Measurement results of DIPIX pixel sensor developed in SOI technology

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12^{th} Pisa Meeting, 20 - 26 May, 2012

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Outline

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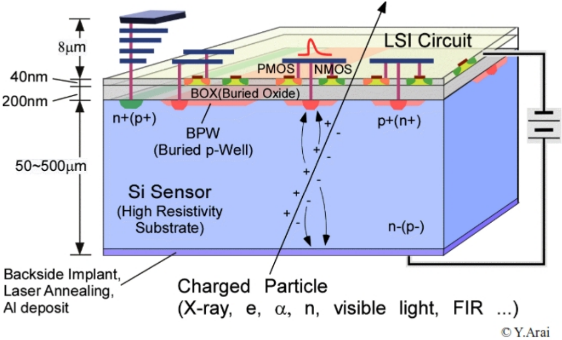
Silicon-on-insulator Technology

- SOI technology separates devices from the substrate using insulator buried oxide (BOX) layer.
- The features of SOI technology are: high speed, low power, good radiation hardness.
- Back gate effect is mitigated by implanting buried P-well (BPW) just below BOX layer.



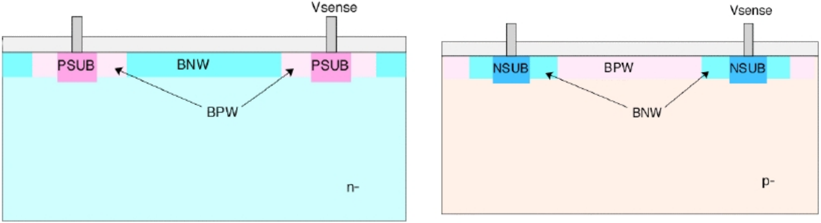
Lapis 0.2 μm FD-SOI process

Process	Lapis 0.2 μm FD-SOI CMOS process, 1 Poly, 5 Metal. MIM Capacitor (1.5 fF/μm^2), DMOS-Cap
SOI wafer	Diameter: 200 mmϕ , 720 μm thick Top Si : Cz, $\sim$18 Ω-cm, $\sim$40 nm thick Buried Oxide : 200 nm thick Handle wafer: 1. Cz-n: $\sim$700 Ω-cm 2. FZ-n: $\sim$7kΩ-cm
Backside Process	Thinned to 260 μm and Plated with Al (200 nm).

DIPIX pixel sensor

- DIPIX is a Dual mode Integration type PIXel with reduced pixel size of 14 μm.
- Circuit is designed to work both in n-type and p-type substrate.
- Internal 10-bit Wilkinson type ADC. (not use in this measurements)

	DIPIX1	DIPIX2
Wafers-Resistivity (k Ω-cm)	CZ-n (0.7)	CZ-n(0.7) and FZ-n (7)
Pixel size (μm) and No. of pixels	14 and 256x256	14 and 128x256x2
Chip area and Effective area (mm^2)	5x5 and 3.584	5x5 and 3.584
CDS in Pixel	yes	yes



Outline

Long time stability test

Long time stability test

Stability test is to check whether the detector is capable of operating in long run measurements.

Test Setup :

Parameters	**DIPIX2**
Environment	Dark
Signal	No
No. of Frames	60000
Integration Time	500μs
Scan Time (pixel readout time)	640 $ns/pixel$
RST time without cds and with cds	2040 ns and 2160 ns
RSTV for N-type wafer	750mV and 1300mV

- The Back voltage for CZ-n = 100 V.

Stability Test of CZ-n pixel sensor

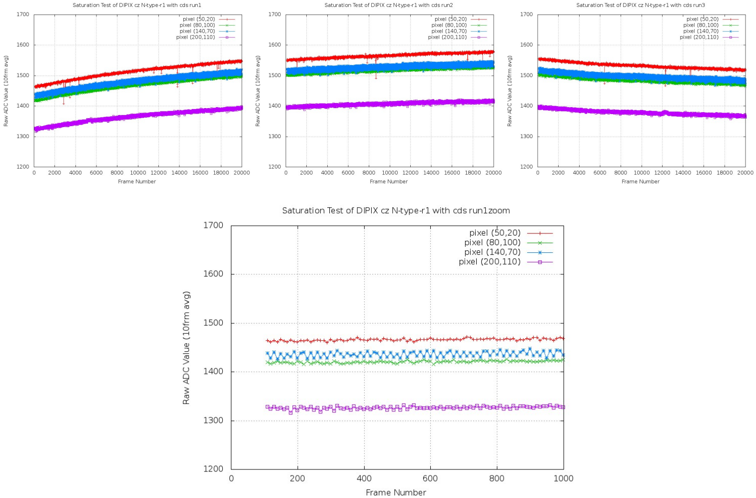


Figure: Stability test of CZ-n with CDS. (top 3 graphs each with 20000 frames measured subsequently and bottom is zoom of initial 1000 frames)

Stability Test

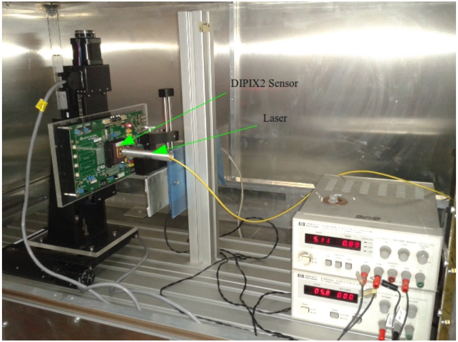
Summary

- DIPIX is stable and so it may work for long time run.
- Small initial changes in number of counts may probably be reduced by maintaining a constant temperature.

Outline

Laser Setup

Laser Details	
Laser Driver	PDL 800-D
Frequency	80 MHz
Modes of operation	Pulse
Laser Head wavelength	1060 nm
3D setup	X,Y and Z



Halo in FZ-n pixel sensor

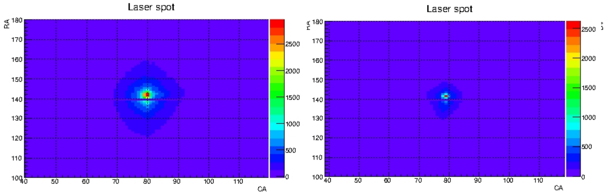


Figure: Back voltage was set to a) Left fig. 10V, b) Right fig. 70V

Halo Effect

- A bunch of pixels around the hit pixel(halo) having 12 to 15 % of hit pixel count is seen.
- This problem is seen in both sensors. The worse is FZ-n.
- Halo depends mostly on Laser Intensity (increase with intensity).

Optimization of Back Voltage and Integration time

Parameters	CZ-n Type	FZ-n Type
Back Voltage	80V	60V
Integration Time	100μs	100μs

Table: Optimized Back Voltage and Integration Time

Optimization

- The presence of Halo, force us to do the scan of back voltage and Integration time to optimize them in order to reduce halo.
- Optimization is used to reduce the Halo and spot size.

FZ-n before and after optimization

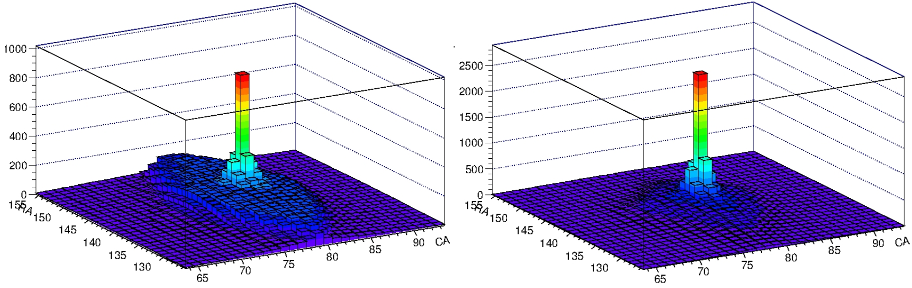


Figure: a) Left fig. Before optimization , b)Right fig. After optimization

Laser Measurements

Summary

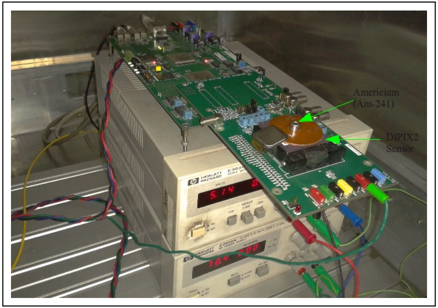
- Halo is seen in both sensors and depends mostly on Intensity. Probably Halo is caused by large charge generation disturbing the electric field.
- Optimized Back voltage and Integration time result in smaller spot size.

Outline

Americium Radiation Data and Setup

- Am-241 source is used with the activity of 10mCi(=370MBq).
- The rate of incident photons is low.
- Setup is placed in black box.

Radiation Data	
Type	Energy
Gamma	59.5KeV
Gamma	26.3KeV
Gamma	13.9KeV
Cu L x-ray	8.01KeV
Np L-x-ray	17.7KeV
Np L-x-ray	20.7KeV



Data Cleaning using CZ-n pixel sensor

Integration Time and Scan Time	100 μs, 640 *ns/pixel*
Back Voltage	80 V
RSTV and RST time	750 mV, 2040 ns
Run Mode	calib data and signal data
Calib run (dark, no source)	500 events
Am-241 run (dark)	20000 events

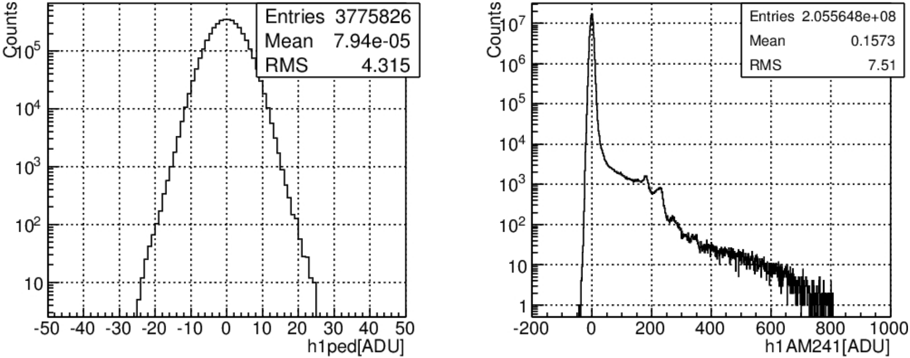
Table: Parameter setting of sensor CZ-n Type

Noise cleaning

- Calib data is used to remove bad pixels.
- Bad frames and common mode noise are removed from both calib and Am-241 run.

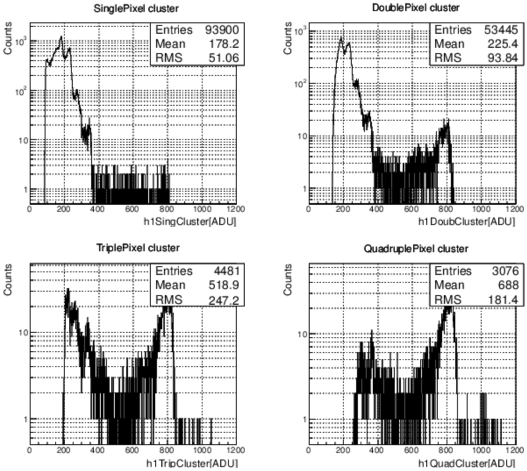
Data Cleaning

- Sensor = CZ-n, CDS = off, No. of frames = 20000 Am-241 and 500 calib runs.
- Back voltage = 80 V, IT = 100 μs, Pixel scan time = 640 ns.

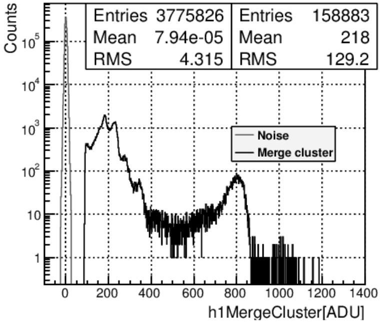


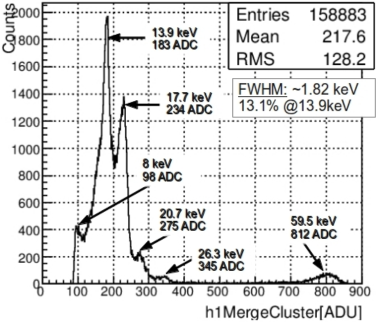
Clustering

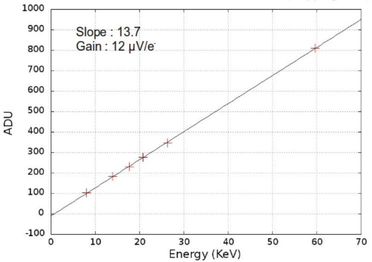
- Number of pixels in a cluster depends on deposited energy.
- Total 4σ threshold is use to get hit pixels and these pixels are used to find the cluster.



CZ-n sensor signal Clusters and Energy plots







ENC and SNR Results

CZ N-Type Without CDS					
Region	IT(μs)	Noise (ADC)	ENC(e^-)	SNR	59.5KeV (ADC)
1	100	4.3	$\simeq$86	$\simeq$189	812
CZ N-Type With CDS					
Region	IT	Noise	ENC(e^-)	SNR	59.5KeV (ADC)
1	100	3.6	$\simeq$85	$\simeq$192	690

FZ N-Type Without CDS					
Region	IT(μs)	Noise (ADC)	ENC(e^-)	SNR	59.5KeV (ADC)
1	100	5.1	$\simeq$127	$\simeq$129	657
2	100	4.7	$\simeq$141	$\simeq$115	543

Summary

- 1st region is the best of both sensor (ENC=85e^- and SNR=189 using Am-241 source 59.6keV), 2nd region is having lot of bad and hot pixels.
- Readout with CDS give similar results.

Outline

Conclusions

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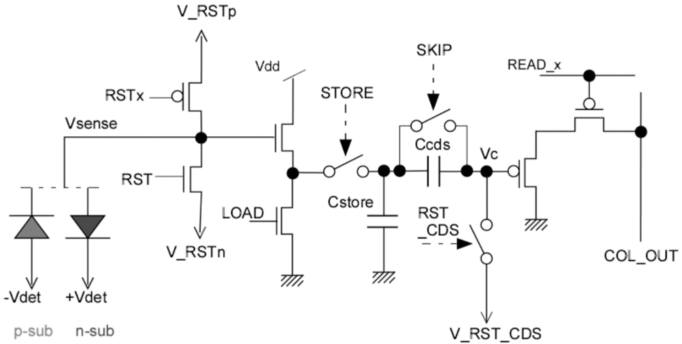
- DIPIX2 shows long time stable operation.
- Halo problem seen with laser can be reduced using small intensity and optimized back voltage. Halo is not seen with americium source.
- CZ-n is having good SNR and ENC ($85e^{-}$), whereas FZ-n is worse ($ENC = \simeq 127e^{-}$).
- More study is needed to understand the CDS readout.

Thanks

Thank you for your attention!

Backup:DIPIX circuit

DIPIX Circuit



Backup: Stability Test of FZ-n

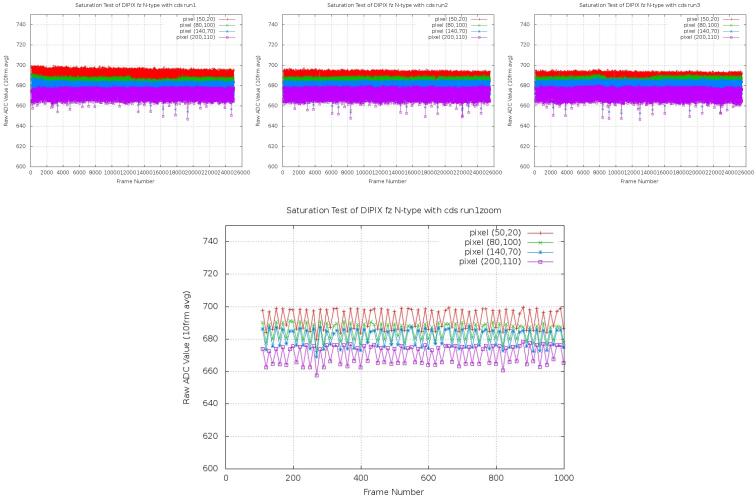


Figure: Stability test of FZ-n with CDS. (top 3 graphs each with 20000 frames measured subsequently and bottom is zoom of initial 1000 frames)

Backup: CZ-n before and after optimization

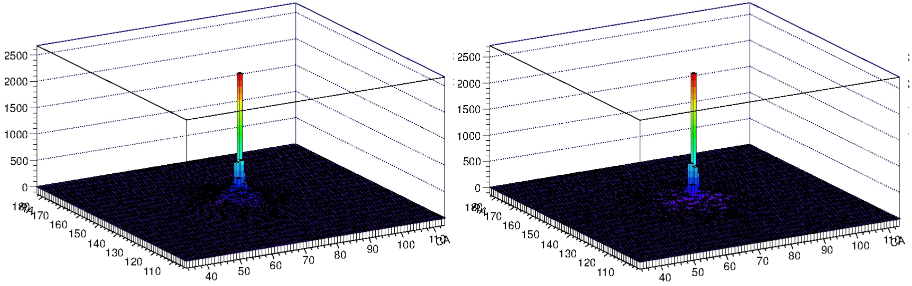


Figure: a) Left fig. Before optimization , b)Right fig. After optimization