LumiCal Alignment System
Status report

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The design of the alignment system

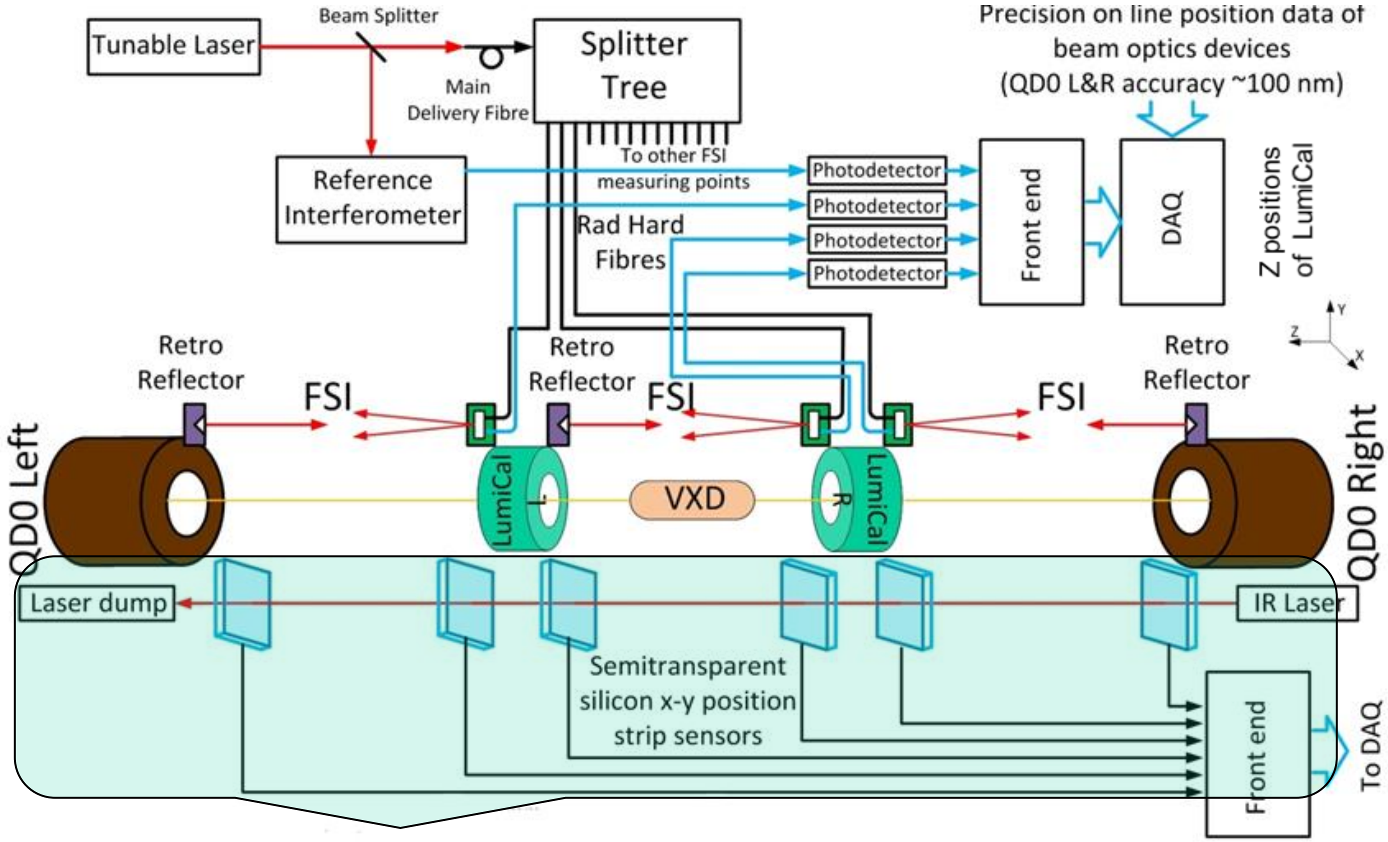
The alignment system may include two components:

- IR laser + PSD system:

infra-red laser beam and semi-transparent position sensitive detectors

- FSI system:

tunable laser(s), beam splitters, isolator, Fabry-Perot interferometer, retroreflectors, fibers, collimators, photodetectors, lens

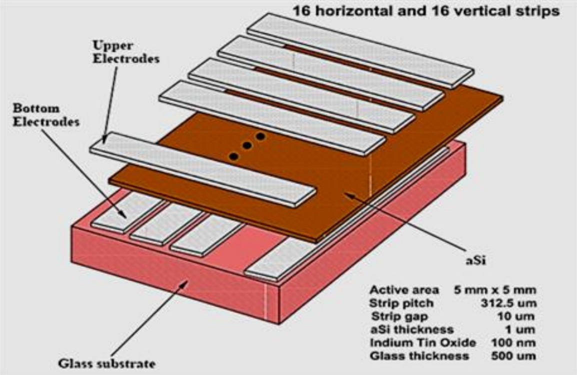


FSI - Frequency Scanned Interferometry

The absolute distance measurements between LumiCal's

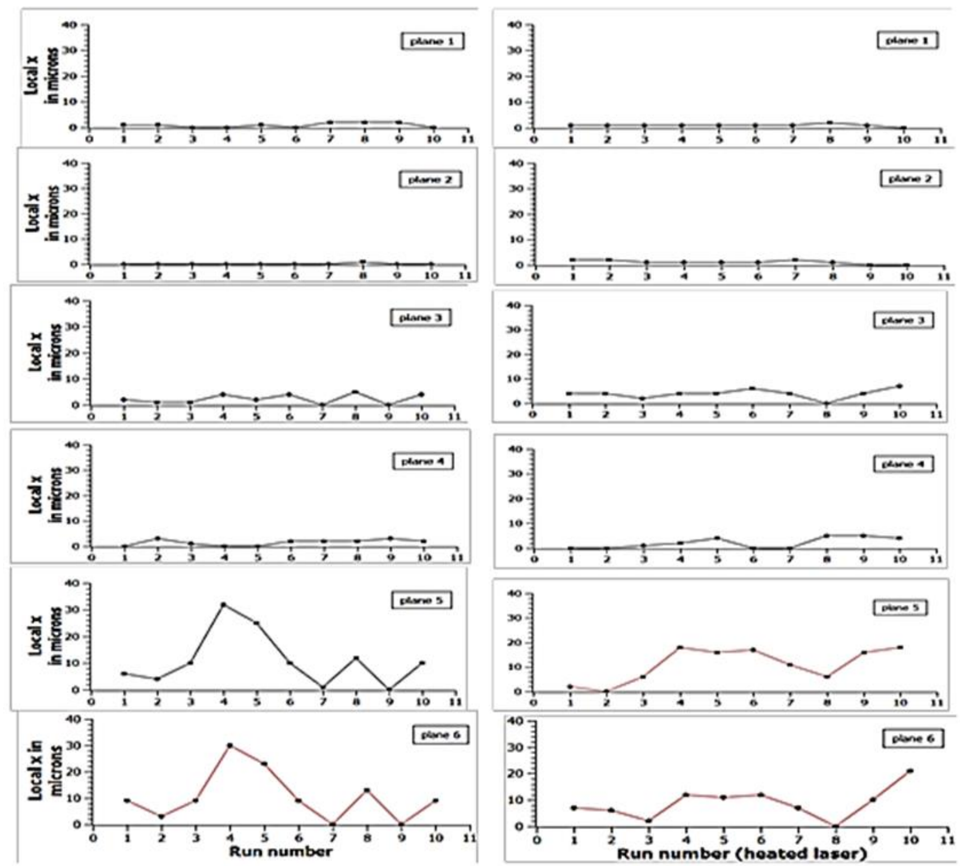
IR Laser + PSD

Relative positions of LumiCal's and displacements of the internal Si layers

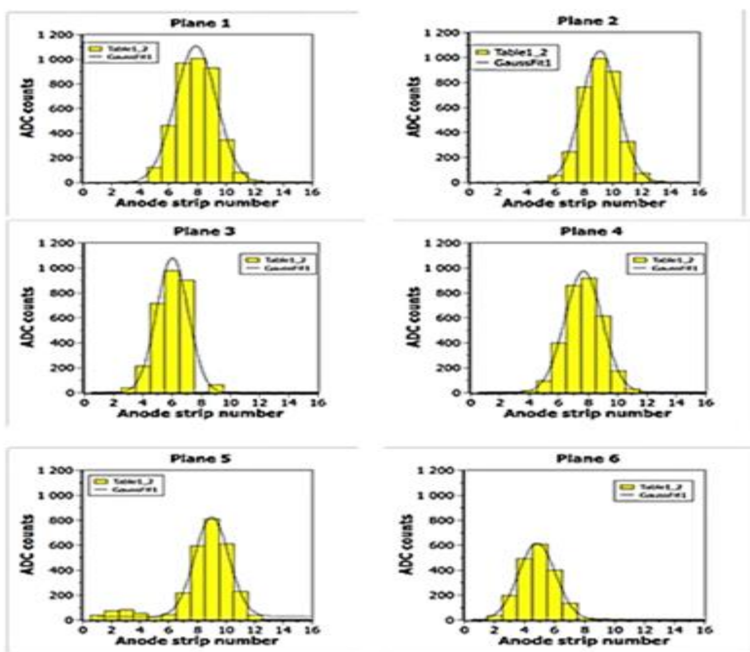


Position sensitive detectors

Laser beam position measurements

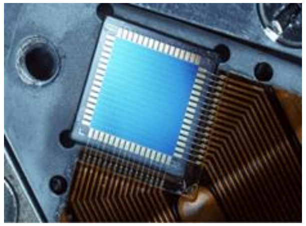


Light transmission: above 85% for λ > 780 nm

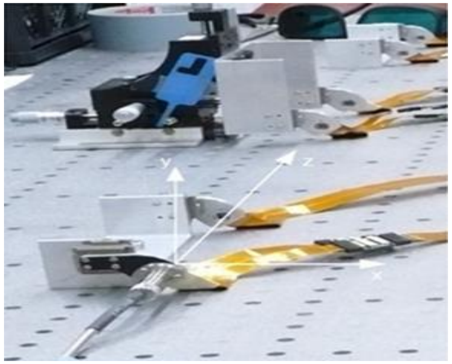


An example: beam profile signals from the X-strips along the moving beam. The available aperture for laser beam is 5 x 5 mm^2 for sensor. The mean positions **mx_i** were obtained from a Gaussian fit to observed signals

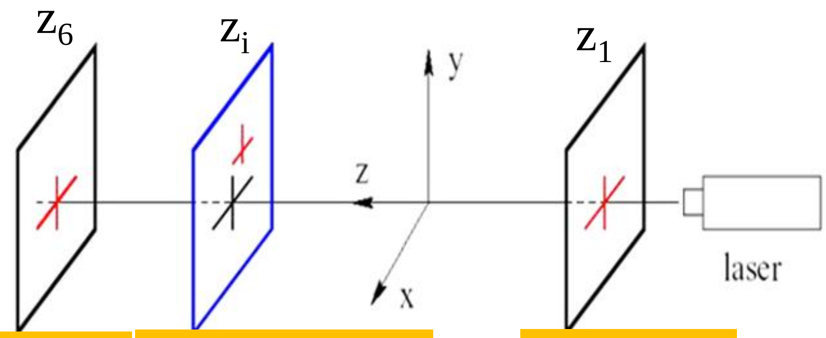
Fluctuations increasing with distance along the laser beam. They can be related to:
laser instability with an increase of beam diameter and noise of the sensor.
Data from laser working for hours show smaller fluctuations



Position measurements



The method of using a residual approach



ref_plane6

plane_i: sensor 3 and 4

ref_plane1

The mean position of sensors 1 and 6, **mx, my** define the reference straight line.

The expected position of the beam at sensor plane i :

$$\boxed{\Delta x_i = mx_1 \frac{z_6 - z_i}{z_6 - z_1} + mx_6 \frac{z_i - z_1}{z_6 - z_1}}$$

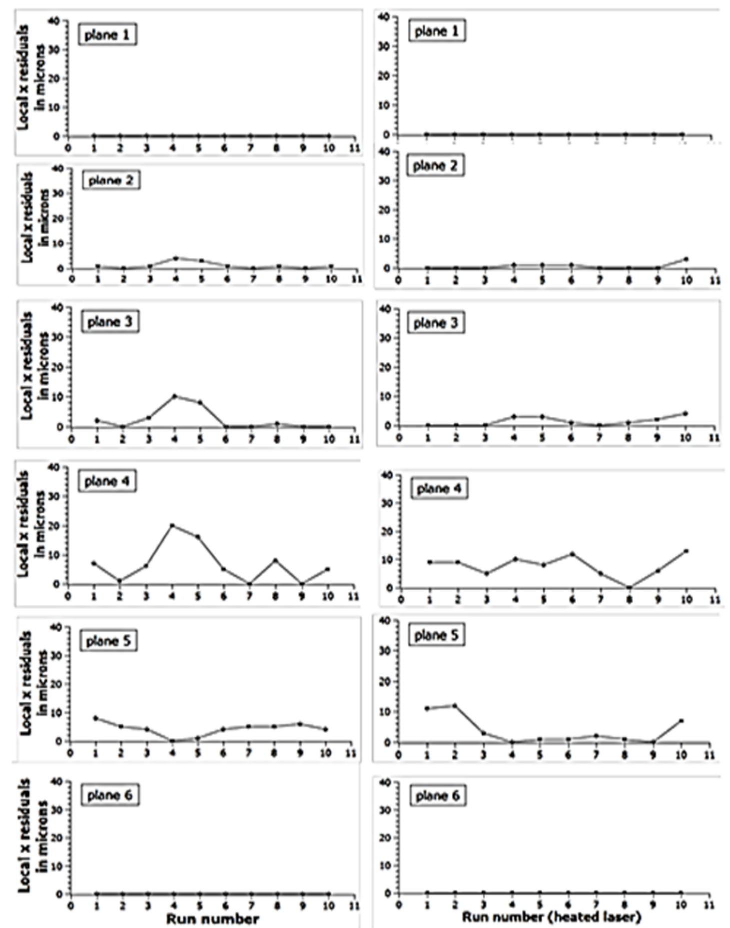
$$\boxed{\Delta y_i = my_1 \frac{z_6 - z_i}{z_6 - z_1} + my_6 \frac{z_i - z_1}{z_6 - z_1}}$$

Residuals:

$Rx_i = \Delta x_i - mx_i$

$Ry_i = \Delta y_i - my_i$

Used residuals for analysis beam pos. data – reduction of fluctuations



Position sensitive detectors: status

- Using the components from University of Oxford (semi-transparent silicon sensors, lasers, readout electronics) we built a simple setup - prototype of the laser alignment system.

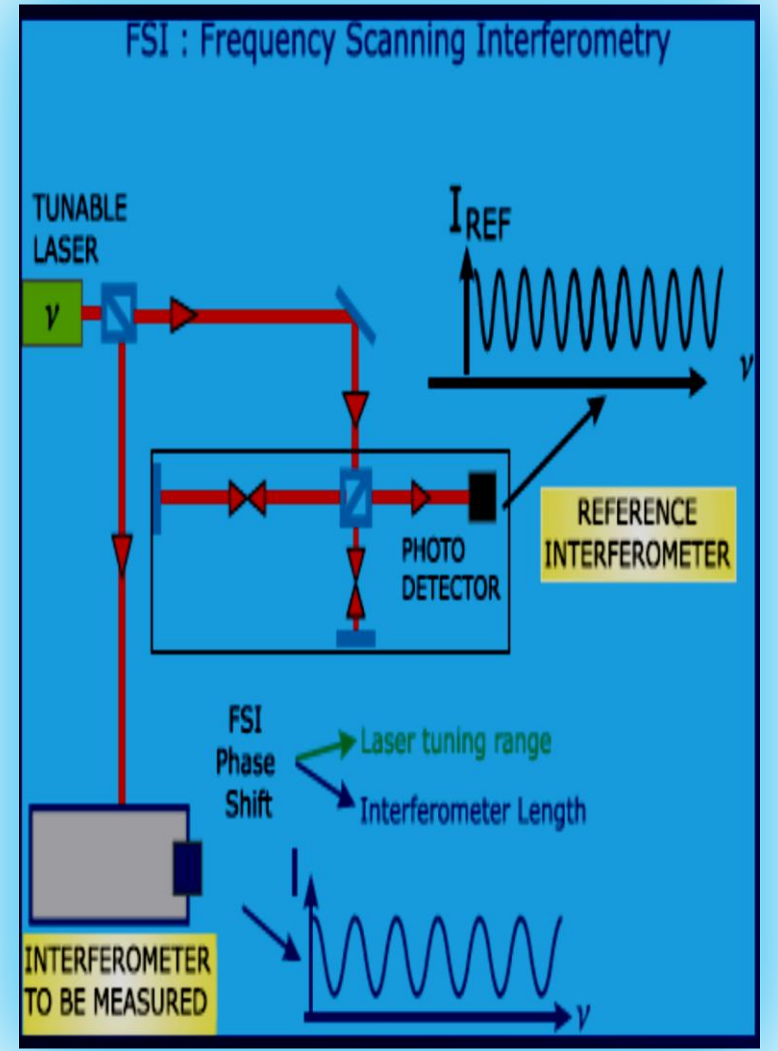
- The measurement of displacements performed with the help of this prototype provided the value of about 20 μm as the accuracy in the measurement positions.
One can expect that such a kind of laser alignment system could be used in the future to monitor the relative displacement of a particular detector.

- The elements used in the prototype (lasers, sensors, readout electronics, DAQ) are older than 10 years and are large and heavy and hence it would be more difficult to install such a system on the test beam. Moreover, minimization is required for future applications.

- Possible solution: as the new X,Y sensors are practically unachievable, one should try to use results of EUDET project on transmissive, microstrip sensors (1x1 cm^2) which give output information related to one plane. X, Y data can be obtained from two such sensors put closely to each other (to build a system Isuch as a telescope (tracker).
The readout and DAQ system for these sensors were built by a Spanish company ALIBAVA and a basic version costs ~ 6000 euros for reading of 16 planes sensors. Of course, additional money will be spent on sensors production.

FSI - interferometric absolute distance measurement

FSI is based on a tunable laser and a frequency scan range subsystem using Fabry-Perot (FP) interferometer.



When optical frequency of the laser is scanned continuously over the range $\Delta\nu$, then for a fixed path interferometer the optical beams will constructively and destructively interfere and will form fringes.

The frequency scan range is defined by:

$\Delta\nu = r * FSR$

FSR – free spectral range – is characteristic for FP

r – number of FSR resonances detected during $\Delta\nu$ scan.

Together with the knowledge about

N – number of detected fringes

n- refractive index of the propagation medium,

the measured distance L

which is optical path difference OPD between two arms of a Michelson interferometer:

is given by:

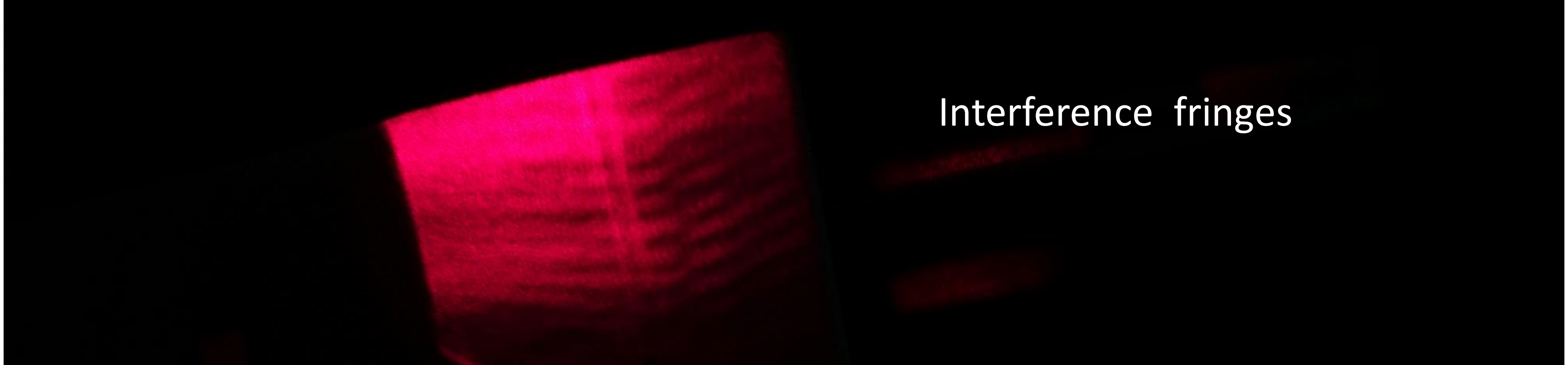
$$L = N/2 * c /(r * FSR * n)$$

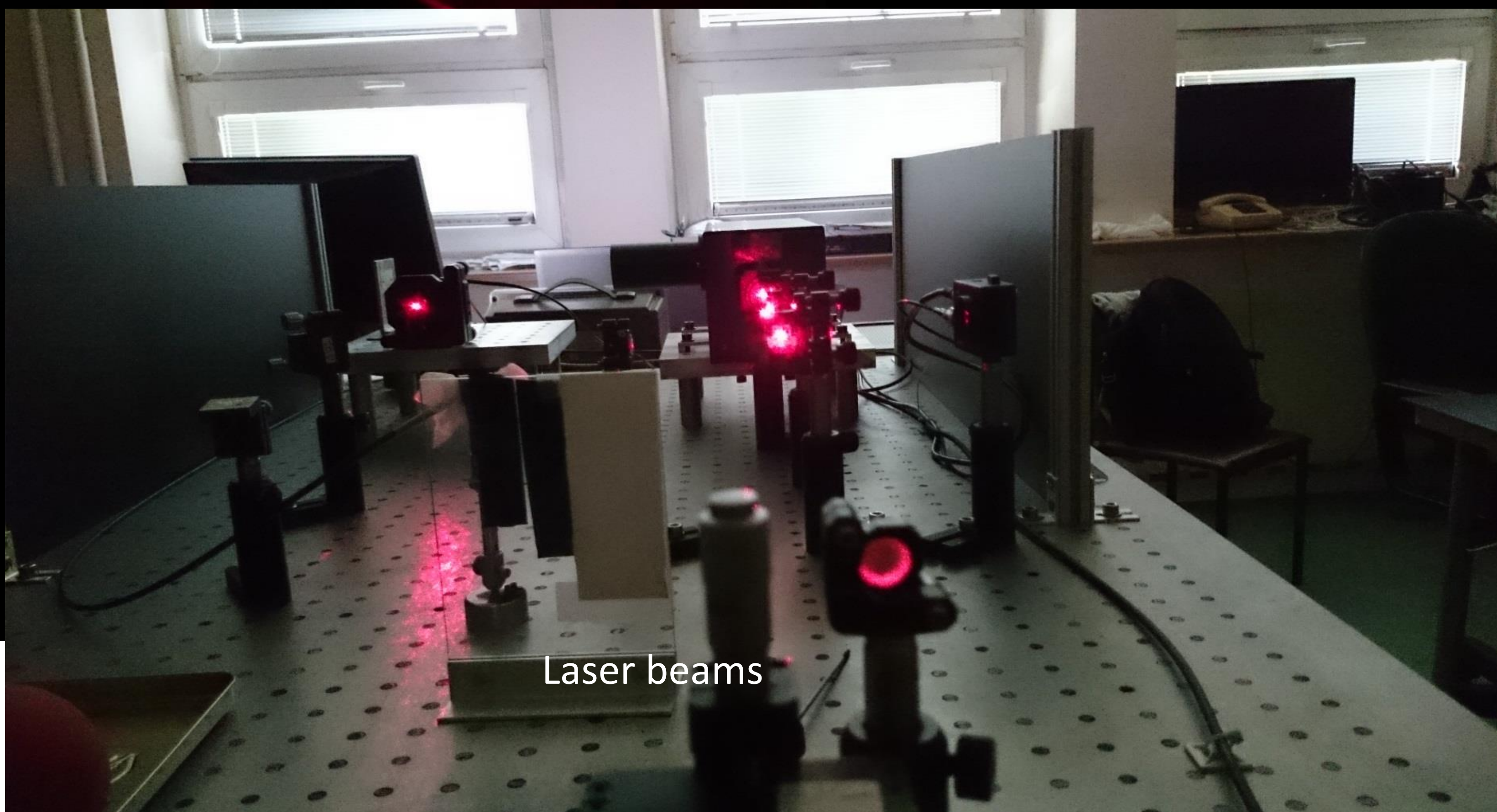
c – speed of light

FSR for FP is equal 1.5 GHz (0.002 nm)

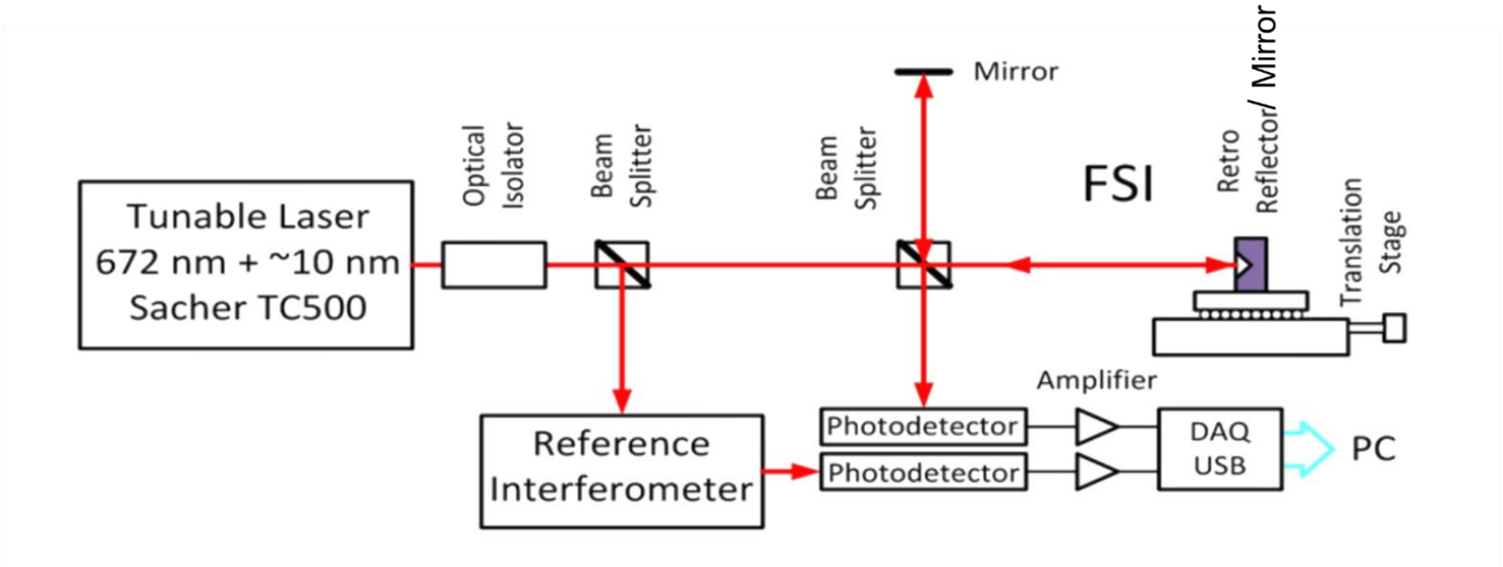
The experimental setup used in the FSI study

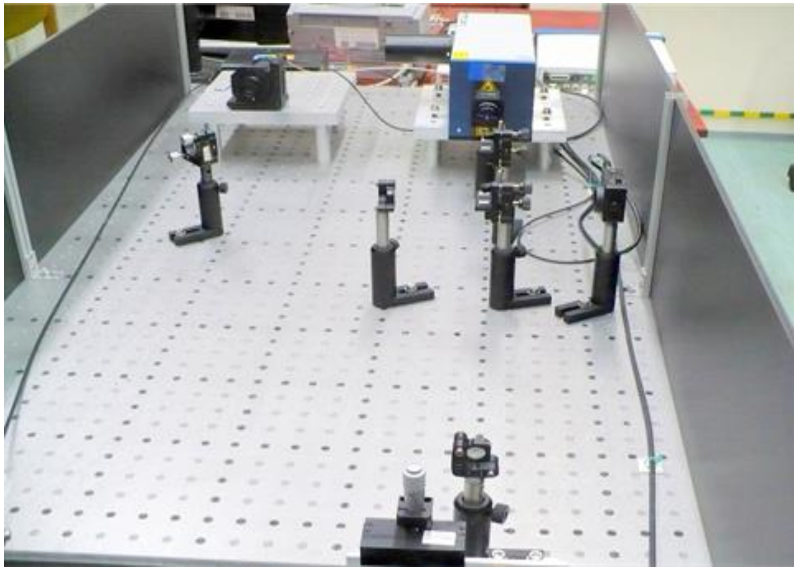
The FSI system demonstration



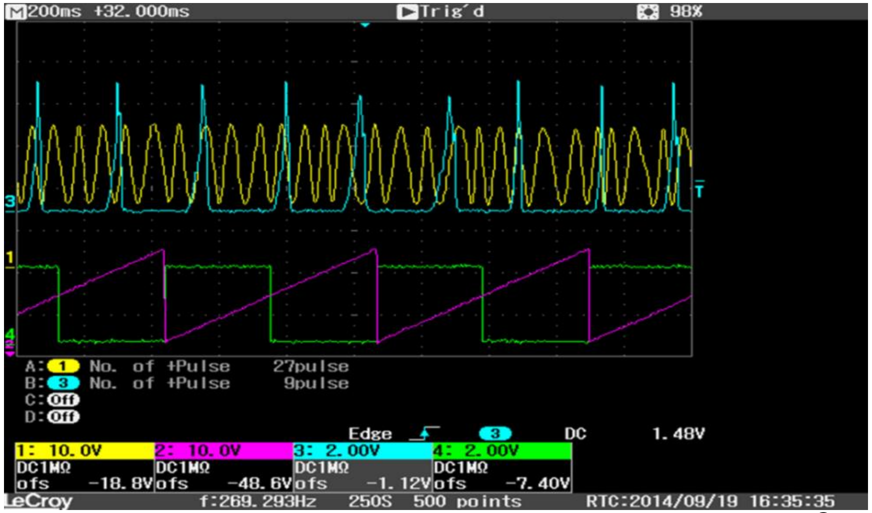


First FSI prototype





Typical view displayed by the oscilloscope



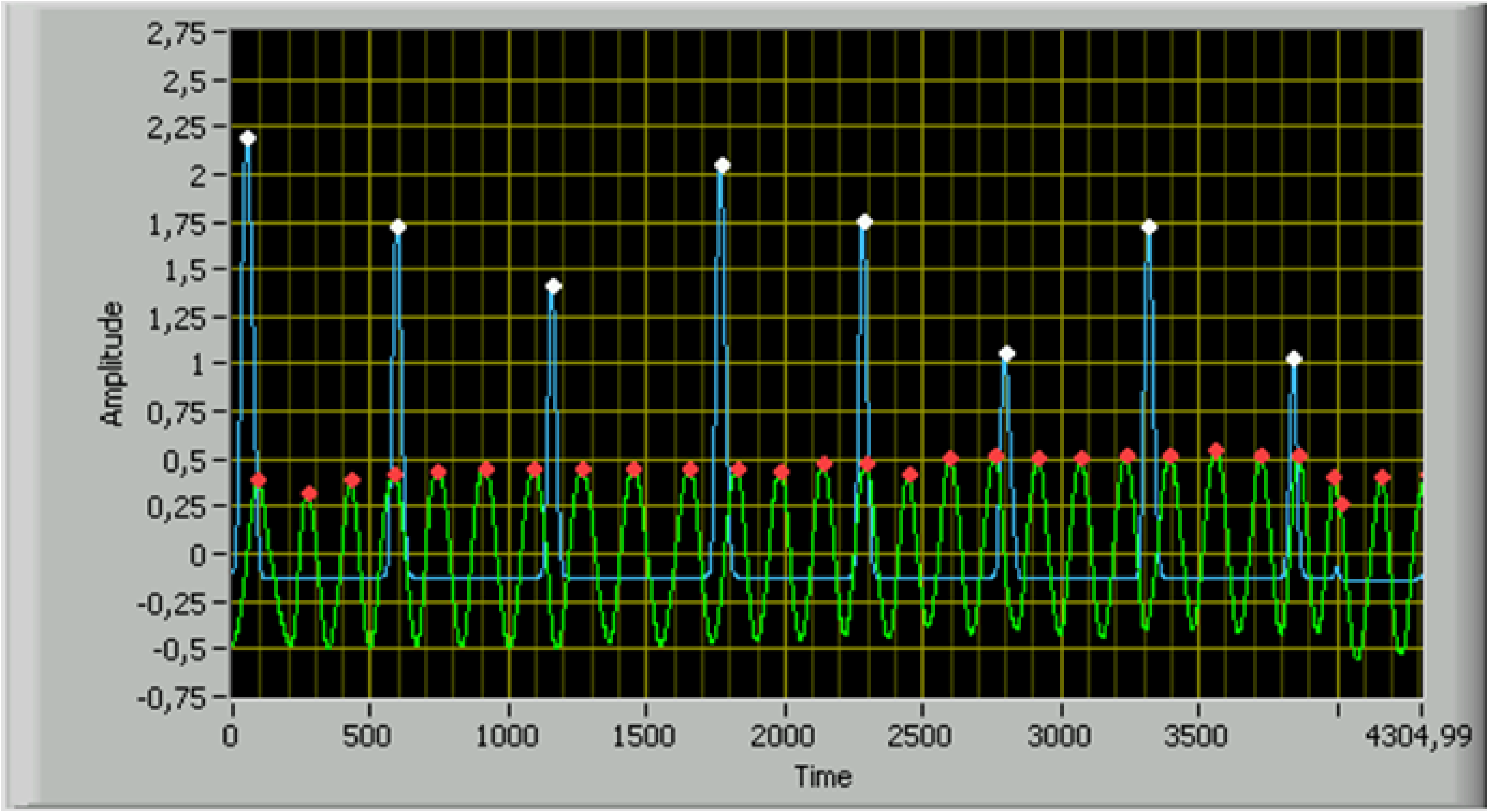
Laboratory: Data Acquisition

Measured signals in 1 sec window

Filtered signals with the same window: 5000 samples/sec

A screenshot of the front panel of the DAQ (LabVIEW environment). Can be also used to control the temperature and movement of laser motor

First measurements

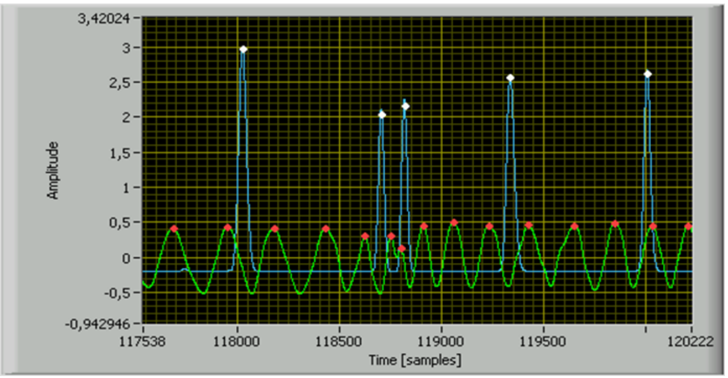


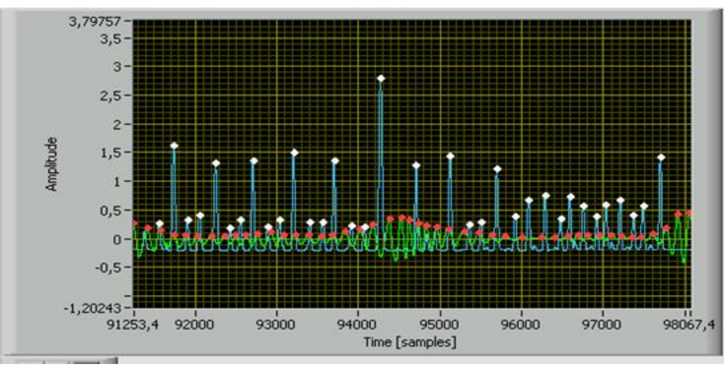
Typical FSI interferometer and Fabry-Perot signals used in distance calculations.
Amplitudes are indicated by dots for illustration. The maximal available $\Delta\nu$ range is above 6 THz.

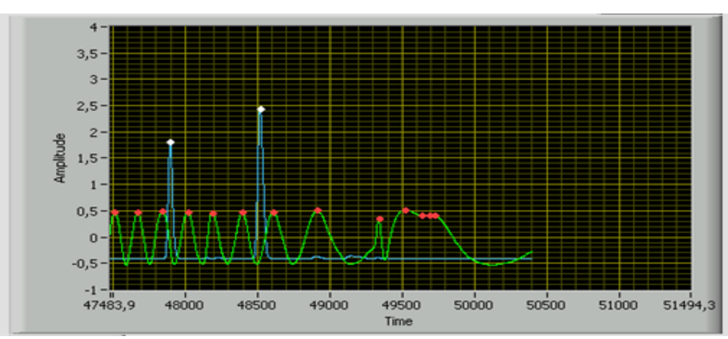
Problem: non standard output

Several non typical output signals were observed during the frequency scan

Examples:







Possible reasons:

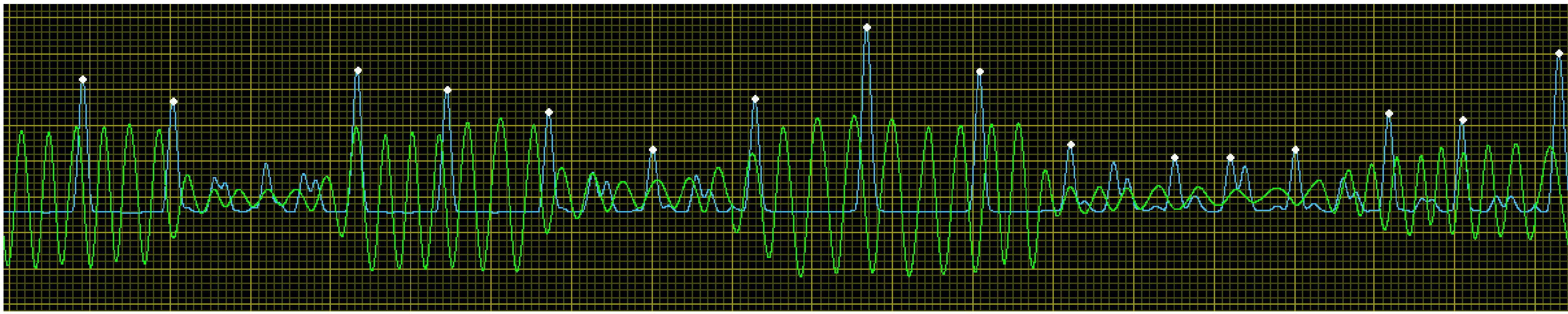
- during the scan over the required $\Delta\nu$ range, the laser (primarily running in a single mode) switches to other (multi) modes - spontaneous „hop”. This behaviour repeats quiet regularly and weakly depends on the velocity of the scan. The most likely explanation is a problem with the running motor.
  Such discontinuities make the measurements problematic and the   possible temporary solution is the scan   composed of the number of shorter frequency scans

- influence of other effects, such as temperature changes, vibration, drift.

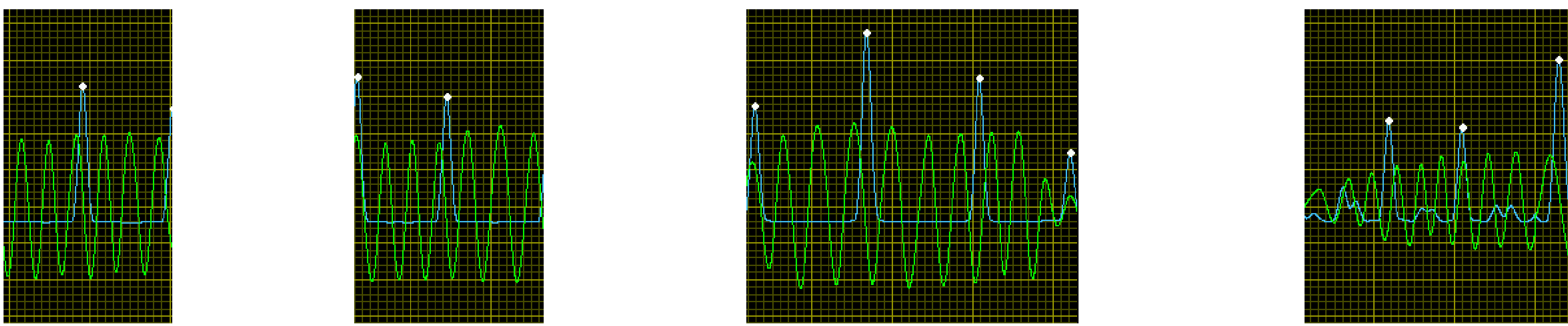
Futher research is necessary, in particular checking the laser quality by the producer.

Method of measurements

Scan over the whole $\Delta\nu$ range



Measurements in the selected regions of $\Delta\nu$ are not perfect but acceptable



FSI - status

- The first experimental setup, including optical elements and DAQ system was built and tested

- During the scan over the available $\Delta\nu$ range several non standard signals were recorded. Most probably, the nature of the observed problems has a source in inproper work of the laser motor and requires the producer intervention.
  An attempt to carry out distance measurements in a continuous manner over the whole range of $\Delta\nu$ leads to large fluctuations in final results with the error exceeding even 1 mm.

- As the results, the measurements can only be made in separated intervals of $\Delta\nu$.
  The first such measurements led to σ error on the level of 150 μm.

- The complete analysis should take into account this restriction together with the impact of other effects such as changes in temperature, vibration, drift, …
  of course if Sacher laser still will allow us to do this.

Conclusion and Future expectations

- The current design of the LumiCal alignment system is based on two methods for displacement measurements. They are related to:
  - semi-transparent sensors
  - and interference phenomena of the laser beams.

- Simple prototypes were built to test both methods.

- The preliminary measurements made with help of both prototypes give hope to use these methods in the future for the final alignment system.

- This will require the global approach to the measurement of the positions of Lumical (if still such a system will be needded).

- However, the implementation of the new system however, will involve high costs (replacement of existing optical elements and the need to purchasing the new ones), man power and possible cooperation with other forward detectors and the machine people (magnets QD0).