Studies on inner detectors alignment in ILD

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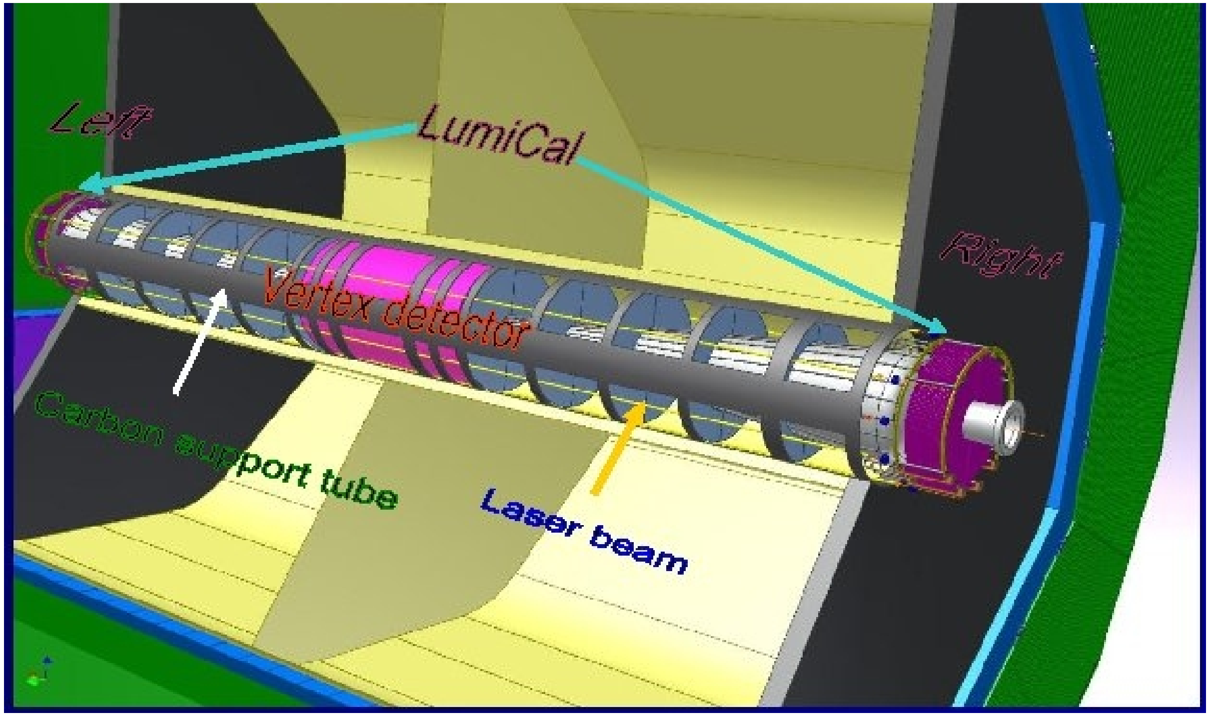
Laser alignment system: LumiCal and Vertex detector

The common laser alignmet system (LAS) for ILD inner detectors: LumiCal and VTX is considered. The system is destined to measure with high precision the positions of LumiCal and Vertex detectors and their components. The important for monitoring will be a knowledge on QD0 magnet and beam pipe current positions



The first step in this direction is to build the prototype of the LAS for LumiCal alone and test it with AIDA LumiCal calorimeter prototype. The work is carry on within the AIDA project.

AIDA task for LAS prototype

Physics requirement for luminosity measurement:

High accuracy in luminosity measurements at ILC/CLIC ($\Delta L/L$ cannot be larger than 10^{-3}) has strong requirement from physics. One of the conditions which allows to achieve this is precisely measurement of the luminosity detector (LumiCal) displacements.

An accuracy below 100 μm in X,Y, Z directions is required.

In addition a possible displacements of the internal silicon sensor layers of LumiCal should be measured with accuracy a few microns.

Goal within AIDA project:

improve and extend the optical alignment system developed in EUDET project which will be useful for LumiCal and Vertex detector.

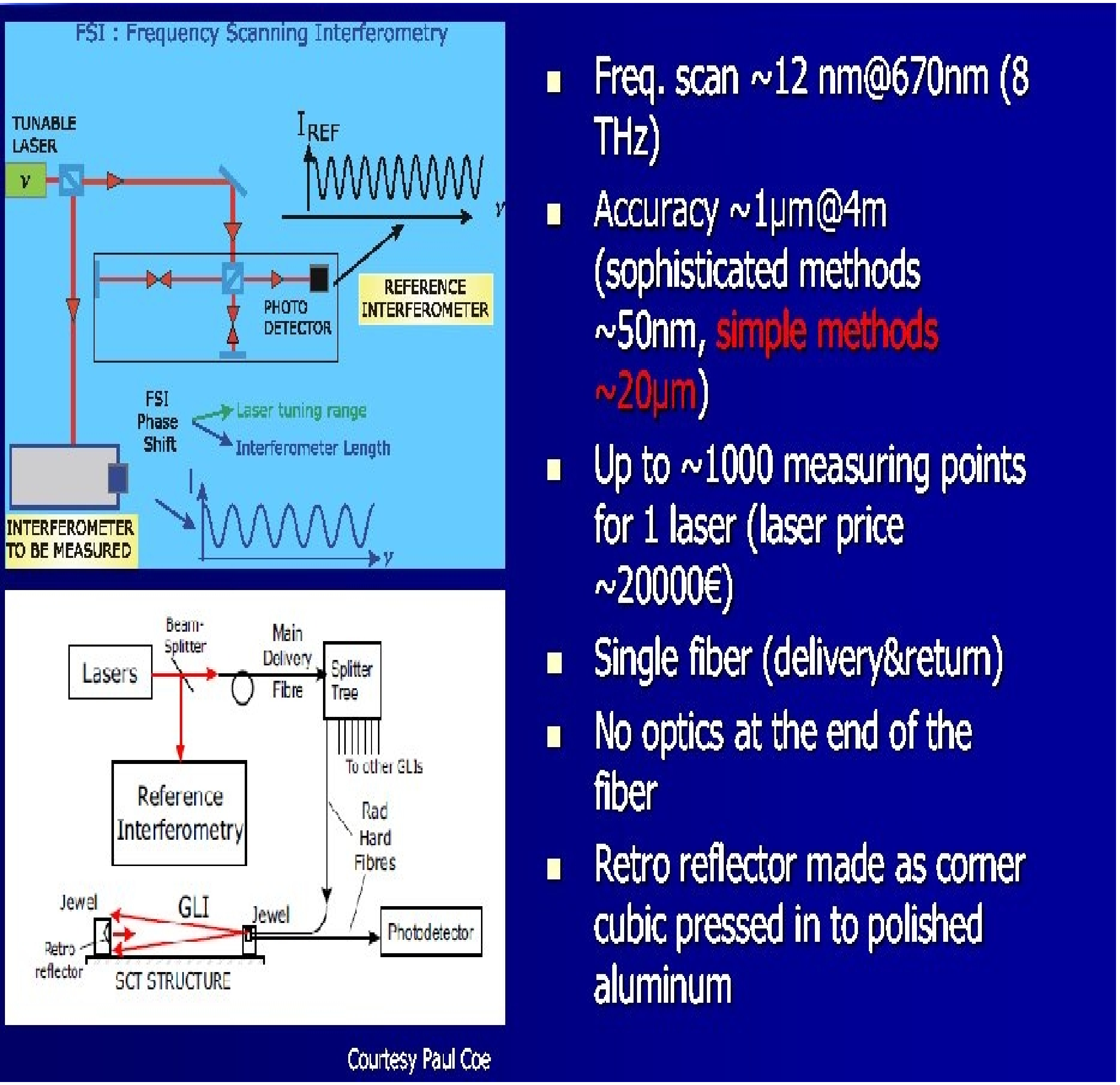
The components of the LAS system

The laser alignment system considered for LumiCal and Vertex detectors will contain the main components:

- Frequency Scanning Interferometry (FSI)
- Transparent silicon position sensors

FSI – Frequency Scanning Interferometry

FSI is robust and versatile technique – measurement of interferometer optical path differences using tunable lasers. It provides an absolute distance measurement.

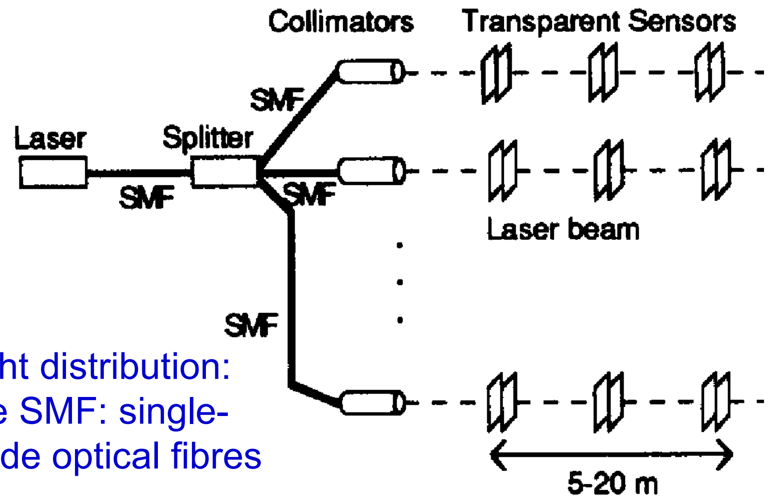


The tunable laser (different frequencies) illuminates interferometer to be measured and a reference interferomer (patterm of distance). When the optical frequency is scanned a phase shift is induced in all interferometers, at rate that is proportional to the length of each interferometer. The phase shift in iterferometers are compared to determine the ratio of interferometer lengths to high precision.

Status: work on the concept - needs to buy in near future a tunable laser (commercial product)

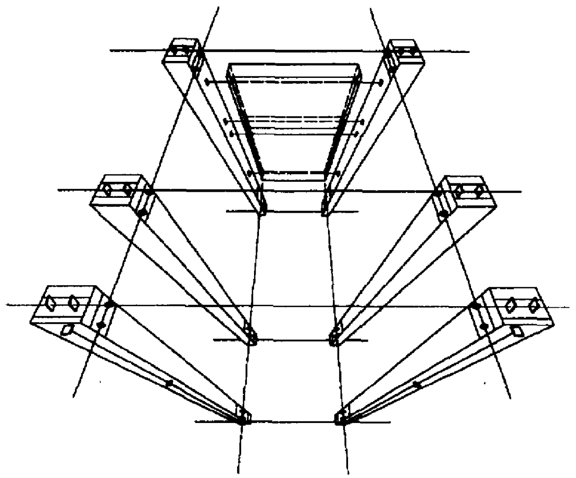
Transparent silicon sensors

Idea of multi-point laser based alignment system with transparent sensors:
split the laser beam into several beams and use several transparent sensors to measure the positions of required detectors



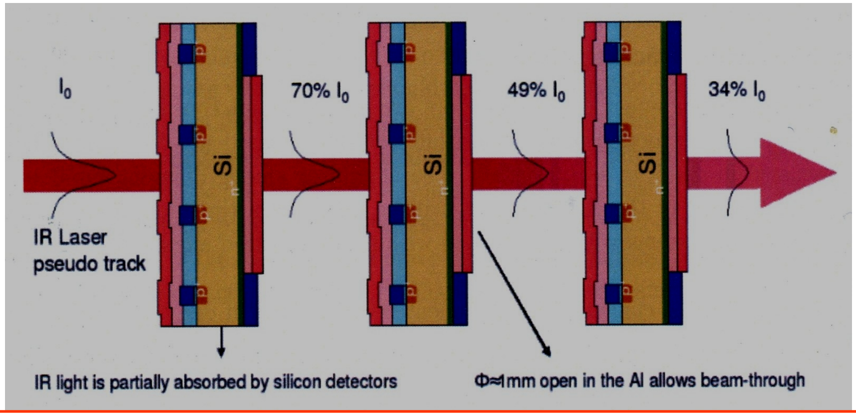
Light distribution:
use SMF: single-mode optical fibres

This method was used in several experiments like:
ZEUS, HERAB, ATLAS, CMS



and is expected to be used in ILD:
silicon based sub-detectors (like VTX)

(ILD LOI, February 2010)

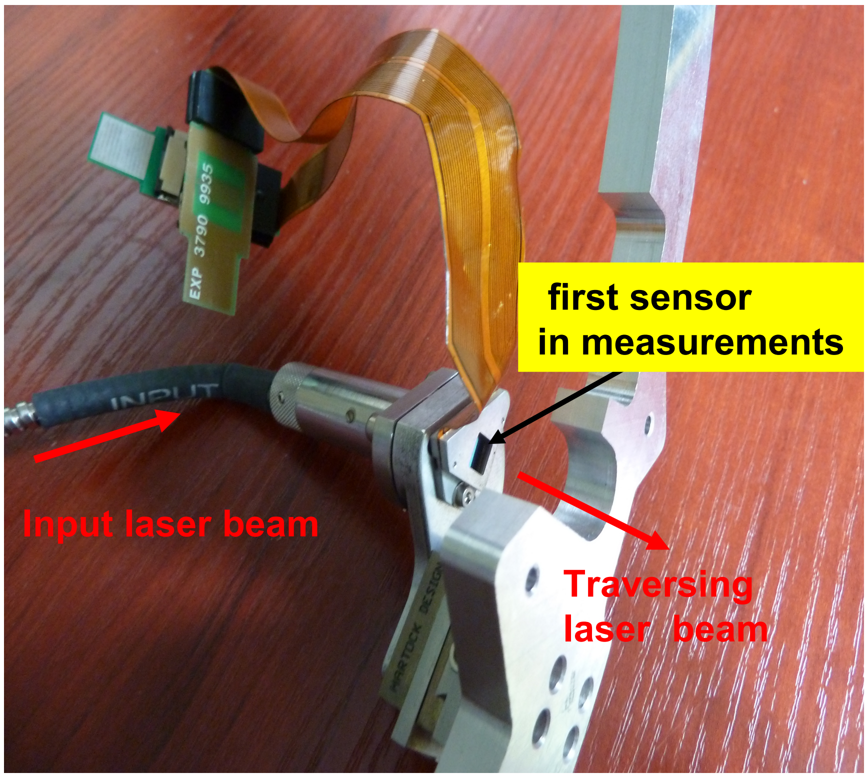


Status: For laboratory and test beam measurements the ZEUS MVD (Microvertex Detector) transparent sensors (DPSD-516) will be used. They arrived to Cracow (IFJ PAN) from Oxford University

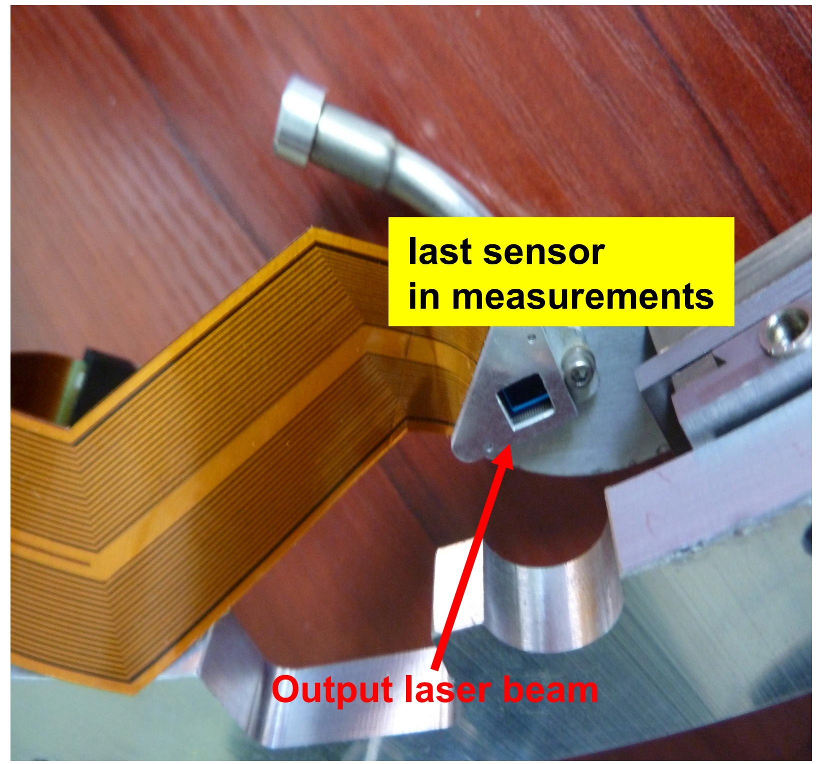
MVD transparent sensors - Oxford University

The sensors were developed by Kroha et al.. (NIM A 367 (1995) 413) and manufactured by EG&G Heimann Optoelectronics in Wiesbaden

Sensor with laser fiber

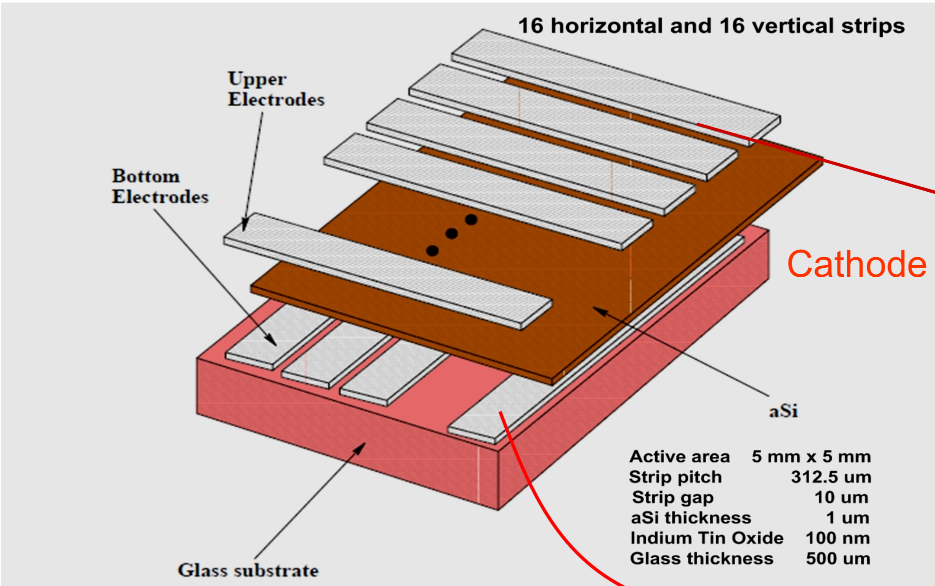


Sensor with laser beam dump
(to prevent reflections)



Transparent sensors (1)

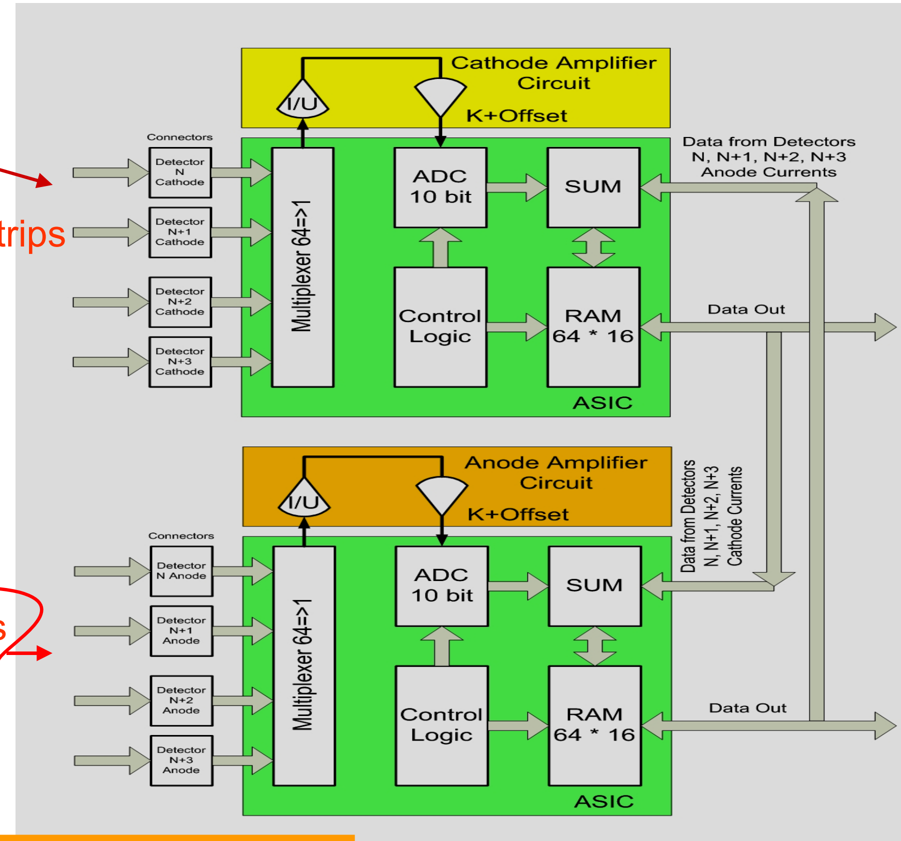
DPSD-516: amorphous silicon strip sensors - high precision position measurements in two coordinates X and Y ~ 10 μm



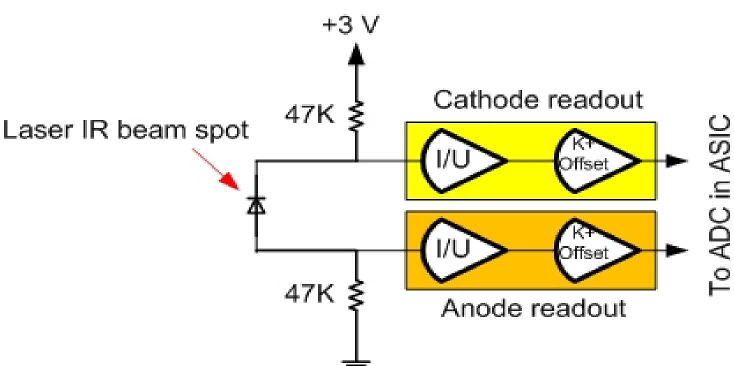
Cathode strips

Anode strips

Schematic view of readout scheme



a-Si –photo-sensitve layer, hydrogenated amorphous silicon, fully active.
ITO transparent electrodes segmented in X,Y strip rows, bottom strips act as ohmic contacts, top operated at 3 V bias voltage



Mean positions ; mx, my

$mx = \Sigma_i \; x_i w_i$

$my = \Sigma_i \; y_i w_i$

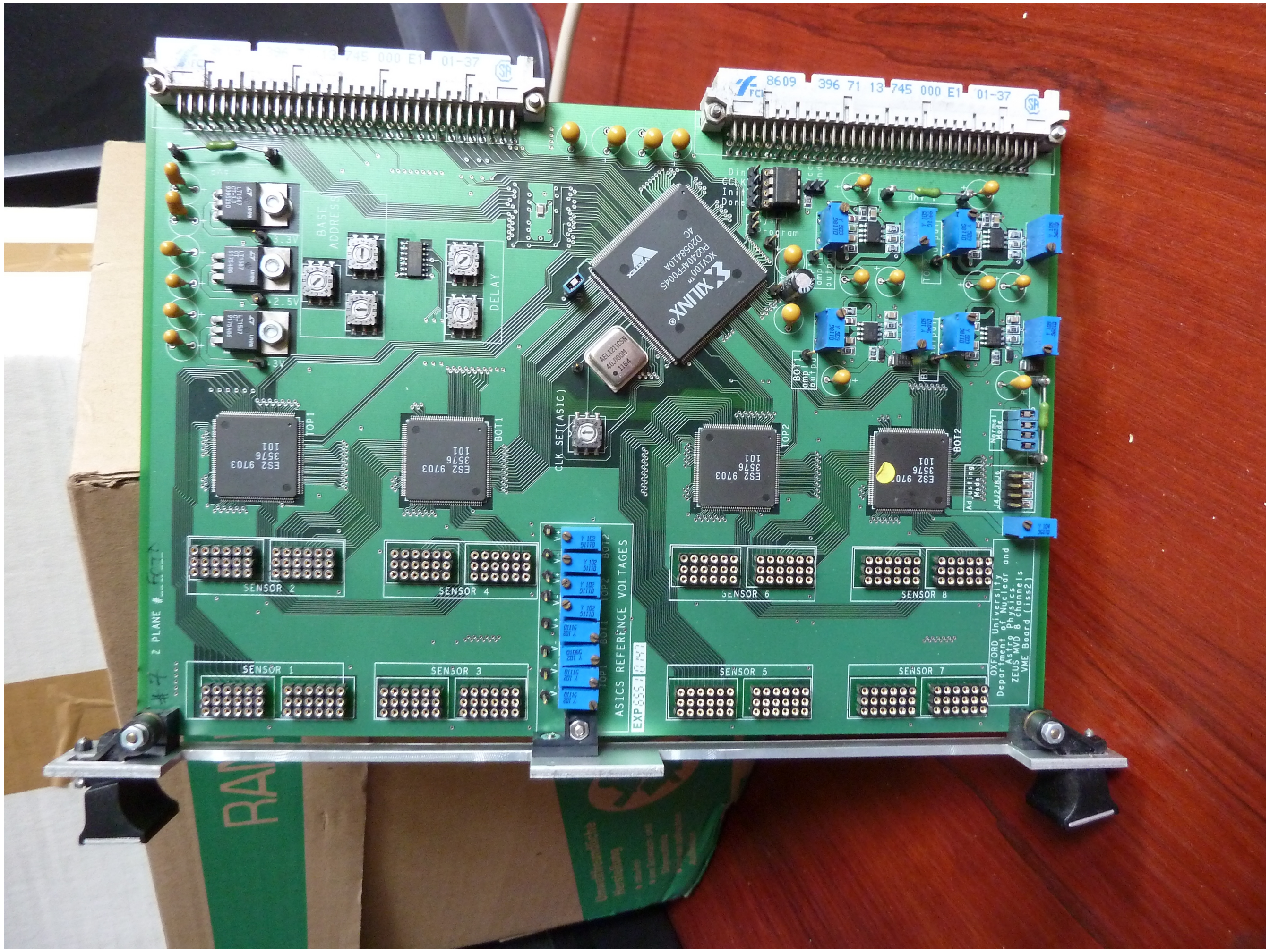
with $w_i = I_i / \Sigma I_i$ $\quad i = 1 \ldots N$

x_i, y_i - strip positions,

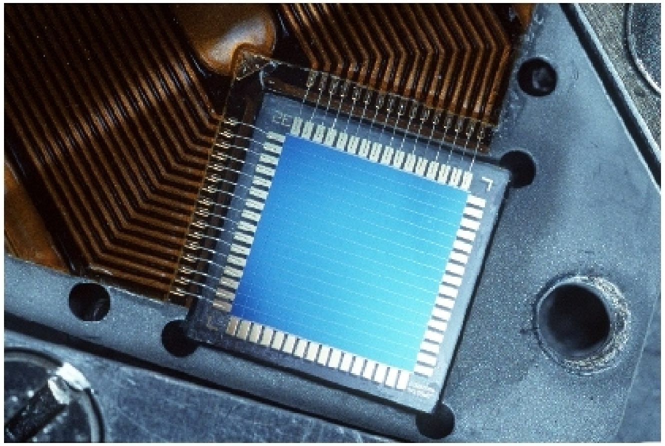
I_i - strip signals

pos. res. depends on signal to noise ratio and geometrical factors Including strip pitch and the number of strips N above some threshold Calculations in local or global coord.

8 channels readout VME board

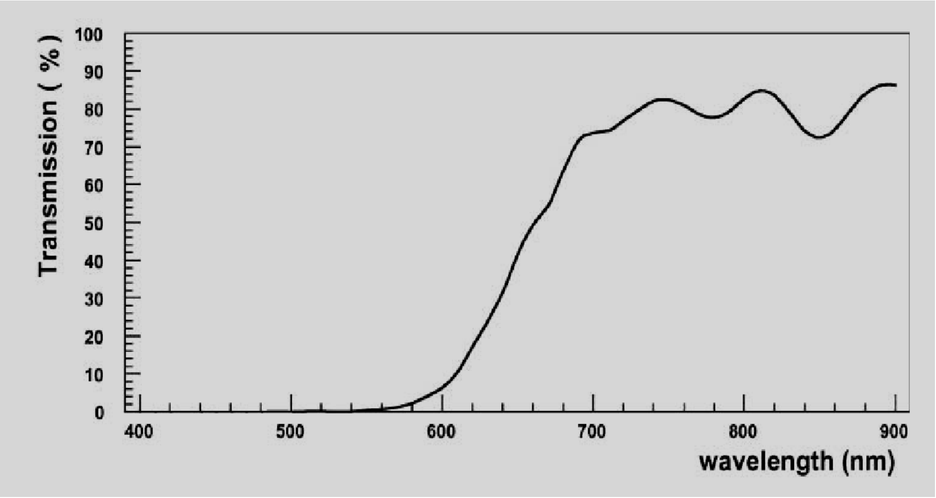


Transparent sensors - Oxford studies (1)

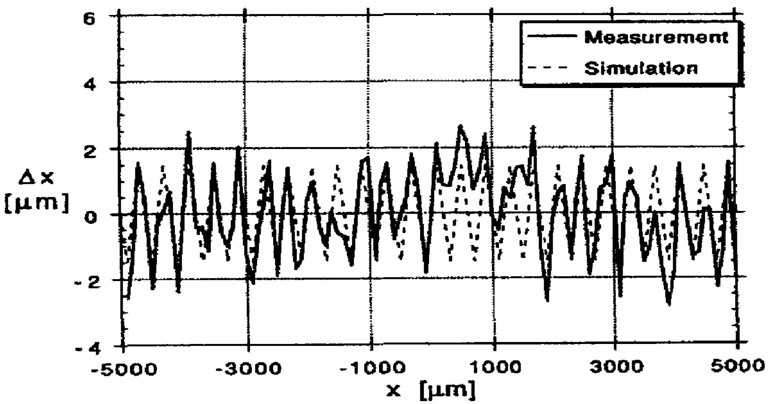


Bonding to flat readout cables

DPSD-516 transmission vs wavelength



Linearity of a-Si sensor



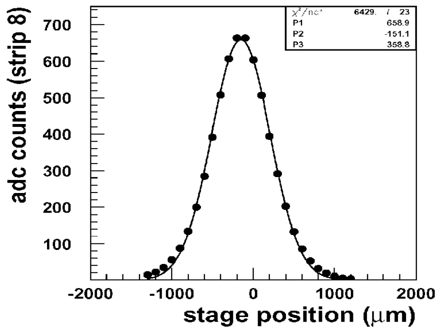
Deviation Δx from true beam position x laser scan (1.8 mm beam diameter) perpendicular to strips

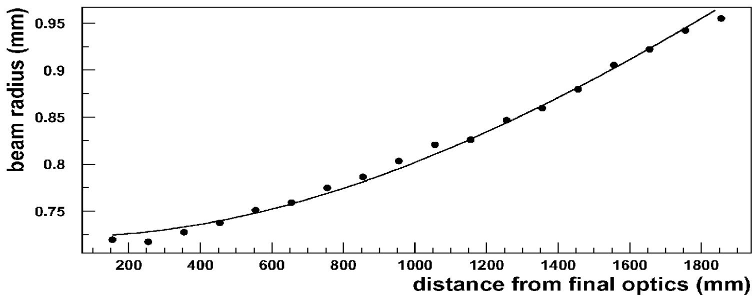
Visible plateau: above 700 μm on the level ~ 85 %.
Such transparency required a choice of the laser with suitable wavelength (~ 780 nm). With high transmission rate one can use several sensors in one laser beam.

Sensor transparency

Transparent sensors – Oxford studies (2)

Shape of laser beam (with λ = 780 nm) was gaussian type and beam divergence was observed. The available active area (also aperture for reference beam) is 5 x 5 mm and beam should be contained in the aperture for required distance in measurements



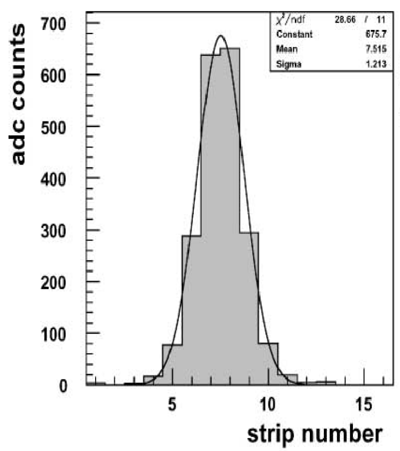


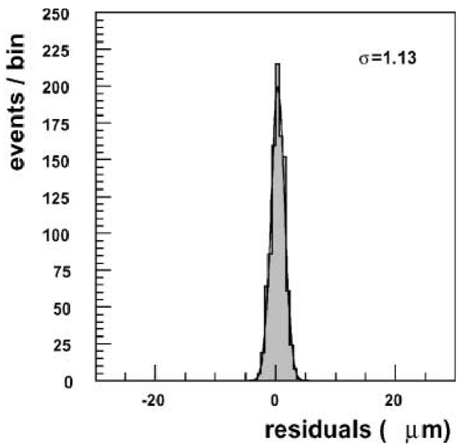
The measured beam profile - Gaussian shape is found

Visible divergence of beam radius values

Studies of characteristics of DPSD sensor mounted on translation stage and on an optical rail system and illuminated by the laser beam. The surface of the sensor was divided into grid and scanned.

Signal distribution from a DPSD sensor



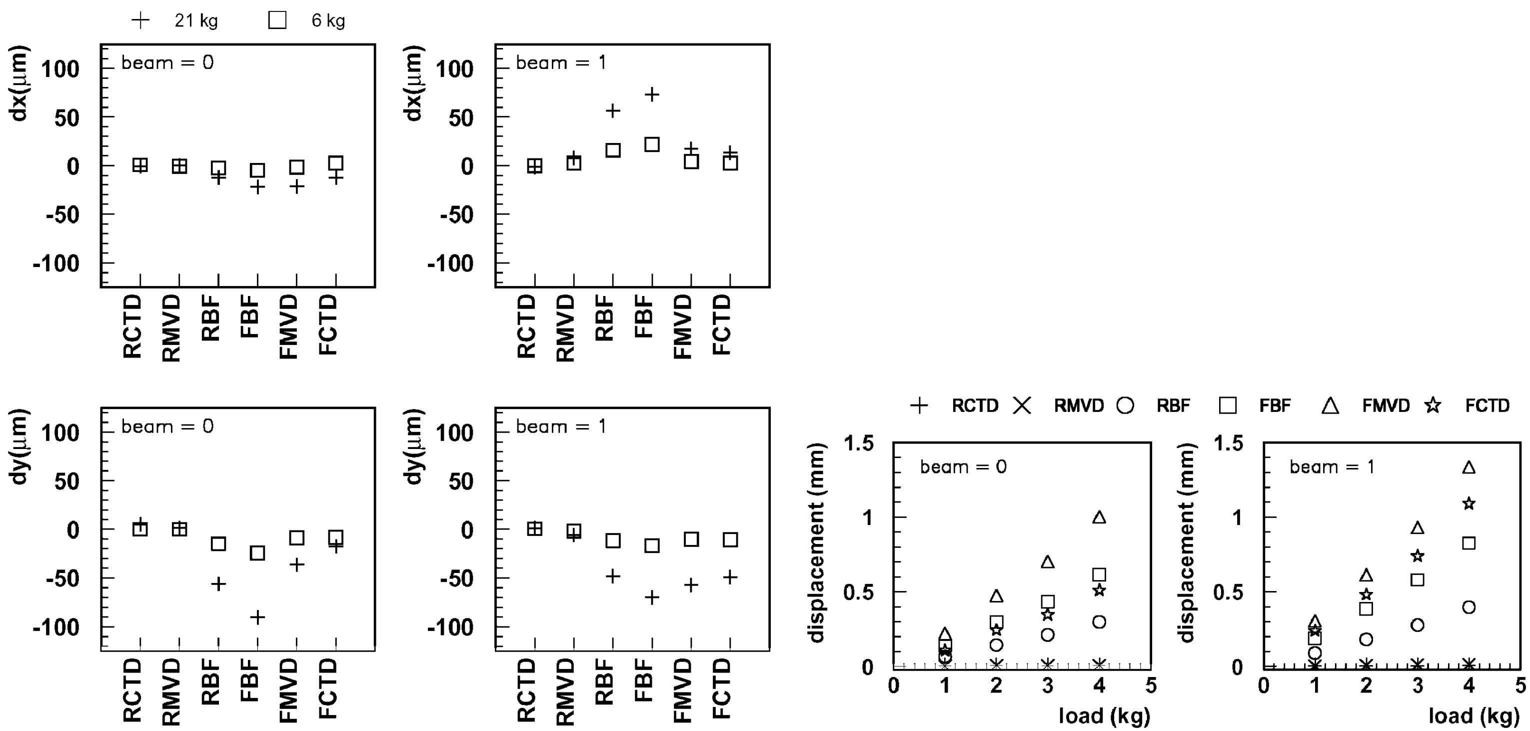


Observaion of ''residuals": calculated as difference between the position of the stage and obtained from sensor – they appeared due to differences in the thickness of the amorphous silicon layer

Transparent sensors – Oxford studies (3)

Sensitivity of measurements on possible sag and/or torsion effect

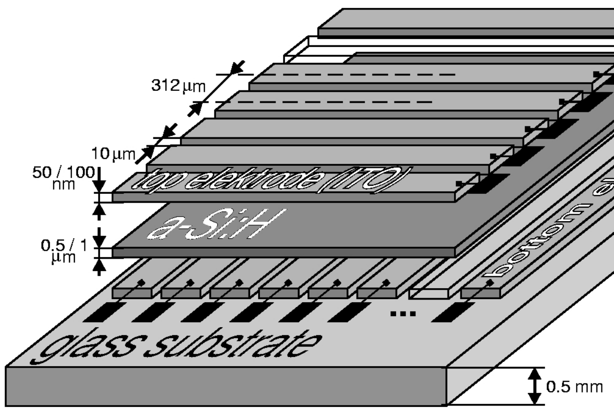
An example of measurements:

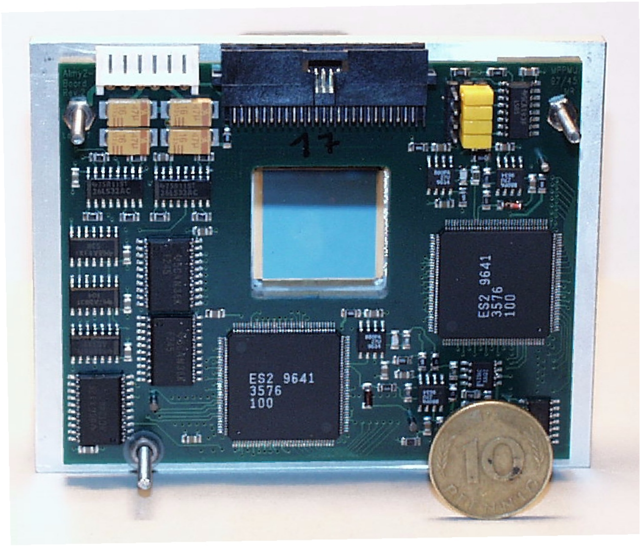


The displacement measured with DPSD sensors were in agrement with expectations

Possible update of LAS system with ALMY sensors

There is a plan in future replace the DPSD sensors by next generation " ALMY" sensors using in CMS





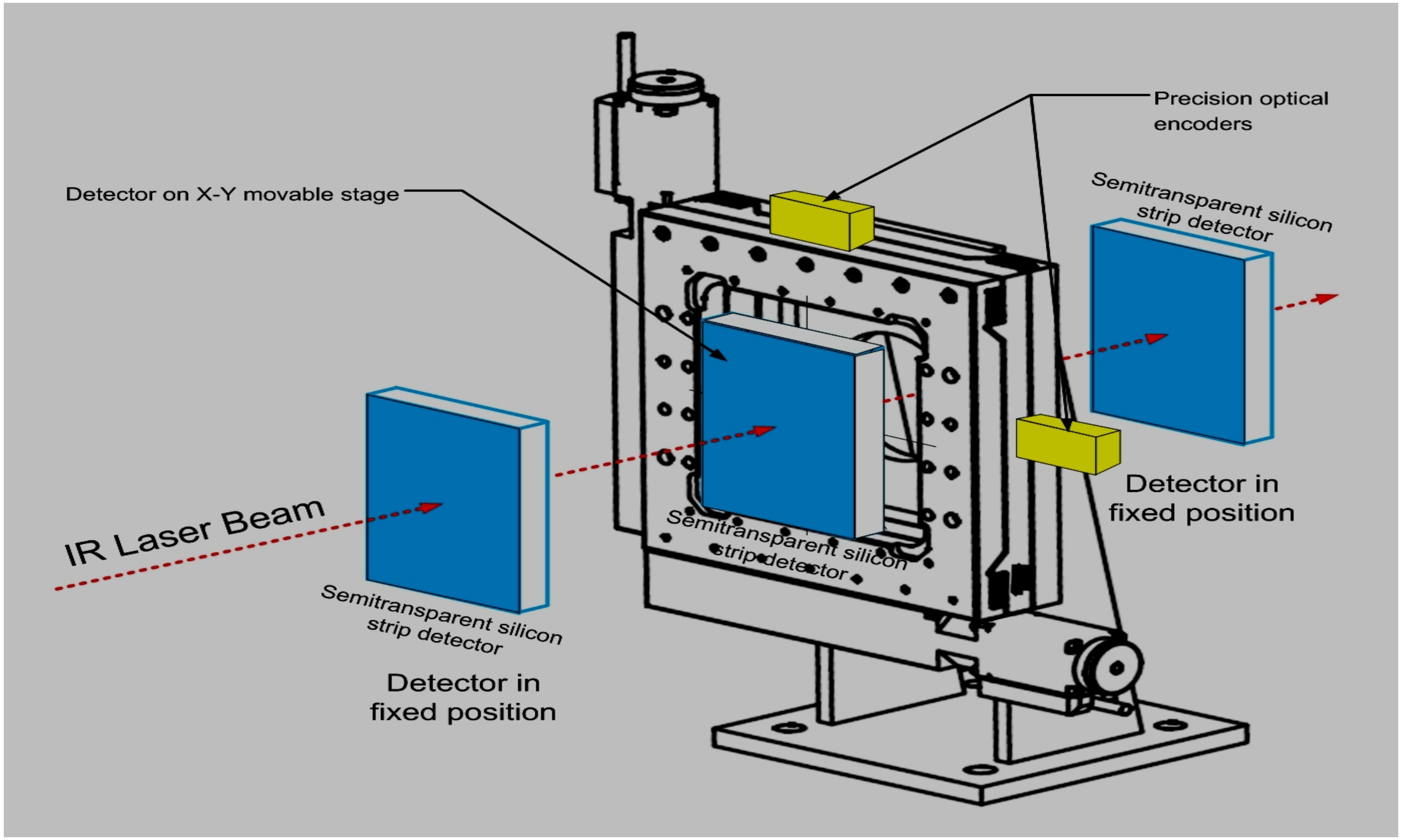
The typical properties of ALMY sensors

Properties of ALMY sensors

Active area	20×20 mm^2
Number of strips	64×64
Strip pitch	312 μm
Strip width	300 μm
a-Si:H thickness	$0.2 - 1$ μm
Bias voltage	$1 - 3$ V
Hall mobility $\mu^H_{p,n}$	$10^{-2} - 10^{-4}$ [cm^2/Vs]
Effective band gap	0.82 eV
Transmittance at $\lambda = 780$ nm	$80 - 90\%$
Position resolution (linearity)	1 μm
Beam deflection error	≤ 3 μrad

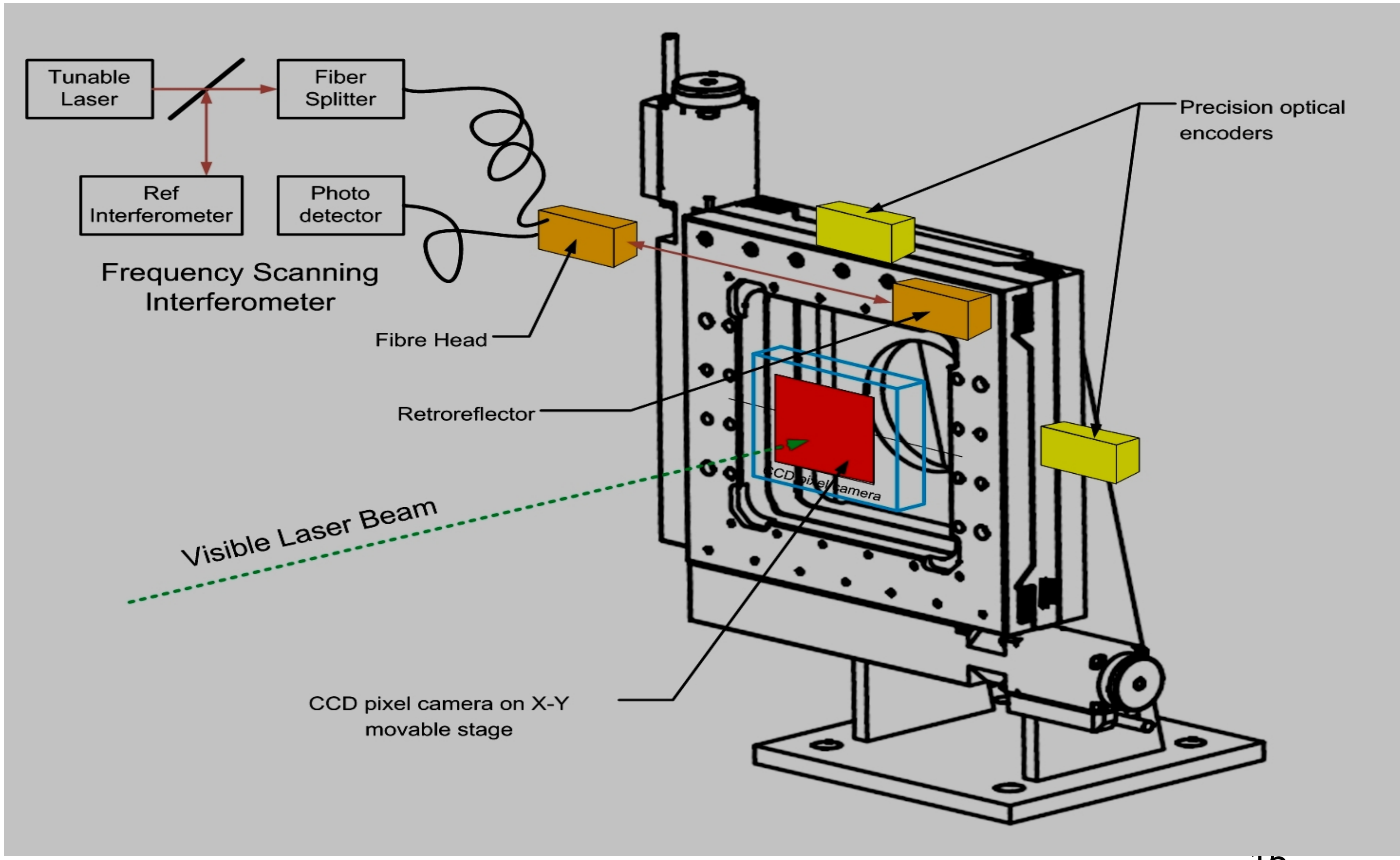
Recent and future activities on LAS development (1)

- Laboratory setup using Oxford sensors, laser, optical and readout electronics elements will be mounted
- Simulation of the setup (using also SIMULGEO program) to compare with laboratory measurements will be performed
- Laboratory and test beam measurements will be done with LumiCal prototype as the next step in work



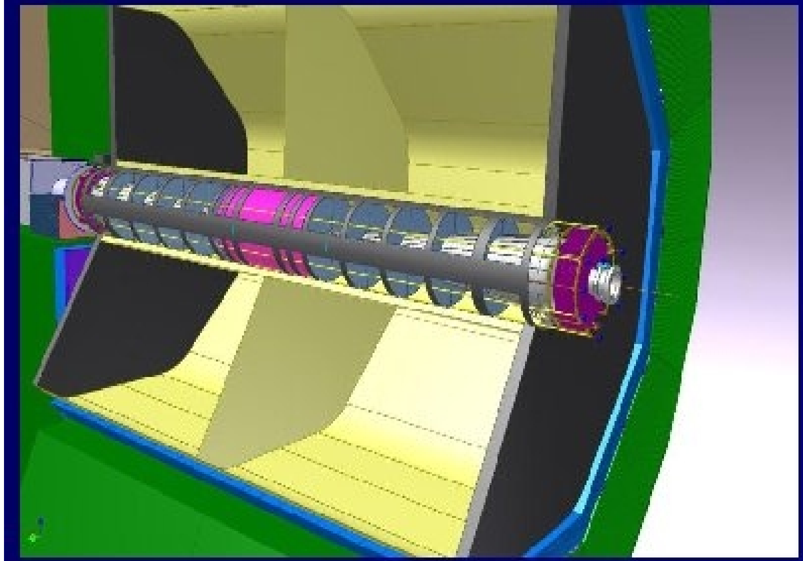
Recent and future activities on LAS development (2)

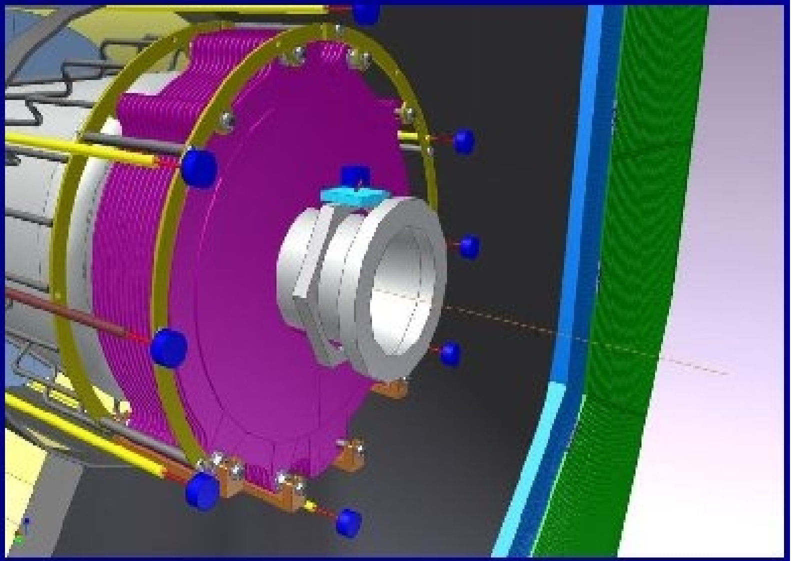
- Build FSI test setup
- LAB and on test beam mesurements
- Combine two LAS elements :transparent sensors and FSI in one alignment system
- Perform the test beam measurements with AIDA LumiCal prototype

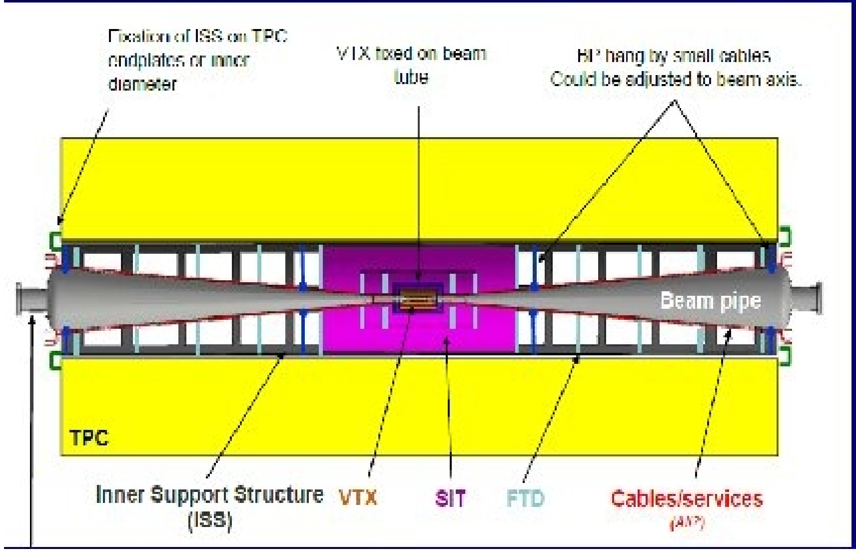


DAQ system of LAS will be included in global DAQ system prepared for ILD

Mechanical aspect of alignment LumiCal calorimeters

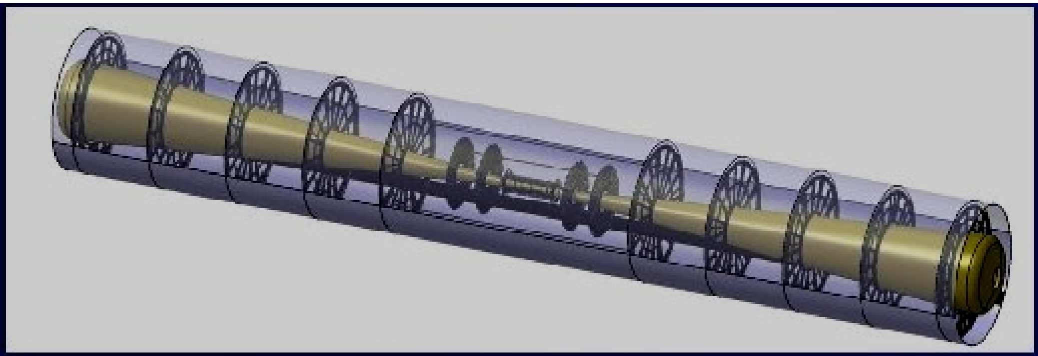


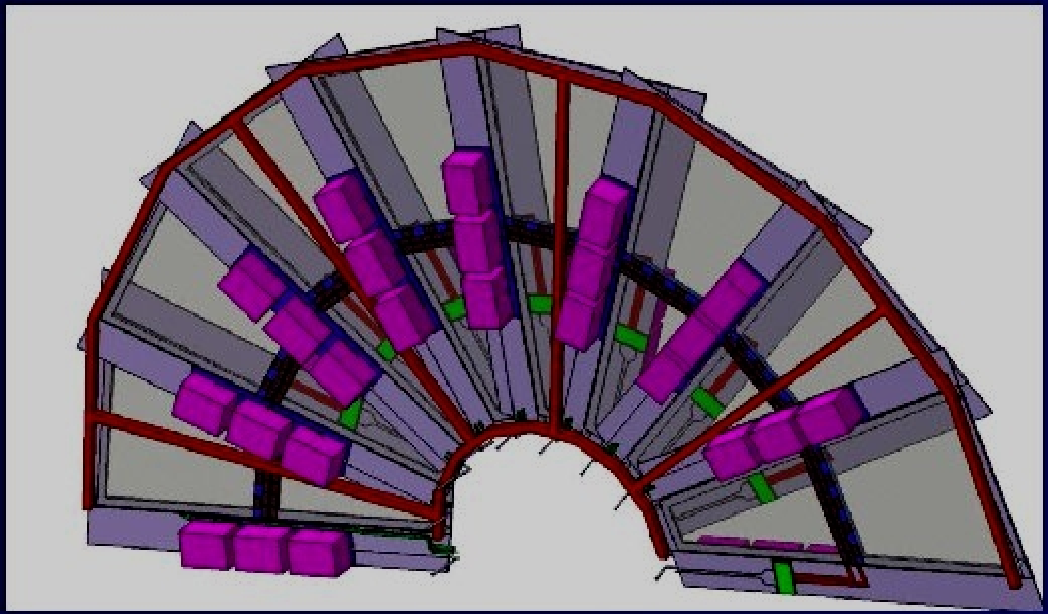


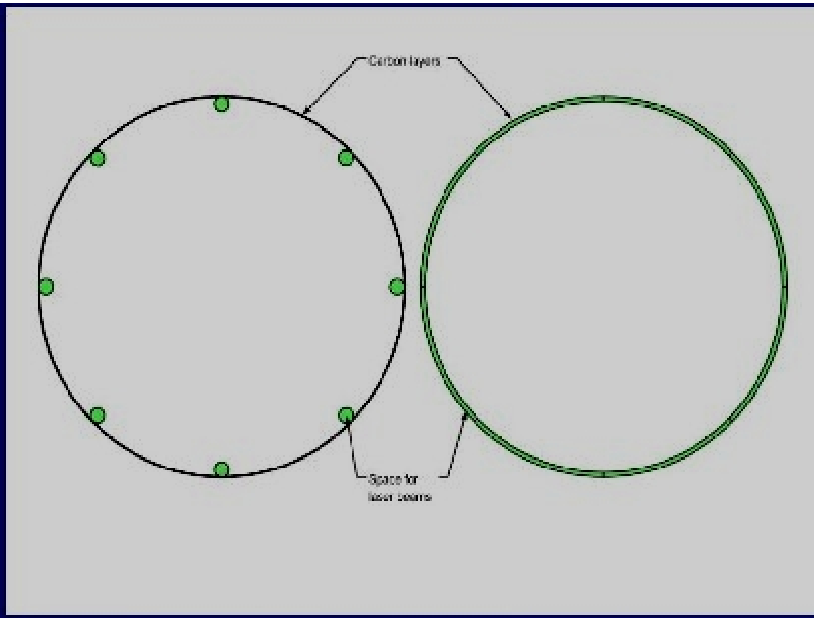


Carbon tube made with pipes for laser beams (higher stiffness)
Possible (?) windows in beam pipe for laser beams

LumiCal calorimeters - space for laser beams



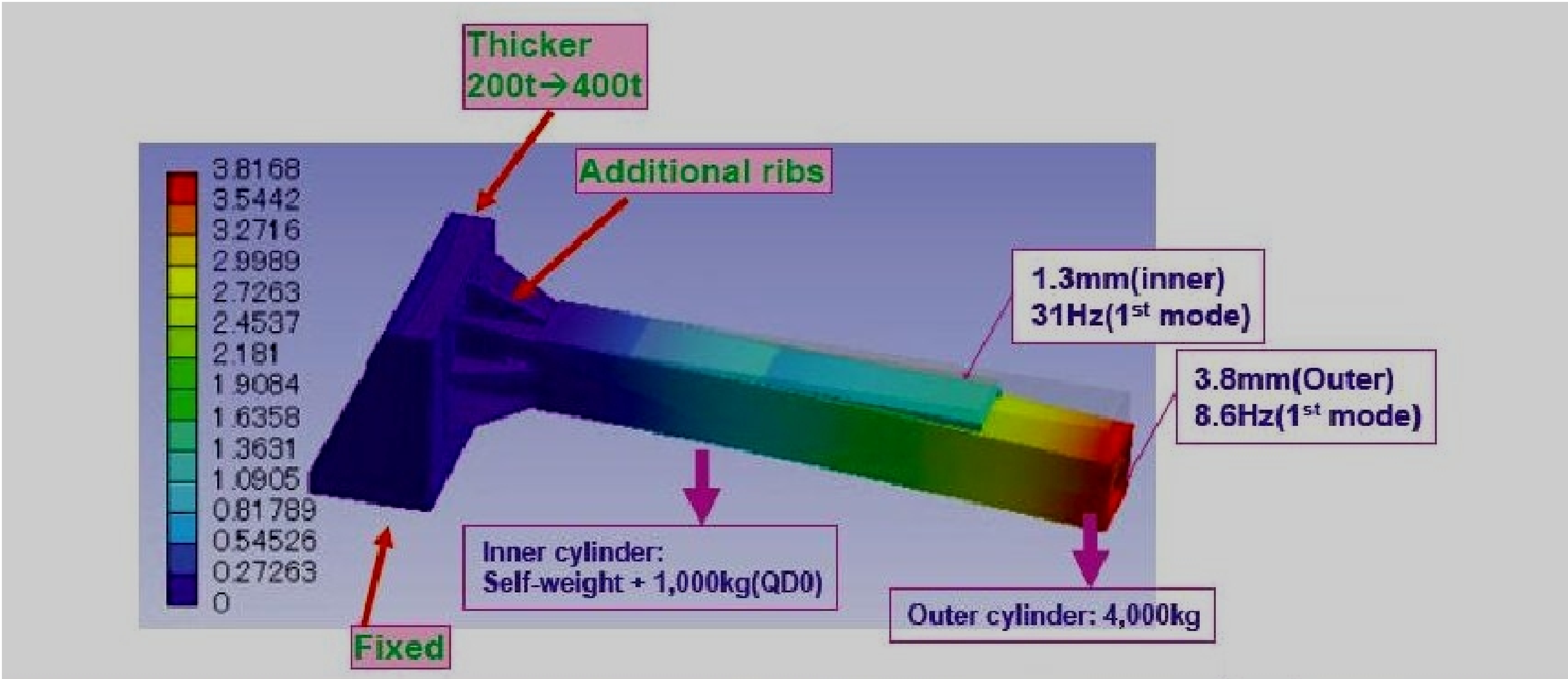




Carbon tube with glued carbon pipes (left) – less material, more stiffness, limited number of laser beams

Double layer carbon tube (right) – less material, more stiffness, lot of space for many laser beams

Initial LumiCal position



Supporting tube for LumiCal (also for BeamCal) will sink ~4 mm under load. Possible problems with initial alignment and during opening/closing ILD Detector.

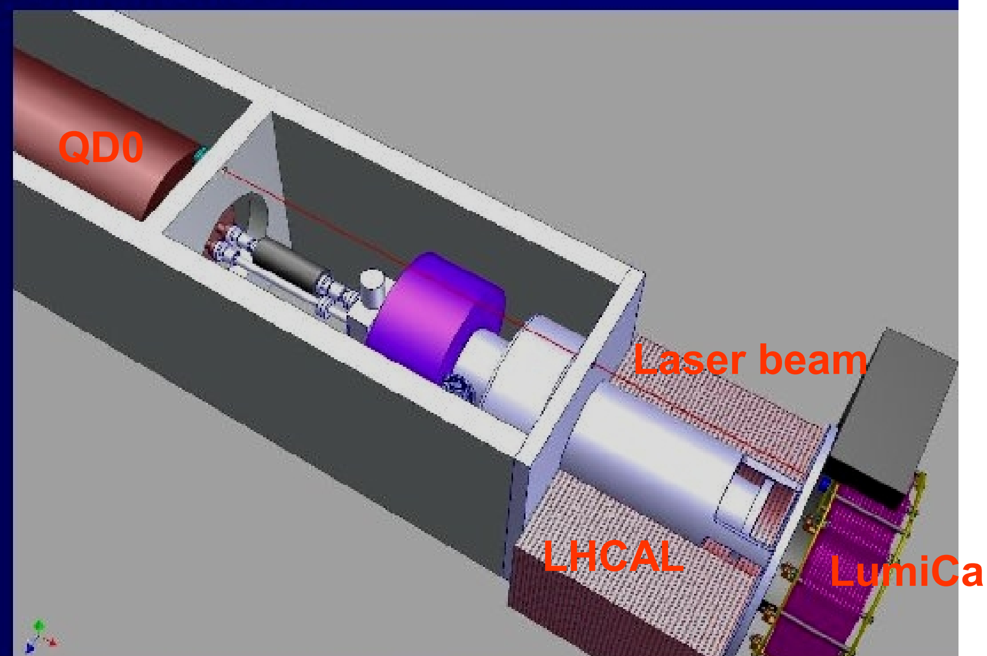
Sag and torsion of supporting tube can be measured with transparent sensors

Reference points

There are several points in LumiCal's neighborhood in ILD to be used as reference for position measurement:

- The best – QD0
- Very good – Beam Position Monitors
- Good (?) – Beam pipe

How to get to them with laser beams?



Possible measurements of the relative distances to QD0 in X,Y and Z directions

Conclusions

- Start work on laser alignment system which can be used by LumiCal and Vertex detectors. The extensive simulations will be the important part of the work. The LAS project required collaboration all inner detectors groups within ILD

- The final system will contain the transparent sensors and FSI

- The reference frame like QD0 magnet will be crucial for alignment system