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Internal report of Prague measurement on 2009 in Prague laser test setup

Summary

Results of new tests of Micro-pixel Avalanche Photodiode (MAPD) detector using a focused pulsed laser beam performed in April and May 2009 are presented. MAPDs were produced by Zecotek Company. The method used was identical to the tests in 2007 and it is described in [1] and [2]. Three samples 3A, 3N and 3N1P were tested using small laser power in level of several hundred photons in pulse in avalanching and proportional acquisition mode.

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New set of tests of Micro-pixel Avalanche Photodiode (MAPD) detector using a focused pulsed laser beam were performed in April and May 2009. Three samples 3A, 3N and 3N1P were tested using small laser power in level of several hundred photons in pulse in avalanching and proportional acquisition mode. The first test was a rough scan over whole area for defocused laser to check homogeneity of response. Here an influence of non-perpendicularity between planes of position stages and MAPD detecting area was found. Then focused laser beam exposed a small region in middle and in all corners od the sensitive area. After fine focusing we achieved $\sigma \approx 2.8 \, \mu m$ or FWHM $\approx 5.5 \mu m$ spot of laser beam. Then a basic set of measurements was done for an avalanche mode of MAPDs. Finaly for some samples were scanned in a proportional mode of working of MAPD.
Chapter 2

MAPD 3A

2.1 MAPD And Tests Description

MAPD 3A sample is a sensor of an older type, size 3×3 mm² with pitch between sensing cells 8 µm in both directions, collecting sense area in cell is 3×5 µm², expected gain is $2 - 3 \times 10^4$. Noise is $\approx 10 \text{ MHz} / 9 \text{ mm}^2$ and PDE 10 - 12 % in blue-green region.

Arrangement of laser tests is shown in Fig. 2.1. Basic parameters of tests are summarized in Table 2.1. Next plots show response in points based on Run Number in Table 2.1 and Fig. 2.1.

2.2 Results

2.2.1 Rough Scan

Rough scans were show in Fig. 2.2.

2.2.2 High Resolution Scans

Fine focused beam scans were shown at Figures 2.3, 2.4, 2.5 and 2.6. Fig. 2.3 shows response on the middle of sensor. Fig. 2.4 shows response on the middle of sensor with high statistics and in proporciional mode. Fig. 2.5 shows response on corners of sensor - it corresponds to position on Fig. 2.1. Fig. 2.6 shows the same as in Fig. 2.5 in detail on sensitive area.
### Table 2.1: List of 3A MAPD scans, Def+0.3mm = defocused beam with spot diameter $\approx 30 \mu m$ far from sensor, Avl = avalanche mode, Prop = proportional mode, bad par = parallelism between position stages and MAPD was not very good and there some changes of a spot size are possible, OptA = setting of an optical attenuator

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CHAPTER 2. MAPD 3A

Figure 2.1: 3A MAPD with arrangement of scans on area. Number of small bubbles on epoxy cover is a source of the dissipation of focused light in laser beam and final response is smeared. Also attempt of cleaning of surface created number of scratches and grease layer on a surface.
CHAPTER 2. MAPD 3A

Figure 2.2: 3A MAPD rough scan. There is no special trend of response distribution. Sensor was perpendicular with xy position stages plane.

Figure 2.3: 3A MAPD response in the centre of the sensor (not very good position - light disipation) (Upper left) and on better place close to a centre (others). Upper right is plot of response in avalanche mode and bottom are two views of one scan in proportional mode, both scans are on the same area.
CHAPTER 2. MAPD 3A

Figure 2.4: 3A MAPD response of the centre of the sensor with high statistics and in proportional mode.

Figure 2.5: 3A MAPD response at the corners of the sensor - it corresponds to position on Fig. 3.1. Note that plots are related to photos with mirroring transformation.
CHAPTER 2. MAPD 3A

Figure 2.6: 3A MAPD response shows the same as in Fig. 2.5 in detail on sensitive area.
Chapter 3

MAPD 3N

3.1 MAPD And Tests Description

MAPD 3N sample is a sensor of a newer type, size $3 \times 3$ mm$^2$ with pitch between sensing cells $8 \, \mu$m in both directions, collecting sense area in cell is $5 \times 5 \, \mu$m$^2$, expected gain is $6 - 7 \times 10^4$. Noise is $5$ MHz / $9$ mm$^2$ and PDE was $28 \%$ for blue(470nm), $25 \%$ for green(530 nm) and $10 \%$ for red(650nm) light.

Arrangement of laser tests is shown in Fig. 3.1. Basic parameters of tests are summarized in Table 3.1. Next plots show result response in points based on Run Number in Table 3.1 and Fig. 3.1.

3.2 Results

3.2.1 Rough Scan

Rough scan was shown on fig 3.2.

3.2.2 High Resolution Scans

Fine focused beam scans are shown on Figures 3.3, 3.4 and 3.5. Fig. 3.3 shows response on the middle of sensor in smaller and higher statistics. Fig. 3.4 shows response on corners of sensor - it corresponds to position on Fig. 3.1. Fig. 3.5 shows interesting response on pad with good visible wire bond - source of dissipating light.
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Table 3.1: List of 3N MAPD scans, Def+0.5mm = defocused beam with spot diameter ≈ 50 µm far from sensor, Avl = avalanche mode, OptA = setting of optical attenuator.
Figure 3.1: 3N MAPD with arrangement of scans on area. Number of small bubbles on epoxy cover is a source of dissipation of focused light in laser beam and final response is smeared. There are also few bigger bubbles. On right photo a few surface defects are visible.
Figure 3.2: 3N MAPD rough scan. Maximum response (gain) is on corner + + side close outer electrode bond pad and than second highest response is on corner - + with the second inner electrode bond pad. Sensor was perpendicular with xy position stages plane, changes ($\approx 20\%$) seem to be an issue of gain.

Figure 3.3: 3N MAPD response on the middle of sensor in smaller 1000 events per point (left) and higher 10 000 events per point (right) statistics. Scans are on different places in the middle.
Figure 3.4: 3N MAPD response on corners of sensor - it corresponds to position on Fig. 3.1. Note that plots are related to photos with mirroring transformation.
Figure 3.5: 3N MAPD interesting response on pad with wire bond well visible- source of disipating light. Photo is mirrored for geometry corresponding with plots.
4.1 MAPD And Tests Description

MAPD 3N1P sample is sensor of a newer type from the last batch of production, size $3 \times 3 \text{ mm}^2$ with pitch between sensing cells $8 \mu m$ in both directions, collecting sense area in cell is $5 \times 5 \mu m^2$, expected gain is $6 - 7 \times 10^4$. Noise should be less than $\approx 5 \text{ MHz} / 9 \text{ mm}^2$ and PDE was 28 % for blue(470nm), 25 % for green(530 nm) and 10 % for red(650nm) light.

Arrangement of laser tests is shown in Fig. 4.1. Basic parameters of tests are summarized on Table 4.1. Next plots show response in points based on Run Number in table 4.1 and picture 4.1.

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Table 4.1: List of 3N1P MAPD performed scans, Def+0.4mm = defocused beam with spot diameter $\approx 40 \mu m$ far from sensor, Avl = avalanche mode, OptA = setting of optical attenuator, SwpAx = swap axes
4.2 Results

4.2.1 Rough Scan

Rough scans were shown on fig 4.2.

4.2.2 High Resolution Scans

Fine focused beam scans are shown on Figures 4.3, 4.4 and 4.5. Fig. 4.3 shows response on the middle of sensor. Fig. 4.4 shows response on corners of sensor - it correspond to position on Fig. 4.1. Fig. 4.5 shows the same as in Fig. 4.4 in detail on sensitive area.
Figure 4.1: 3N1P MAPD with arrangement of scans on area. Number of small bubbles on epoxy cover is a source of dissipation of focused light in laser beam and final response is smeared. Also attempt of cleaning of surface created number of scratches and grease layer on surface.
CHAPTER 4. MAPD 3N1P

Figure 4.2: 3N1P MAPD rough scan. Maximum response (right) (gain) is on corner ++ side close outer electorde bond pad and than second highest response is on corner -+ with second inner electrode bond pad. Sensor was not good perpendicular with xy position stages plane, checking of response in very good focus explain half ($\approx 10\%$) of difference in response, so half of changes ($\approx 10\%$) seems is issue of gain. Left plot was turned 180 deg.

Figure 4.3: 3N1P MAPD response on the middle of sensor
Figure 4.4: 3N1P MAPD response on corners of sensor - it correspond to position on Fig. 4.1. Note that plots are related to photos with mirroring transformation.

Figure 4.5: 3N1P MAPD response show the same as in Fig. 4.4 in detail on sensitive area.
Chapter 5

Summary And Conclusions

Further tuning of laser setup was performed. Method of focusing was successfully applied and efficiently used. Basic set of scans takes approximately 1 day.

Plots show in one dimension clear visible structure on response. There are some changes on large area response - gain seems to change on range 10% and its maximum is close to pads for bonding. There is visible also a change of response in cell area at a level of 10 - 20%, which can be an effect of response from few more cells at the same places. The observed structure is periodical. More, there is a nice response in high statistics measurement in proportional mode.

Statistics of 1000 measurements in one position is good for quick checking, 5000 events per point is very stable and much better and precise for very fine scanning of response. Nice results are also in proportional mode of MAPD.

Analysis is done by simple determination of peak, excluding pedestals (read from signal before pulse) and integration of signal in peak. Then this was fitted by Gauss and mean value was found. This is preliminary method without fine tuning. Some improvement of analysis is possible.

Measurement method is well under control, it is easy and quickly applicable for samples and should give good feedback to MAPD designers.
Acknowledgement

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Bibliography

