CERN

Laser Based Alignment Systems for CLIC

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Outline

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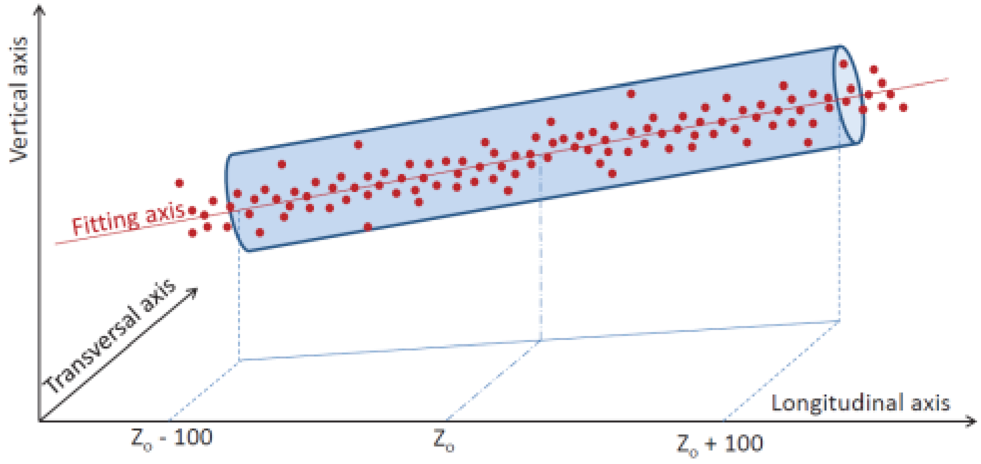
2. CLIC study and pre-alignment
3. LAMBDA project at CERN
4. Comparison with other laser based alignment systems
5. Summary and outlook

Background

- **PhD student** in the Large Scale Metrology section of CERN
- **Large Scale Metrology** section responsible for the metrology and alignment of accelerators and detectors at CERN
- **Typical alignment accuracy**
  - From a few mm down to a few µm
- **Typical techniques**
  - Standard surveying instrumentation (total stations, optical levels, digital photogrammetry, laser trackers)
  - Micrometric alignment systems (Wire Positioning Systems and Hydrostatic Levelling Systems)

CLIC study

- CLIC: Compact Linear Collider
- Study for a future positron/electron collider
- Error budget allocated to the absolute positioning of the zeroes of components: radius of the cylinder 10µm (1σ) over 200m



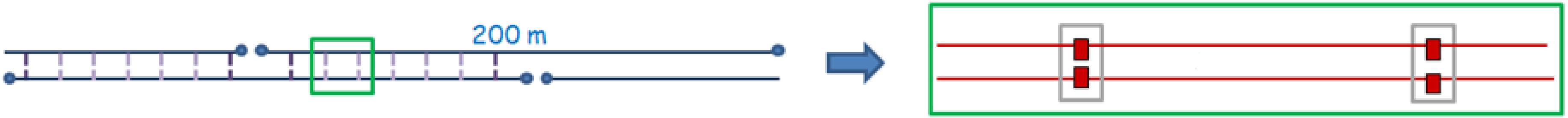
Pre-alignment

- Key issue for beam emittance preservation
- Takes place without beams in the linacs, in order to implement beam based alignment and beam based feedbacks

Type of pre-alignment	Accuracy (rms)
Standard (as in other accelerators)	100 µm
Active (for CLIC)	Down to 10 µm

Pre-alignment strategy (1)

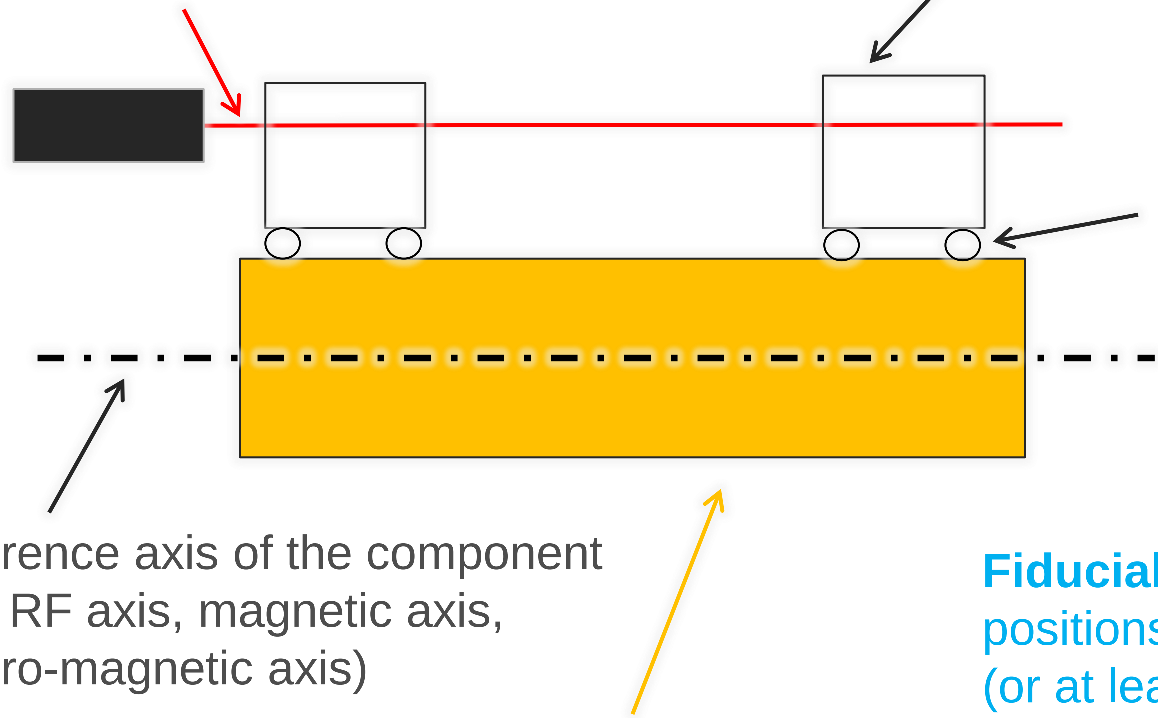
- Alignment reference: stretched wire or laser beam
- Combination: sensors + actuators
- Overlapping sections of 200m



Pre-alignment strategy (2)

Straight line reference (e.g. laser beam)

Sensor provides **radial and vertical** offsets w.r.t. the laser beam in the sensor coordinates system



Kinematic interface

Reference axis of the component (e.g. RF axis, magnetic axis, electro-magnetic axis)

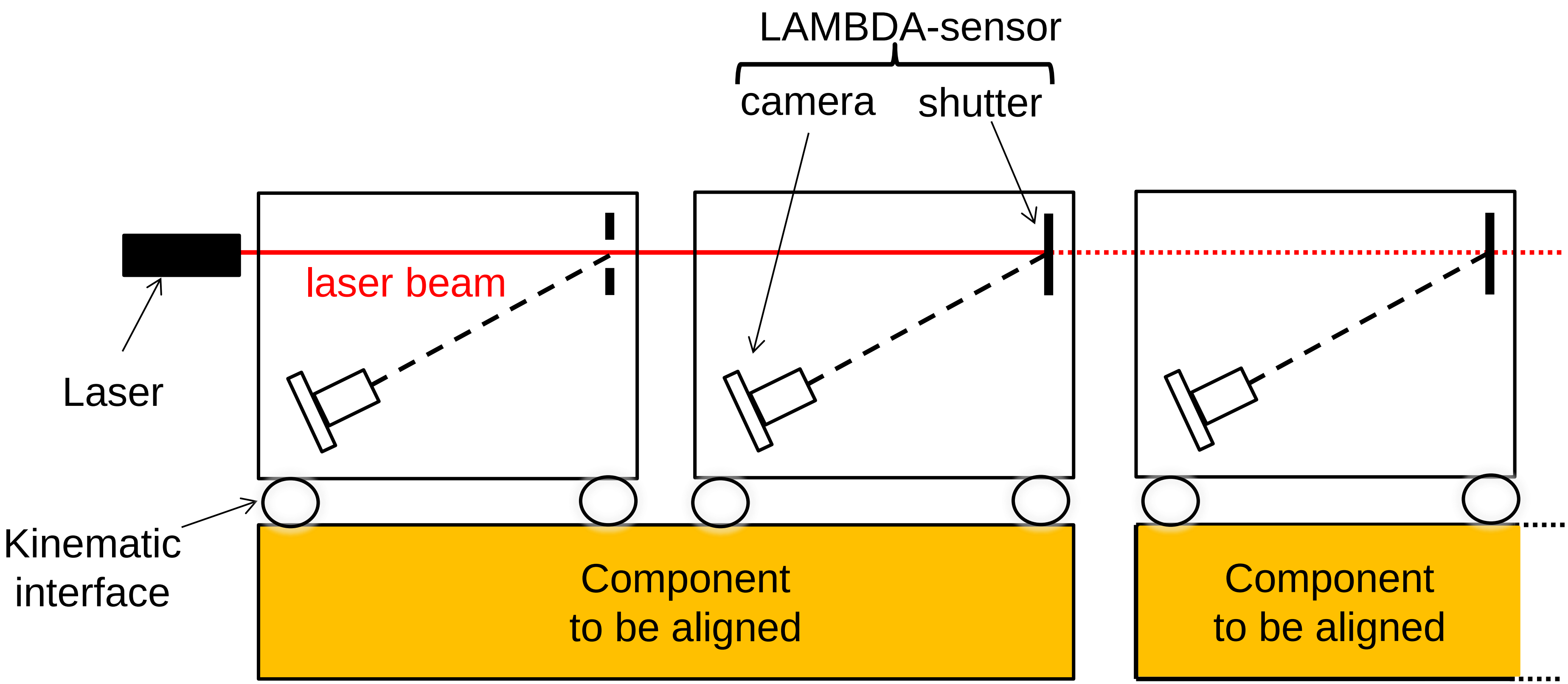
CLIC component to be aligned

Fiducialisation process provides positions of the sensors (or at least their kinematic interfaces) w.r.t. reference axis of the component

LAMBDA project

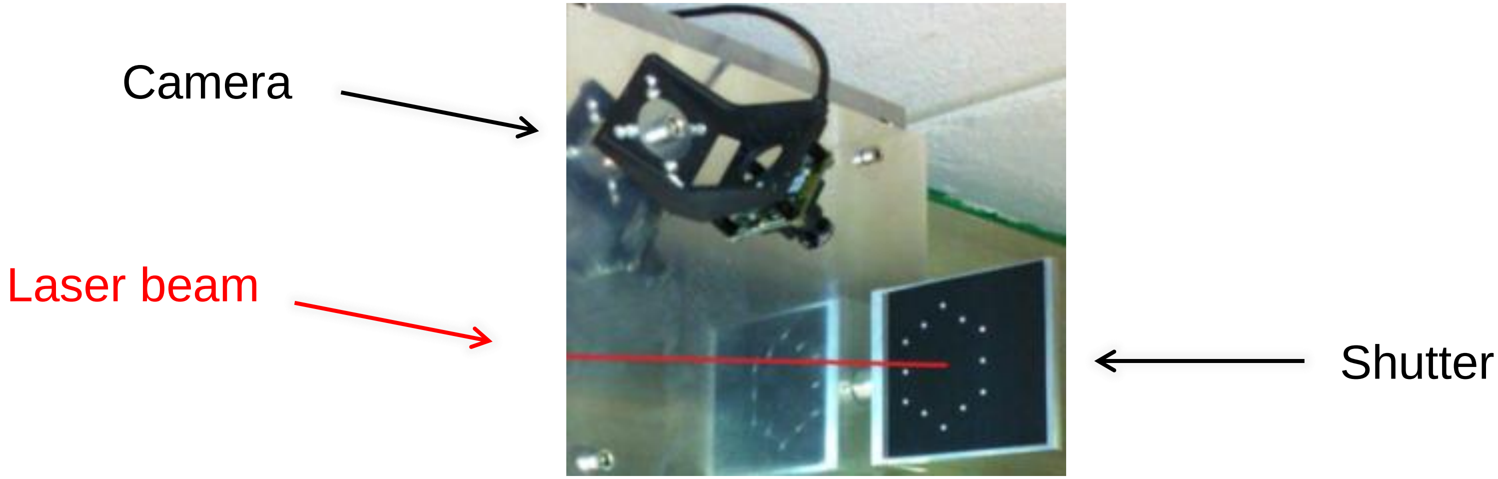
- LAMBDA: Laser Alignment Multipoint Based Design Approach
- Idea:
  - Laser beam (under vacuum) as straight line reference
  - Camera/shutter assemblies to measure distance to laser beam
- Proposal first described in 2010, launching the idea of PhD project

LAMBDA project: principle



LAMBDA project: sensor

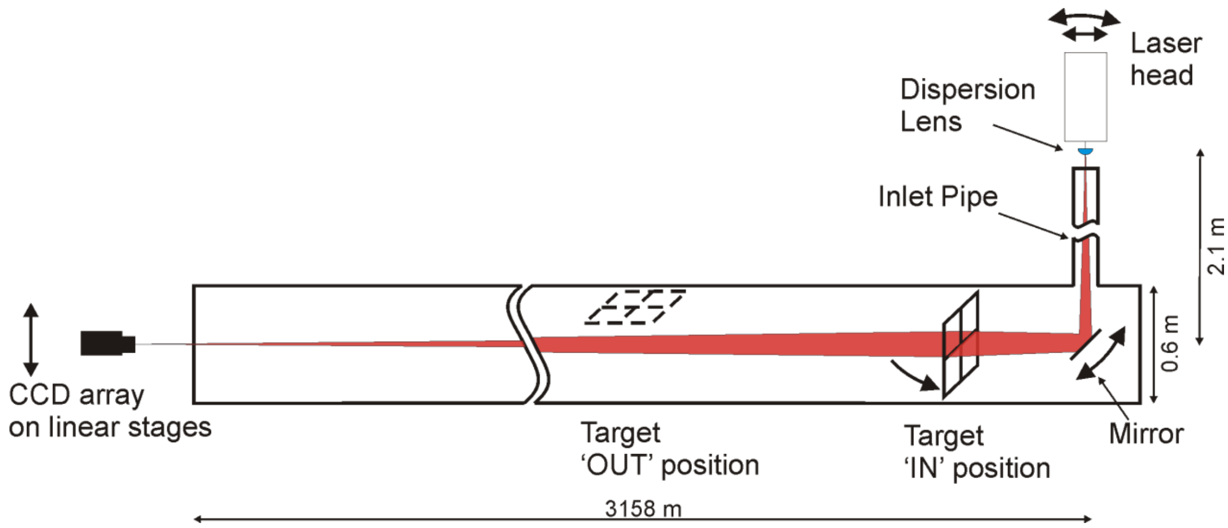
- Requirements
  - Compact and compatible with its environment
  - Measurement repeatability 1µm, accuracy 5µm
  - Low cost
  - Micrometric repositioning of each shutter at a frequency above 50 Hz



LAMBDA project: lessons learnt from first tests

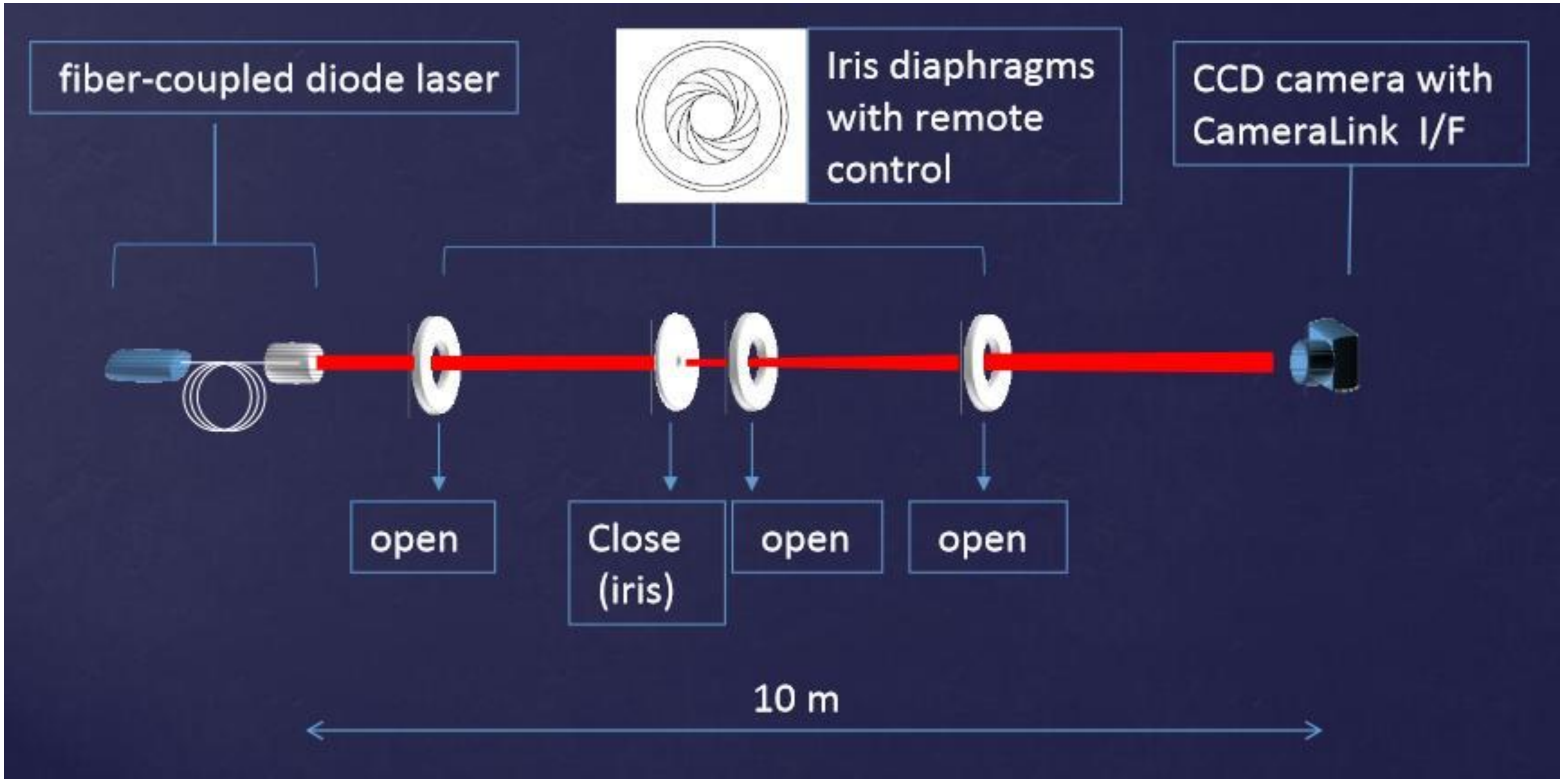
- Laser spot stability within **5 µm** over 35 m (under vacuum)
- Measurements to be done within **short time interval** (few seconds)
- **Shutter roughness** to be chosen similar in x and y directions
- **Beam expander** needed to have laser beam diameter within few centimetres
- **Vacuum pipe** needed to improve laser spot stability

Observing diffraction pattern of Fresnel zones plates (SLAC)



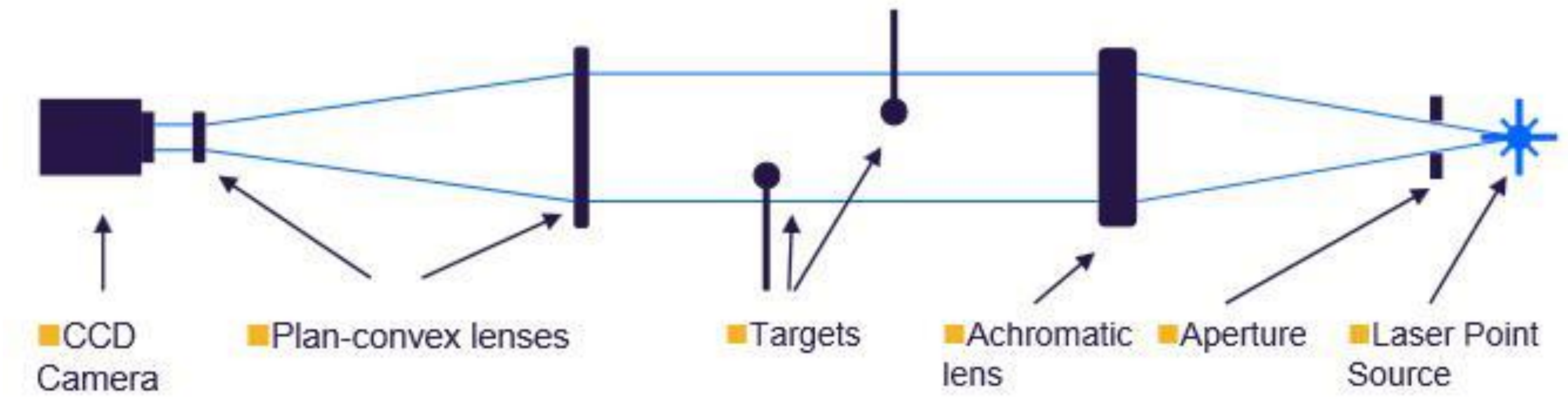
Advantages	Drawbacks
Large number of targets (~300)	Repositioning of targets
Rad-hard	Non compact targets

Observing diffraction pattern of an iris (Spring 8)



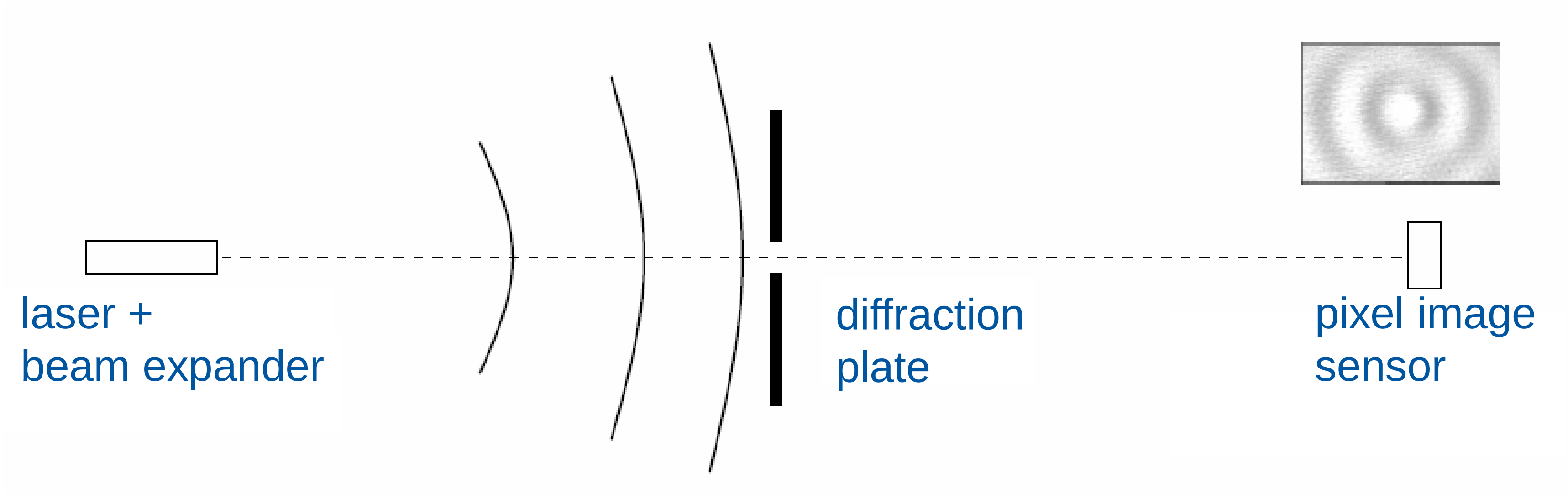
Advantages	Drawbacks
Static targets	Measurement uncertainty depends on longitudinal position

Observing diffraction pattern of spheres (DESY)



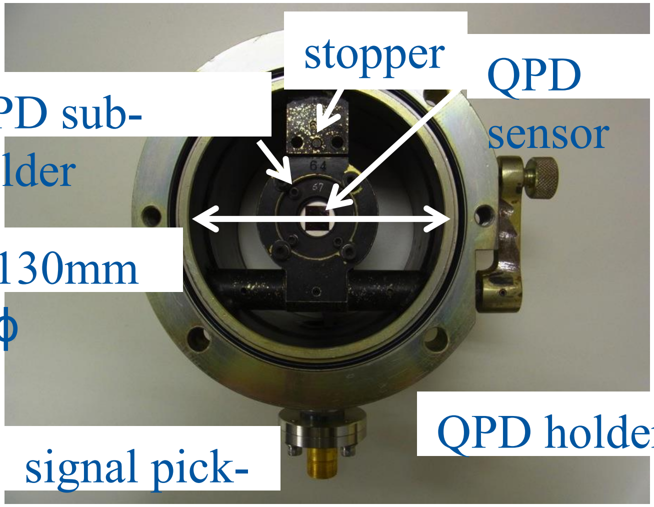
Advantages	Drawbacks
Static targets	Limited number of targets (~16)
	Measurement uncertainty depends on longitudinal position

Observing diffraction pattern of a plate (NIKHEF)



Advantages	Drawbacks
Static plate	Only 1 target

Observing laser spot with open / close QPD's (KEK)



QPD: quadrant photo-detectors

Advantages	Drawbacks
Large number of photo-detectors	Uncertainty due to open/close photo-detectors

Comparison of several laser based alignment systems

		Wanted accuracy	**Already achieved**
Observing diffraction pattern	…of Fresnel zone plates (SLAC)	500µm (1σ) over 3000m	Estimated accuracy: 500µm (1σ) over 3000m
	…of an iris (SPRING 8)	10µm (2σ) over 10m	Pointing stability: 10µm (2σ) over 10m
	…of spheres (DESY)	300µm (1σ) over 150m	Estimated achievable accuracy: 100/200 µm (1σ) over 150m
	… of diffraction plate (NIKHEF)	10µm (1σ) over 200m	Estimated achievable accuracy: 1µm (1σ) over 140m
Observing laser spot	…with open/close quadrant photo-detectors (KEK)	100µm (1σ) over 500m	Pointing stability: 40µm Estimated accuracy: 100µm (1σ) over 500m
	…with open/close shutters (CERN)	10µm (1σ) over 200m	Pointing stability: 5µm (1σ) over 35m

Summary and outlook

- (Active) pre-alignment of CLIC requires 10µm accuracy at 1σ over 200m
- No existing system meets such requirements
- Proposal of a CERN laser based alignment system
  - Laser beam as straight line reference
  - Camera/shutter sensors to measure distance to laser beam
  - Already achieved: 5µm pointing stability at 1σ over 35m
- Future steps for sensor development
  - Testing different shutter types (e.g. ceramic)
  - Testing open/close mechanism

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