Laser Tests of Silicon Strip Sensors

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SEMICONDUCTOR DETECTOR

- Silicon, 280 μm, $V_d < 100$ V, max. 500 V
- 768 aluminum strips
- $I_L < 6 \, \mu A@150$ V
- 99% efficiency
- typical signal 25000 electrons
STRIP DETECTORS: TESTING METHODS

Tests on beam <-> beta tests <-> laser tests

• Tests on beam of high energy particles (beam tests):
  Most similar conditions to real experiment
  Available only few times in year and complicated organization
  High coast

• Tests used $\beta$ particles from radioactive sources:
  Lower coast and good availability, used real particles
  Wide spectra of energies without their measurement possibility
  Unknown interaction point between particle and sensor, no space resolution information

• Tests with laser light:
  Exact precise space resolution, lower coast, good availability
  Depth penetration setting using different light energy (wavelength)
  Complication on absolute efficiency measurement from energy from photon beam
Laser: CERN product (Maurice Glaser)
  Laser energy of photon: 1.170 eV
  Wavelength of light: 1060 nm
Module: ATLAS SCT end caps
Detector: Hamamatsu & CiS silicon 0.27mm wedge-shaped, single-sided, p-in-n type
Microstrips: pitch 80μm 2x60mm length
Readout: analogue/digital binary ABCD chips with 128 channels, 12 per module, MUSTARD/SLOG electronics in VME crate, PC, SCTDAQ sw
2D motion system, step <1μm
SIGNAL IN BINARY READOUT SYSTEM

Calibration or laser pulse

Real MIP signal

To know properties of input signal needs always threshold scan
BIAS SCAN

Bias Scan, Module Laser000006 Det. Type: Ham, Strip 100
Vcc 3.48 - 3.52 (940 - 960) Vdd 4.00 - 4.02 (570 - 570) bias 10 - 300 (0.123 - 0.553)
temperature 35 - 35, date:time 2005/02/16:170912 - 2005/02/16:191151, time per scan 108.0 - 124.0 s
run 1261 - 1317, x 42.840 - 42.840, z 23.111 - 23.111

Charge Collection in Maximal Bias:
Maximal Collected Charge in Sum of Strips: 3.79 fC at 126.0 s
Charge Collection in Minimal Bias:
Minimal Collected Charge in Sum of Stripes: -1.22 fC at 18.8 s
Collected Charge at max X in Sum of Stripes: 3.12 fC at 300.0 s
Ratio of Collected Charge in Sum of Stripes: -0.33 (1/-0.33)
Difference of Collected Charge in Sum of Stripes: 4.92 fC

In Mid Plots: B=CollectedCharge,R=ChargeValue,G=TimePerScan
SlowControl:Black=Vcc/5,Green=Vdd/5,Red=Icc/2000,Blue=Vdd/2000
DEPTH SCAN – MEASUREMENT VS. THEORY (HAMAMATSU)

- Simulation
- Measurement

Graphs showing the collected charge as a function of depth.
REFLECTIVITY OF MODULE – THEORY

Module CiS
- Chip calibration factor 1.041
- Strip: pitch 74 um, width 18 um, reflectance 1.000
- Collected charge in focus 12.37 fC, defocus 9.34 fC

Module Ham
- Chip calibration factor 1.026
- Strip: pitch 74 um, width 24 um, reflectance 1.000
- Collected charge in focus 16.60 fC, defocus 11.22 fC
- Ratio of defocus collected charge CiS / Ham = 1.513

Calculation and simulations of differences between two types of modules with including of some factory and experimental values
BETA TESTS FOR CONFIRMATION OF PROPERTIES OF COMPARING MODULES

6 scans, 20000 ev./scan + 100k events confirmation
Basic scans full beam error ~ 0.02

L1 left  L1 spine  right  31,36

Ham  3,02  2,91  2,99
CiS  3,02  2,88  3,05

Ham L1 right  CiS L1 left
3,03  3,01
3,03  3,02
3,05  3,00
3,03  3,03
3,04  3,00

MODULES HAVE THE SAME PROPERTIES OF PARTICLE DETECTING
REFLECTIVITY MEASUREMENT - ARRANGEMENT
REFLECTIVITY MEASUREMENT IN URE AVCR, CiS / HAMAMATSU

![Graph showing reflectivity measurements for different materials and samples.](image)
Normalized Reflectivity

Wavelength [nm]

Reflex Energy

Corrected

Gold  Inner 1  Inner 2  Hamamatsu  CiS 1  CiS 2

Reflectivity – Measurement, CiS & Hamamatsu
REFLECTIVITY – SIMULATION VS. MEASUREMENT, CiS & HAMAMATSU

Simulation based on thin layers on detector surface (Pavel Bažant)

CiS detector, two surface layers SiNO + SiO2

Hamamatsu detector, one surface layer SiO2

Simulation based on thin layers on detector surface (Pavel Bažant)
STRIPS IN SCOPE – GRANULATION OF SURFACE

Hamamatsu strip reflectivity < 22%

CiS strip reflectivity < 30%
STATUS

- Test setup built in IFIC Valencia (fully working) and Charles University Prague (in progress)
- Stable mechanical arrangement
- Laser detection in only one side (metal back side of detectors – no transparent for light).
- Strip position detection working up to 1 minute
- Few method of focusing was tuned
- Automatic focusing done up to 20 minutes with precision 40μm in z and 4 um in x
- No effect of interference between chip channels is observed
- Testing at low temperatures was tuned and is done up to –20 deg in chillers (4 deg in T-hybrid of ALTAS SCT module) in dry air or nitrogen
- Special atmosphere is possible
- Automatic logbook generated and saved with all important information
- Quality of laser focusing (sigma < 3.3μm)
- Many systematic effects under control (thickness, refractive index, surface quality)
TESTS PERFORMED

- **The bond mixing test** done up to 30 minutes per detector – test for production modules
- The channels from mask file (bad channels) tested independently using two methods
- **Punch through (pin hole) channels** test (gain confirmation) for response done
- Other special channels tested
- **Pulse shape reconstruction** done
- Different wavelength for different depth of bulk penetration is used
- Test of homogeneity of response from detector in full area is possible
- Detail response from inter-strip position is measured
- **Bias scan of detector** is simply possible and is setting depletion voltage
- Temperature scan is possible and done
- **Pulse shape for ATLAS detectors** was measured via strip for checking of response properties
- **Space resolution of noise bumps on CiS ATLAS detectors** was checked and measured
CONCLUSIONS - USABILITY

Laser tests are useful in:
- precise space resolution studies
- time walk and time shape measurements
- functionality of problematic part of detectors (response measurement)
- surface charge collection and also deep charge generation from \( \sim \mu m@650\text{nm} \) up to \( 300\mu m@1060\text{nm} \)

Quality of tests depends from:
- top layers: thickness, refractive index, surface quality
- geometry of pads on top, their material, surface of them, protected layers
- back layers: material, quality, thickness (only if sensor is transparent for using wavelength of light)
- laser light beam quality, coherent properties, long time stability, aperture, wavelength

Laser test are:
- extremely useful for tuning of individual sensor and readout settings to find optimal working parameters
- good for comparison between the same type of detectors with exactly the same top surface properties
- of limited use in absolute measurement of efficiency of semiconductor detectors, this field area is under study

Next tasks? …
PHOTOS 1

First arrangement of workspace

Module in test box with window for laser spot, optical fibre for laser light (yellow cover), insulated plastic support for module

Laser end with focusing lens above module sensor

Black box with 2D stages inside and chiller below them
PHOTOS 2

Final arrangement of workspace

General view to laser tests workplace with black box (left) with 2D stages inside and chiller below them, readout electronics (right) and DAQ computer

Black box with module box connecting to cooling and DAQ electronics

Block of connectors for in/out puts of cooling, air or nitrogen, optical fibre of laser light and command wires of position stages
PHOTOS 3

Final arrangement of workspace

Position stages arrangement

Laser end with focusing lens above module sensor and module test box with two windows for testing of both sensors (one is closed for save cool dry atmosphere inside)