Study and Development of a Laser Based Alignment System

1. Introduction

Background

- Compact Linear Collider (CLIC study) requires tight pre-alignment of beam related components
- Components to be aligned with 10 µm accuracy (1σ) over a sliding window of 200 m along the 20 km of linac

Problem

- Existing systems (based on stretched wire, water level) not fully satisfying because of cost, difficult implementation
- Existing systems to be compared with a system based on different technological principle

Proposal of solution

- Laser beam as straight line reference
- Camera combined with open/close shutter to measure distance between laser beam and components to be aligned
- Project name: LAMBDA (Laser Alignment Multipoint Based Design Approach)

2. Alignment principle

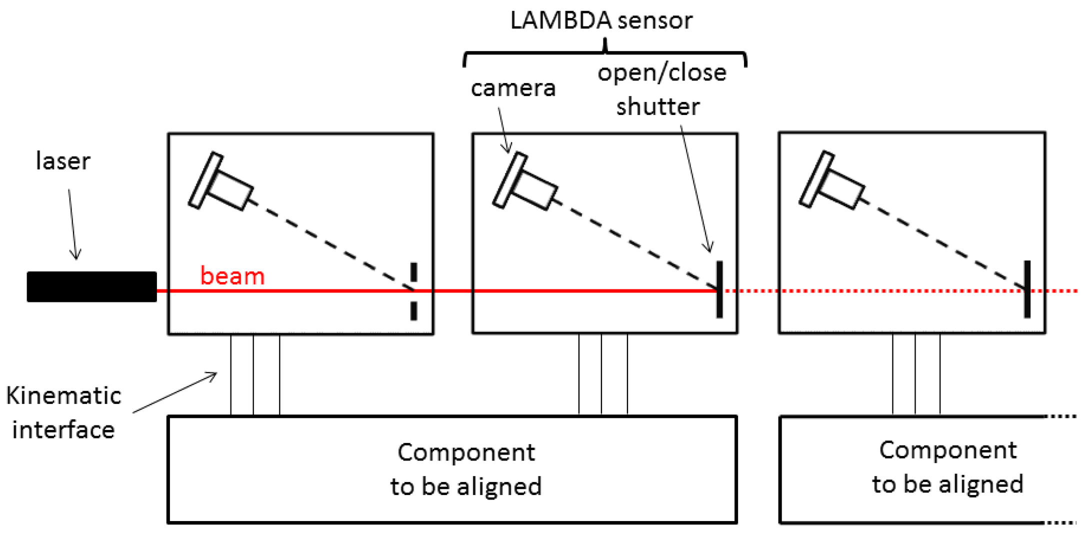


Figure 1: To check if all components are aligned, their positions have to be measured. This is done by LAMBDA sensors (2 of them installed on each component). One by one:

1. Close shutter to interrupt laser beam propagation
2. Capture picture of laser spot on shutter
3. Compute coordinates of laser spot on shutter
4. Deduct positions of components to be aligned
5. Open shutter so that laser beam propagates to next closed shutter

3. Challenge

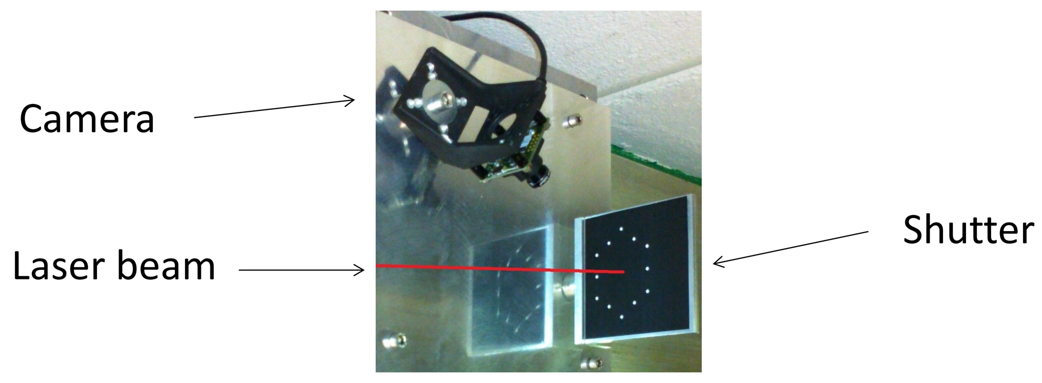


Figure 2: Top view of LAMBDA sensor

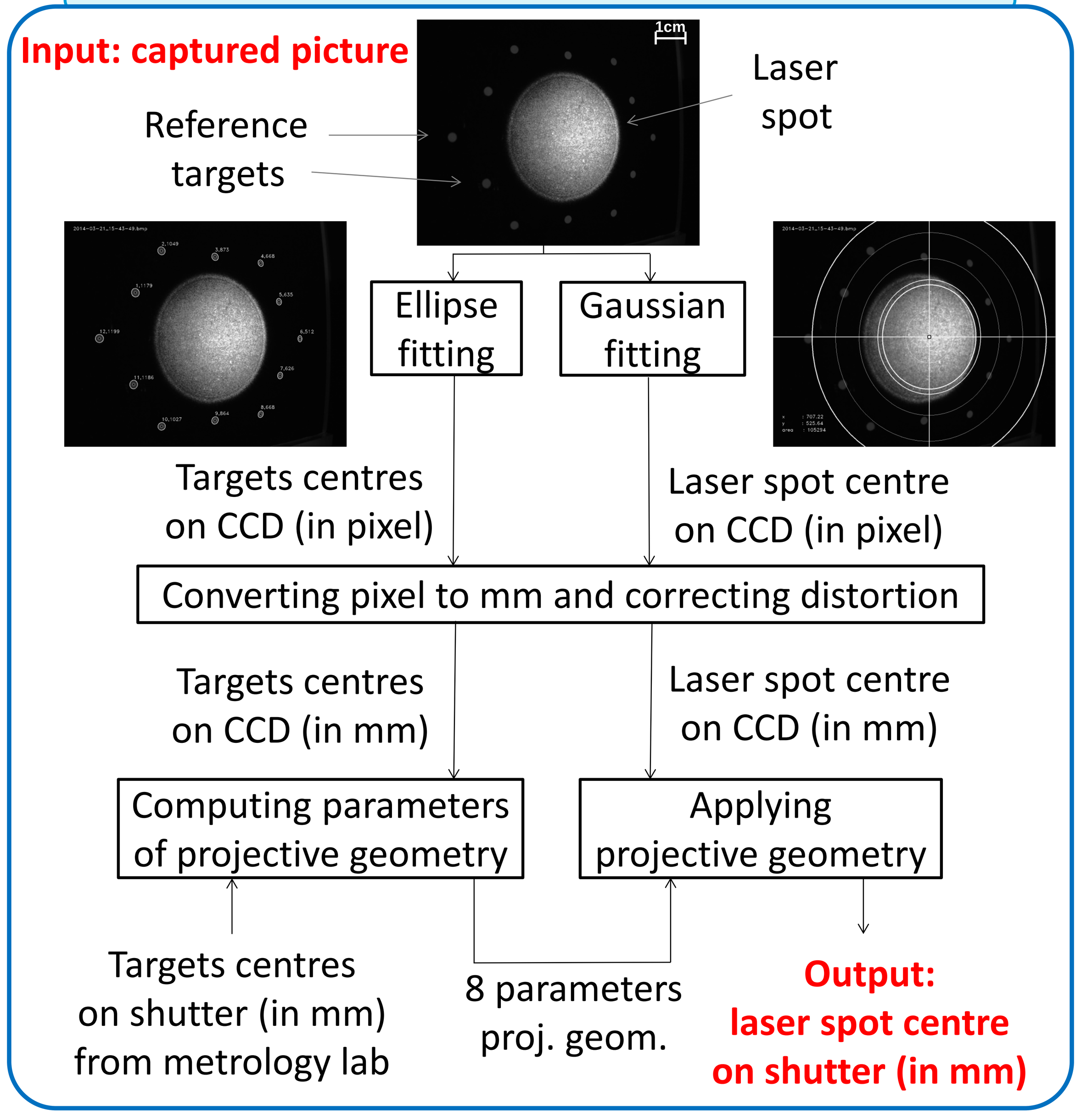
Goal: LAMBDA sensor with the following requirements

- Compact
- Low cost
- Compatible with its environment
- Measurement repeatability 1 µm
- Measurement accuracy 5 µm

Problem: sources of uncertainty

- Laser beam as straight line reference?
- Measurement of laser spot on shutter?
- Sensor in its environment?

4. Image processing



5. Short distance test results (laser propagates over 3 m)

Laser spot stability over time

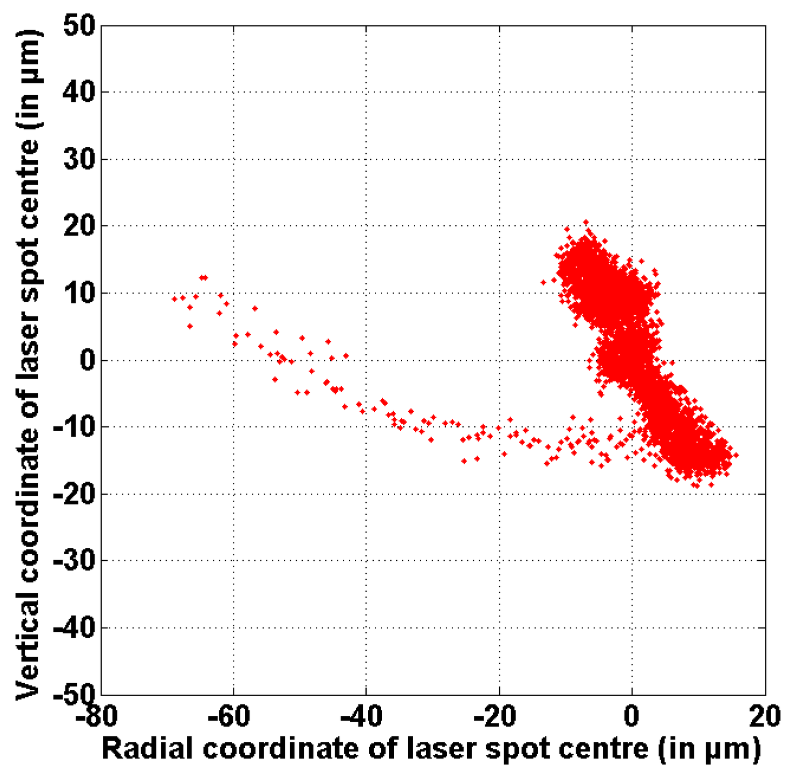


Figure 3: Laser spot coordinates are measured every minute during a whole week-end. Both coordinates present a drift in the first 2 h (laser warm up time) and then remain stable within 40 µm.

Laser spot stability with respect to position of shutter

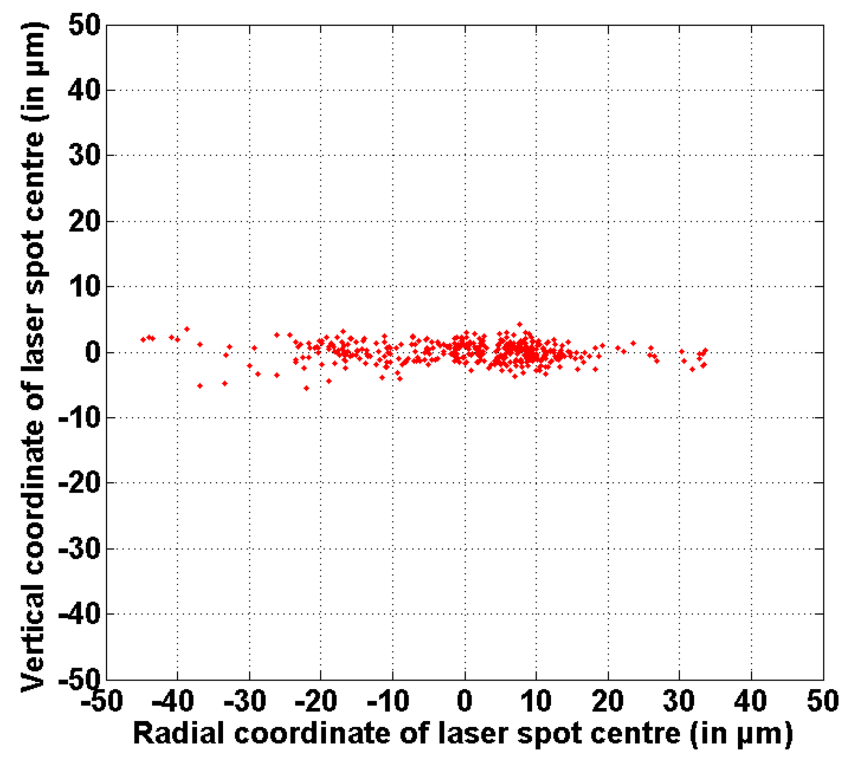


Figure 4: Laser spot coordinates are measured for several positions of shutter. Radial coordinate is 10 times more spread than vertical coordinate. Possible reason: different shutter roughness along radial and vertical directions due to machining of aluminium plate.

6. Long distance test results (laser propagates over 200 m)

Laser beam diameter with respect to distance

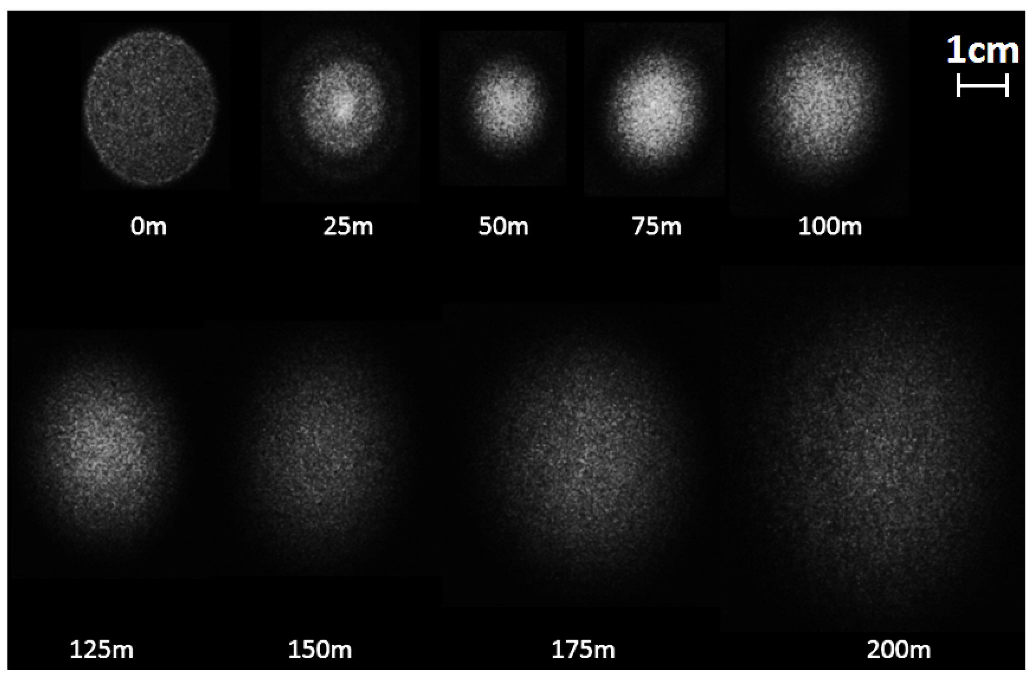


Figure 5: Overview of laser spot shape when propagating over 200m. When a beam expander of magnifying power x15 is used, the diameter of the laser spot remains smaller than 4cm, which allows us to have a compact sensor.

Laser spot stability with respect to distance of propagation and environment

		Distance of propagation	
		35 m	200 m
Environment	Air	st. dev. = 200 µm	st. dev. = 2000 µm
	Vacuum	st. dev. = 5 µm	No results yet

Table 1: Laser spot coordinates are measured 40 times for different distances of propagation and in different environments. Standard deviation is computed for each series of 40 measurements. Results confirm that a vacuum pipe is needed to meet CLIC requirements.

7. Conclusion and outlook

Lessons learnt from short distance tests

- Measurements to be done in short time interval for laser spot stability
- Shutter roughness to be chosen similar in radial and vertical directions in order to reflect laser light homogeneously

Lessons learnt from long distance tests

- Beam expander needed
- Vacuum pipe needed

Future steps

- Ceramic shutters to be tested (metal and paper surface already tested)
- Motorised open/close shutter to be tested
- Experiments in vacuum to be continued (in particular different distances of propagation to be tested)

Doctoral student poster session

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