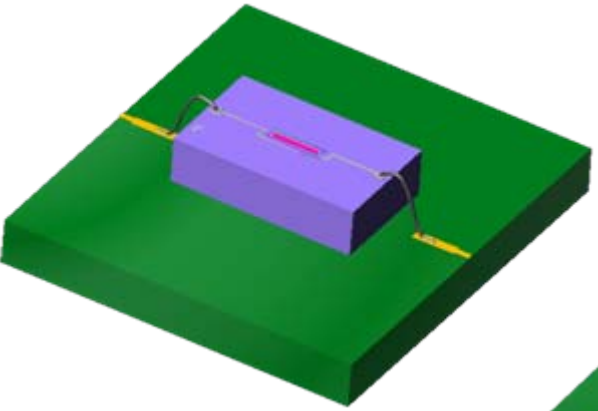




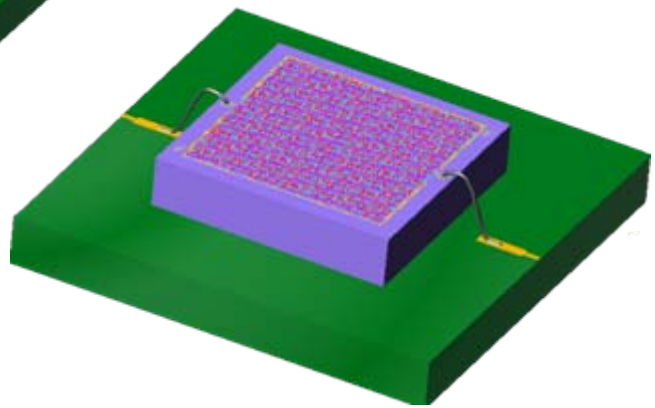
http://www.SensL.com

Core Competence

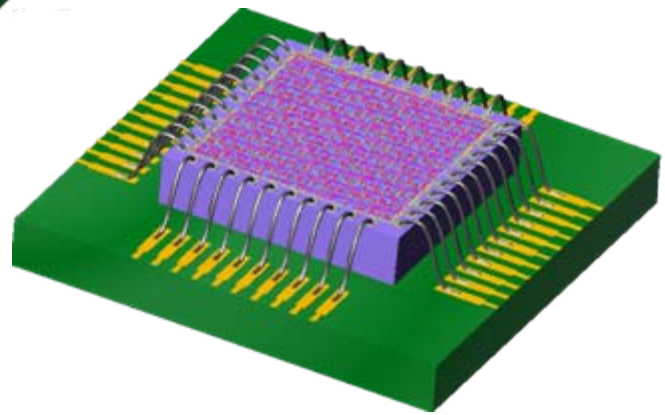
Single Photon Counting
(SPC)



Silicon Photomultiplier
(SPM)



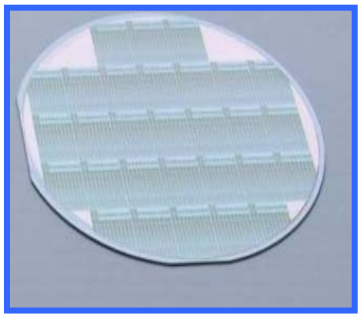
Photon Counting /
Timing
(DigitalAPD)



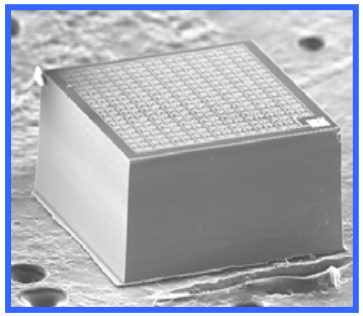
Identical Core Technology

Multiple Configurations

SPM Product



SPM 100/150mm
Wafer

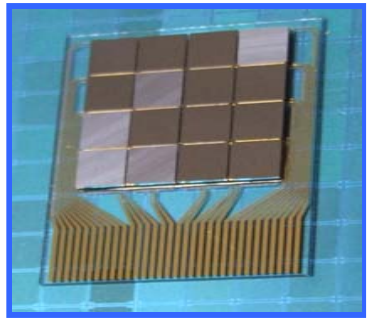


SPM 1mm^2, 9mm^2
Singulated Die

TOX SPM
Packaged

SPM Module

- SPMMicro
- SPMMini
- SPMScint

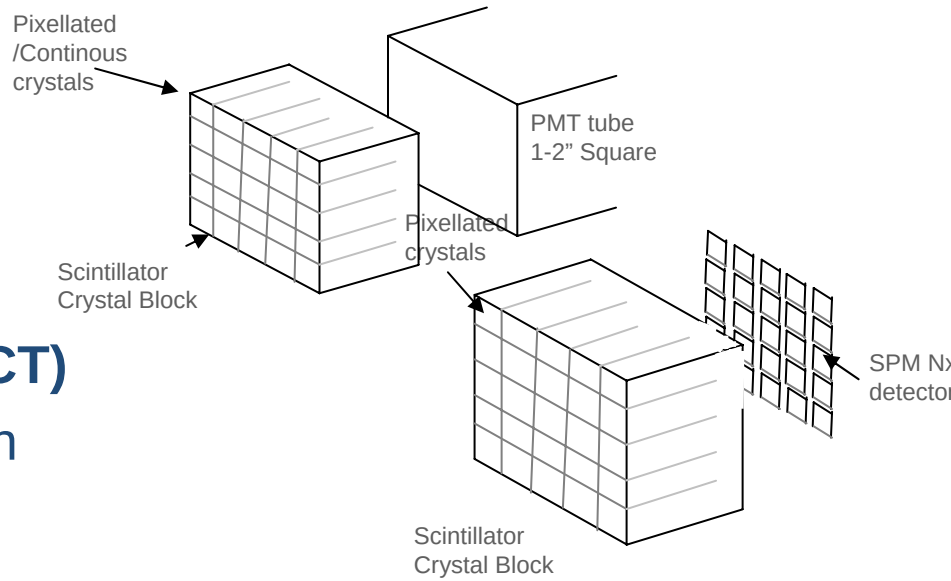


SPM Arrays

**Multiple Configuration Options,
see our Website!**

Large Area Detection

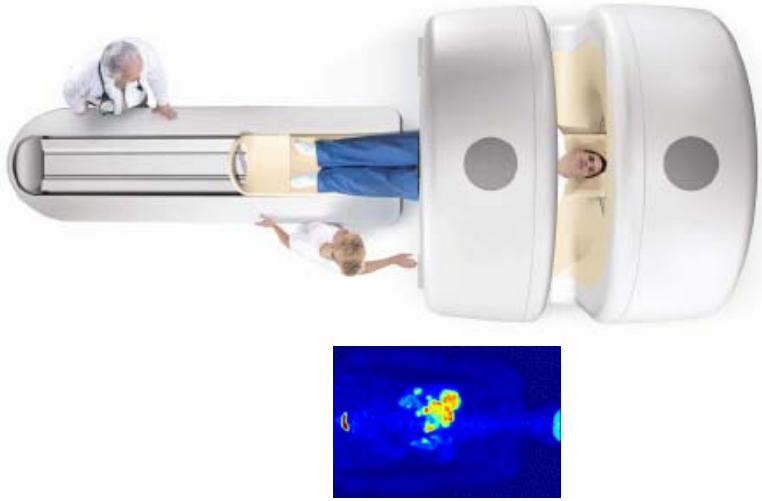
- Advances in solid state sensor technology (SPM) combined smart interconnect/ packaging solutions.
  - Large Area >1” (PMT size)
  - 2D spatial imaging
- Primary Applications
  - Radiation Monitoring
  - **Medical Imaging (PET, SPECT)**
  - High Energy Particle Detection
  - X Ray Detection
  - Flow Cytrometry
  - Confocal Microscopy
  - Microarray Scanning



Medical Imaging

Conventional PET Detection (1978-2006)

- Improving Imaging performance
  - New Scintillation Materials
  - Improved Detector Performance/System Integration
  - Reliable Detection Modules
- Dual Modality
  - PET/MR



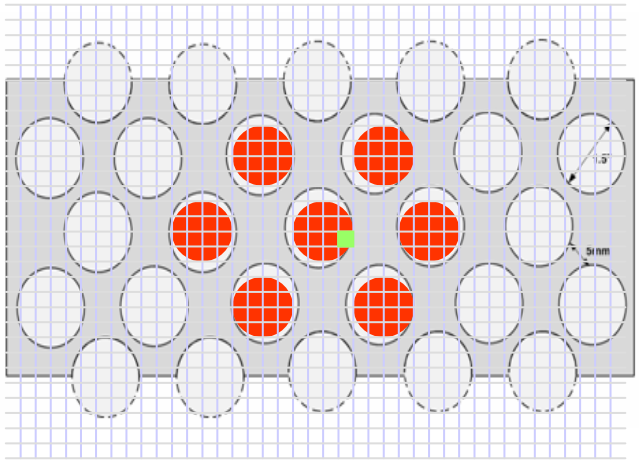
Time-of-Flight PET System
(PET/CT 2007)

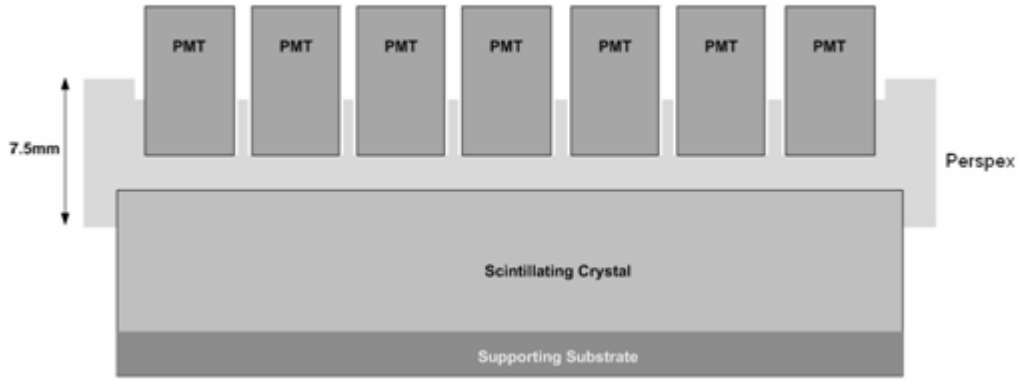
PET Detection Module

Type	Trends	Impact
Improved Scintillators	*New Scintillation materials (BGO → GSO → LYSO (LSO) → $LaBr_3$*	• *Improved Timing Accuracy – reduced random event rates* • *Better Energy Resolution*
	Optimising crystal geometry	*Better Spatial resolution*
	Reliability (less brittle e.g. $LaBr_3$)	*Handling*
Scintillation Detection	*Match detector size & response with pixellated scintillator output*	*Energy resolution (<10%), CRT <500ps*
	Stability & uniform gain across large area	*Uptime, less calibration → more reliable detection system*
	Improved Detection Formats: e.g. from conventional block detection to Honeycomb detection architectures	• *Better identification* • *Less light collection variability* • *No Drop off at side of FOV*
	Magnetic insensitivity	*Dual Modality with MRI*
Electronics	• *Less Bulky/Power hungry & Reliable* • *Fast electronics to match intrinsic timing properties of detection module + multichannel readouts (ASIC's)*	*High Channel Sampling*

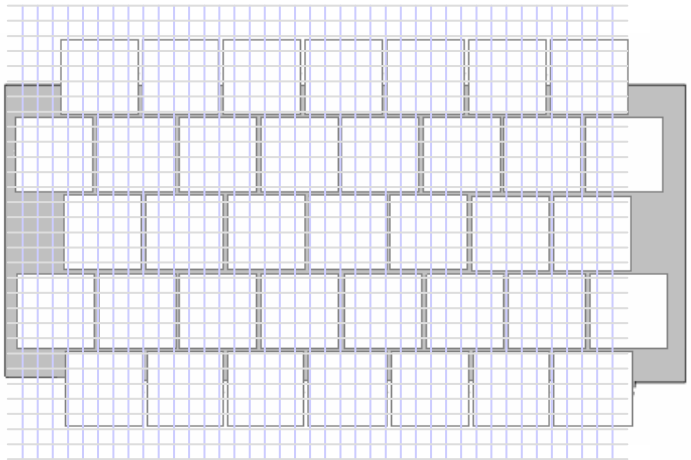
PET Detection Module Format

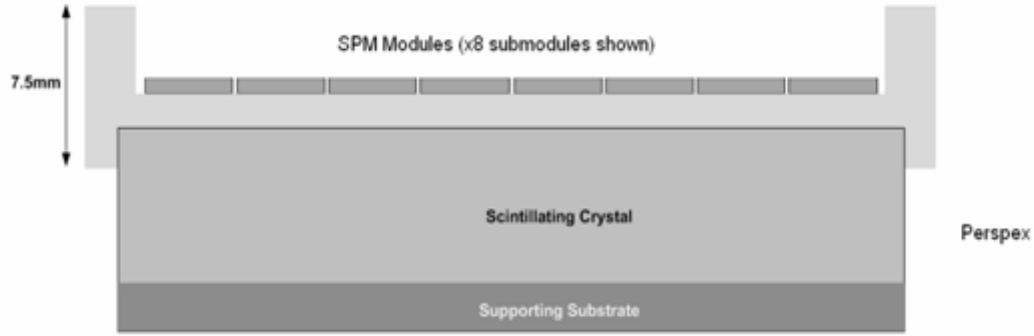
Typical PMT Format



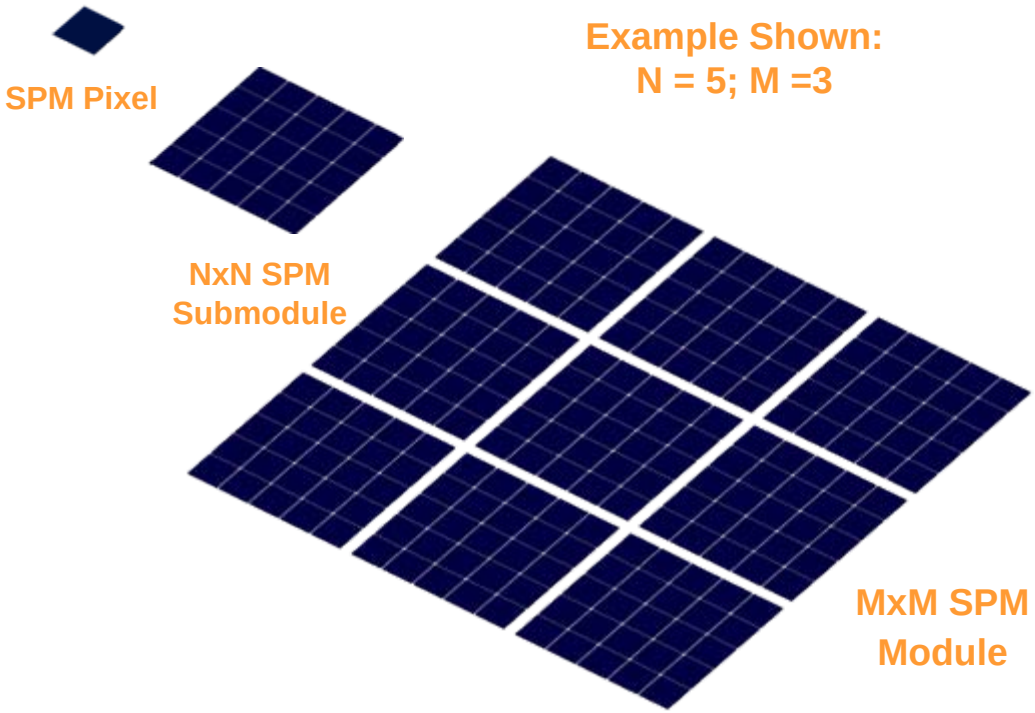


SPM Equivalent Format





SPM Packaging for PET



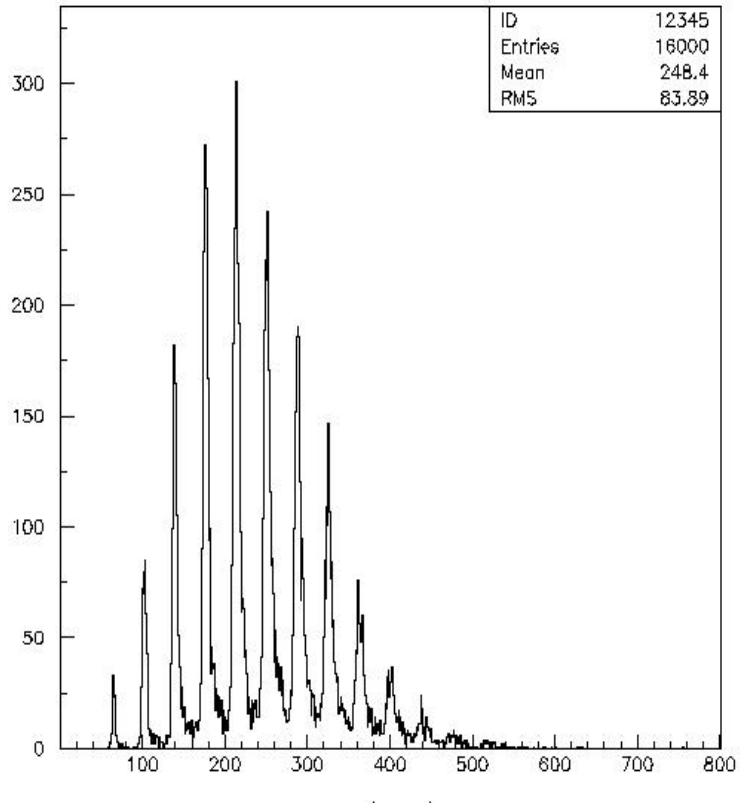
- Scaled SPM array architecture – **0.5m² (total area)/PET system**
- Submodules equivalent to 1.5” PMT sizes
- 4 side buttable
- electronics integration

Why SPM?

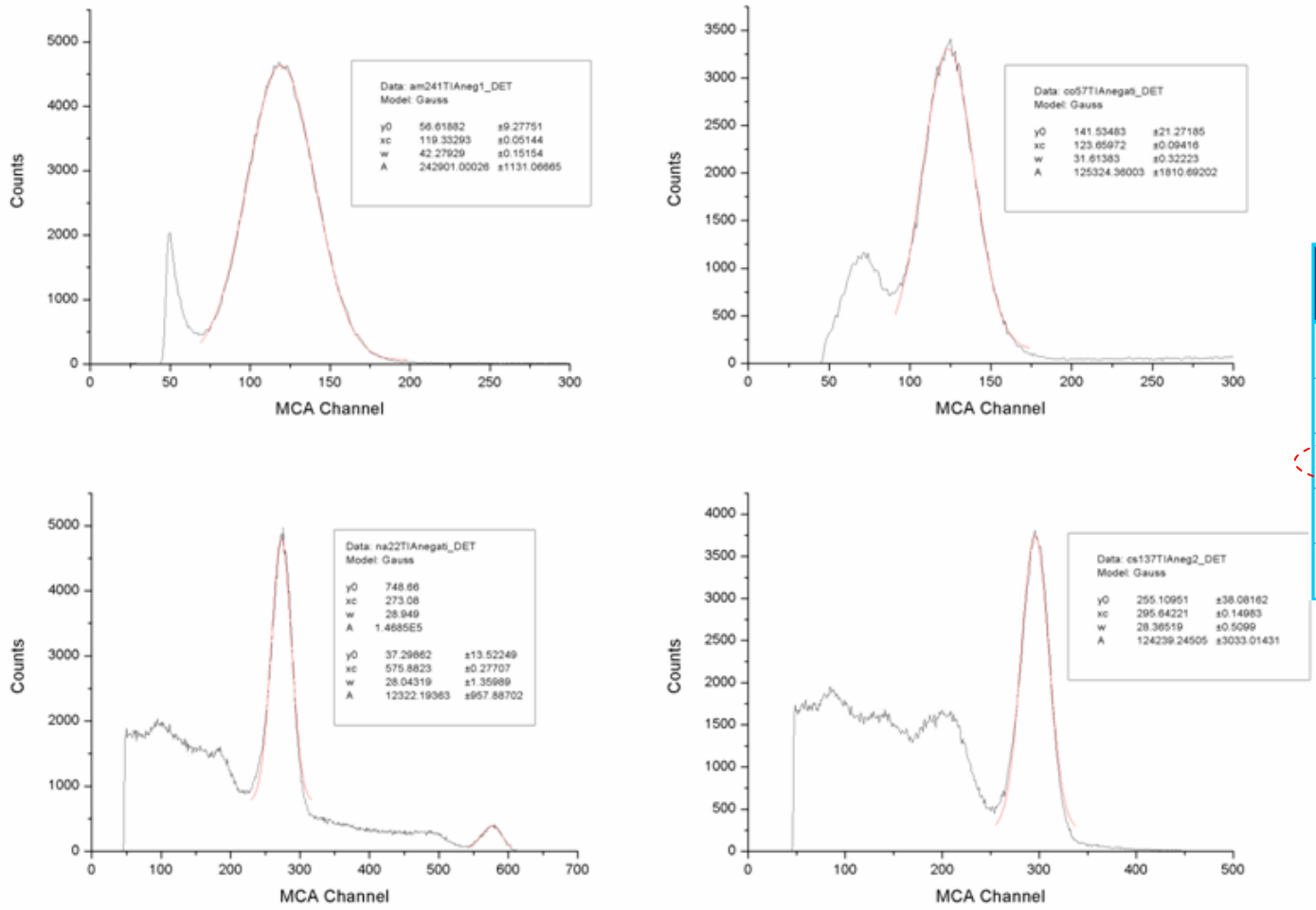
- ≥ PMT performance
- Large Area requires High Volume capabilities
- Manufacturability (Solid-State)
  - Scalable, stable, reliable, repeatable
  - Cost ≤ PMT cost
- Form Factor (System Integration)
- Dual Modality

SPM Key Properties

- Sensitive to single photons
- Excellent Photon Counting (Resolvable Photoelectron Peaks)
- 1mm^2 and 9mm^2 available
- High Intrinsic Gain 10^6
- High PDE
  - 25-40% Green/Red
  - 40-60% Blue/UV
- Good Dynamic Range/Linearity
- Low Operating Voltage <40V
- Insensitive to Magnetic Fields



Energy Resolution



Energy (keV)	Energy Resolution (%)
60	41.6
122	30.6
511	12.5
662	11.3
1274	5.7

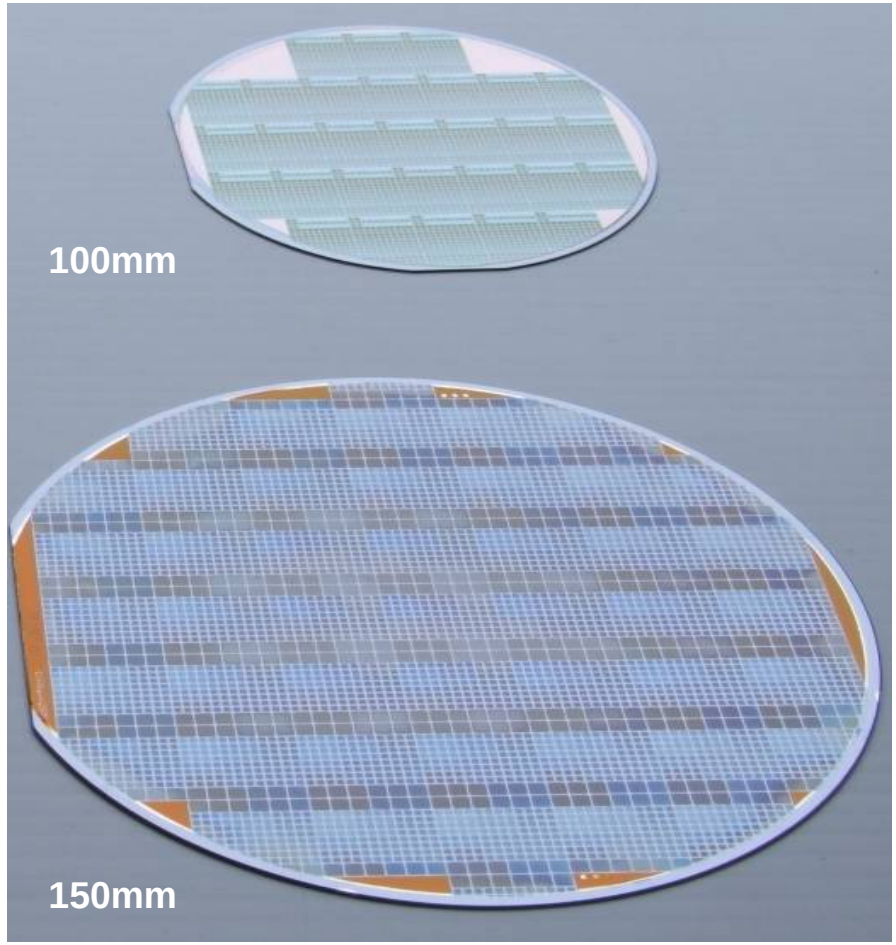
LSO Pulse height spectra for (clockwise from top left): Am-241(60keV), Co-57 (122keV), Cs-137 (662keV) and Na-22 (511keV and 1274keV).

SensL Die Manufacturing

- **Manufacturability is KEY**

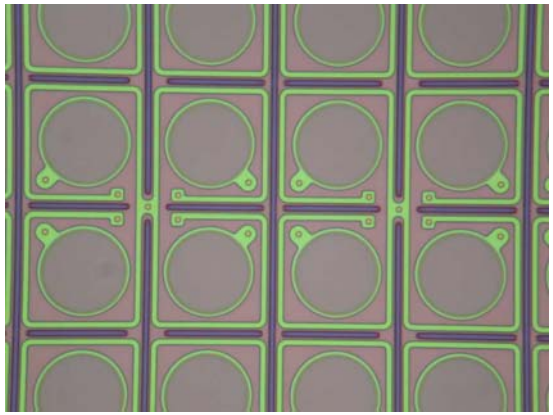
Tyndall National Institute

Commercial Foundry

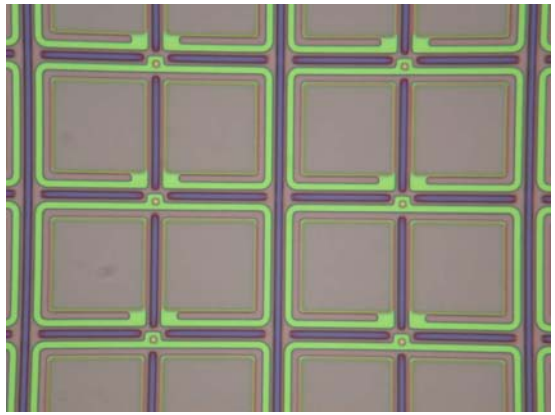


Geometrical efficiency

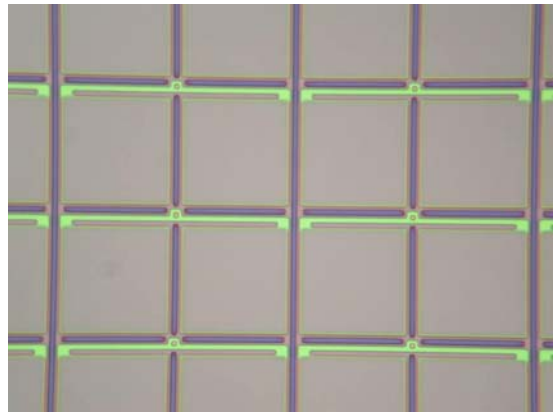
- A35H - 60% Fill Factor
- A50H – 70%



C20
17%



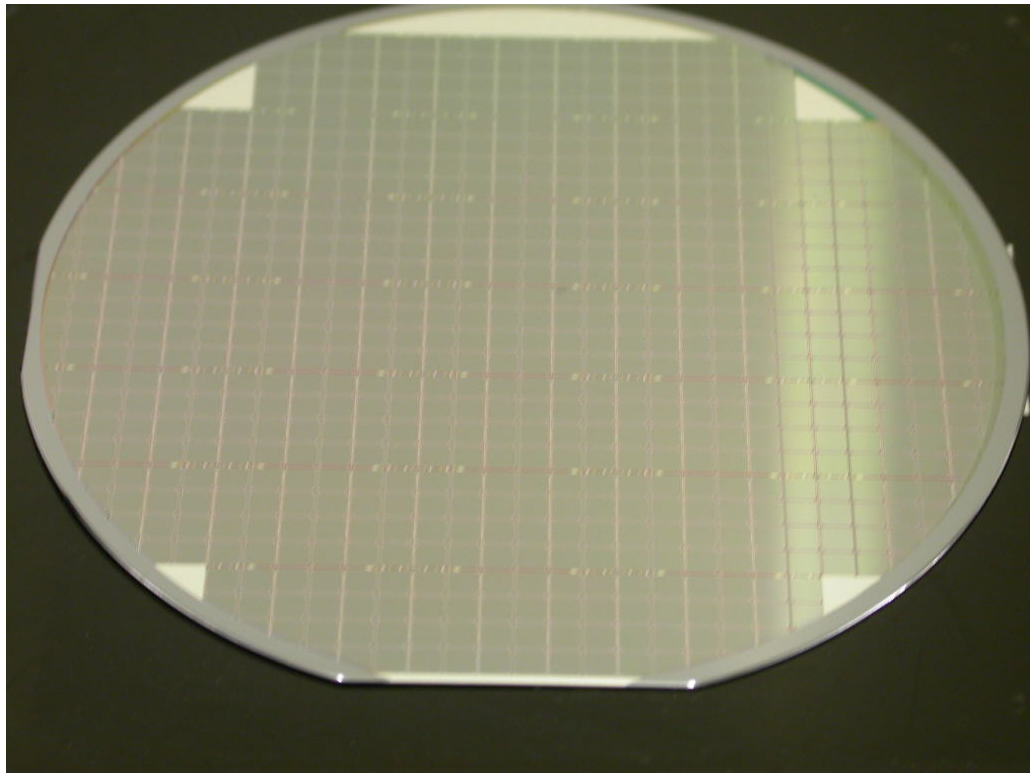
A20L
34%

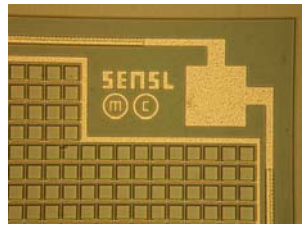


A20H
43%

- PDE = *effective* QE x Fill Factor

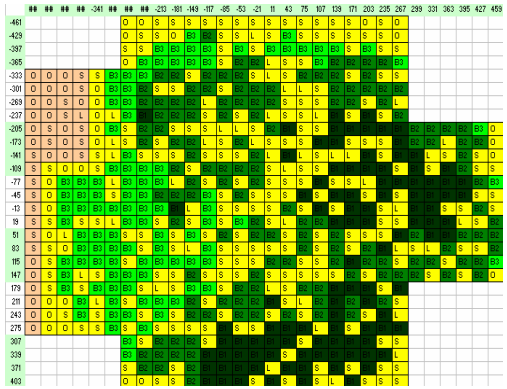
100 mm wafer at metal etch



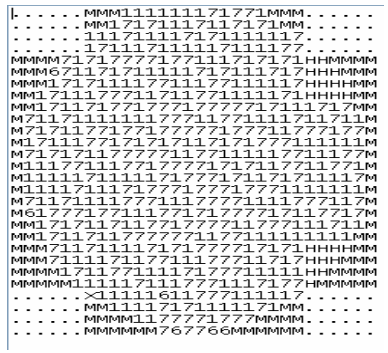


SPM8 – 3MM SPM A20H
700 DIE PER WAFER X 8640 MICROCELLS = 6 MILLION PHOTON COUNTING DETECTORS

Inkless Wafer Sort to Assembly

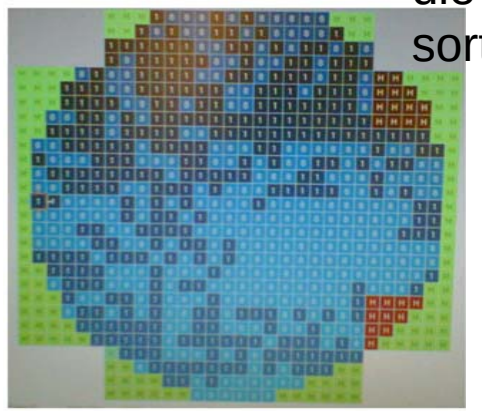


Wafer binning output

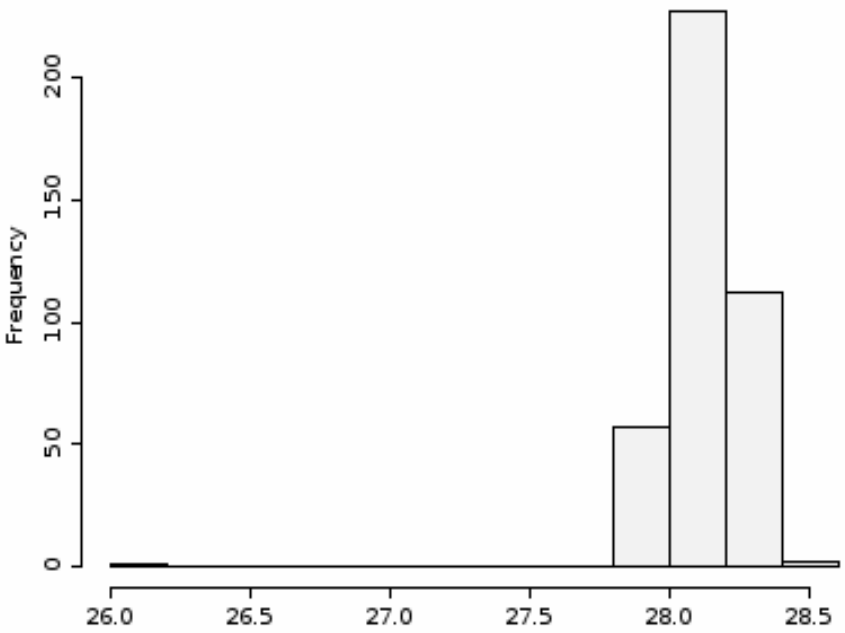


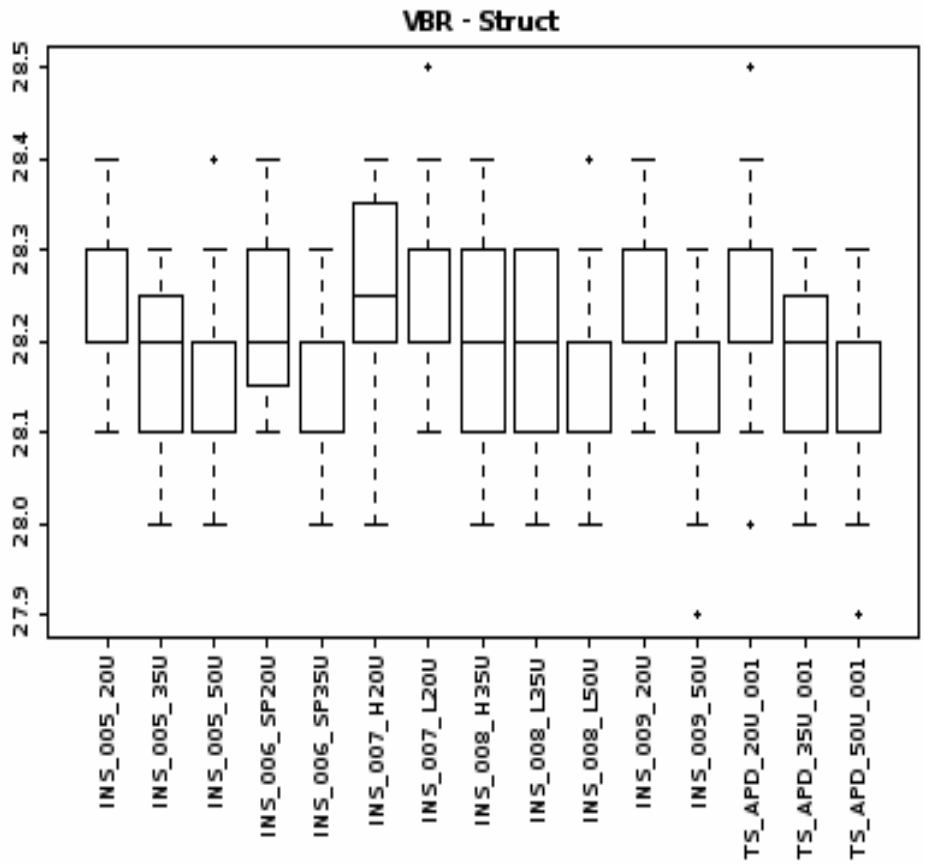
Inkless wafer map

Automatic die pick & sort



Example Breakdown Uniformities

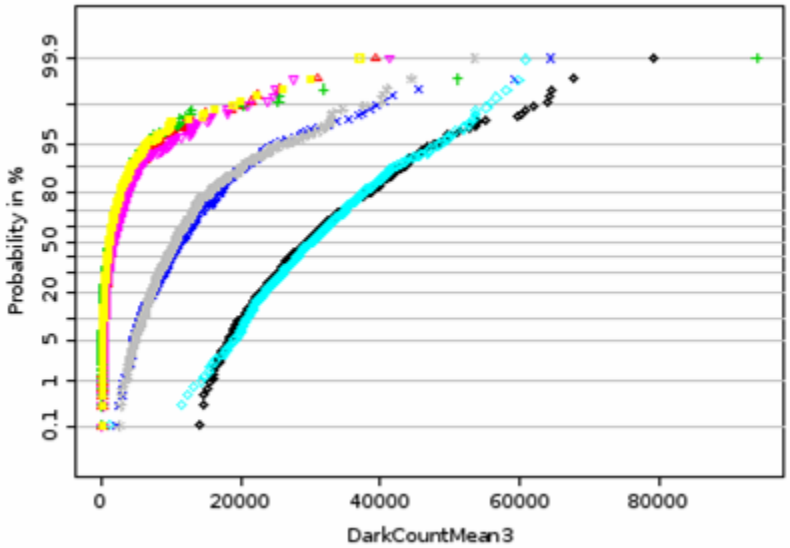


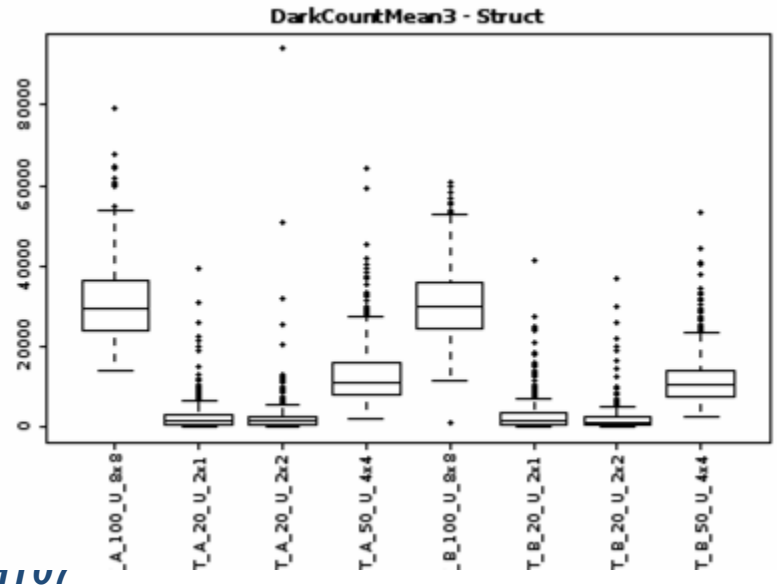


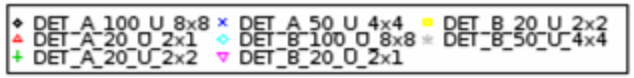
Tight distributions, across wafer, wafer to wafer, run to run
Breakdown voltage **independent of diode structure, size**

Parametric Testing

EXAMPLE - SPM6 PRODUCT TEST REPORTING - DARK COUNT PARAMETERS



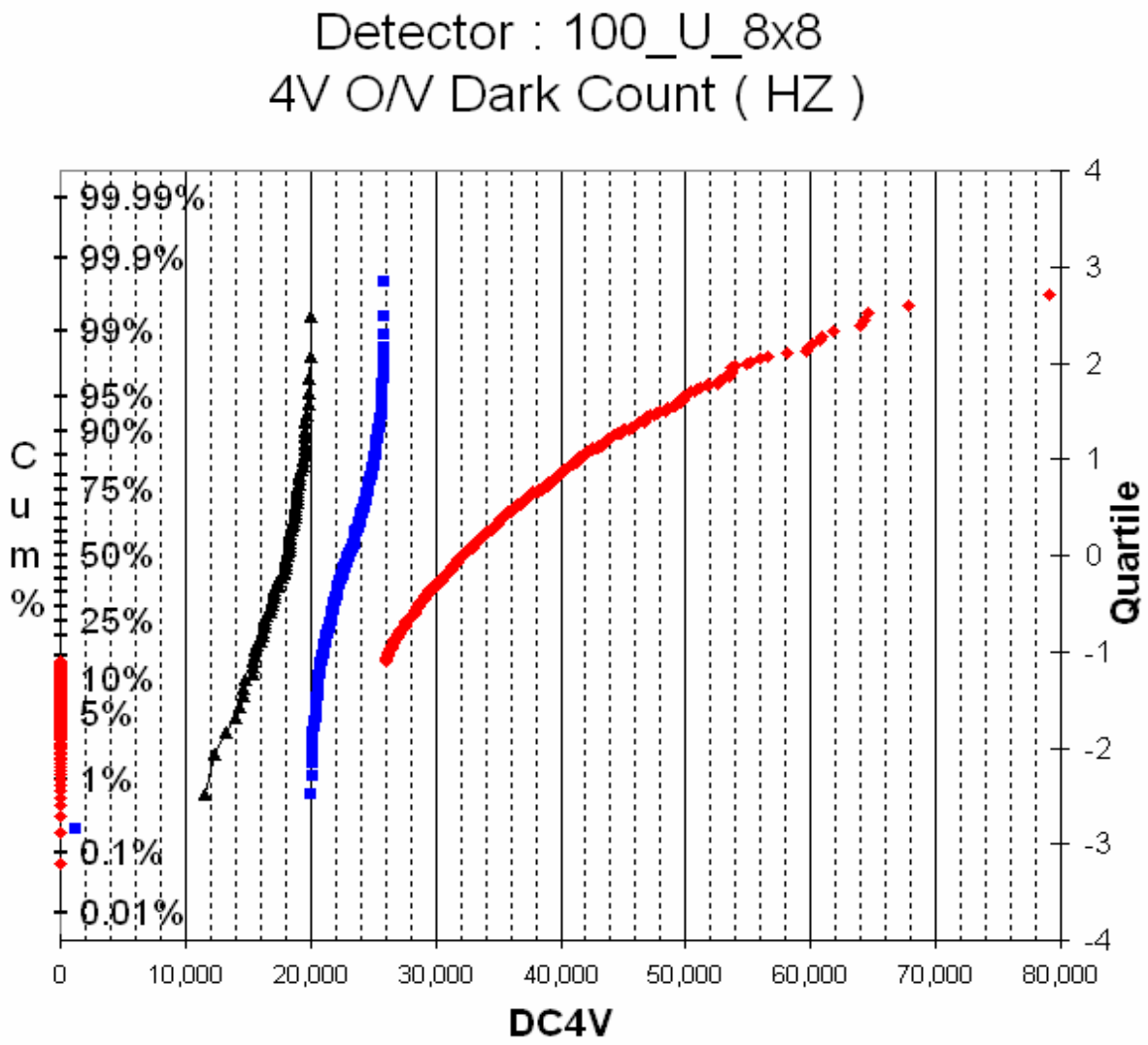




722

SPC Detectors 20U, 50U, 100U , multiple layout types
- 4 V O/V
-wafer level test at room temperature
- measure several bias points to characterise voltage and temperature dependence of dark count
- allows die selection based on dark count performance

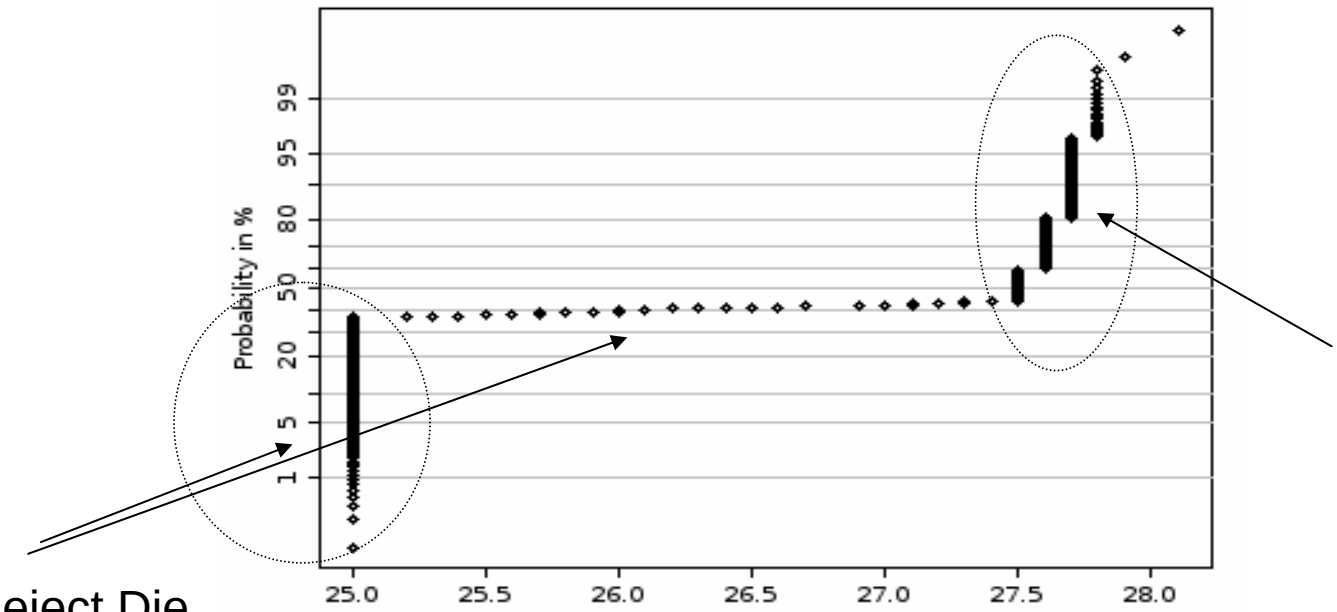
100U detector binning DC4V – RT



WHAT THIS MEANS :

P2:Bin A : 10KHz – 20KHz
P3: Bin B : 20 KHz – 26KHz
REJ: Bin F : all others

A35H SPM Parameteric testing



Potential Good Die
To Binning Flow

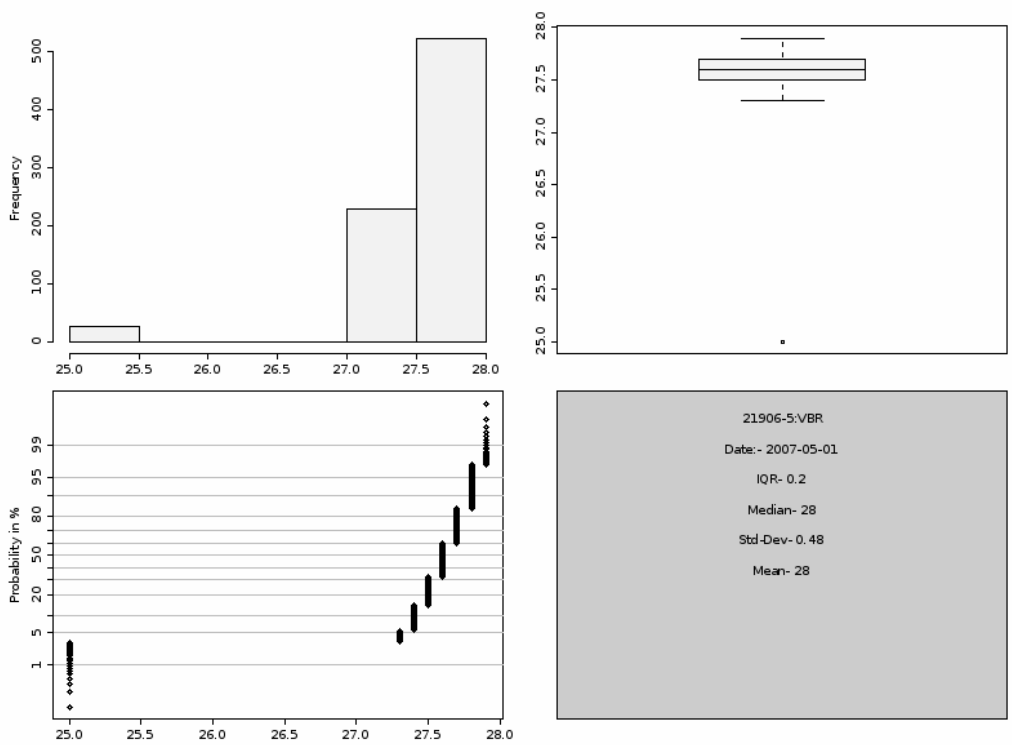
Reject Die

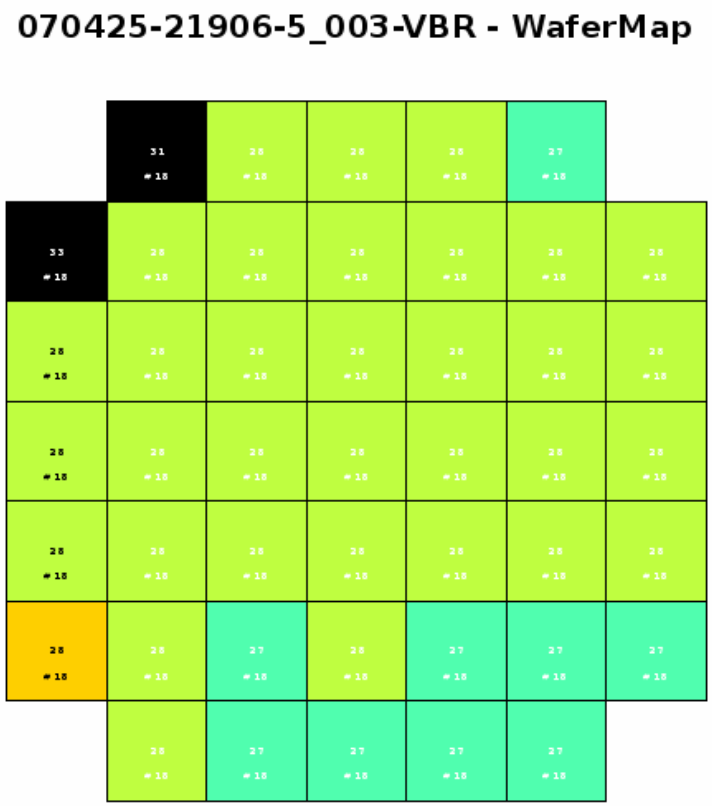
PARAMETER	DEFINITION	LOWER SCREEN LIMIT	UPPER SCREEN LIMIT
VBR	BREAKDOWN VOLTAGE – REVERSE BIAS VOLTAGE AT WHICH 10nA FLOWS	27.5 V	27.9 V
IR30	DARK CURRENT, MEASURED AT 30V REVERSE BIAS	5.0E-7 A	5.0E-5 A
IR32	DARK CURRENT, MEASURED AT 32V REVERSE BIAS	5.0E-6 A	1.0E-2 A*

*Tighter screen limit of 6.0E-5A is used for A35HD device on wafer X3615-9

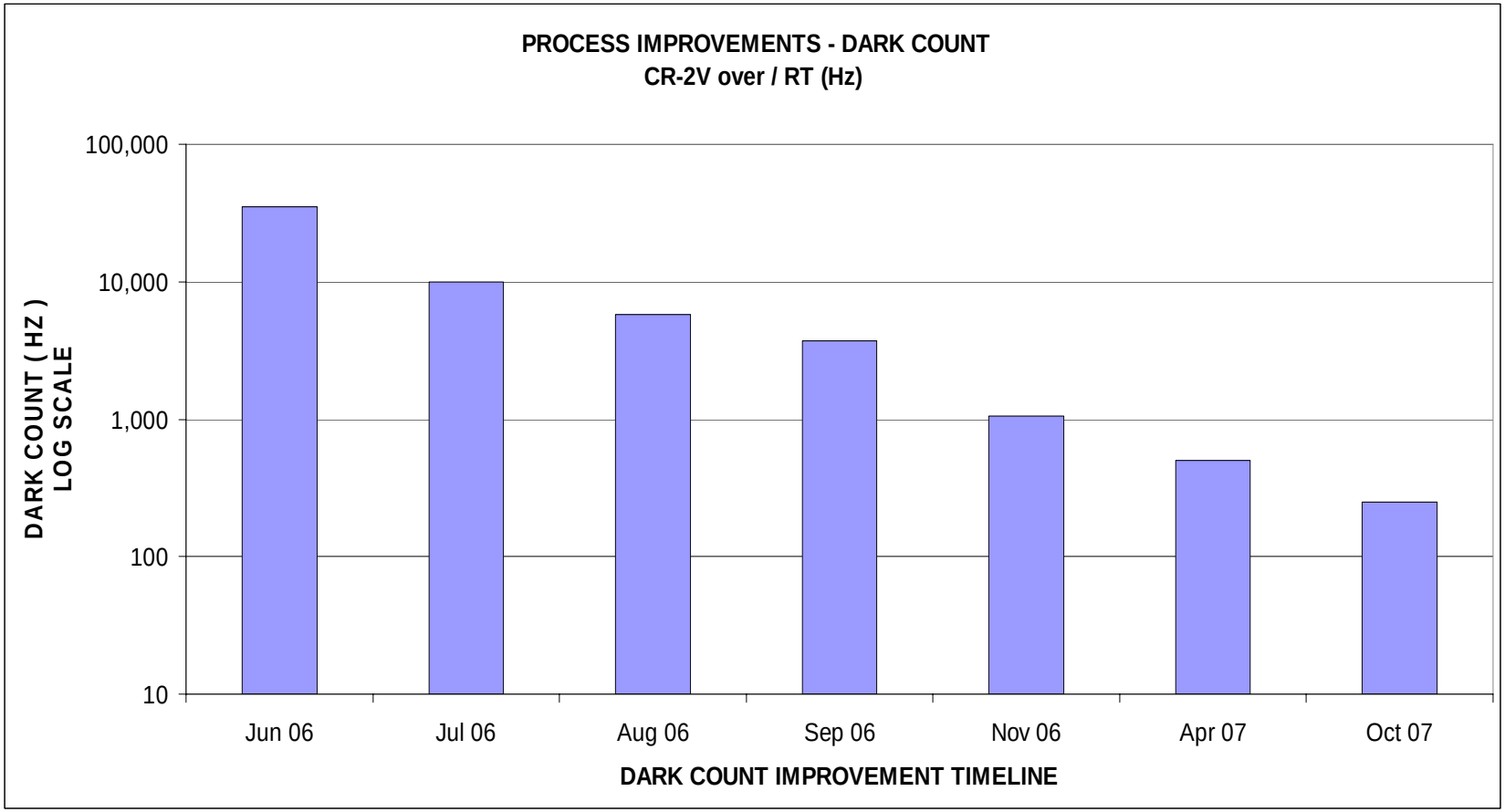
Parametric Testing

- **150mm wafer (Foundry)**

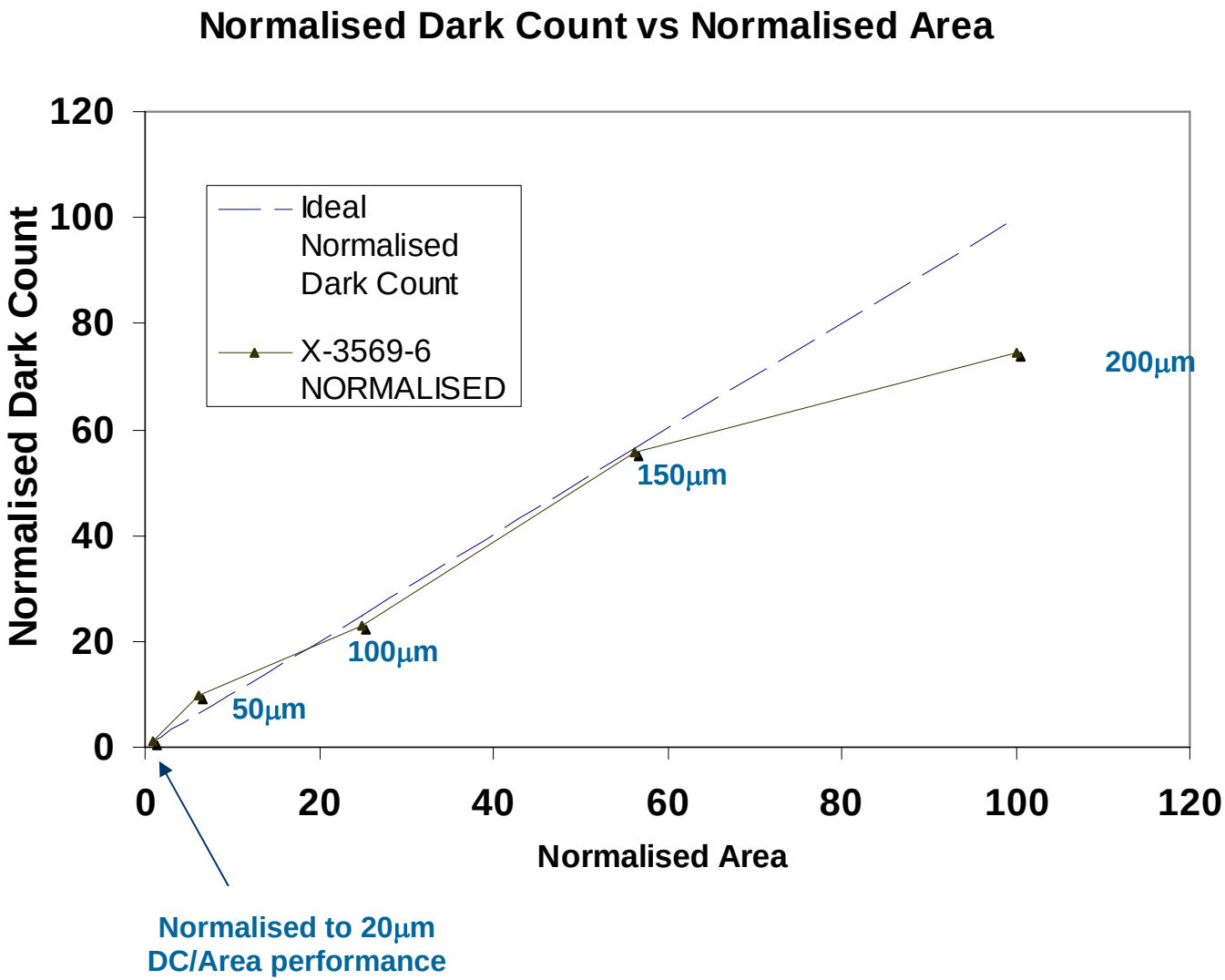




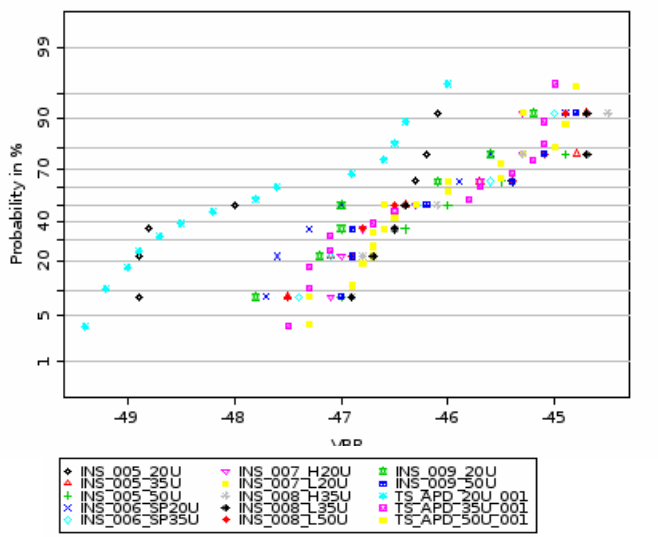
Dark Count RoadMap

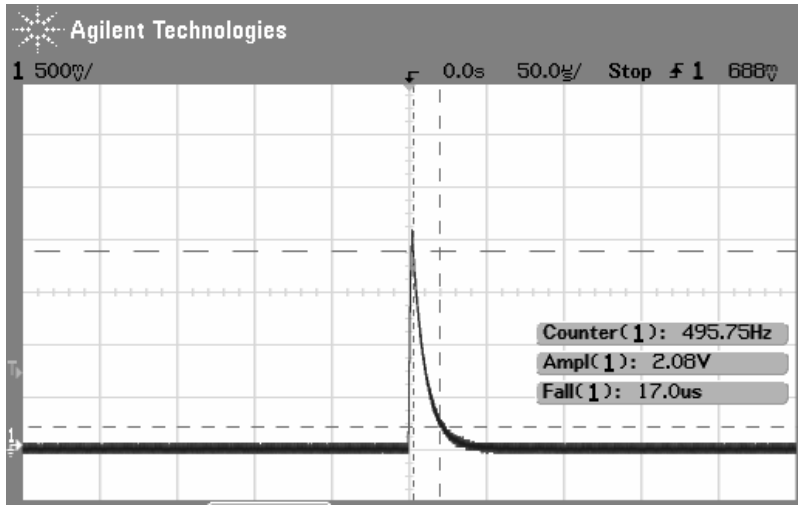


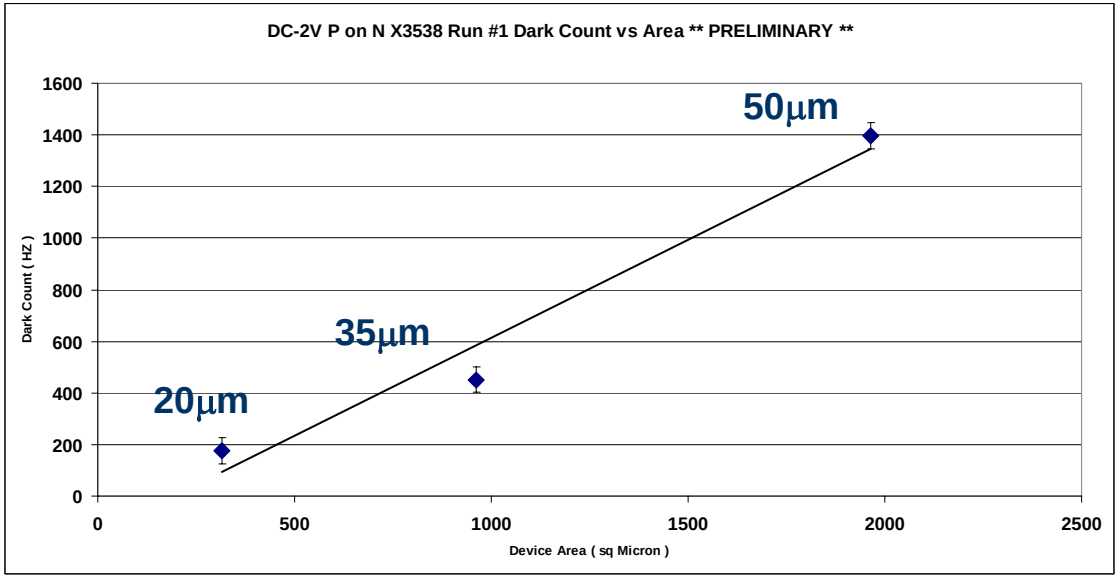
NonP process



P on N Process

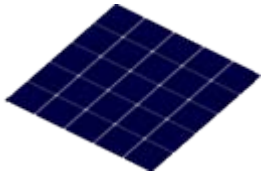






- Breakdown voltage distribution
- Dark count pulse (35U detector, 2V O/V)
- Dark count vs area scaling, wafer medians for circular test structures

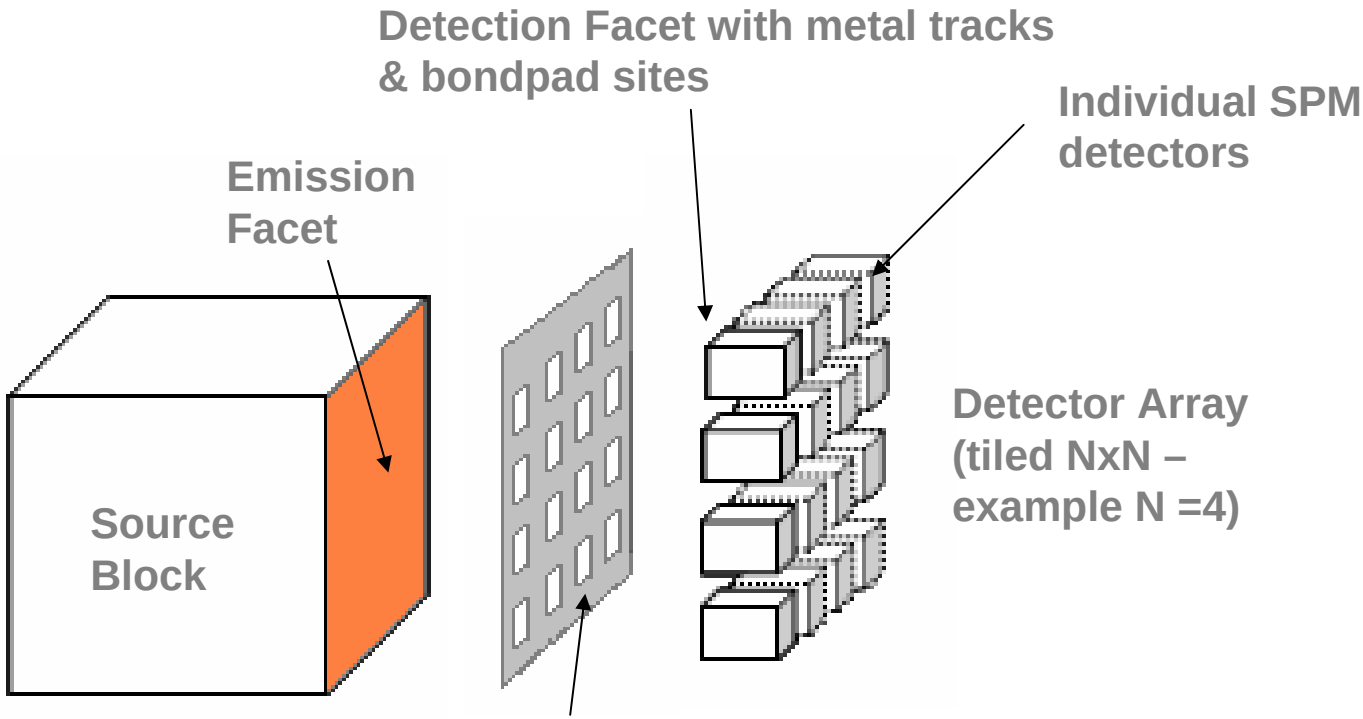
Large Area SPM



- PMT area equivalents >0.5”
- 3 Array Approaches Pursued
  - Flex Arrays
  - Glass Arrays
  - Ceramic Arrays
- Pixellated/Summed Ouputs
- Buttable Submodules (Pixellated) – PET
- Coupling Efficiency – Ideally butt coupled

Flex Arrays

Detector Interconnection

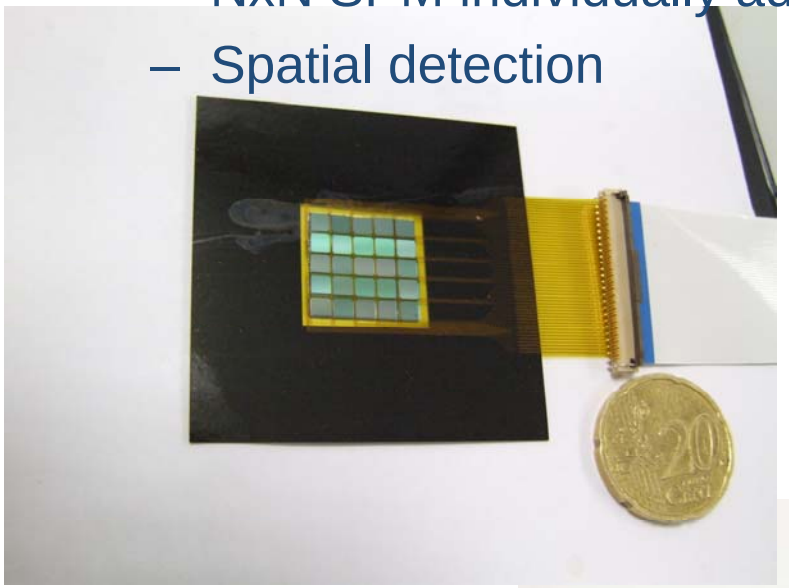


Transparent or perforated thin film sheet (polyimide flex) with metal tracks (tracks not shown) sandwiched between source & detector.

Flex Arrays

SPMArray

- NxN SPM individually addressed
- Spatial detection



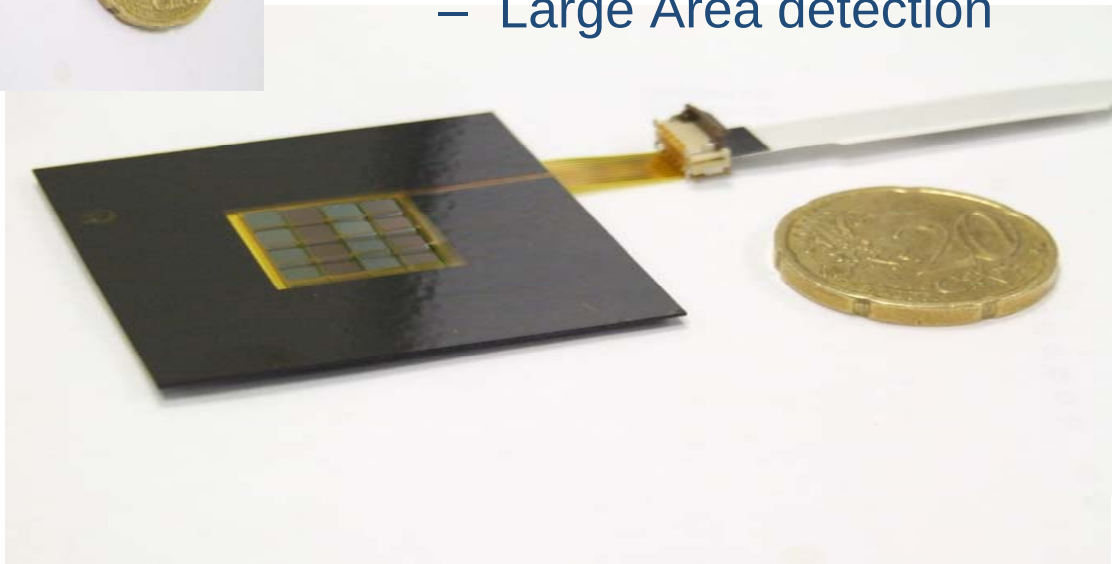
British Patent Application No. 0621495.1, October 2006.

Flex Benefits

- Low cost/Lightweight
- Scalable
- Simplified electrical interconnections
- Small Form Factor

SPMPlus

- NxN array summed output
- Large Area detection



Applications

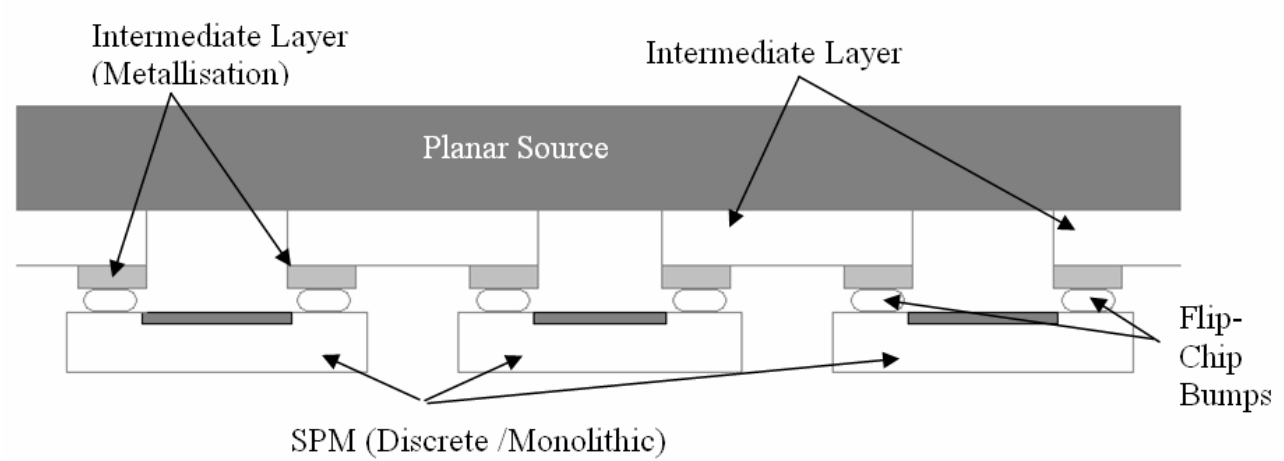


Figure 2 British Patent Application No. **0621495.1**

Package Concepts

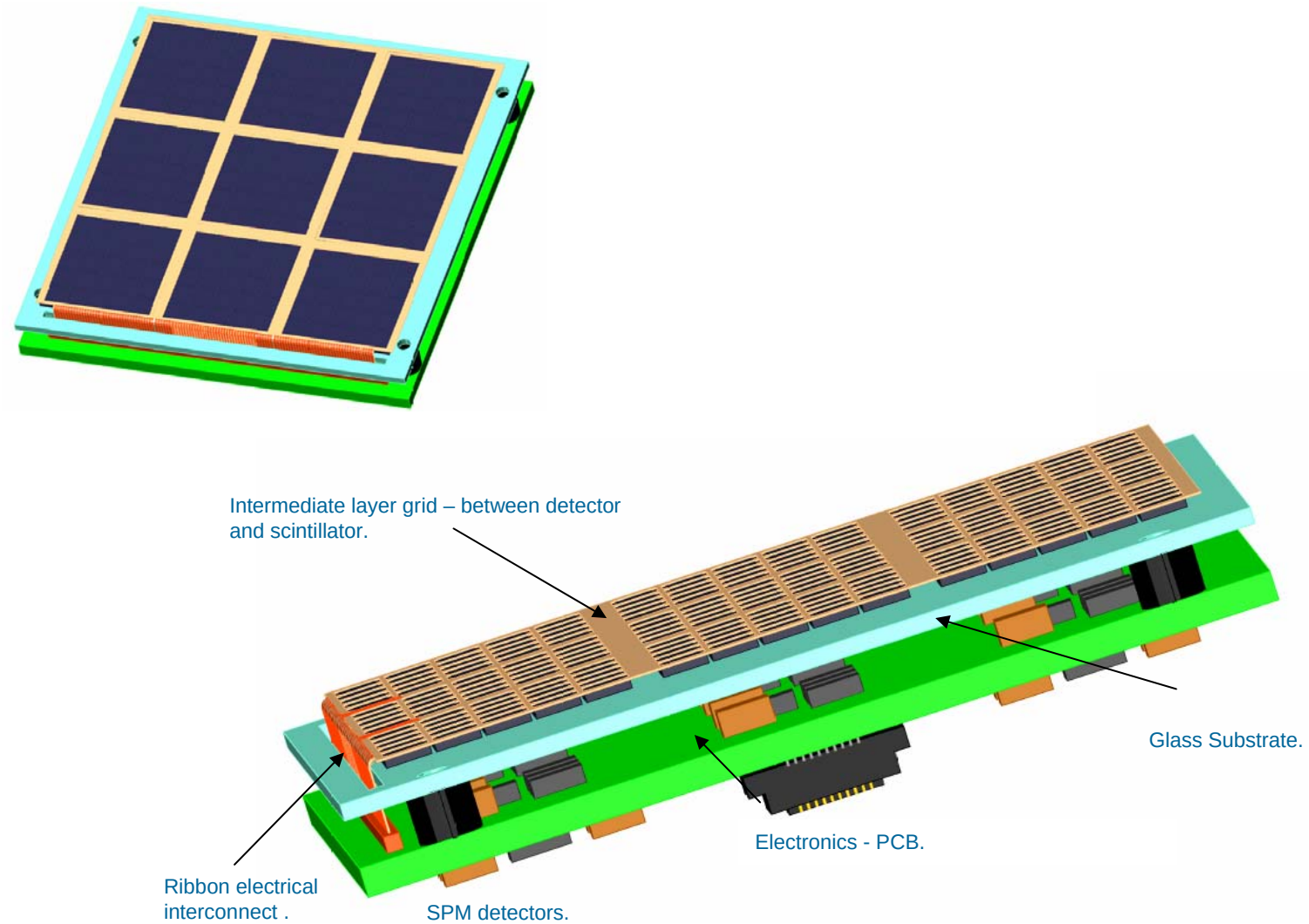
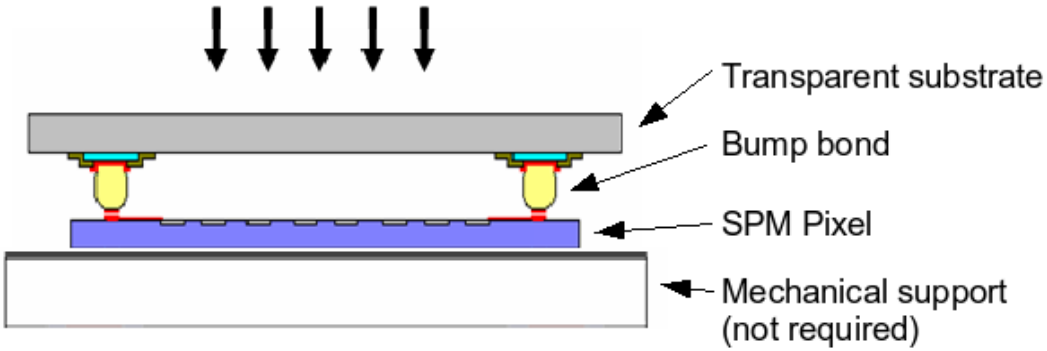
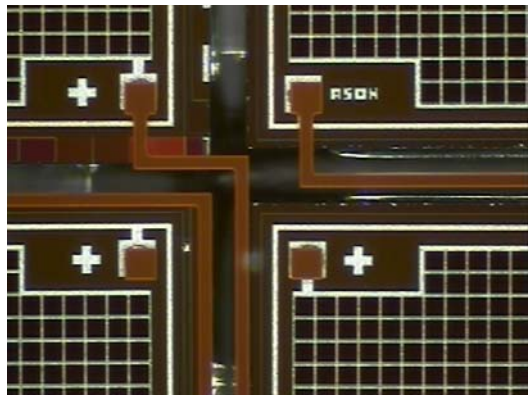


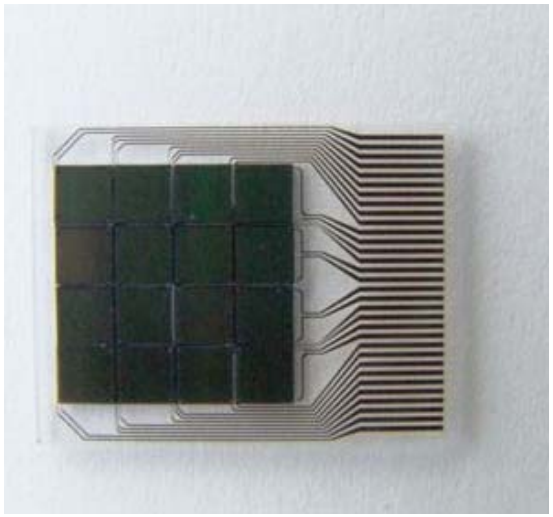
Fig. 2: Concept for full module assembly – 1x3 module shown. (Drawings not to scale).

Glass Arrays

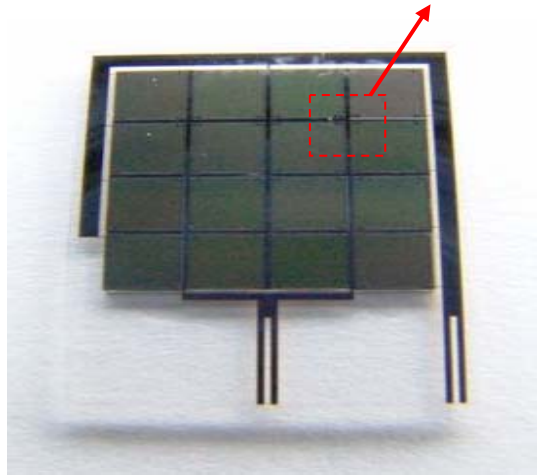
- **SPM flip-chip on glass**







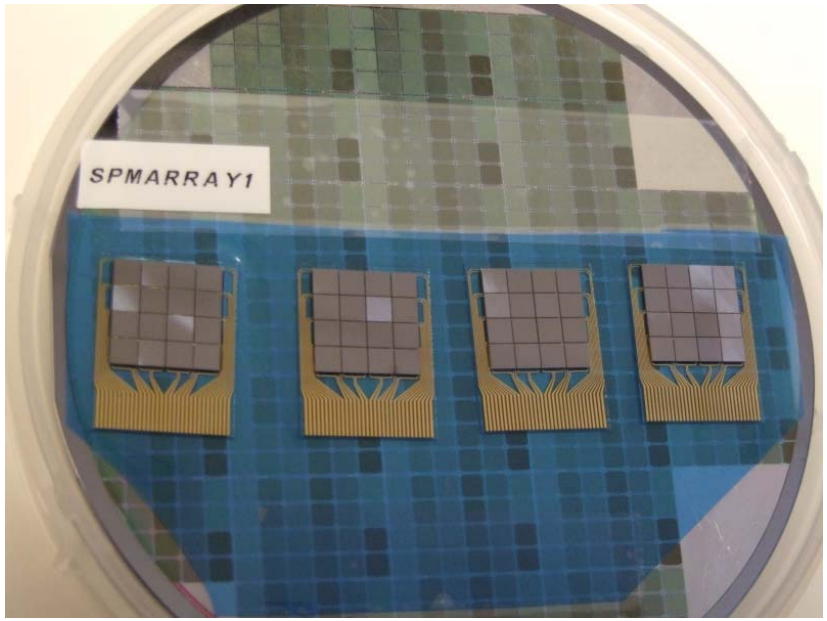
4x4 SPM Pixellated Ouput

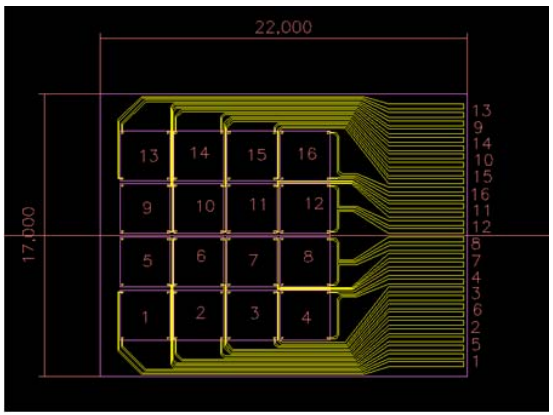


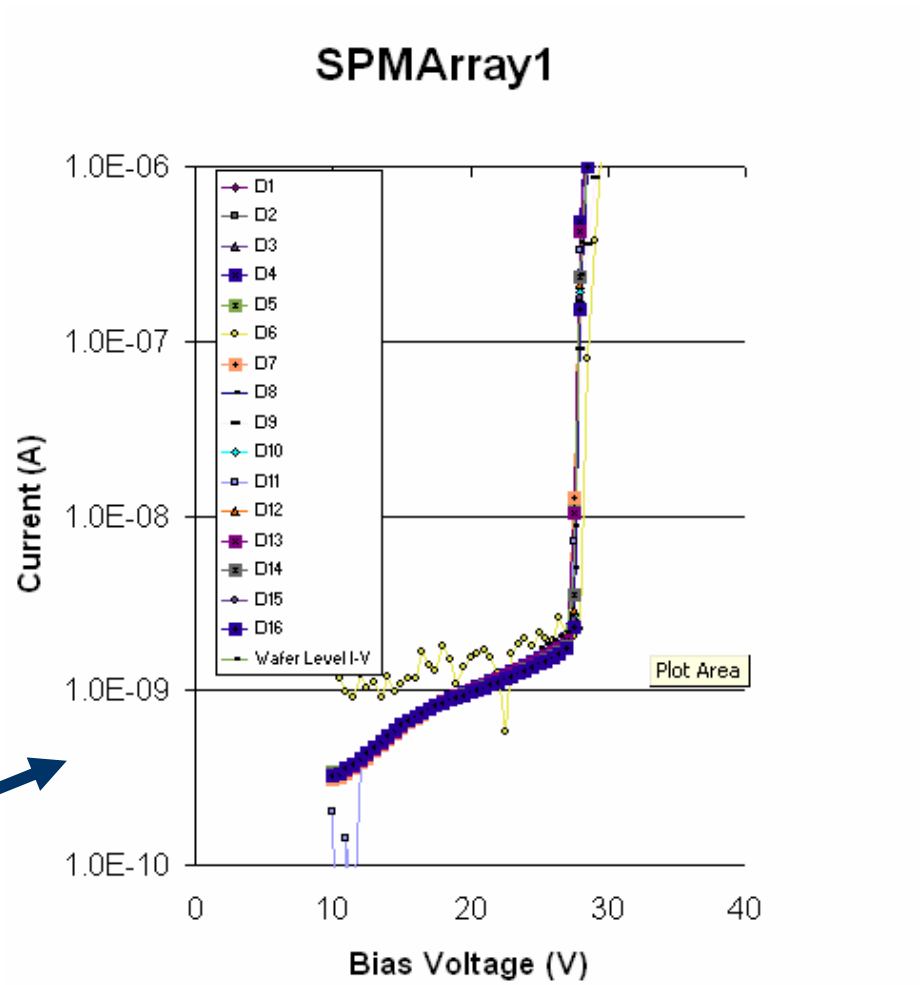
4x4 SPM Summed Ouput

Glass Manufacture

- **Shipping prototypes to customers**

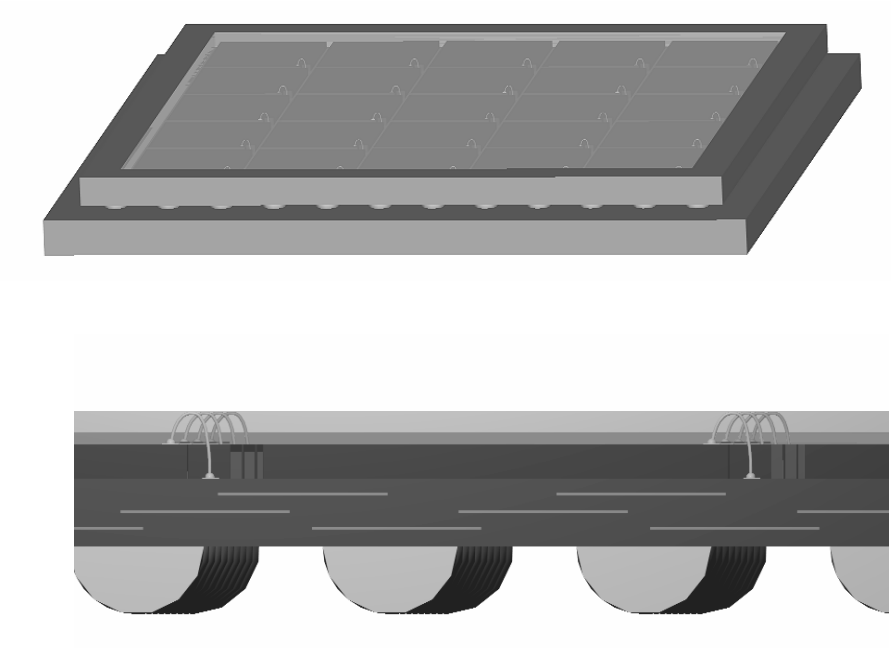






Ceramics Arrays

- **In Assembly – due Nov. ’07**
- **4 side buttable solution – *SensL’s PET solution***



Specification	*Value*
SPM submodule size	*Variable from 0.5” to 1.5” (present)*
Pixel to pixel spacing within submodule	*<200µm (target 100µm)*
N x N Submodule Fill Factor	*Typ. 46.6%*
Submodule to submodule spacing	*Minimum 1mm*
Submodule Substrate	*Ceramic with BGA*
Optical Encapsulant	*OPTOCAST, DYMAX and EPOTEK*

Summary

- **SensL has developed novel SPM technology for Large Area Detection**
- **Ability to manufacture in High Volumes critical**
- **Medical Imaging**
  - **RoadMap: Higher sensitivity/spatial resolution**
  - **SPM form factor an ideal technology solution**
- **Products:**
  - **SPMPlus & SPMArray**
  - **Flexible architectures & High Volume capabilities**

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THE LOW LIGHT SENSING COMPANY

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The first Solid State solution for Low Light Sensing

SensL's vision is to become the brand and partner of choice for users (particularly OEMs) of low light detectors and imaging systems. We will enable our customers to radically improve system performance by providing a unique and disruptive technology that frees them from the limitations of existing Photomultiplier Tube (PMT) based detectors, thereby creating a range of new applications.

This breakthrough in low light detection solutions has been achieved by leveraging our core Geiger Mode Photodiode technology to create three distinct low light detector platforms. Our Photon Counting, Silicon Photomultiplier and Low Light Imager products enable the development of new systems for applications such as Bio-diagnostics, Medical Imaging, LIDAR, Environmental Monitoring and High Energy Physics.

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Ranging from a low cost entry level photon counting device to a full plug and play stand alone photon timing system all incorporating excellent timing jitter, quantum efficiency, dark count and after-pulsing.

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News

- **SensL Launches Innovative New Product: the SPMScint**
  SensL is pleased to announce the release of SPMScint, designed for use with scintillators in radiation detection applications.
- **SensL Opens U.S. Office**
  To better serve our U.S. customers we are pleased to announce the opening of our U.S. office in Mountain View, California.
- **SensL Named One of 30 Hot Companies by SVASE**
  SensL announces their nomination as one of The 30 Hot Companies Selected For Product Debut Demos at "Launch: Silicon Valley" by the Silicon Valley Association of Startup Entrepreneurs (SVASE).
- **Careers in SensL**
  Are you interested in working at SensL?

Upcoming Events

- **Light '07**
  23-28 Sep 2007
  Munich, Germany
- **2007 Nuclear Science Symposium and Medical Imaging Conference**
  28 Oct - 3 Nov 2007
  Honolulu, HI, USA
  Booth #37
- **BiOS Exhibition 2008**
  19-20 January 2008
  San Jose, CA, USA
- **SPIE Photonics West 2008**
  22-24 January 2008
  San Jose, CA, USA
  Space #6345

Thank You
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