Nanometer Scale Patterning and Processing

Spring 2016

Lecture 20

Vector Beam Performance and Operation (continued)

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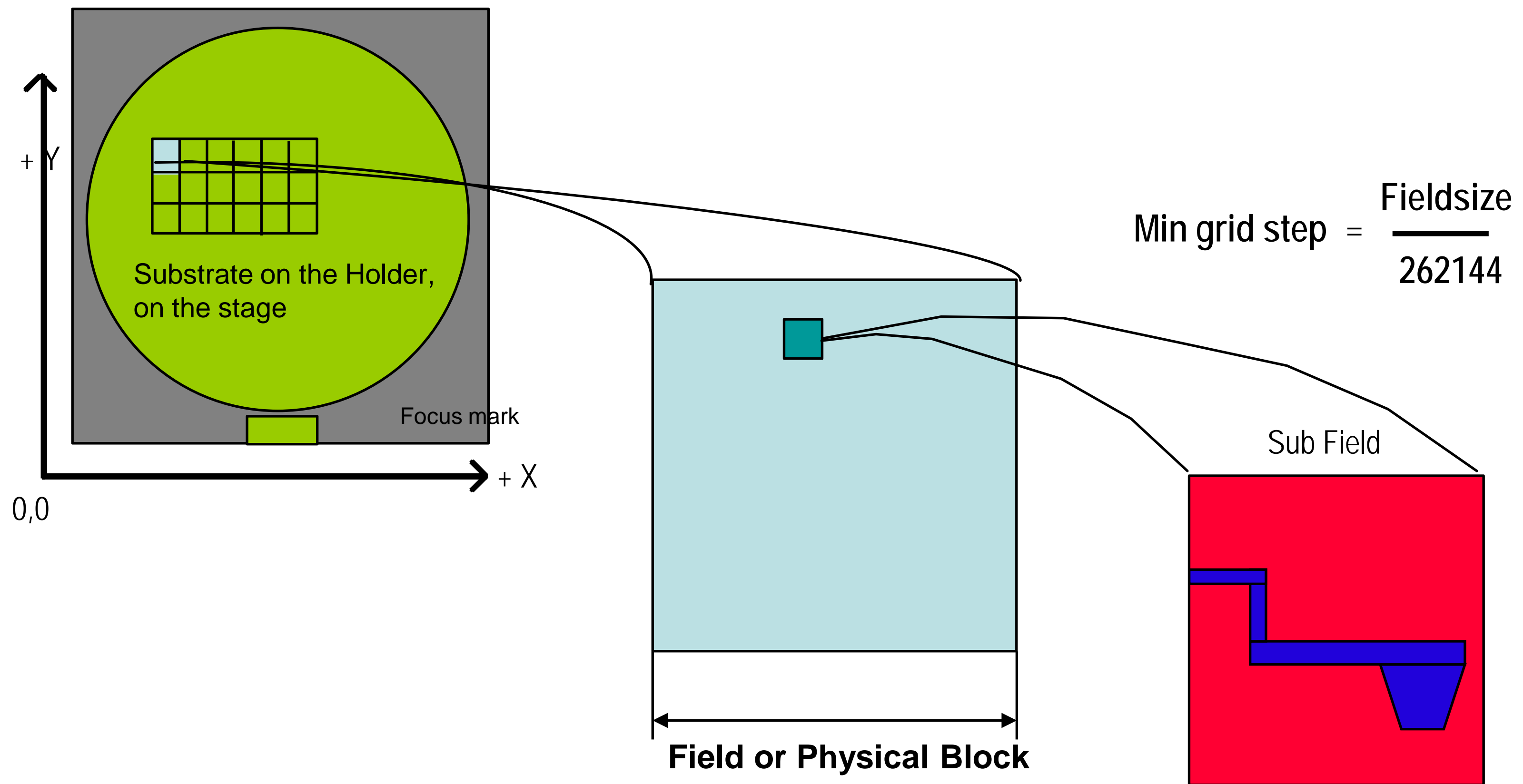
Writing Strategy (Wide Field)



1. Stage moved to position of Field or Physical Block within pattern.

2. Sub-field positioned by Main deflection scan

3. Subfield area scanned by "Trapezium scan coils"

Dose Control

The correct dose is achieved by setting the time duration that the beam dwells at each exposure point within the pattern.

This time duration is determined by the frequency of the **DOSE CLOCK.**

A clock frequency of 1MHz sets the exposure time per exel to 1 micro-second.

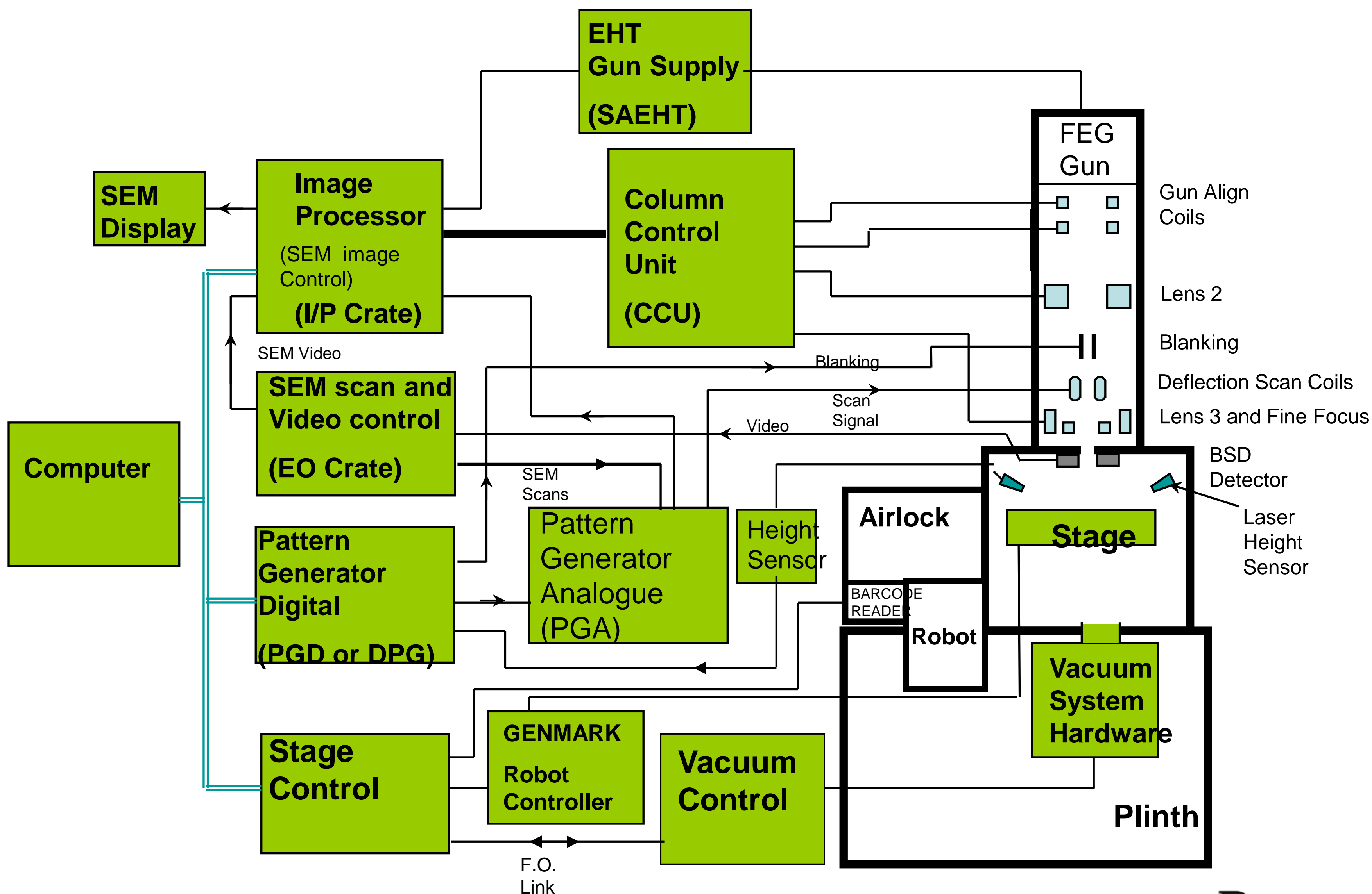
A pattern shape containing 10,000,000 exposure points will take 1 Second to expose with a clock set to 10MHz.

The maximum frequency possible is 25MHz

The Dose required for correct exposure depends on the

- Resist Sensitivity
- Field Size
- Beam Current
- EHT
- Variable Resolution factor (VRU)
- Electron beam back-scatter

Vectorbeam VB6 System Overview



Stage Position Error Correction

- The Stage mechanical positional error is measured and then corrected for by deflecting the electron beam by a distance equal in magnitude and direction to this error. This results in it pointing to the exact coordinate position specified in the stage move.
- This is called "**Beam Error Feedback**" or "**BEF**"
-
- Initial stage position error is measured and corrected by "Static" Beam Error Feedback.
  Range of Static BEF = ± 20 microns
- Continuous monitoring of errors measures subsequent position errors.
- Continuous correction of variable errors by "Dynamic" Beam Error Feedback
- Range of Dynamic BEF = ± 5 microns
- Continuous monitoring of the stage position ensures continuous correction for any subsequent position errors - positional drift or small vibrations.

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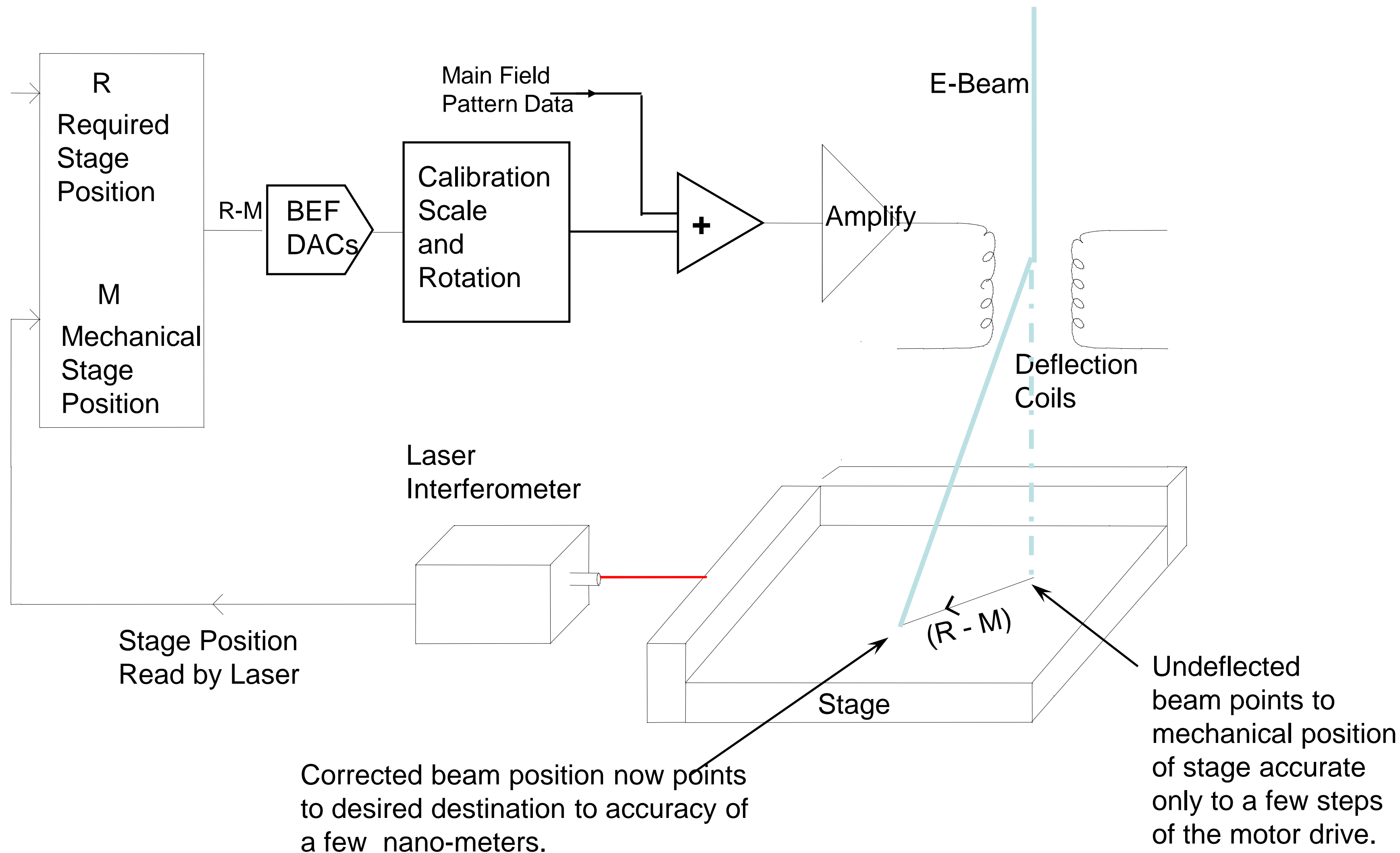
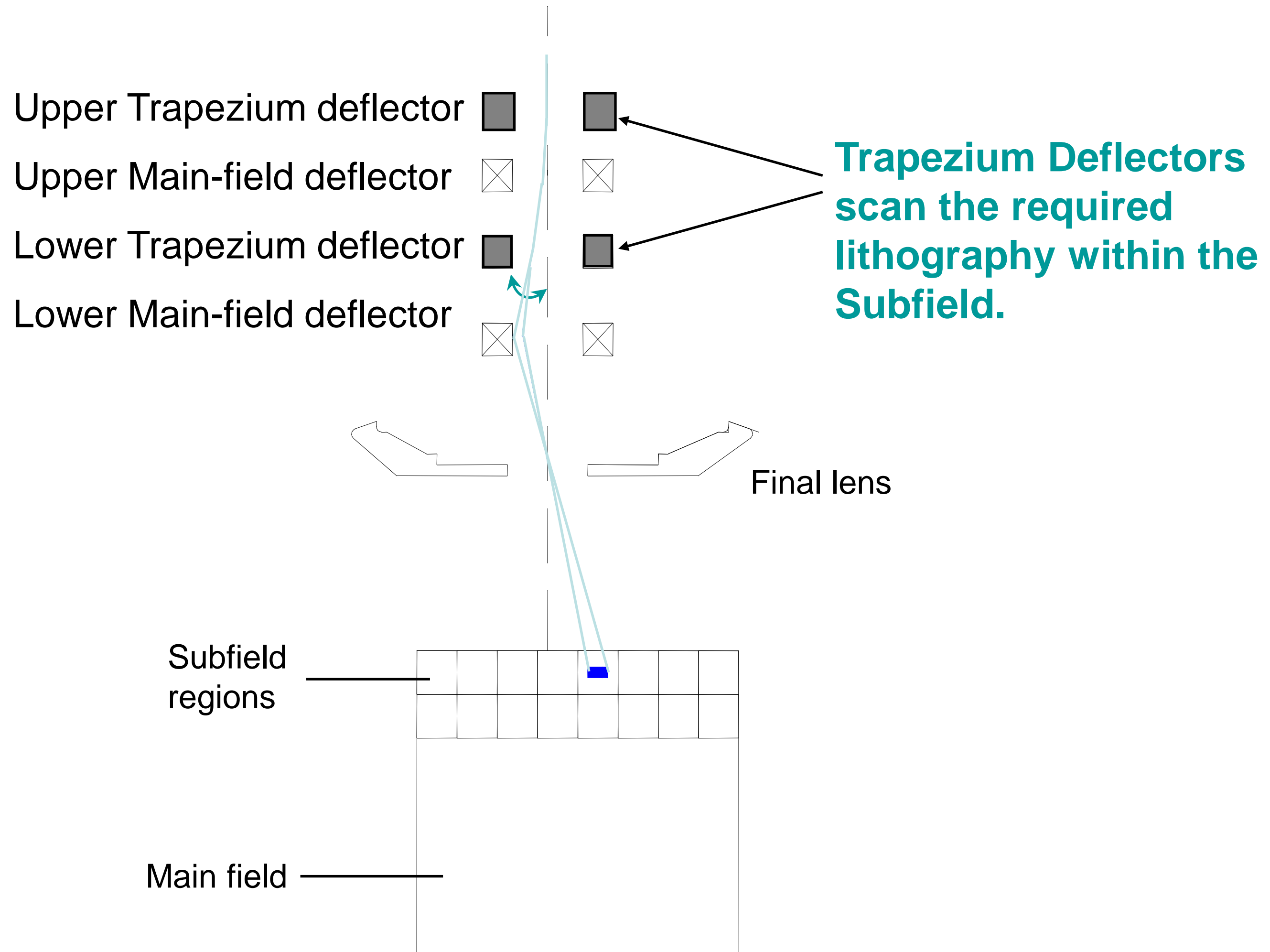
Elements of Beam Error Feedback



Exposure Scan Strategy (VB-UHR)



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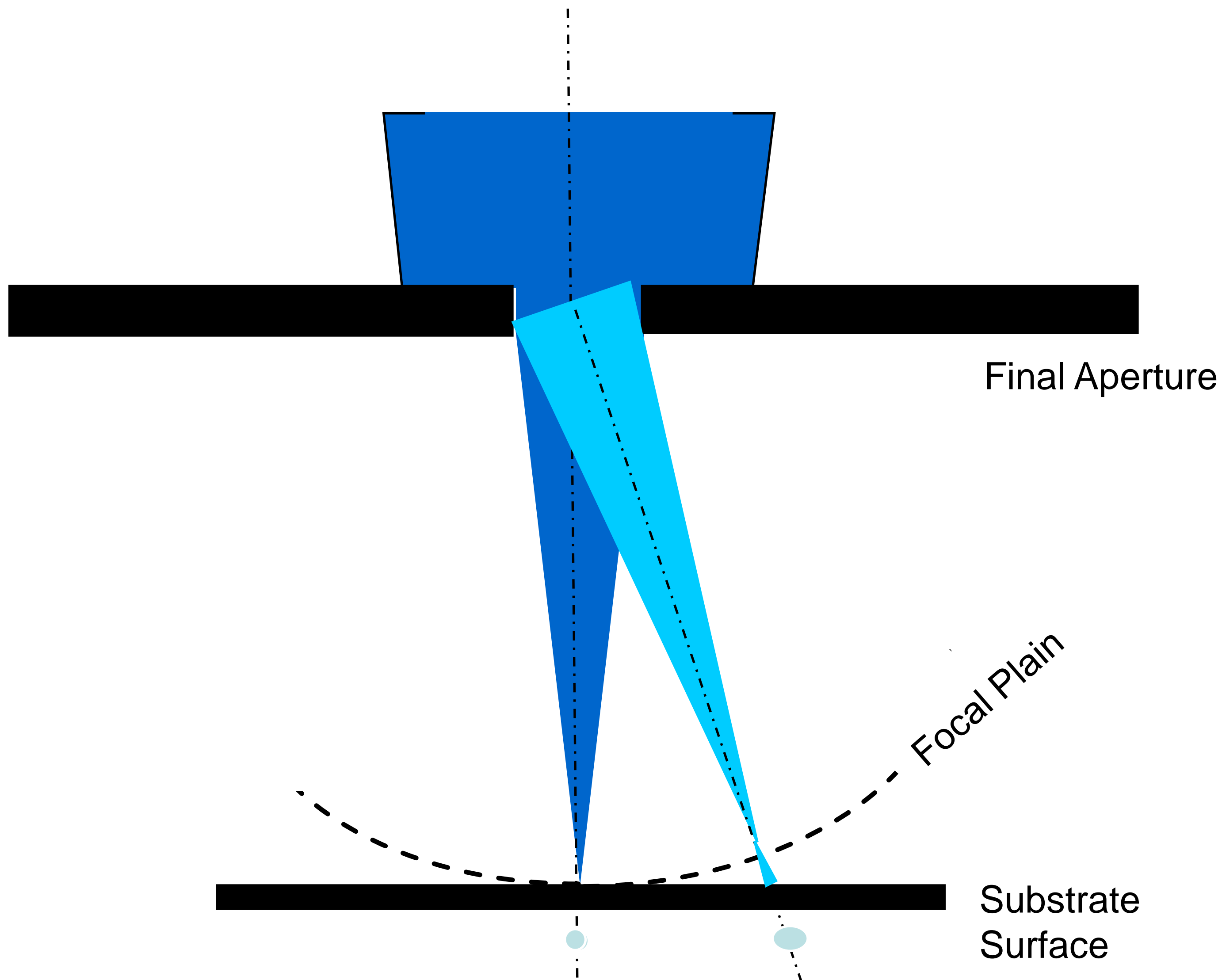
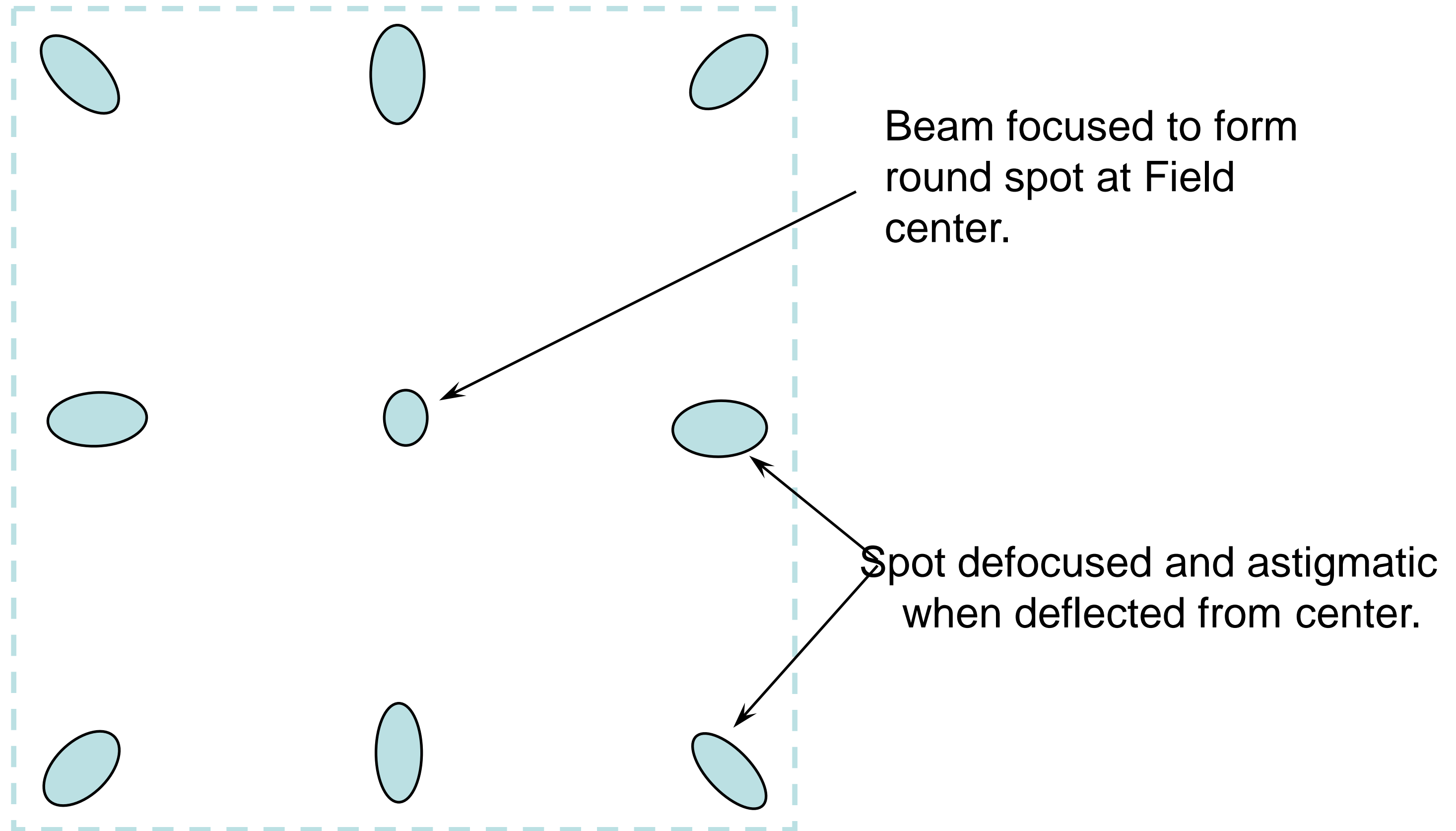
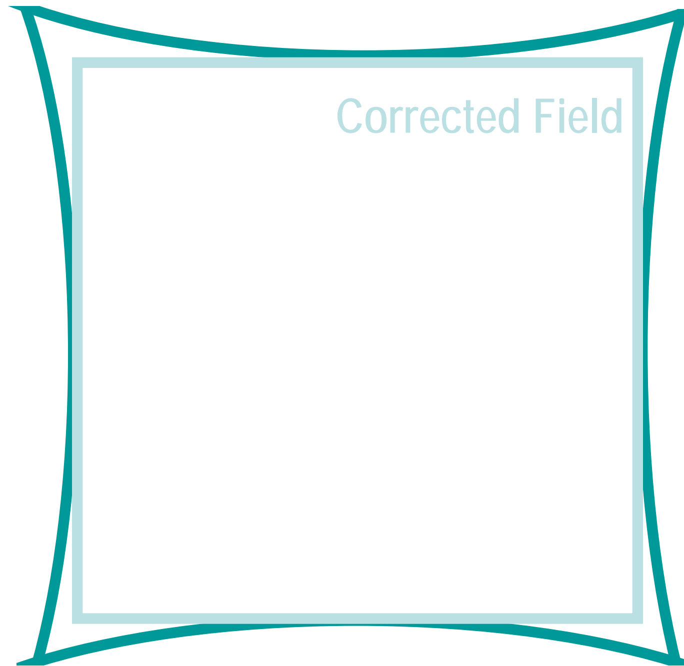
Effect of Beam Deflection on the Beam



Effect of Beam Deflection on the Focus

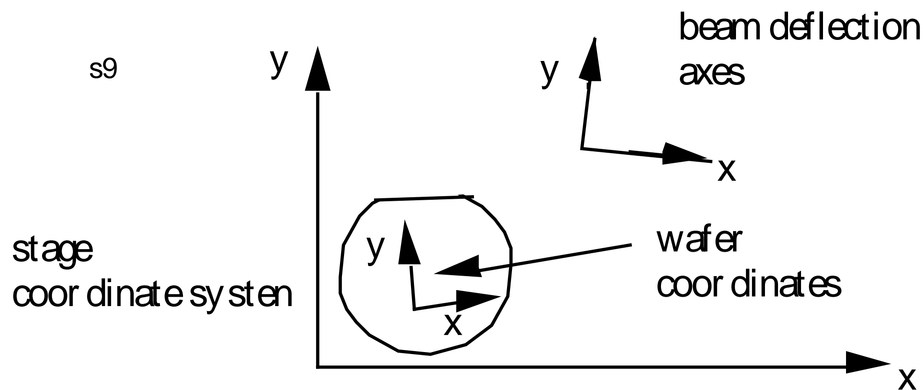


Field Distortion caused by Beam Deflection

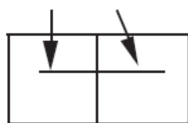


Field distortion is removed by applying corrections to the Main and Subfield scanning system

Field Stitching and coordinate systems

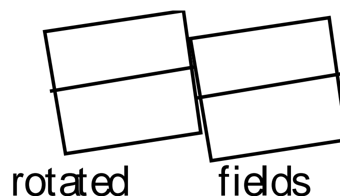


line spans
two fields



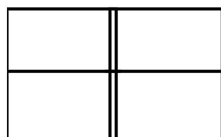
two fields

this results in a straight, continuous line if the scan and sample axes are aligned and magnification is correct



s11

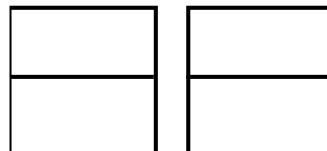
Typically caused by focus change



fields
overlap

result

overexposure at
overlap

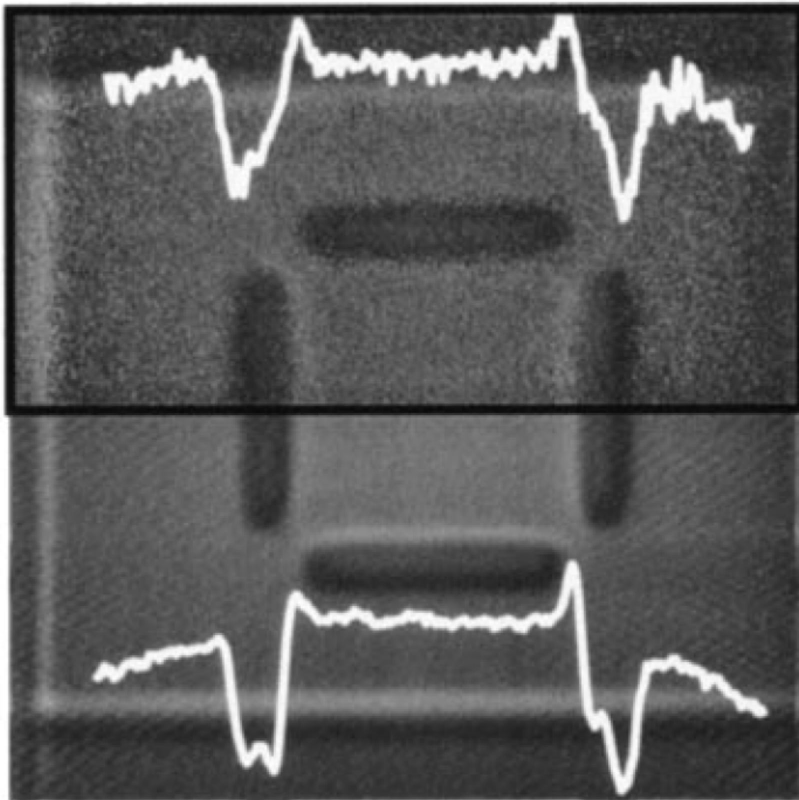


s13

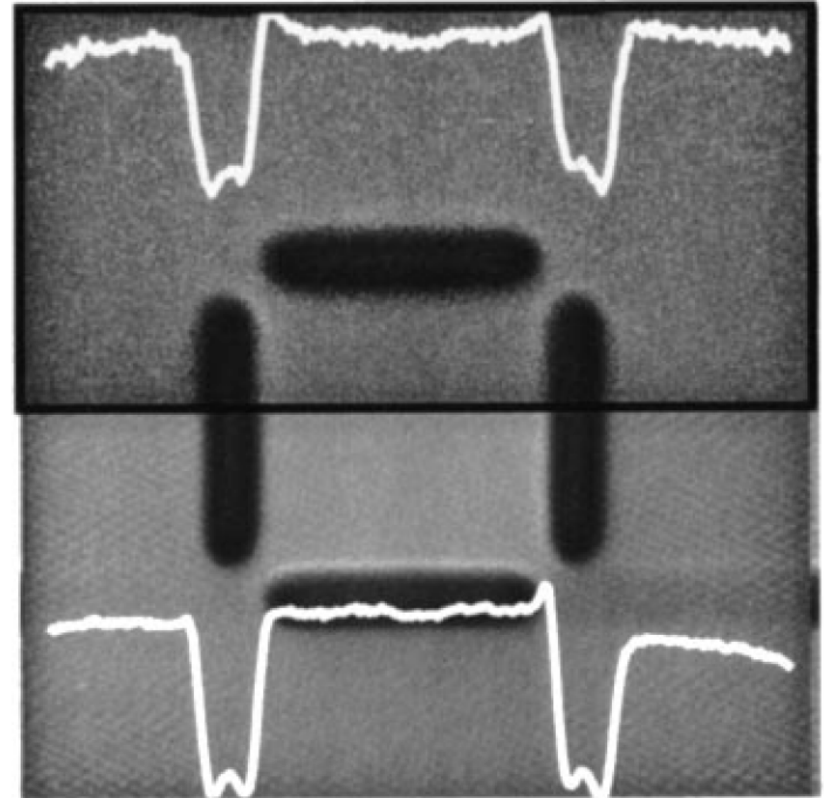
Field calibration is needed before exposure

Detection of alignment marks

Low contrast

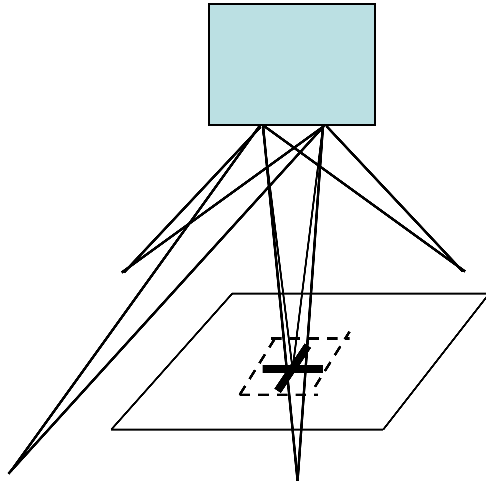


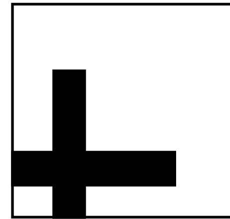
High contrast

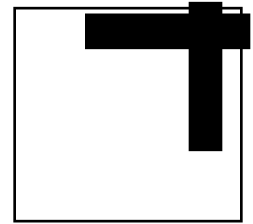


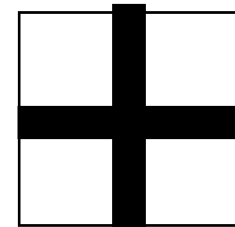
Algorithm looks for symmetry and calculates the center of the mark

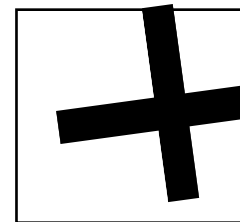
Field Calibration and Alignment

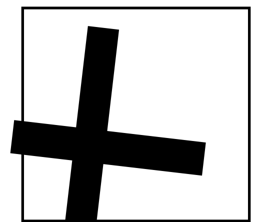






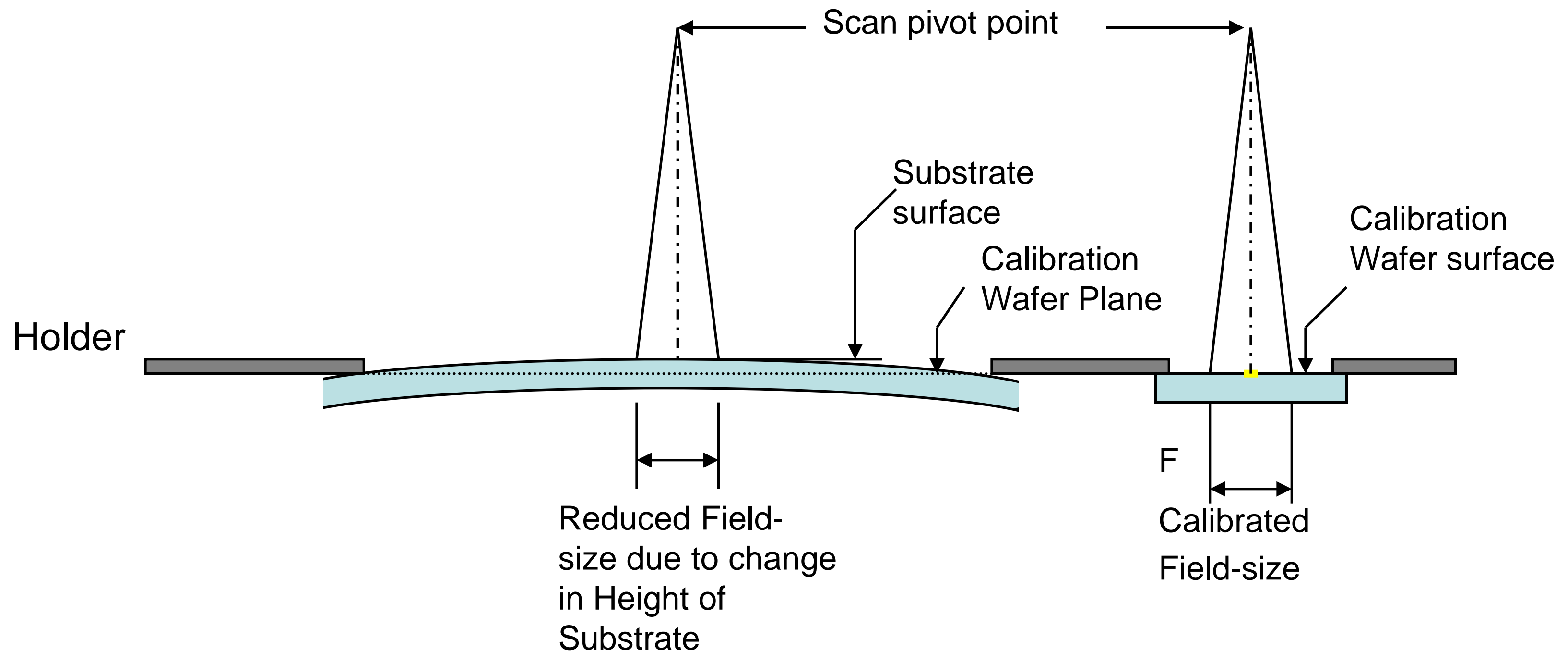






- Align the deflection directions along the stage coordinates
- Also can align to marks defined in previous layers

Effects of Substrate Height Variation

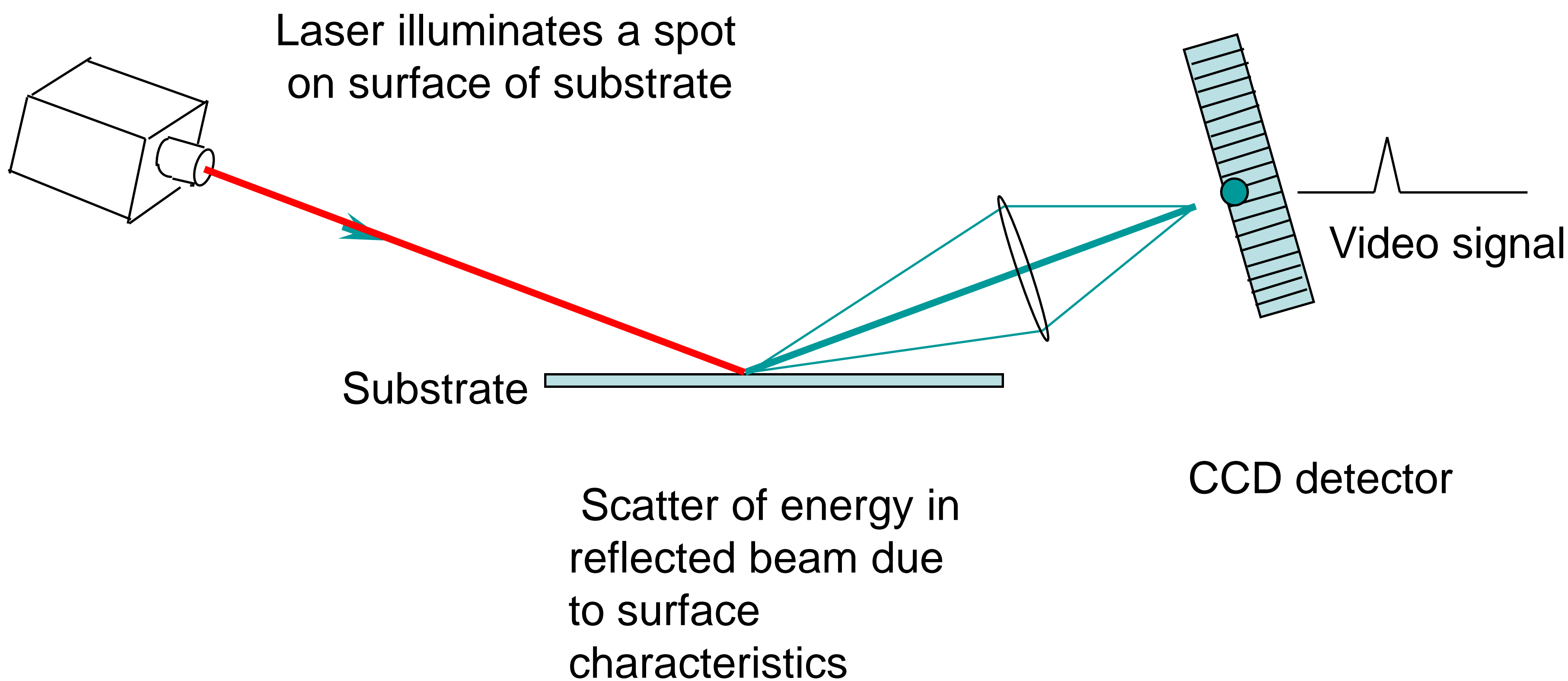


Changes in Substrate surface height relative to plane of the Calibration wafer result in

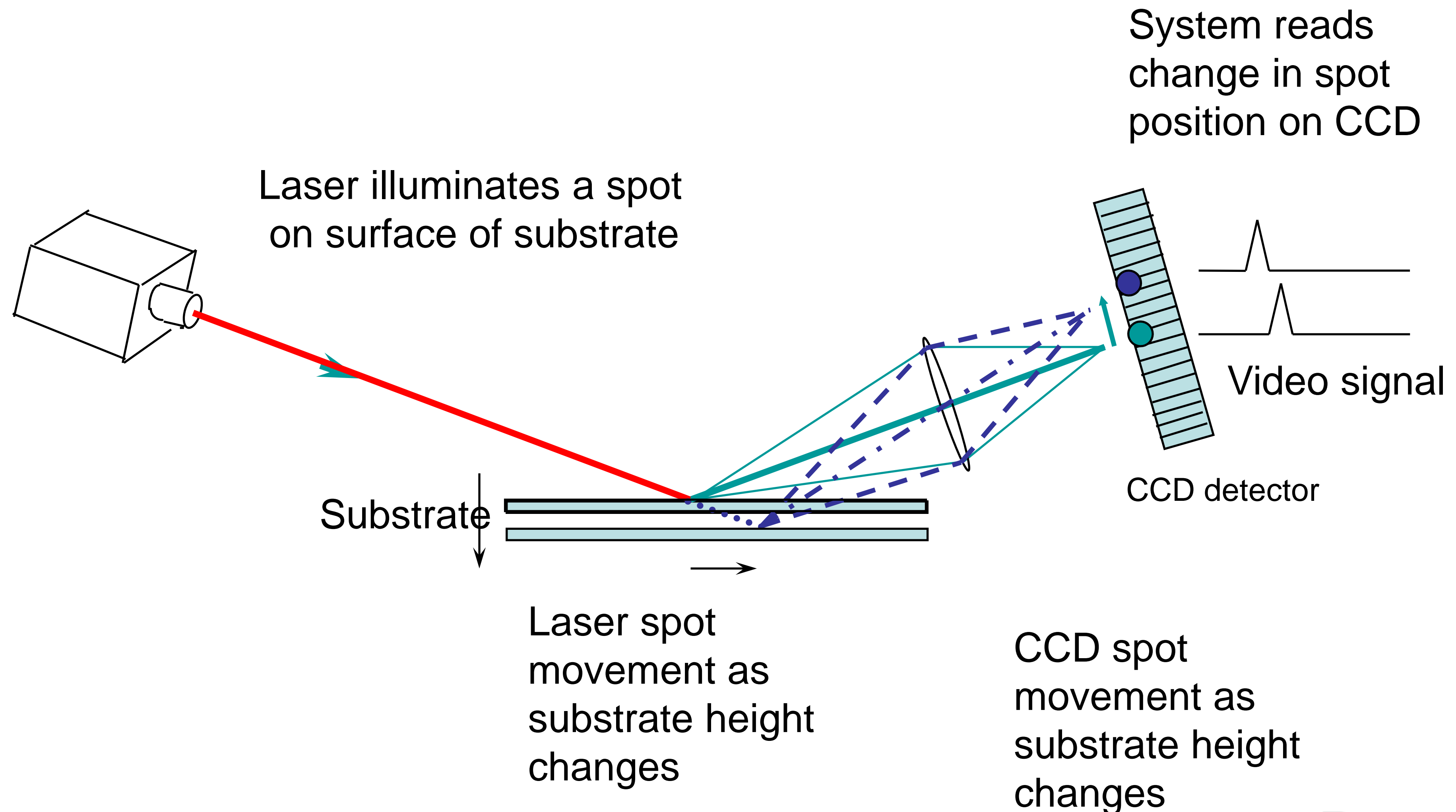
a) Incorrect Field size

b) Defocused beam

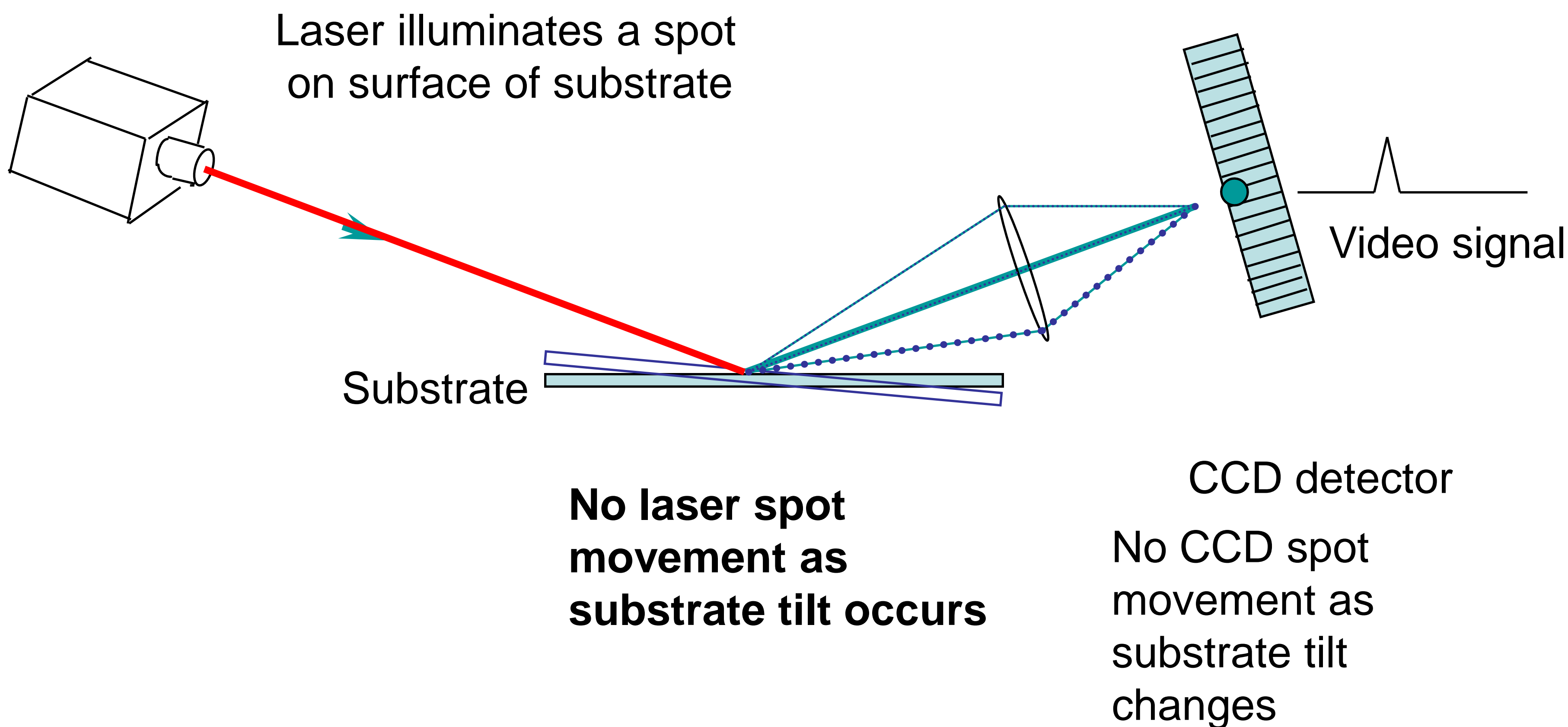
Laser Height Sensor



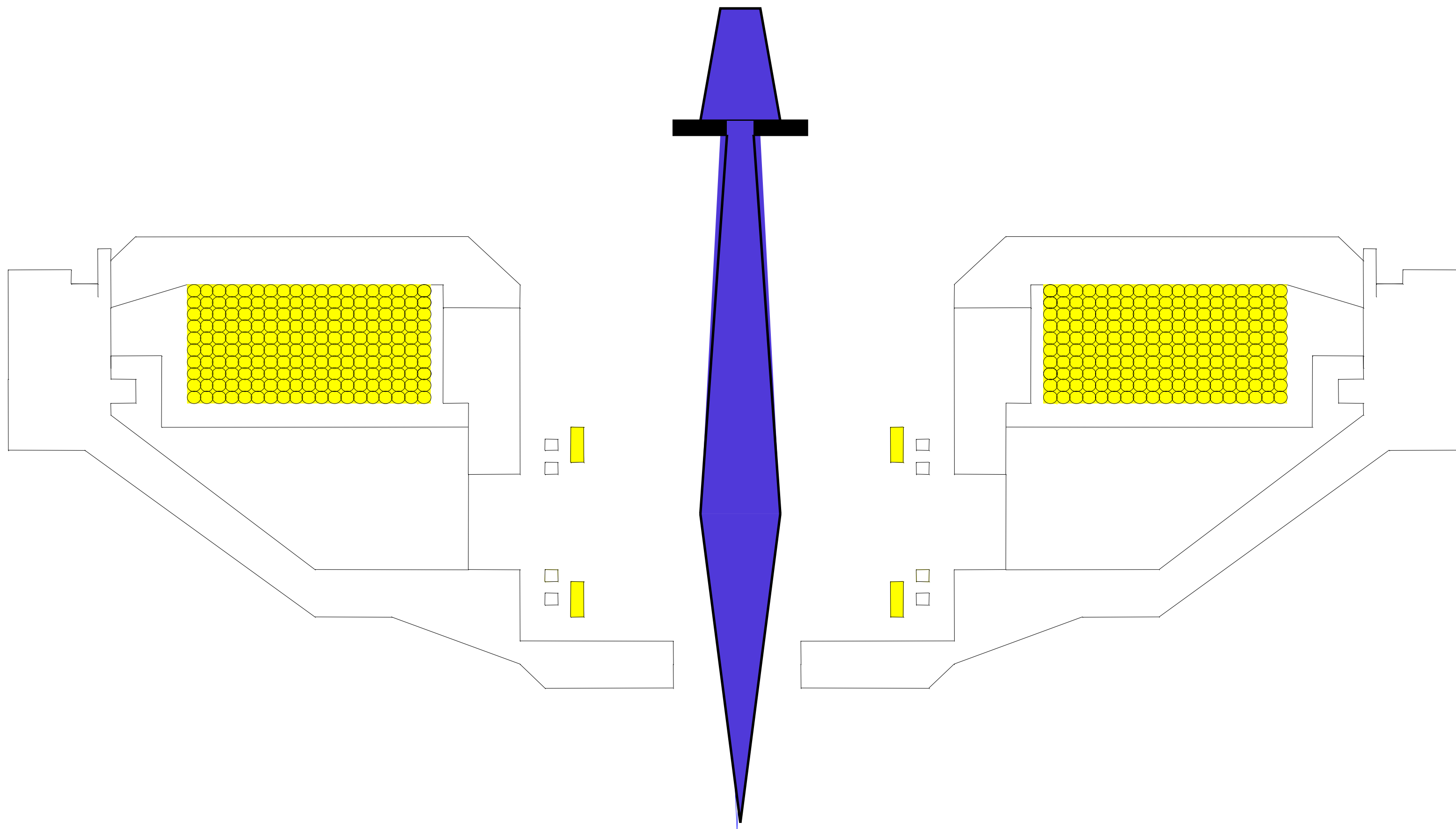
Laser Height Sensor



Laser Height Sensor

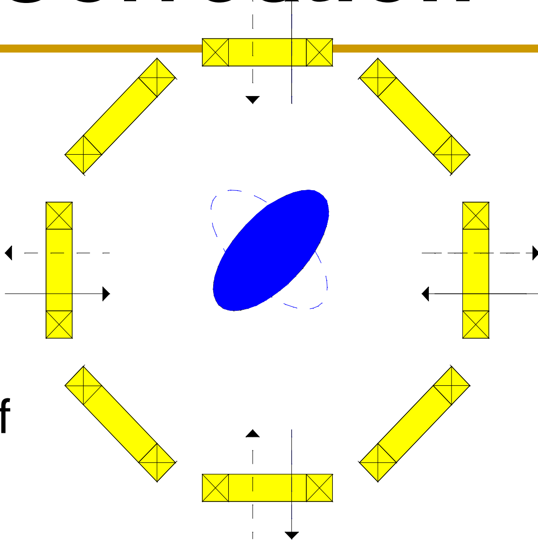


Final (Focus) Lens 3



- The Final Lens focuses the electron beam onto the surface of the substrate. It consists of concentric lenses. The outer lens is the main one, for coarse focus; the inner lens is for automatic fine focus.
- A six (“Final”) aperture is located above the lens construction.
- The stigmation correction coils are also located here.

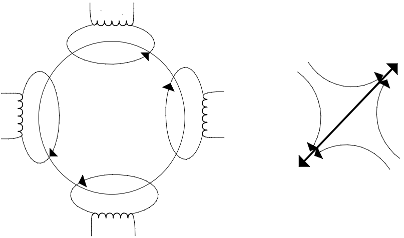
Stigmation Correction



By adjusting the strength of the magnetic field in the 8 coils the beam can be “squeezed” in the direction required for correcting the astigmatic beam.

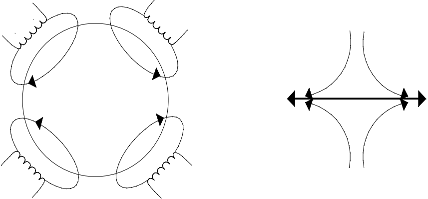
STIGMATOR COILS

2x4 STIGMATOR COILS IN FINAL LENS



Resultant field

Diagonal stigmator coils



Resultant field

Axis stigmator coils

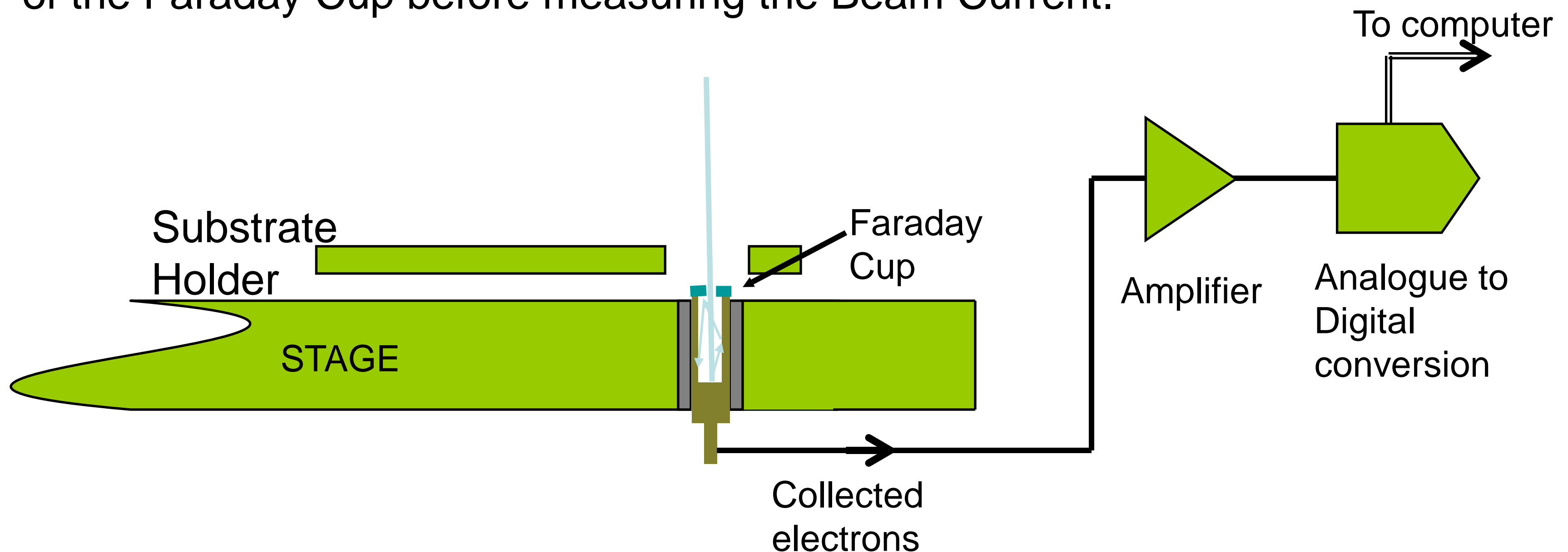
Current Measurement

Beam current is measured by the “Faraday Cup” mounted in the Stage below the Substrate Holder.

The Faraday Cup is isolated from the Stage and designed to trap all electrons entering it.

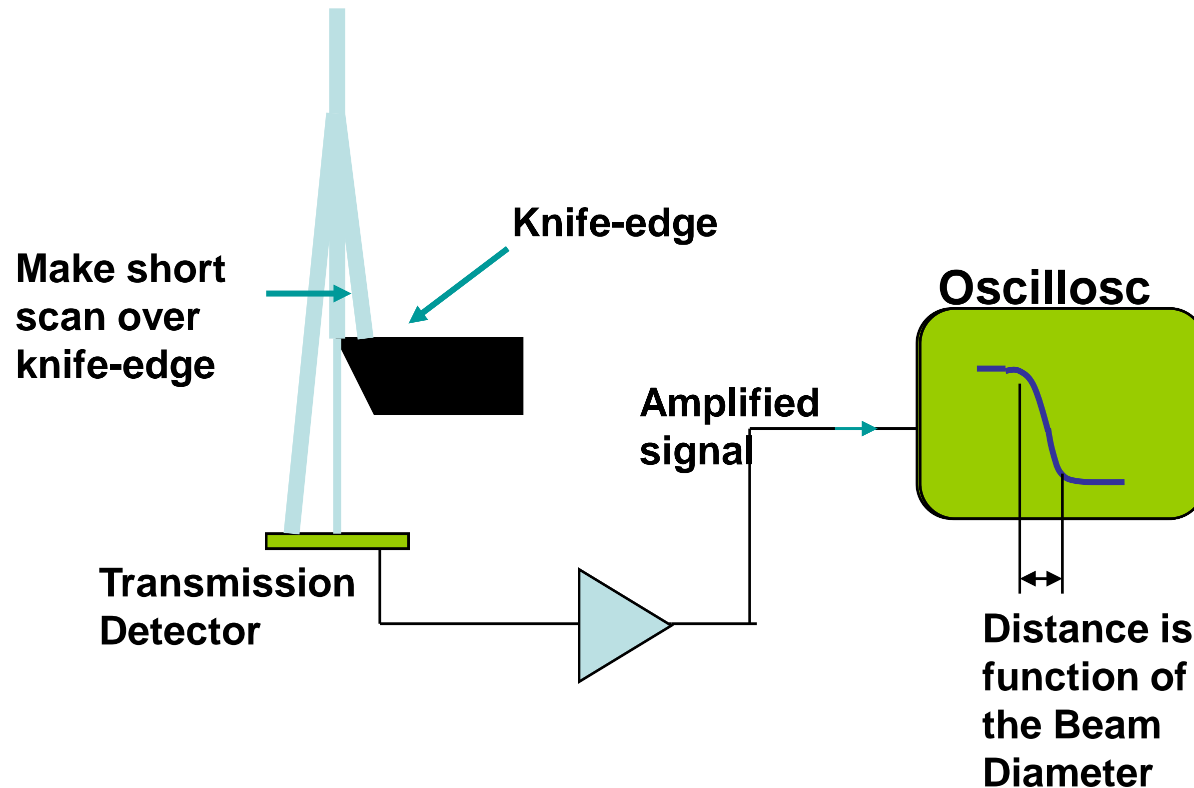
If the electron beam is not completely entering the Faraday Cup then a false measurement will result.

It is therefore essential that the stage is moved to the correct coordinate position of the Faraday Cup before measuring the Beam Current.



Transmission Detector

- For facilitating the measurement of beam diameter a detector is mounted on the stage.
- When the beam is scanned across a knife-edge device on one of the substrate holders, the signal received from this detector changes between zero and maximum with a transient rate dependant on the beam diameter.



3~5 nm

Corrections

Corrections are applied in real time for:

Main field scan corrections

- Scale, rotation & keystone over the main field

Trapezium field scan corrections

- Scale, rotation & keystone over the main field

Focus and Astigmatism

- Focus and Stigmation correction over main field
- Focus correction for each stage position dependant on substrate height

Beam Error Feedback

- Scale and Rotation corrections dependant on mainfield deflection.

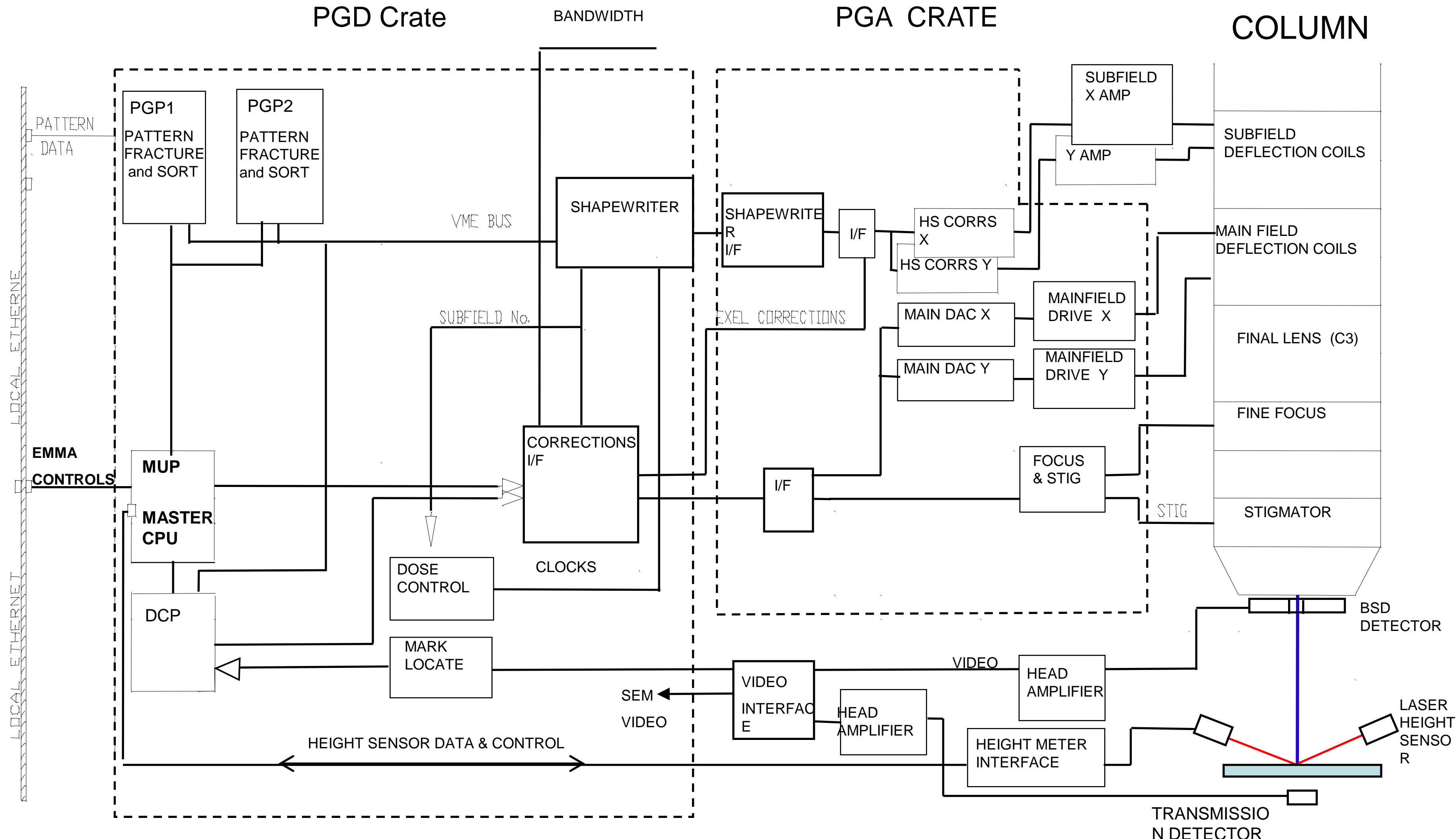
Height

- Real time or Pre-map corrections of focus and deflection scan rotation

Stage Position

- Beam Error Feedback
- Magnetic effect
- Orthogonality
- Machine mapping

VB6 Pattern Manipulation System



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