Uniformity measurements across the area of the multi-cell avalanche photodiodes

N. Godinovic
University of Split
FESB

Outline:
✓ Setup(s) for uniformity scan
✓ Previous experience with uniformity scan
✓ Preliminary results of the spatial uniformity scan
✓ Summary
Set-up for uniformity measurements

2.5 microns – minimum step
Previous experience: (CMS APD Gain uniformity)

- Gains can go to over 2000
- We demand good behaviour up to gain 400
- Operating at gain 50 has excellent spatial uniformity

NIM A 545 (2005) 139-144
Previous experience: CMS APD Gain & Illumination

Light spot (430 nm) ~25 μm diameter, step 25 μm

Light sensitivity of the edge regions must be taken into account when determining the mean APD response

\[
M(V_r) = \frac{I_{ph}(V_r)}{I_{ph}(V_o)} \quad V_o = 20V
\]

\[
\Delta V_r(M) = V_R^{\text{full ill}}(M) - V_R^{\text{central ill}}(M) \approx 3V, \ M = 50
\]
Previous experience: CMS APD - Quantum Efficiency

PbWO peak emission 430 nm

Q.E. is 75% at peak emission
QE has excellent spatial uniformity

Light spot (430 nm) ~200 μm diameter
CMS VPT – QE spatial uniformity (1)

CMS Internal Note 2005/09
CMS VPT – QE spatial uniformity (2)

- VPT # 354
  - $\langle I \rangle = 3.7$ nA
  - RMS(%) = 14.6

- VPT # 134
  - $\langle I \rangle = 3.09$ nA
  - RMS(%) = 7.25

- VPT # 864
  - $\langle I \rangle = 35.36$ nA
  - RMS(%) = 18.27

- VPT # 728
  - $\langle I \rangle = 26.9$ nA
  - RMS(%) = 37.73
G-APD – working principle

- G-APD up to 1000 APD/mm²
- Single cell size 30-50 μm²
- Cell should be in principle electrically and optically isolated, each cell has \( \sim 1 \, \text{MΩ} \) resistance in series.
- Cell are connected in parallel
- Working bias few volts above breakdown voltage
- There is no proportionality between signal at the output and the incoming light signal. Output signal is the same for one photon or several photons entering the same cell
  \( A_i \sim C_i(V-V_b) \)
With the same magnification photo of the blue light spot has been taken. Light spot occupies 8 division at ocular, and from the previous measurement one division at ocular corresponds to 1,4 micrometer at objective plate.

\[ \frac{100}{72} = 1,4 \text{ microns} \]
\[ 8 \times 1,4 = 11,2 \text{ microns} \]
Light spot with microscope

SSPM-050701GR-T028, provided by Photonique

- **Light spot with webcam**
- We plan to build setup to measure uniformity inside one cell and between cells in order to estimate geometrical factor and to study the uniformity of the PDE, cross-talk, …
Gain @ 470 nm, T=19°C

SSPM-050701GR-T028, provided by Photonique
Uniformity with DC light spot, $V_b=1$ V

470 nm LED light source

Uniformity across one line: scan step 2.5 microns, $V_b=1$ V

$T=20.8$ C; $M=1$
Reproducibility?

Uniformity: scan step 2.5 microns, Vb=10V, 470 nm LED light source

Same line, one time scan from left to right and second time from right to left

T=21.72°C
V=10 (V) M=1, LED light: 470 nm
V=10 (V) M=1, LED light: 470 nm

Uniformity: scan step 2.5 microns, Vb=10V, 470 nm LED light source
M=360 000 @ Vb=39 V, \( \lambda = 470 \) nm
M=677 266 @Vb=40 V, \lambda=470 \text{ nm}

Uniformity: scan step 2.5 microns, Vb=40V, 470 nm LED light source

T=20.8; M=677 266
Uniformity at different gains with 470 nm

Photonique Green-Red SSPM-050702GR-T028

Uniformity across one line: scan step 2.5 microns, Vb=10V, 470 nm LED light source

Vb=10 V, M=1

Vb=30 V M=1.6

Vb=35 V M=5

M=130 000

N. Godinovic

Light 07. Ringberg Castle, Tegernsee September 23 - 28, 2007
Summary

- Need more measurements to fully understand setup

- Improve setup:
  - check/improve the light collimation in order to perform scan inside one single cell
  - better and firm placement of the diode in order to have the light perpendicular to the photosensitive area.

- Web cam to take and record the photo of the light spot position before each measurements.

- Equip setup with collimated pulsed light of very low intensity and with MCA in order to study cross-talk, PDE, …
Gain at 470 nm (LED), 660 nm (red laser)
V=37 (V) 470 nm (Blue LED light)
V=37 (V), 660 nm (red LASER light)