Charles University Prague
Institute of Particle and Nuclear Physics

Laser Tests of Silicon Detectors

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Comparisons

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 β 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

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Laser tests

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 reflections

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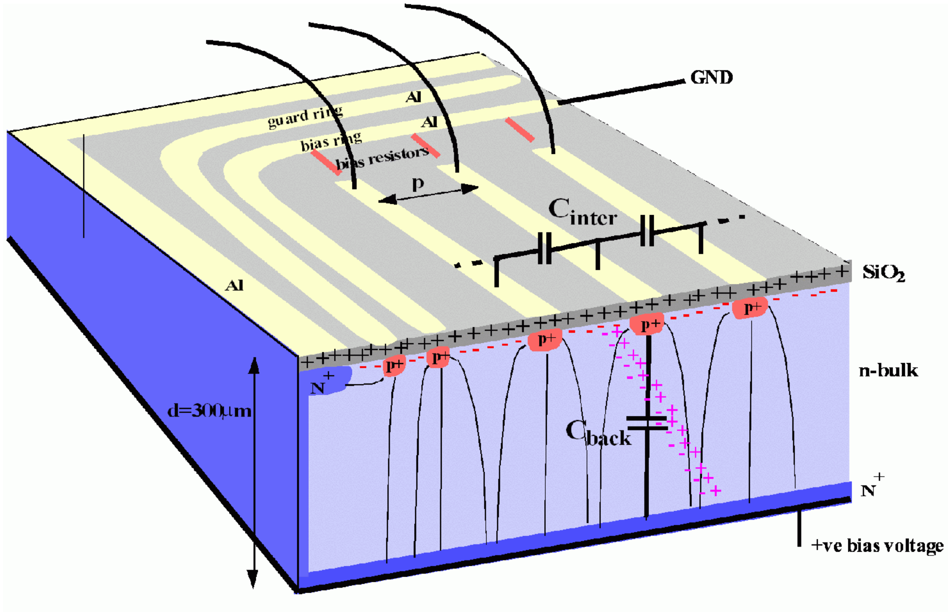
Silicon Microstrip Detector

Principle:

- collection of charge released in the depleted volume of a reverse biased diode
- spatial resolution through segmentation of diode
- p strips on n substrate
- AC coupling to keep leakage current away from read-out electronics
- biasing through polysilicon or implanted resistors
- Irradiation in SCT volume up to **1.2x10^{14} 1-MeV-n/cm^2 for 10 years** of LHC running

Properties:

- leakage current
- depletion voltage and substrate resistivity
- interstrip capacitance
- backplane capacitance
- crystal orientation
- charge collection
- signal to noise



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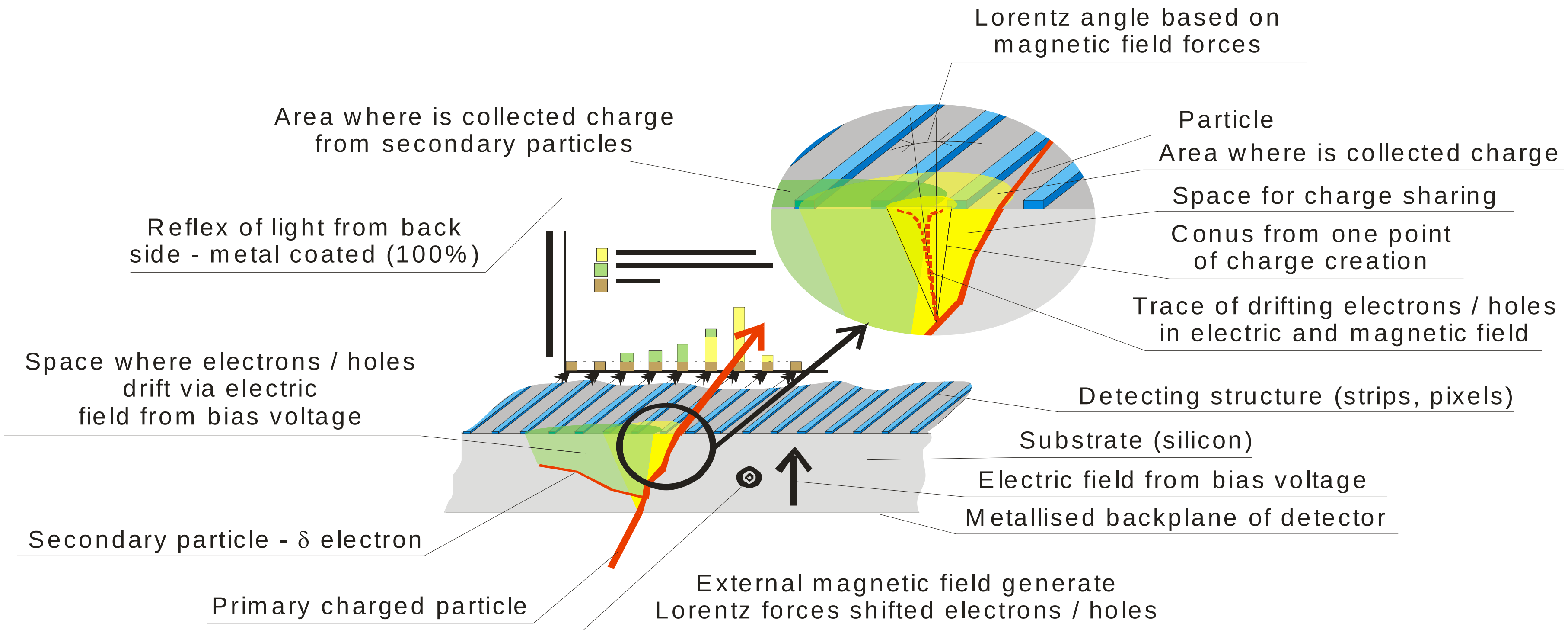
Charge generation in silicon induced by particles



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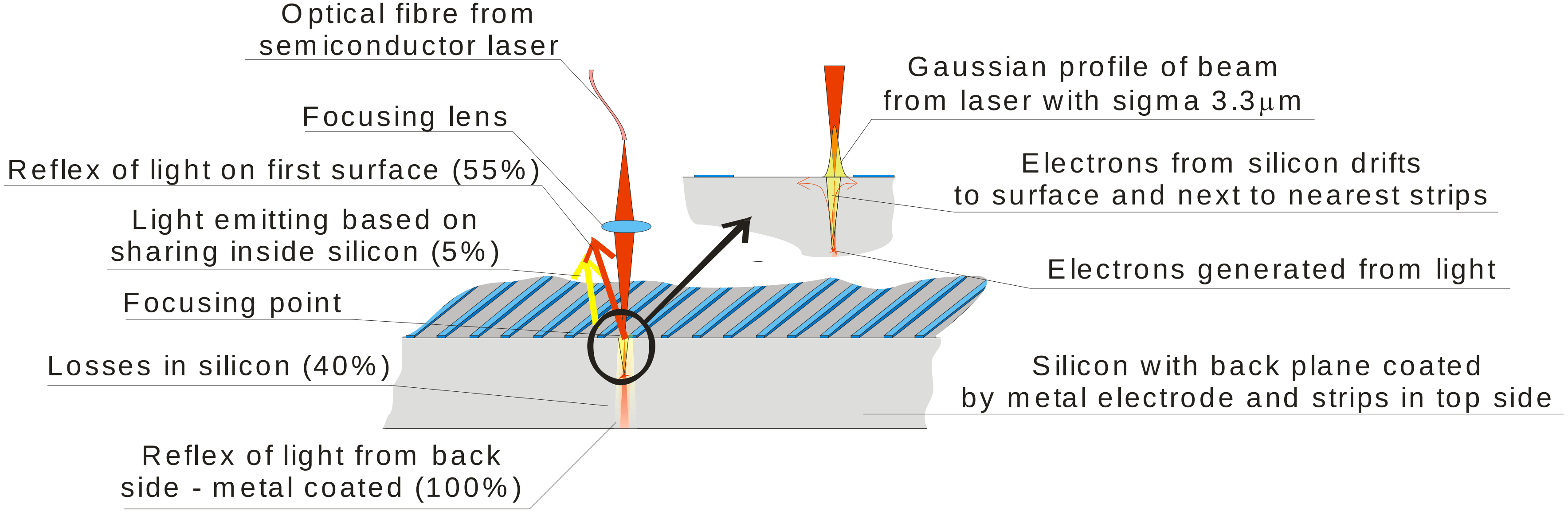
Charge generation in silicon induced by laser beam



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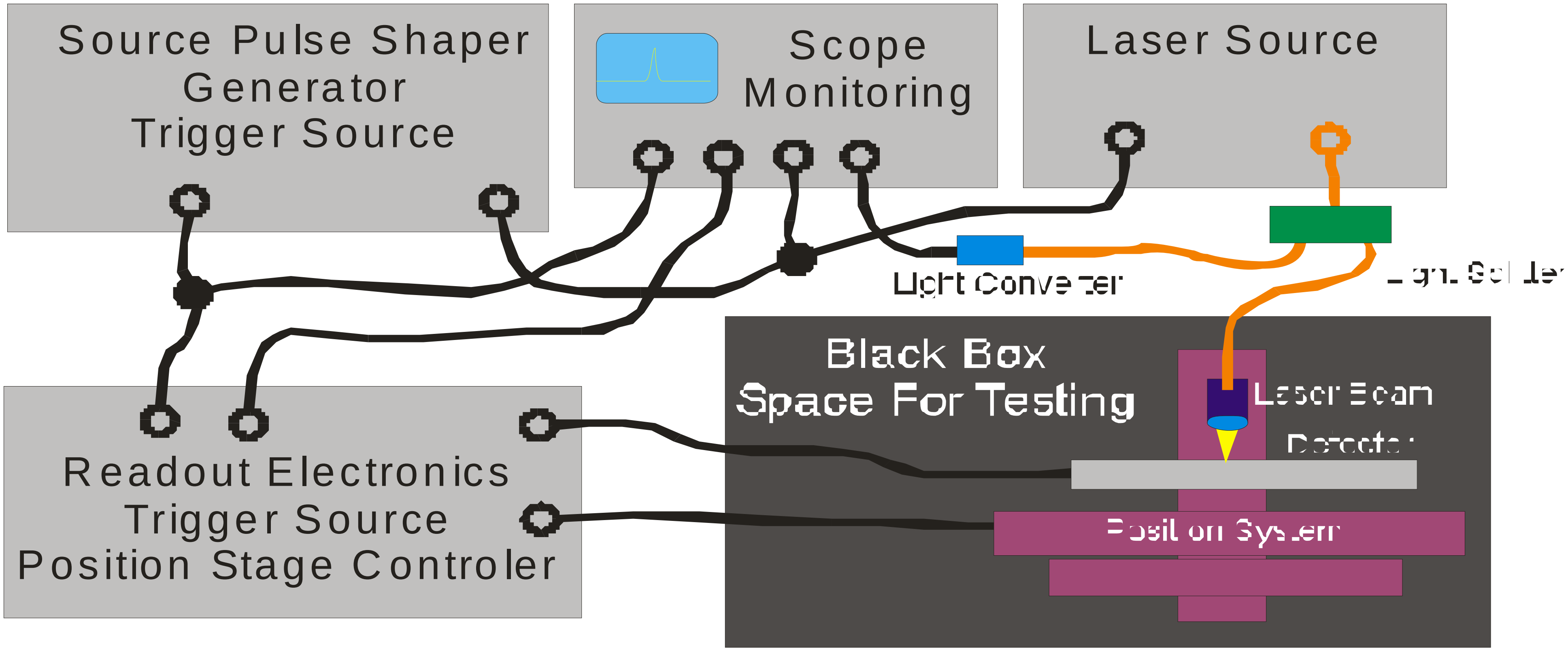
Most typical arrangement of laser tests



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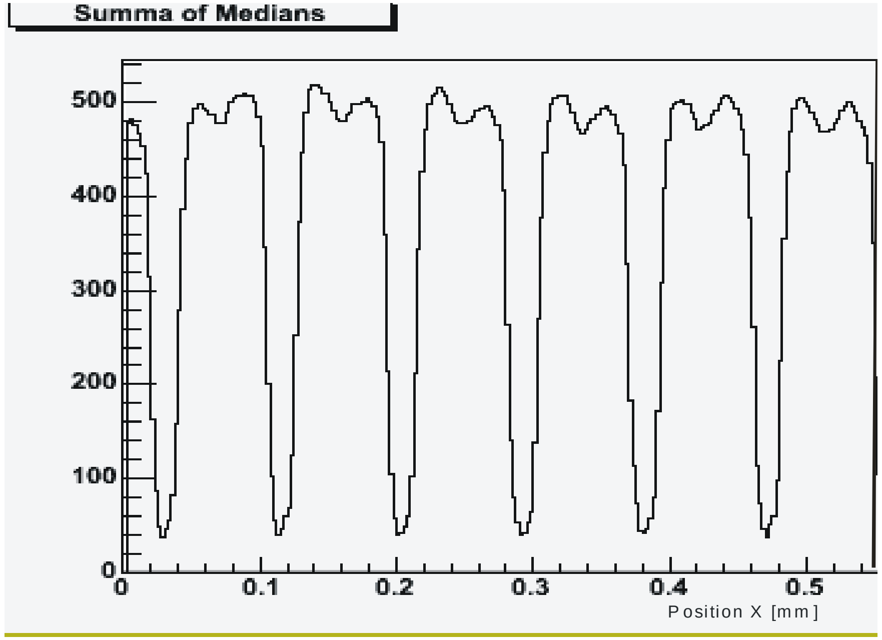
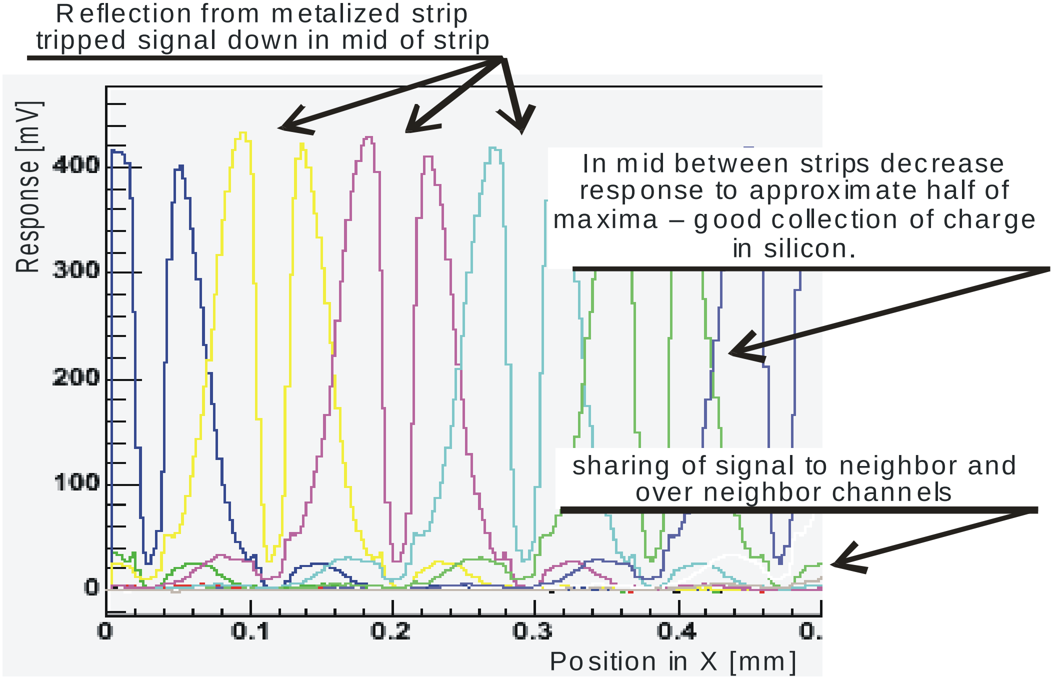
Response of testing modules

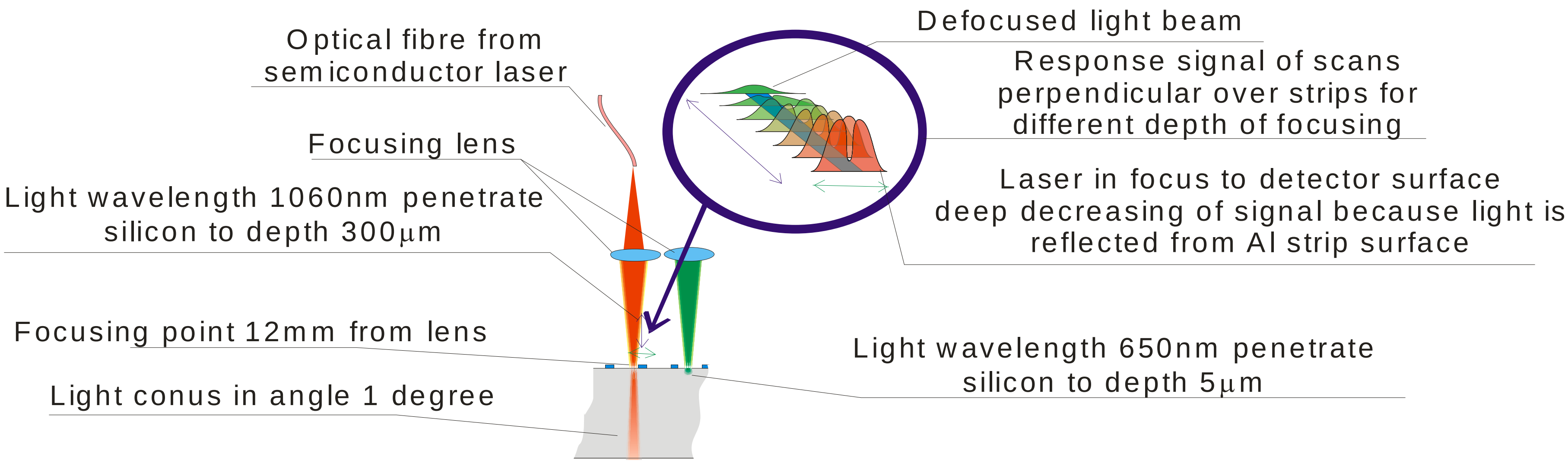


Sum of signal of 12 adjacent strips show that collected signal in one channel is 85% from whole collected charge in detector.



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

Laser tests - focusing



Principle used for laser focusing

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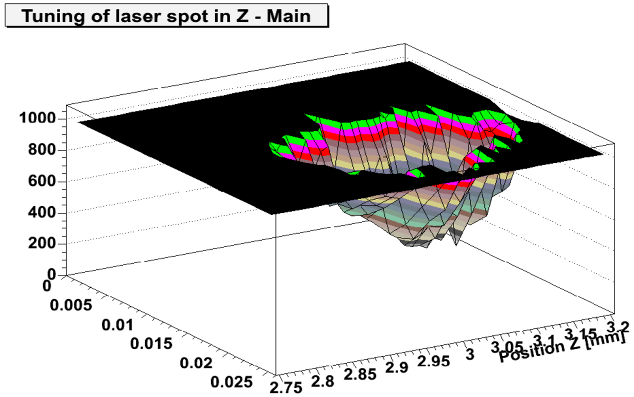
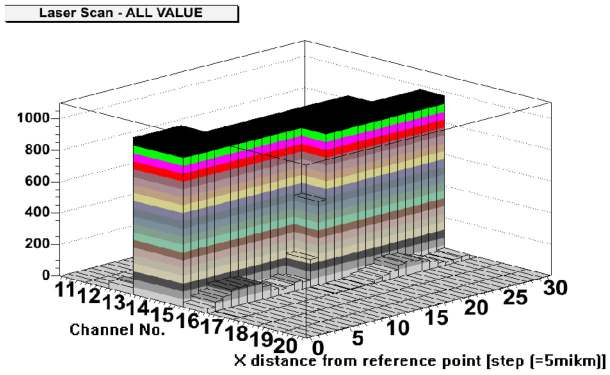
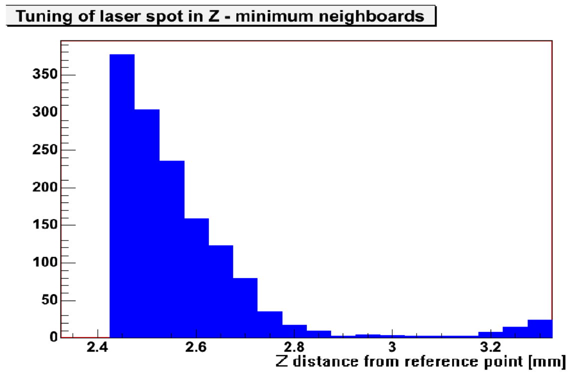
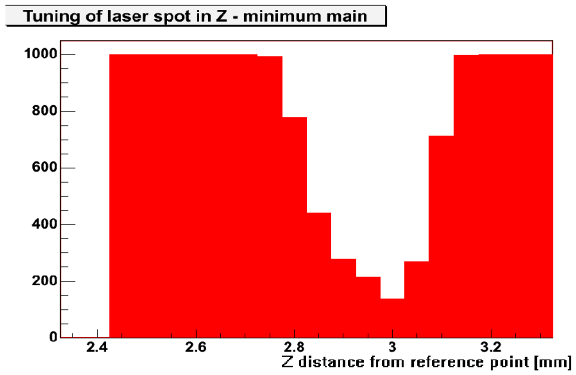
Laser tests - focusing



Main conclusion: there is possibility to tune laser focusing to smallest spot using reflectivity from strip metal material, sensitivity of focusing of our type of laser output is very high, focus range is less 50 μm (from factory is declared good focus range about 1 mm).







Laser Tests - Applications

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
- Pulse shape reconstruction
- Test of homogeneity of response from detector in full area is possible
- Detail response vs. inter-strip position
- Bias scan of detectors
- Temperature scan
- Spatial resolution of noise bump-strips on CiS detectors was checked and measured

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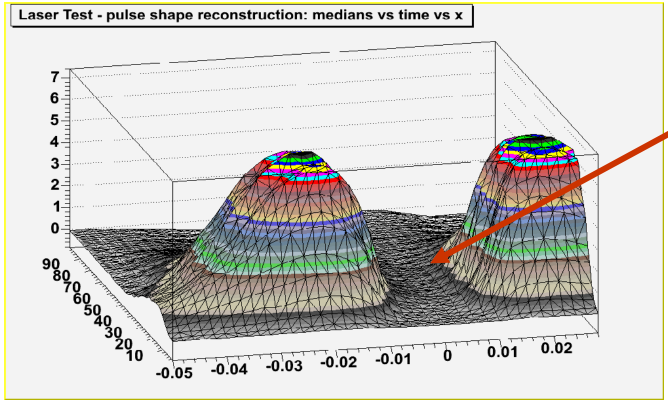
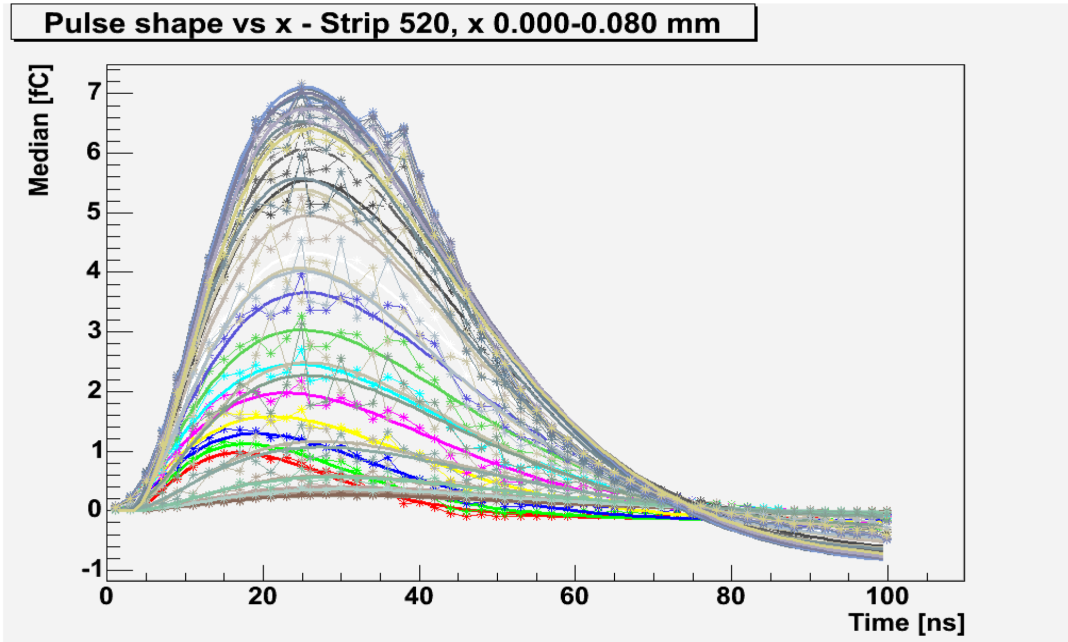
Pulse shape reconstruction



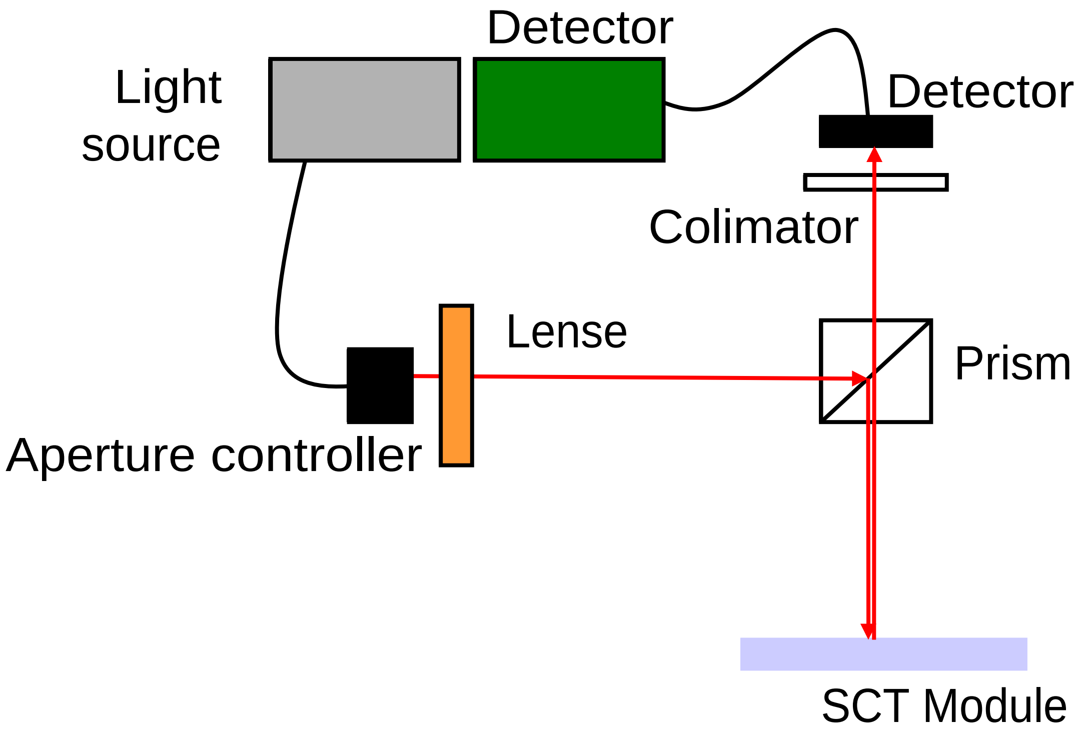
Strip position

2D graph of medians in time shift vs. x, strip metal part is on point 0 where practically whole light beam is reflected out

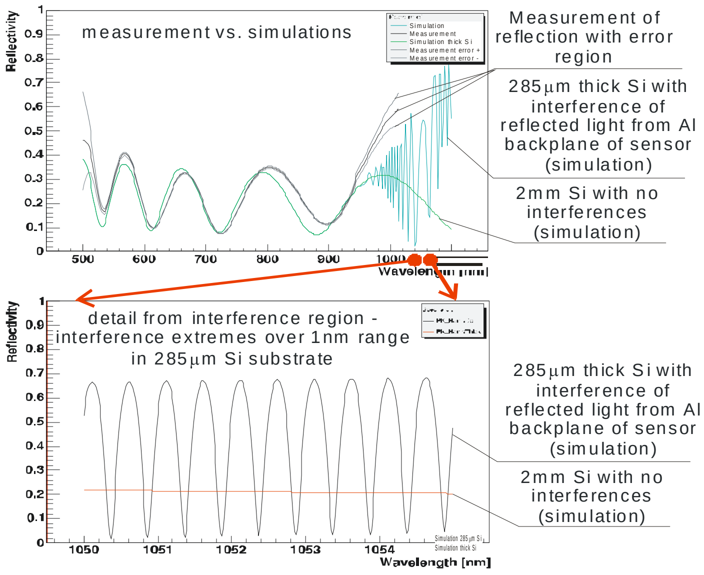
Pulse shape fit for all x positions



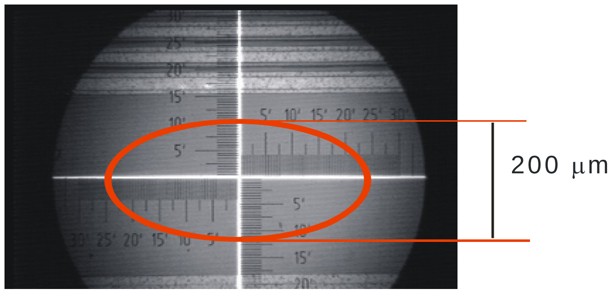
Reflectivity measurement



Optical properties



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



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

- 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)

Refractive index and thickness of layers was measured on spot in range 300 - 800nm of wavelength.

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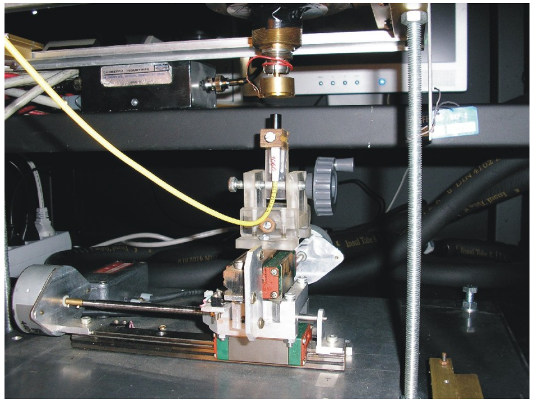
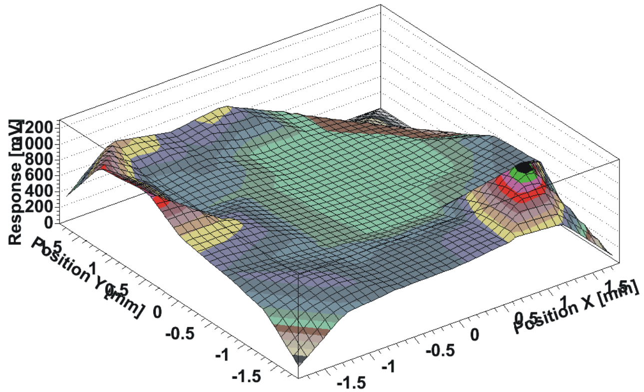
New Tests

- large area diodes tests
- depfet strustures

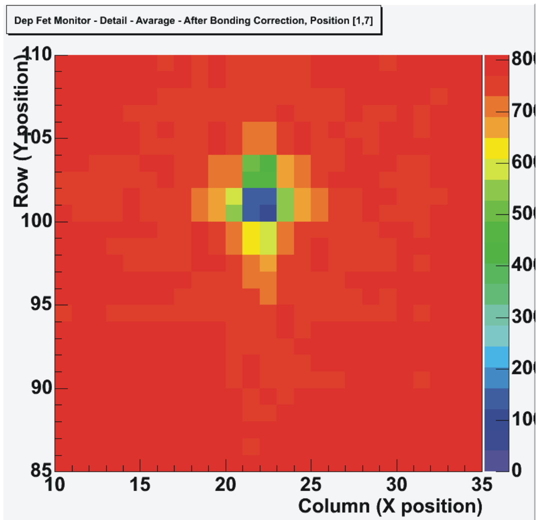
Stability of laser pulse:
Amplitude: σ < 1.5% @ 1.8MeV deposited
Timing jitter: σ < 0.4ns @ 32MeV deposited



Arrangement of tests



Response of Si pad detector for 1060nm light wavelength



Response of DEPFET detector

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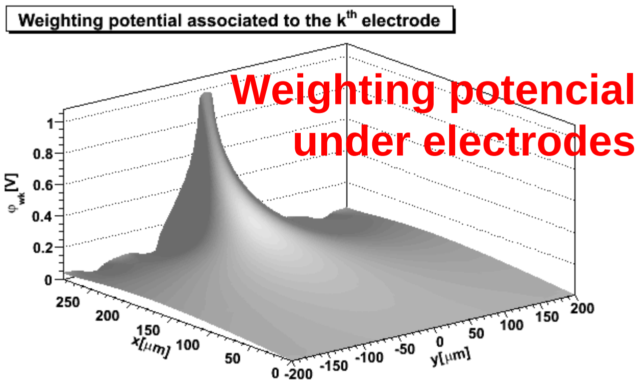
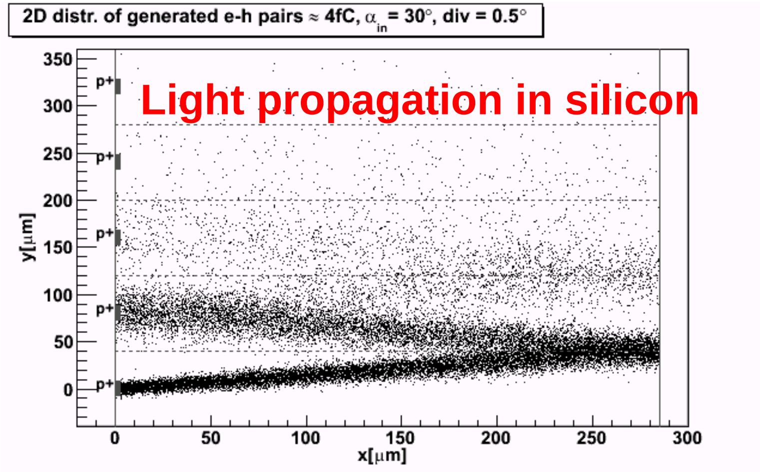
Laser Tests And Simulations

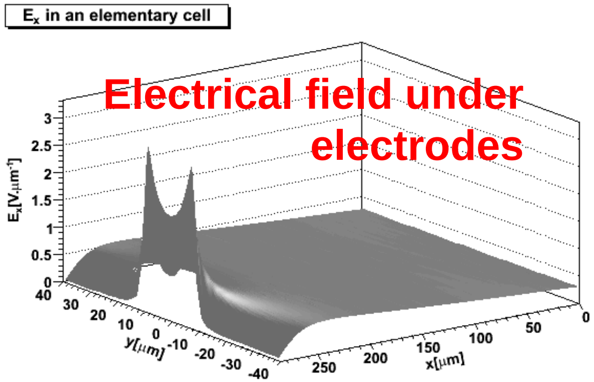
How is signal on detector created

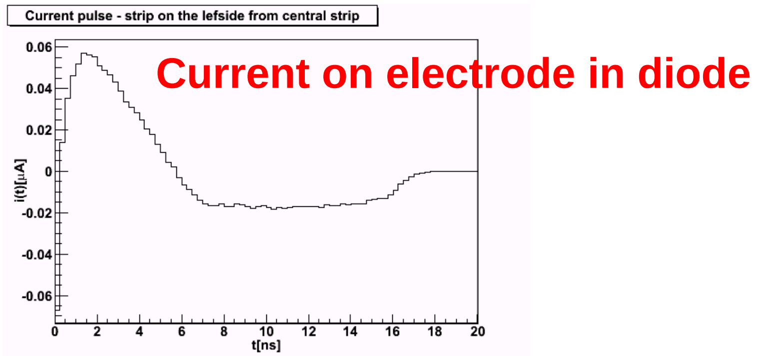




Cooperation:

- University of Bari (Italy)
- Lappeenranta University of Technology (Finland)





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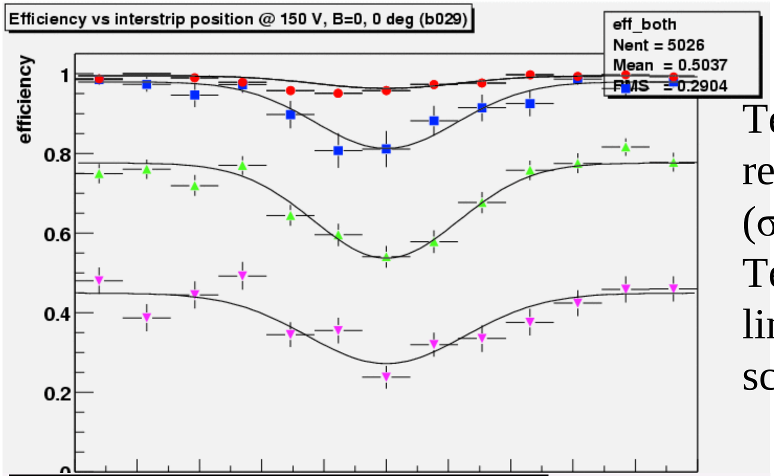
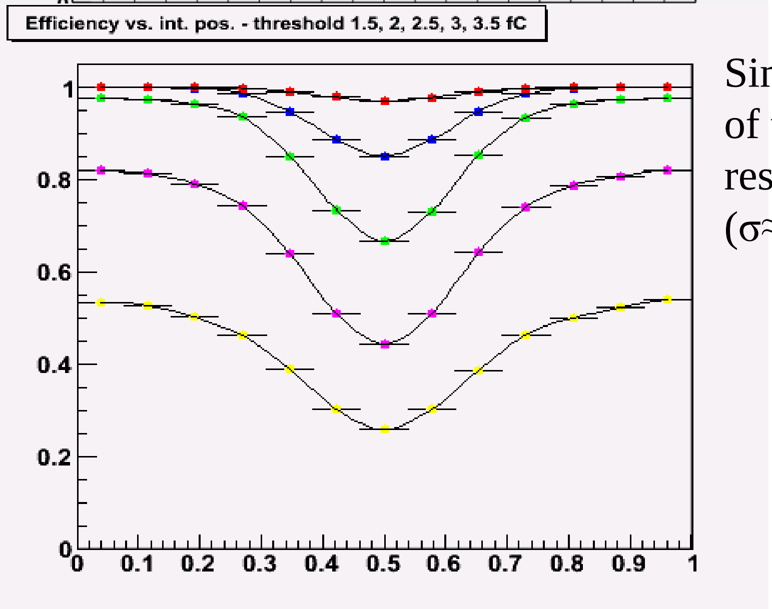
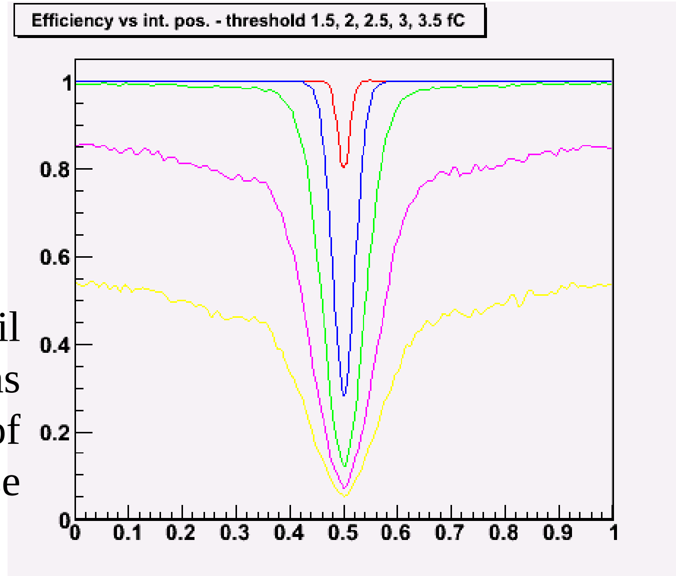
Space Resolutions Measurements



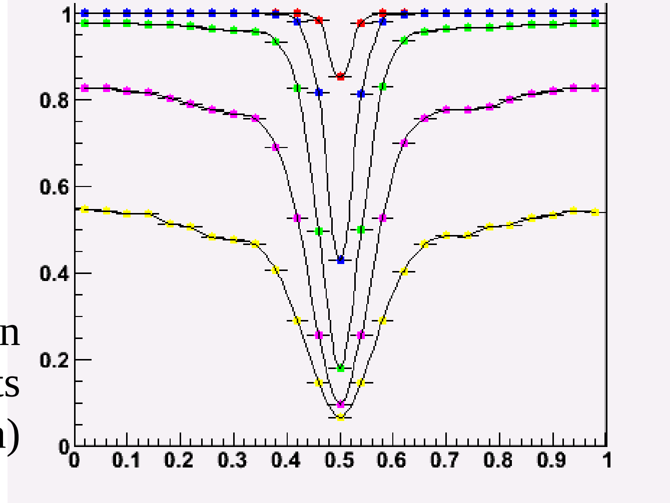
Test beam results (σ≈10μm) Telescope limitation & scattering



Simulation of test beam results (σ≈10μm)



Detail simulations (σ≈1μm) of response



Simulation of laser tests (σ≈4μm)

Cooperation

- Help in building of new laser test laboratories: MPI Mnichov, University Freiburg
- Looking for examples for testing around
- Cooperation with:
    - ÚRE AVČR Prague
    - University of Freiburg
    - MPI Mnichov
    - University of Bonn
    - University of Lancaster
    - University of Bari
    - Lappeenranta University of Technology

Conclusions

Laser tests are useful in:

- precise space resolution studies
- time walk and time shape measurements
- functionality of problematic part of detectors
- surface charge collection and deep charge generation from 4 mm@650nm up to 1mm@1060nm

Quality of tests depends from:

- top layers: thickness, refractive index, surface quality
- geometry of pads on top, their material, surface of them, protected layers
- laser light beam quality, coherent properties, long time stability, aperture, wavelength

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Usability

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 (under study)

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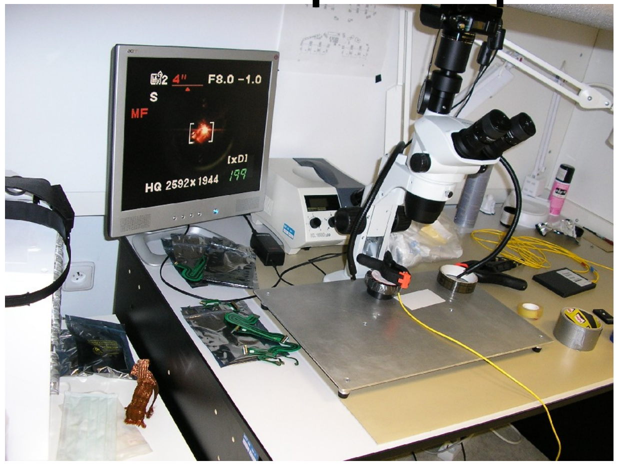
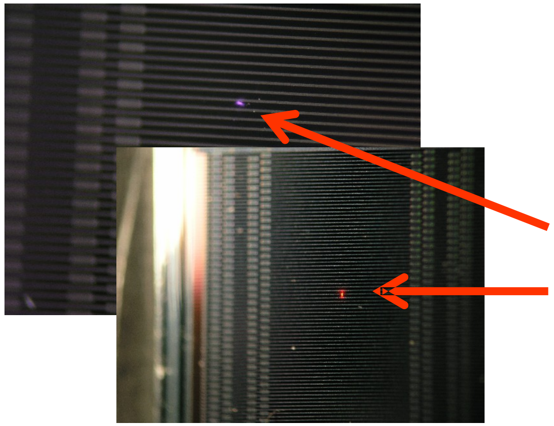
Place Of Laser Tests

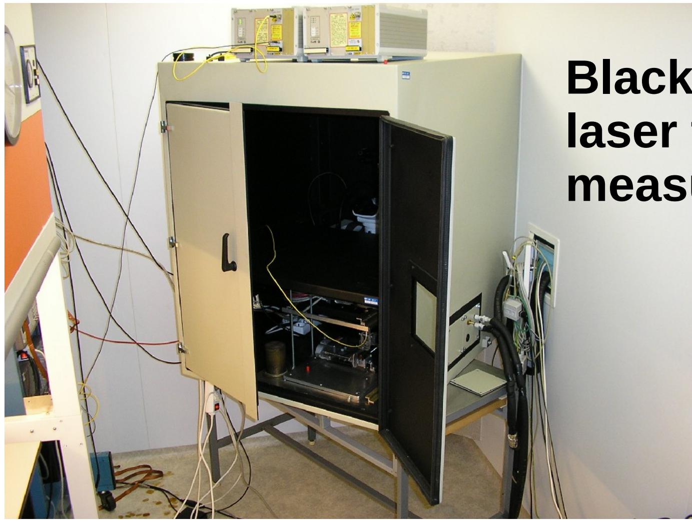
Clean room in Prague Charles University with laser black box and readout electronics stands

Visual inspection place





Laser spot on detectors in 1060nm and 660 nm wavelength, strip pitch is 80 μm



Black box for laser test measurements

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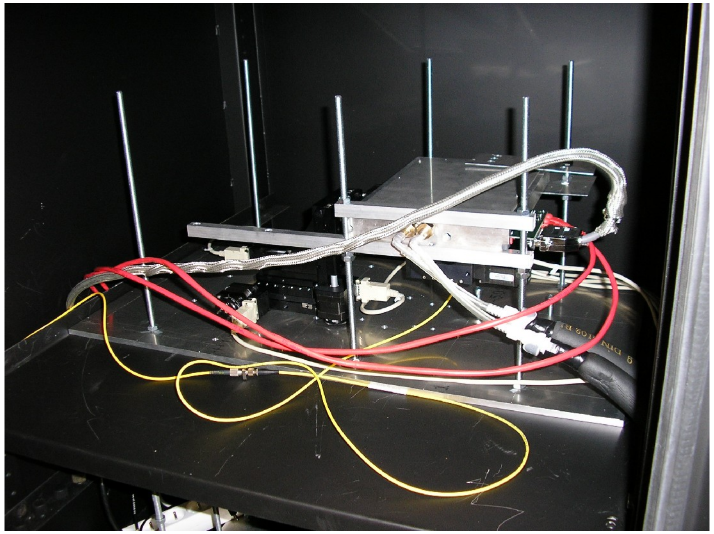
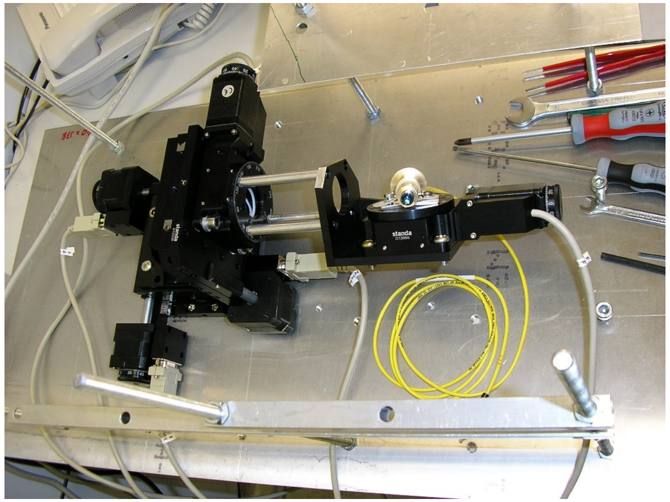
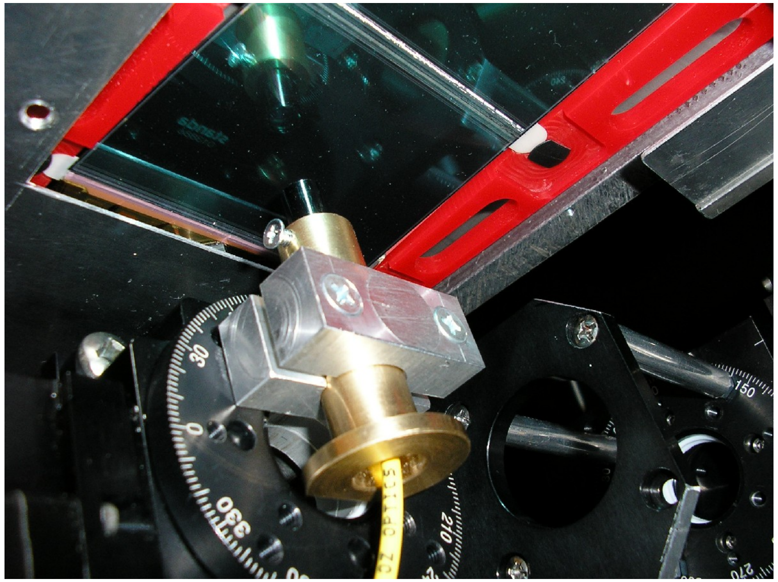
3D2R moving system

Arrangement in black box

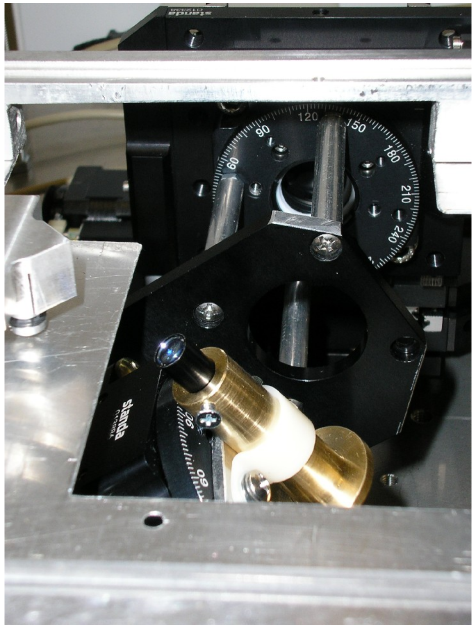


3D2R Laser System





Lighting to detector



Tilting of laser beam before mounting of detector