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Laser Tests Of Silicon Strip Detectors

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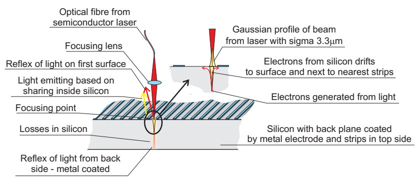
Principle Of Laser Testing

Basic differences between particles and light beam in silicon:
- laser tests used beam of light with nonzero width
- different method of electron generation
- some effects missing:
  - δ – drift electrons
  - energy of particles
- some effects added:
  - primary and secondary reflection

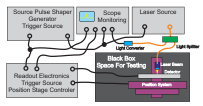


Charge generation in silicon induced by laser beam

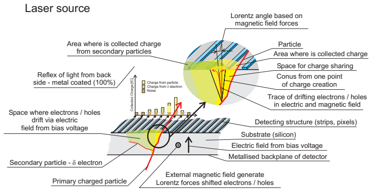

Laser source

Stability of laser pulse:
Amplitude: $\sigma < 1.5\%$ @ 1.8MeV deposited
Timing jitter: $\sigma < 0.4$ns @ 32MeV deposited

Laser: CERN product (Maurice Glaser)
Energy of photon: 1.88 & 1.170 eV
Wavelength of light: 660 & 1060 nm

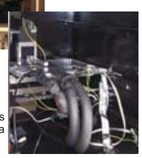


Typical setup of laser tests



Charge generation in silicon induced by particles

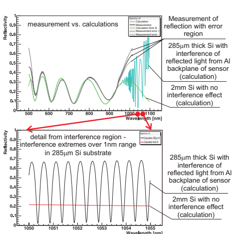

Real measurements in Prague


Real measurements in IFIC Valencia

Absolute Measurement Of Response

Tests And Calculations, Optical Properties

Absolute response measurements are problematic: deposition of defined charge in the sensor is difficult because of many optical effects:
- part of light is reflected
- sometime transparent layers are not homogenous because technology of covering use also transport of atoms between layers so borders between layers are gradients and no steps
- refractive index for some materials must be measured because big spread of value depends of using deposition and surface polishing technology
- sensitivity of reflection measurement depend of quality of spectroscope
- thick and transparent substrates gives hardly defined conditions for reflectivity calculation
- the best is use the same laser beam for also reflectivity measurement (method of this is on the way)



Plots comparing reflectivity measurement and calculation from thickness of layers in range 300 - 1100nm of wavelength

Refractive index of layers was measured on spot in range 300 - 800nm of wavelength, clear are also optical un-homogenities close strips (Aluminum is covered with protection layers of SiO_2 or SiN_xO_y with overlap to interstrip area)

Where Laser Tests Are Useful?

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 cost

Tests with β particles from radioactive sources:
- Lower cost and good availability, real particles used
- Wide spectra of energies (large spread of energy deposited in the sensor)
- Unknown interaction point between particle and sensor, no spatial resolution information

Tests with laser light:
- Precise spatial resolution, lower cost, good availability
- Depth penetration setting using different light energy (wavelength)
- Complicated of absolute measurement (calibration is difficult)

Laser tests are useful in:
- precise space resolution studies
- time walk and pulse shape measurements
- functionality of problematic part of detectors (response measurement)
- surface charge collection and also deep charge generation from ~μm@650nm up to ~mm@1060nm

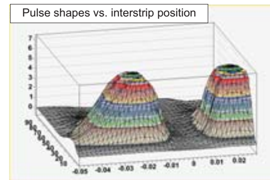
Laser test are:
- extremely useful for tuning individual sensor and readout settings to find optimal working parameters and checking of bonding arrangement
- good for comparison between the same type of detectors with exactly the same top surface properties
- of limited use in absolute response measurement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

Conditions And Dependencies

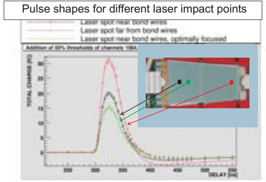
Test setup built in IFIC Valencia, Charles University Prague, CERN, Melbourne University:
- Stable mechanical arrangement
- Several focusing methods tuned
- Automatic focusing done in 20 minutes with precision 40μm in z and 4 μm in x
- Interference effects between chip channels were inspected (ATLAS end caps SCT)
- Testing at low temperatures down to –20 deg in chillers in dry air or nitrogen
- Special atmosphere possible
- Quality of laser focusing (determined sigma < 3.3μm)
- Many systematic effects under control (thickness, refractive index, surface quality)

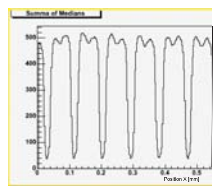
Quality of tests depends from:
- top layers: thickness, refractive index, surface quality
- geometry of pads on top, their material, surface of them, protected layers
- back layers: material, quality, thickness (only if sensor is transparent for used wavelength)
- laser light beam quality, coherent properties,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

Pulse shapes vs. interstrip position



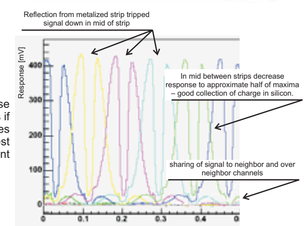
Pulse shapes for different laser impact points

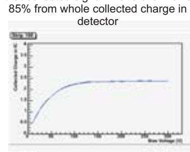


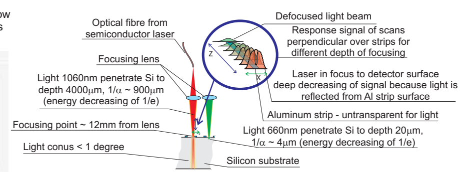


Sum of signal of 12 adjacent strips show that collected signal in one channel is 85% from whole collected charge in detector

Typical response from few channels if laser beam moves across strips in best focused point




Response vs. bias



Principle used for laser focusing

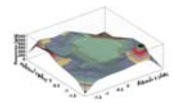
Applications

ATLAS SCT End Cap Modules

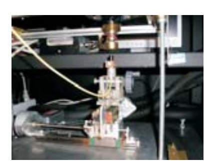

ATLAS end cap SCT short middle module

Numerous tests of ATLAS end cap SCT modules were developed and 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
- Other special channels tested
- Pulse shape reconstruction
- Different wavelength for different depth of bulk penetration is used
- Test of homogeneity of response from detector in full area is possible
- Detail response vs. inter-strip position
- Bias scan of detectors
- Temperature scan
- Pulse shape for ATLAS detectors was measured along strip for checking of response properties
- Spatial resolution of noise bump-strips on CiS detectors was checked and measured

Large Area Diode Measurements

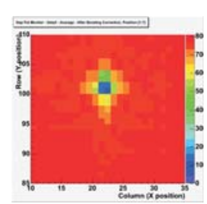

Response of Si pad detector for 1060nm light wavelength

Preparing of tests of silicon pad (~100mm^2) detectors for n-d experiment of Van de Graaff laboratory in Charles University. Un-homogeneties in sensitivity of diodes have influence on neutron properties and final neutron beam quality.


Arrangement of tests

DEPFET Detectors Tests

In cooperation with MPI- HLL Munich laser tests of DEPFET detectors were performed with first preliminary observations:
- channel mis-assignment
- grounding and shielding optimizing
- common-mode noise effects are observed via rows
- charge sharing between neighbour cells in columns
- back side laser beam irradiation arrangement in preparation



Response of DEPFET detector