VB6 SYSTEM OVERVIEW
(18 bit Widefield)

What does it do?

The E-Beam tool “writes” the extremely small circuit pattern details required in the process of making Integrated circuits (commonly referred to as the SILICON CHIP).

It can also be used for writing the patterns of extremely small mechanical and electro-mechanical parts.

How is the Electron-Beam Used?

A film of electron-sensitive "RESIST" is applied to the surface of the substrate (wafer) to be processed.

The desired pattern details are written with an incredibly thin beam of electrons on the surface of the wafer.

The areas of resist exposed to the electron beam are dissolved away in a "developer" process
(Just like processing the film in your camera.)

The unexposed area of resist remains unaffected on the surface, forming a "stencil" containing the required pattern.

This then allows the wafer to be coated with other materials through this stencil or to be etched.

How small?

The electron beam is scanned in a similar way to the pictures scanned onto your TV screen at home.

A TV scans the picture with 625 lines over the whole screen area.
However, the Vectorbeam tool typically writes the patterns with 262144 dots every 1mm.

That's the equivalent of writing 68,000 dots on the end of a human hair!

Why Use E-Beam?

It has resolution beyond optical methods

It has large intrinsic depth of focus

It can be used by very fast pattern generators

It can be made to operate for both
“Mask making” and
“Direct Write” on wafer substrates

It can stimulate resist exposure effects not possible by other methods

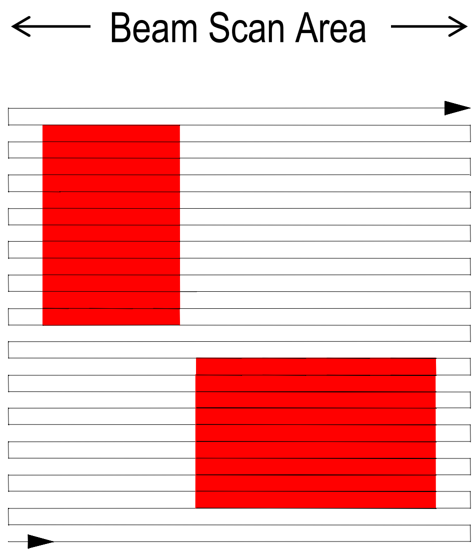
Do You Know Moore's Law?

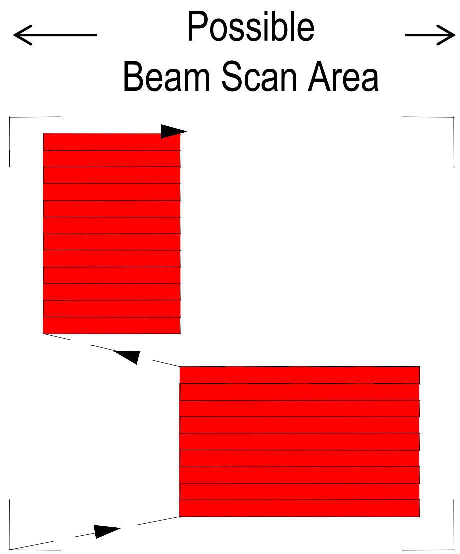
The size of the features in the Silicon Chip components has divided by two every 18 months for the past 25 years!

If a typical modern 1Cm size chip were expanded to the size of a football field, then the smallest detail would still only be 1mm.

Without our E-beam tools there would be no modern mobile phones or communication between telephone exchanges using fibre-optics transmission technology.

Scanning Techniques for E-Beam Lithography





1. Raster Scan

The electron beam is scanned backwards and forwards over a fixed area as shown.
The beam is enabled (“unblanked”) where a shape is required and disabled (“blanked”) where no shapes are required.

2. Vectorscan

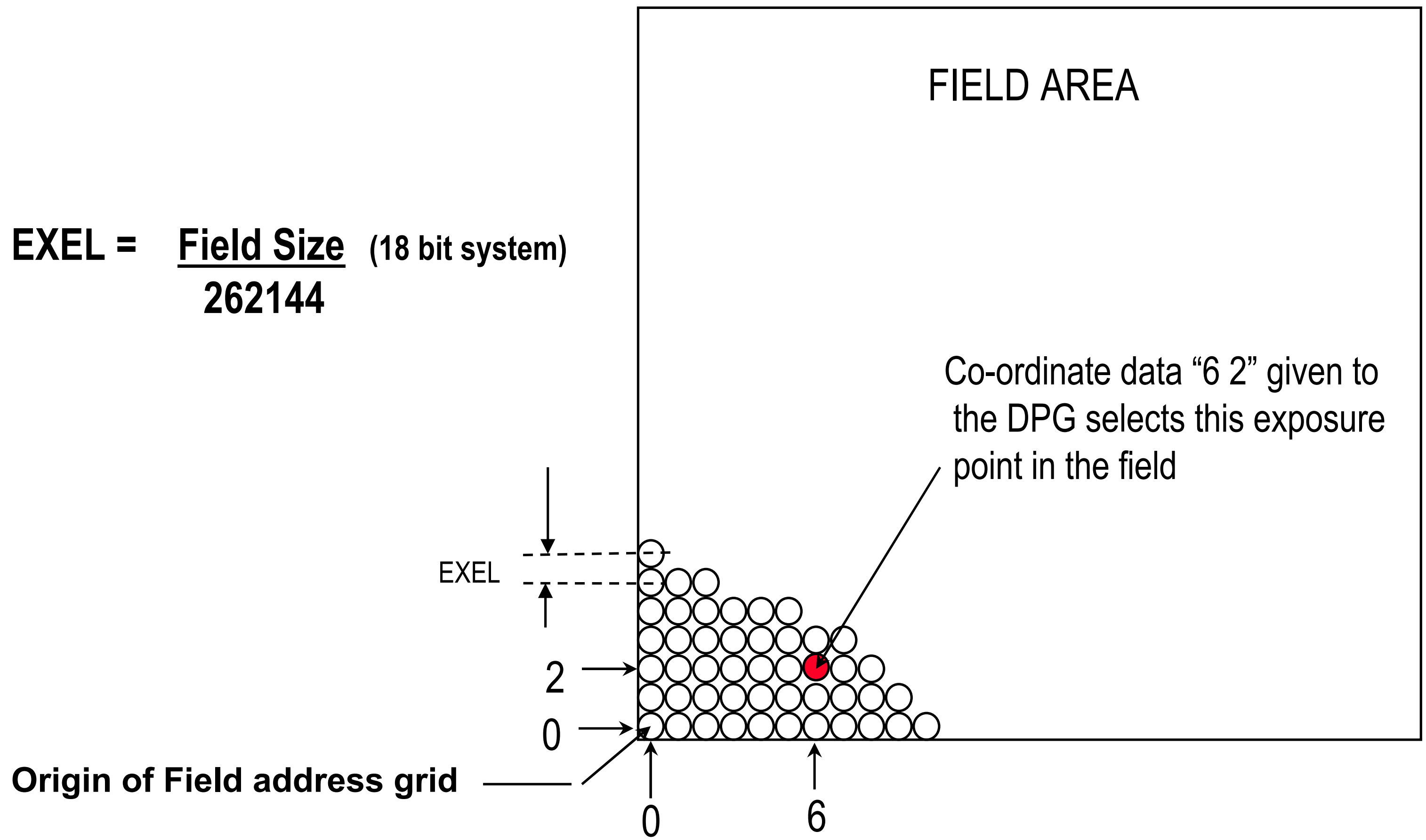
(used by the Vectorbeam and EBPG)
A fixed area called a “Field” is set up.
The electron beam can point to anywhere within this area very accurately.
With the electron beam disabled (“blanked”), it is pointed to the corner position of a required shape.
The beam is then enabled (“unblanked”) and scanned over the area where the shape is required.
When the shape is completed the beam is again blanked.
The process is repeated for the next shape.

Address Grid Resolution of the DPG Field

(2^{18} bit systems)

There are 262144 (2^{18}) possible exposure positions of the beam in each axis.
Selecting the size of the Field determines the interval between each exposure position and the exact location of each exposure point within the Field.
This interval is called an "EXEL" and is often referred to as the "Resolution".

$$\textbf{EXEL} = \frac{\textbf{Field Size}}{\textbf{262144}} \quad \textbf{(18 bit system)}$$



Field Address Resolution

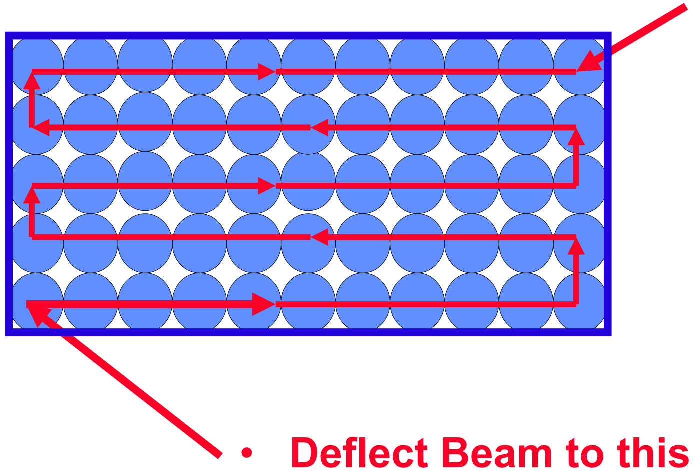
2^{18} bit Systems

The dimension of the Field Size can be set to any value between about 100 micron and 1.31072mm depending on the operating EHT and the version of Vectorbeam System.

This can be used to enable the exposure to reproduce the pattern dimensions precisely.

Field Address Resolution nm/Exel	Field Size (um)	Exels/um
5	1310.72	200
4	1048.576	250
3.0	786.432	333.333
2.5	655.36	400
2.0	524.288	500
1	262.144	1000
0.5	131.072	2000

Vector Scan of a Rectangle Shape

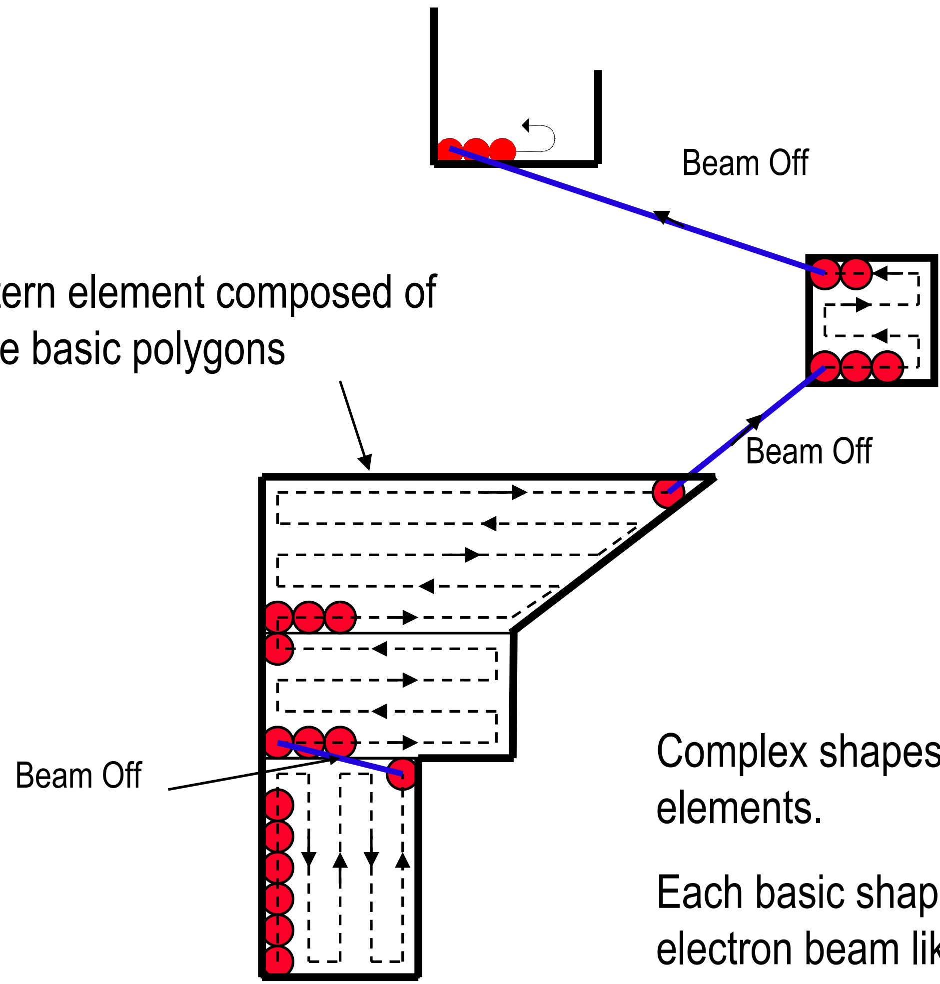


- Deflect Beam to this coordinate position in the Field.
- Allow Beam to settle.
  (delay time depends on distance from end of previous shape)
- Un-blank the beam and start scan exposure sequence

The Beam is stepped to each location in sequence.
The Beam remains at each step-position for a duration determined by the **Dose Clock**.

The size of the rectangle is determined by the step distance
The step distance is determined by the Field Size

Principle of Vectorscan Fill-In Method



Complex shapes are fractured into basic shape elements.

Each basic shape is “shaded” in by scanning the electron beam like a crayon.

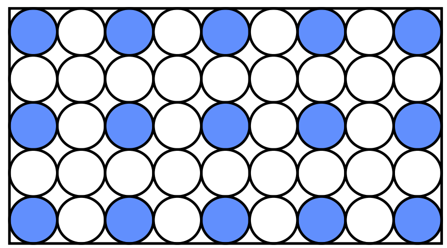
Use of “Variable Resolution”

The start of all shapes is normally on the coordinates of the design data.

However if a Variable Resolution factor or “VRU” is issued then the beam steps in intervals greater than the Field resolution while writing the shapes.

Hence a VRU factor of 2 will cause the beam to step by two exels.

(Valid values 1, 2, 4, 8,16 & 32).



Field Address Resolution with VRU of 18 bit System (Widefield)

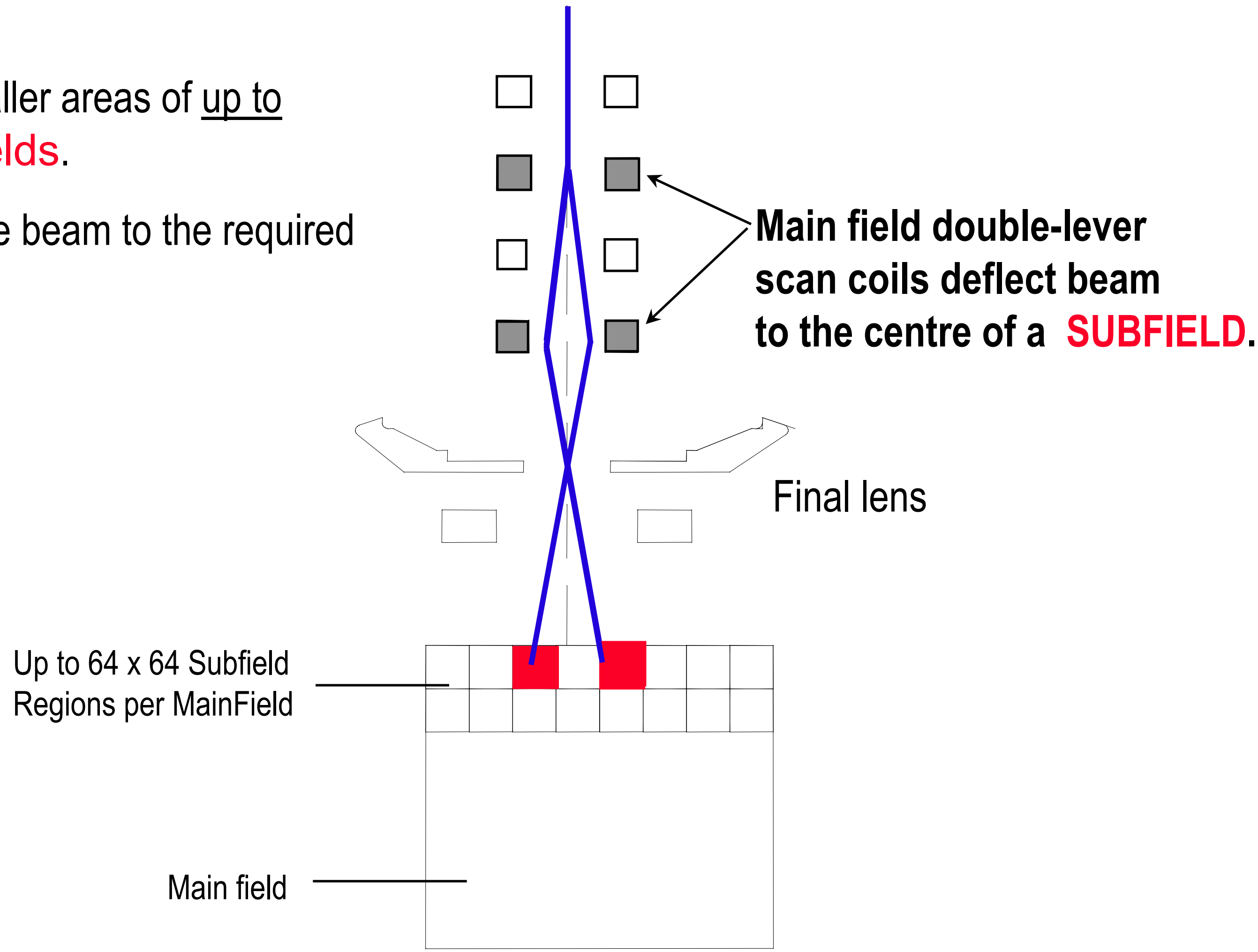
The following is a selection of some commonly used Field-sizes.

Field Size (microns)	Beam Step interval in nano-meters for increasing VRU					
	1	2	4	8	16	32
1310.72	5.000	10.00	20.000	40.000	80.000	160.000
1048.576	4.000	8.000	16.000	32.000	64.000	128.000
819.2	3.125	6.250	12.500	25.000	50.000	100.000
655.36	2.500	5.000	10.000	20.000	40.000	80.000
524.288	2.000	4.000	8.000	16.000	32.000	64.000
327.68	1.250	2.500	5.000	10.000	20.000	40.000
262.144	1.000	2.000	4.000	8.000	16.000	32.000
131.072	0.500	1.000	2.000	4.000	8.000	16.000

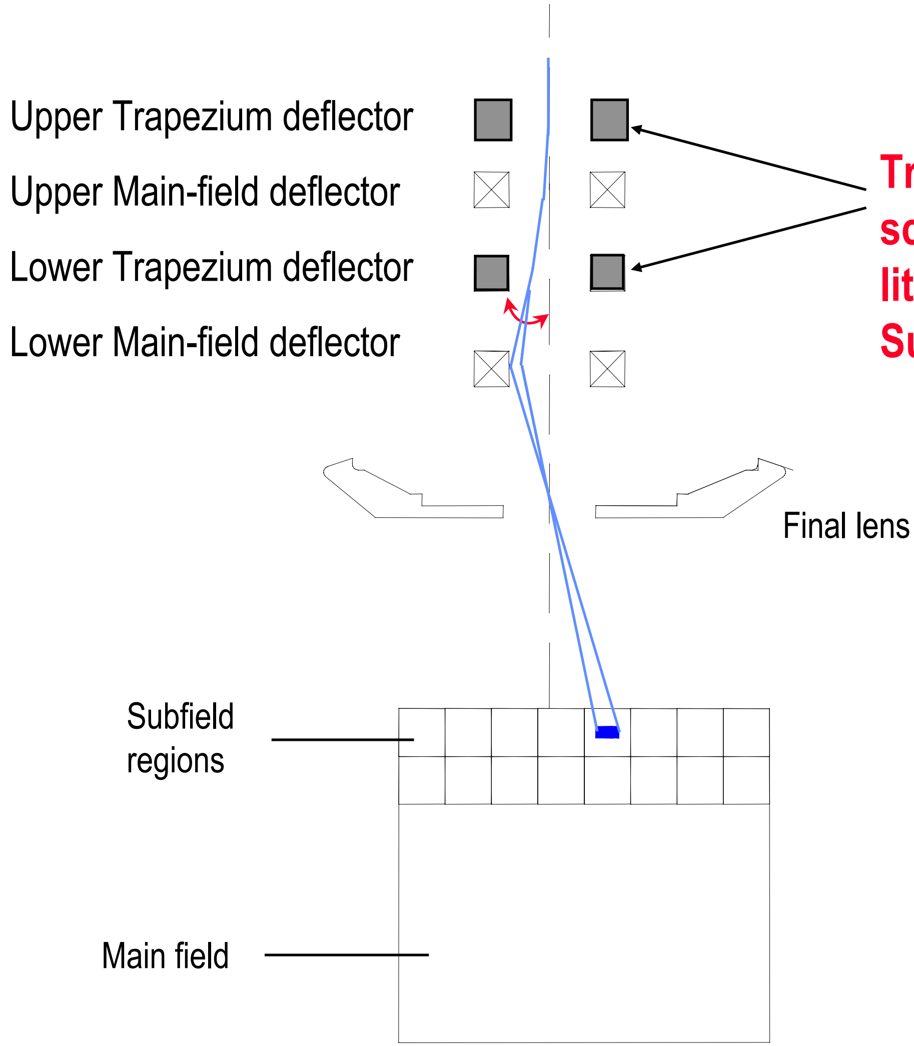
Exposure Scan Strategy
(UHR /2^{20}bit system)

The Main Field is fractured into smaller areas of up to 65536 x 65536 Exels called Subfields.

The Main Field scan coils deflect the beam to the required subfield.



Exposure Scan Strategy
(VB-UHR)



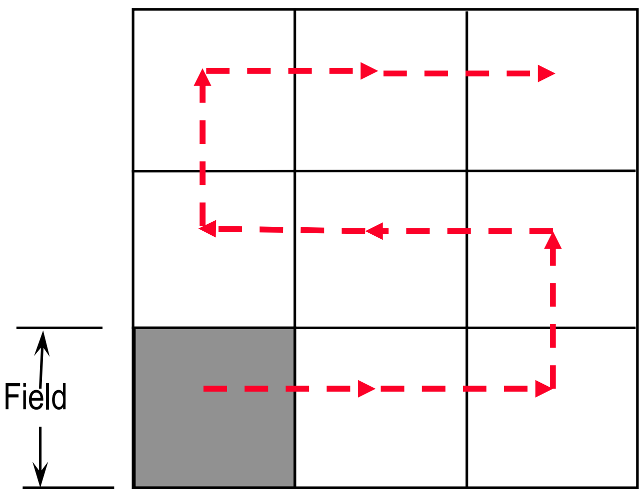
Trapezium Deflectors scan the required lithography within the Subfield.

Exposure of Multiple-Field Patterns

Most patterns extend over an area much larger than the field size.

The pattern data is fractured by the CATS converter into areas equal to the Field.

The Pattern Generator exposes all the shapes within each field using controlled stage movements between fields to seamlessly abut adjacent fields until the entire pattern is completed.



Stage Moves between Field exposures

Exposure of Field Physical Blocks

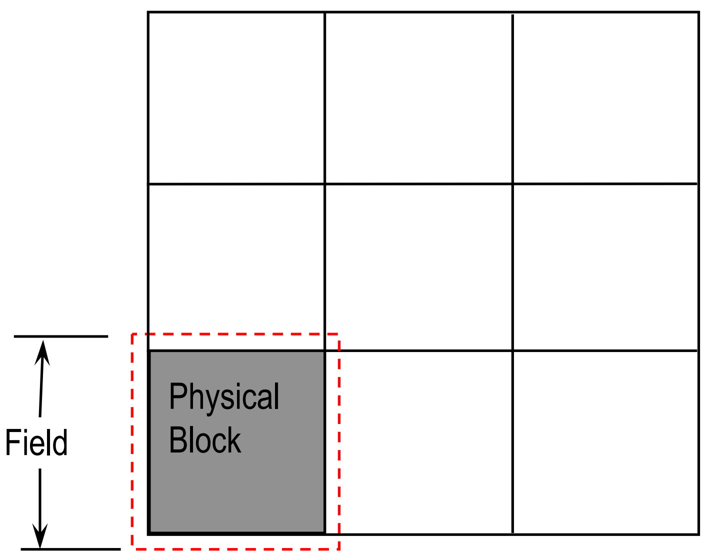
The whole area of the Field need not always be used.

The Pattern Generator can handle areas smaller than the Field called **PHYSICAL BLOCKS**.

The CATS converter determines the size of the Physical Block

In this case, stage movements equal to a Block size are used to “stitch” each Block of exposed data.

This can be used to avoid exposing critical features that would otherwise overlap a field boundary



Multiple-field Pattern made up of multiple Physical Blocks

Subfields and Shape Fracturing.

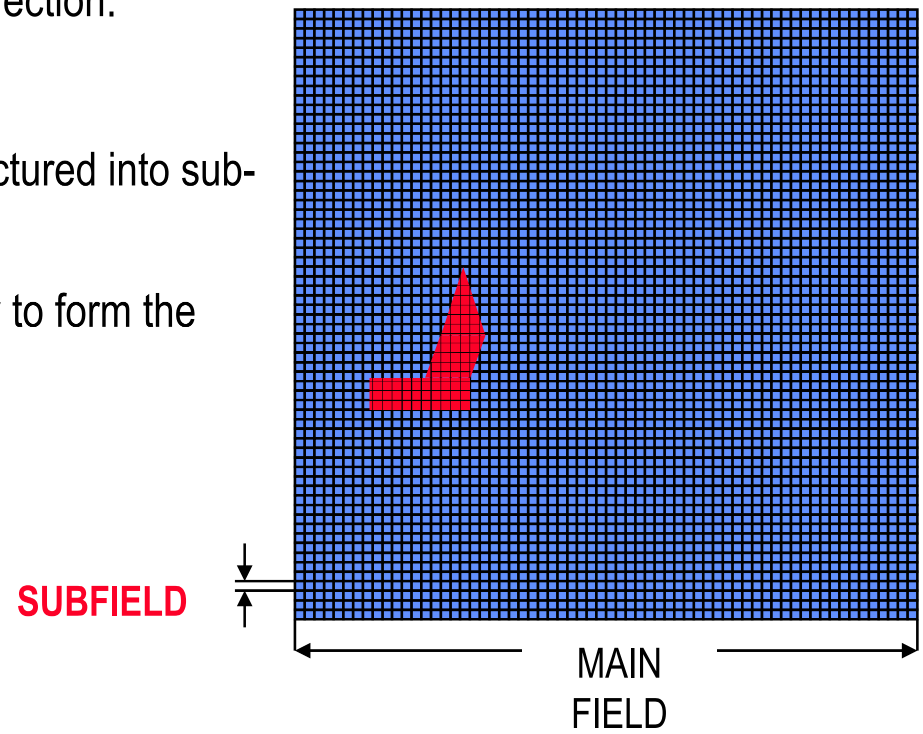
The Main Field area is divided into **SUBFIELDS**
The number of these subfields created can be selected to be either:

- 64 subfields having 16384 exels per axis
- 32 subfields having 32768 exels per axis
- 16 subfields having 65536 exels per axis

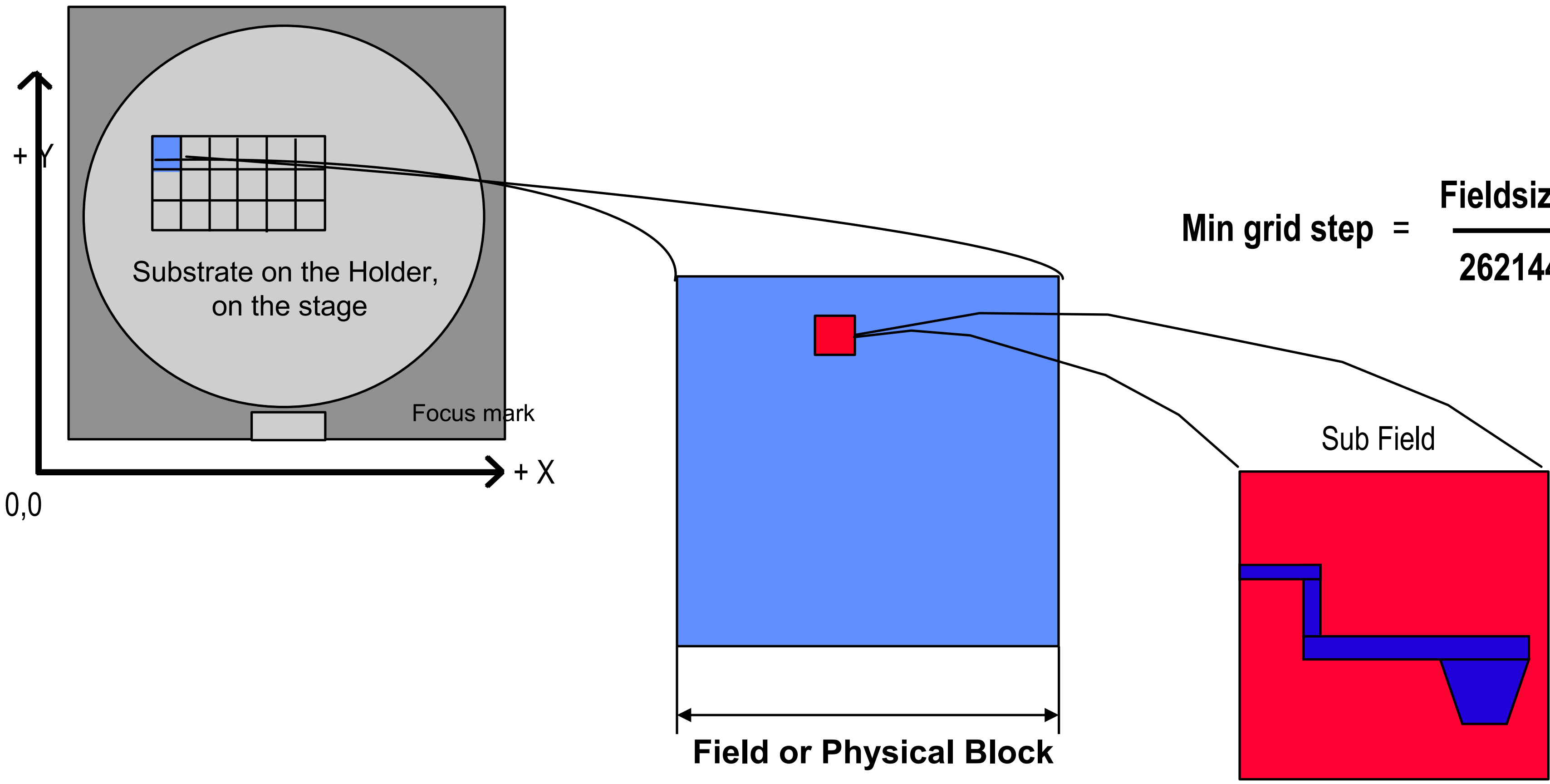
Thus maintaining the same resolution as the main field deflection.
Typically most applications use 64 subfields .

Any shape which overlaps these subfield boundaries is fractured into sub-elements bounded by the subfield locations.

When exposed, the sub-elements butt together seamlessly to form the original total shape.



Writing Strategy
(Widefield)



Min grid step = $\frac{\text{Fieldsize}}{262144}$

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.

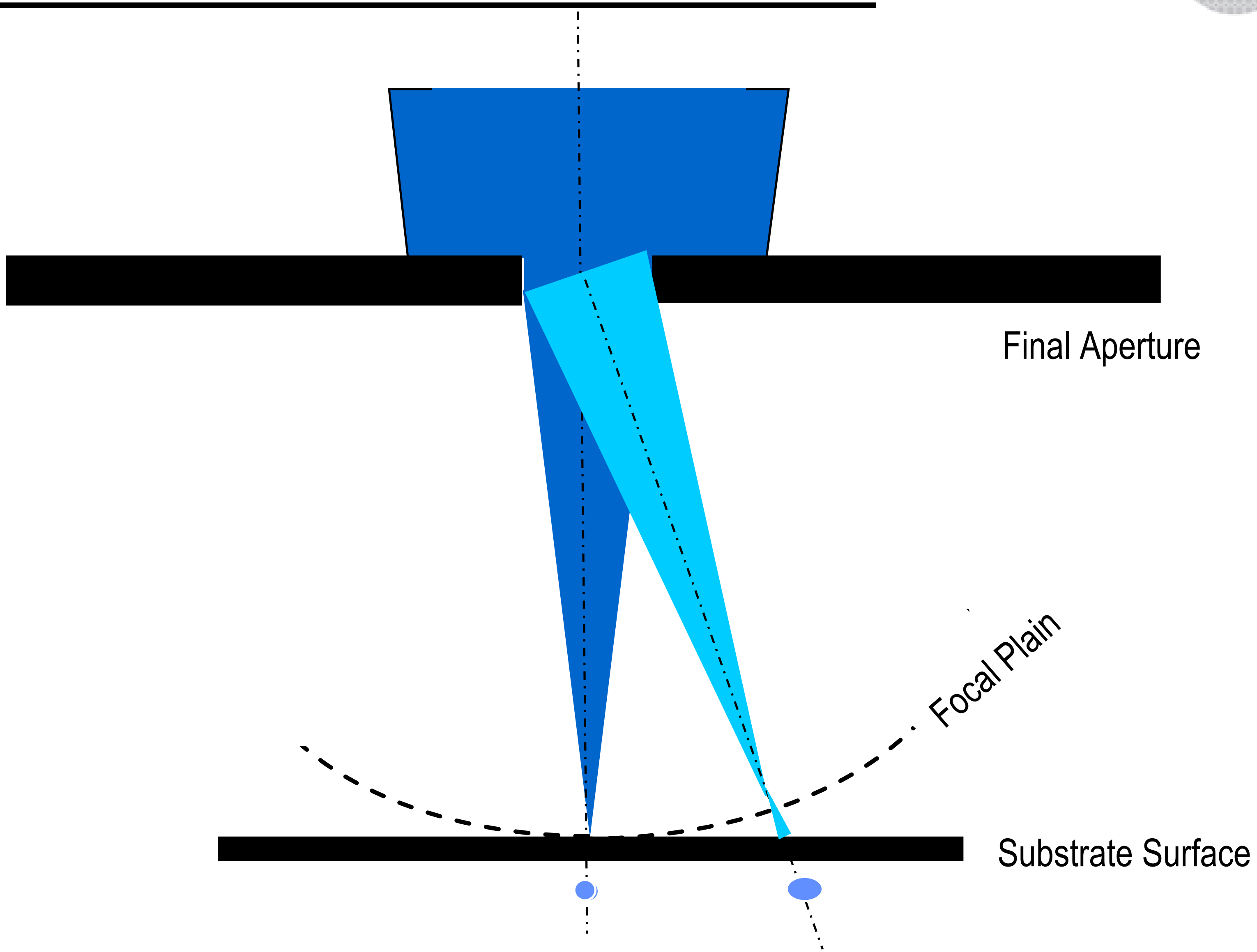
A pattern shape containing 10,000,000 exposure points will take 1 Second to expose with a clock set to 10MHz.

The maximum frequency possible is 25MHz

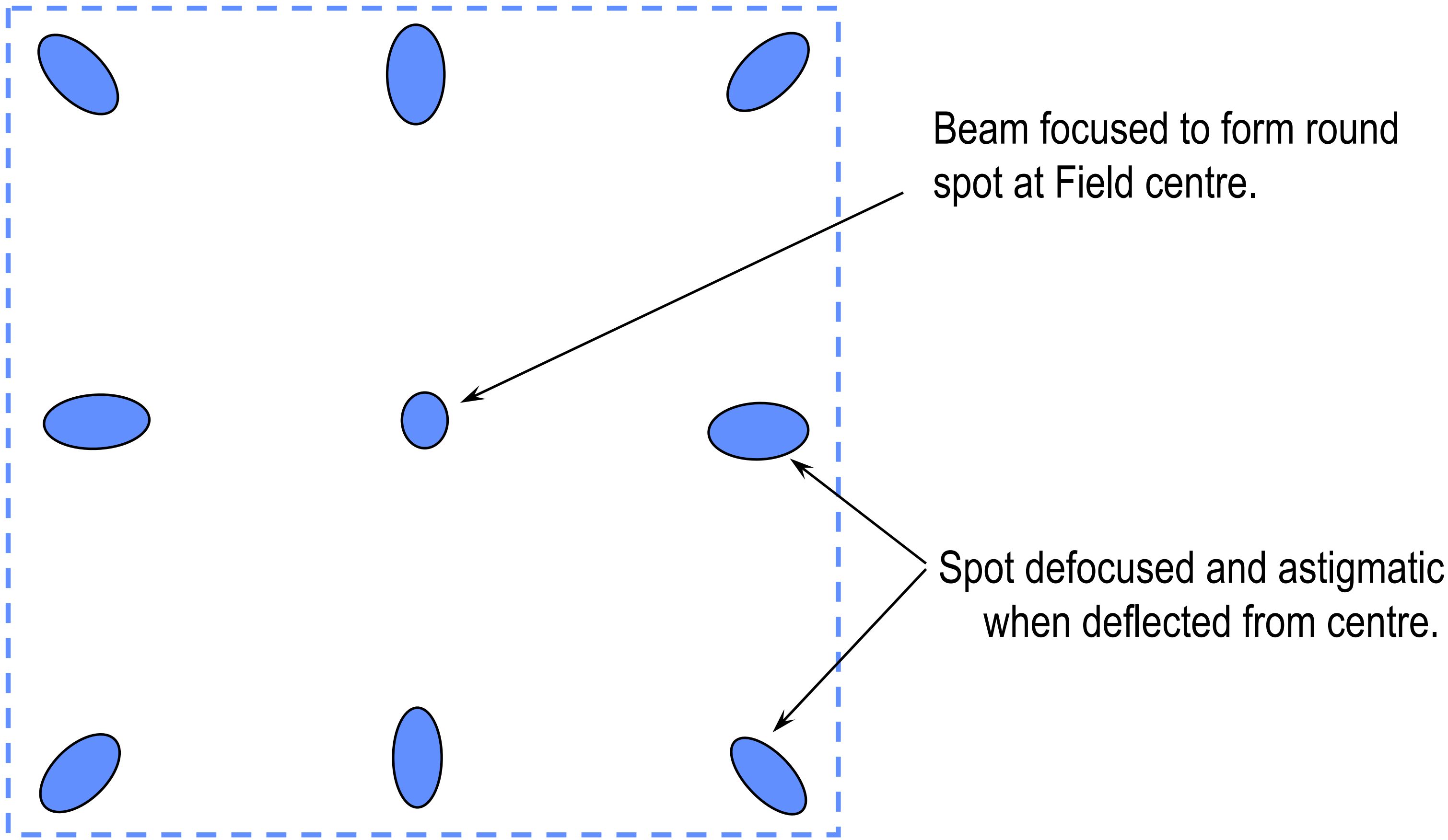
The Dose required for correct exposure depends on the

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

Effect of Beam Deflection on the Beam

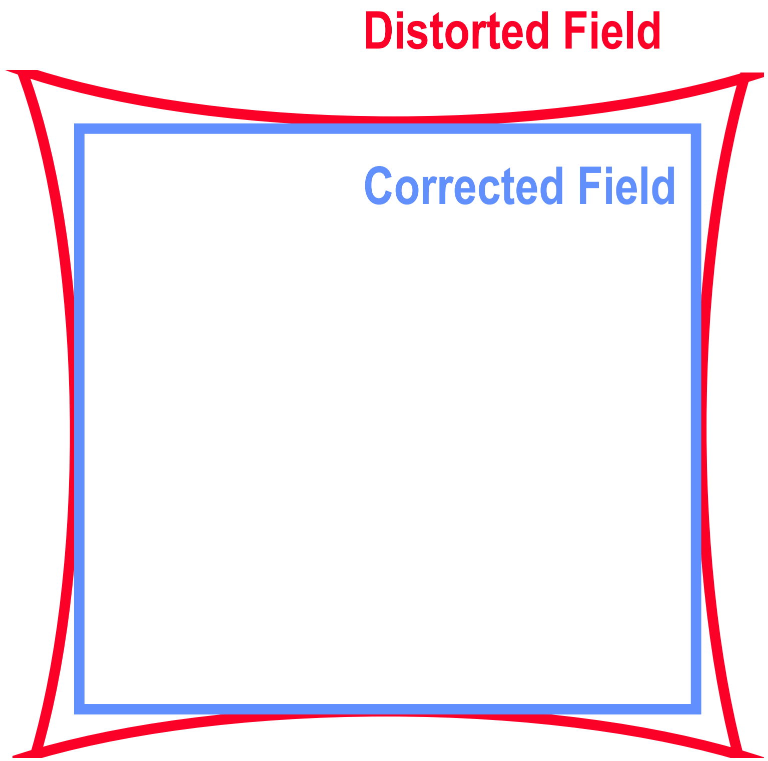


Effect of Beam Deflection on the Focus

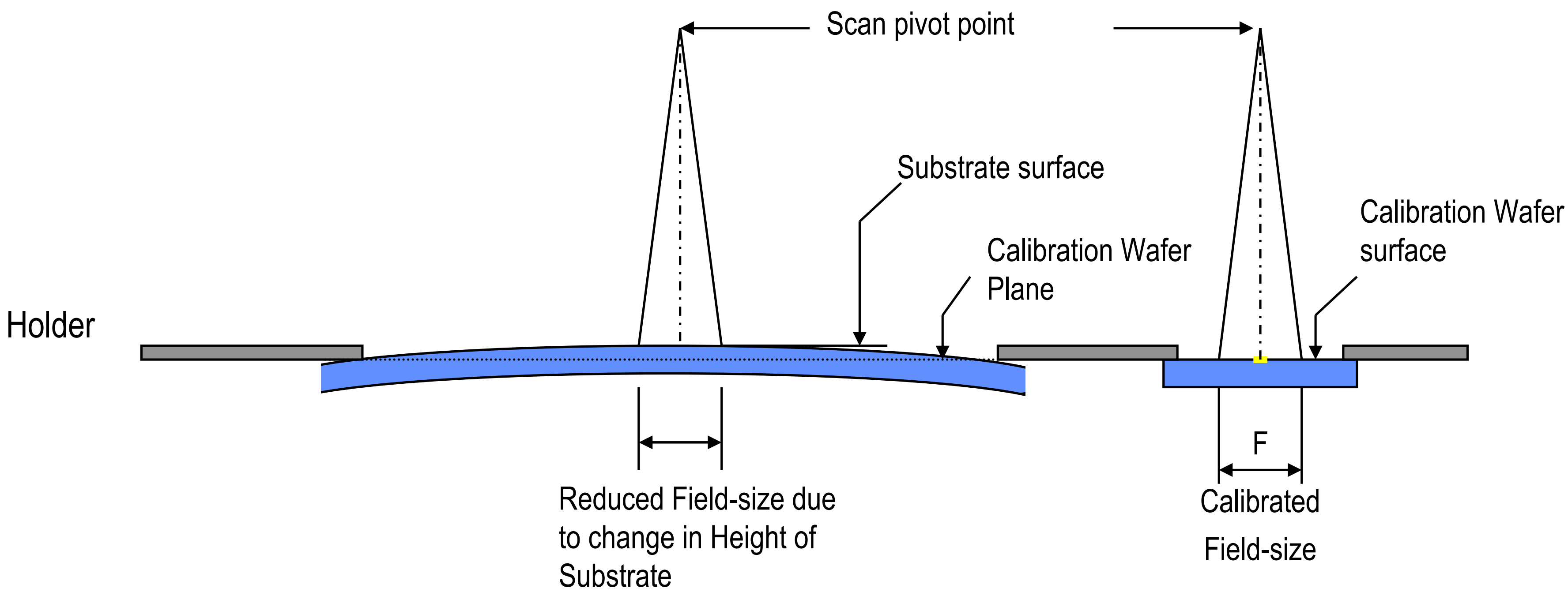


Field Distortion caused by Beam Deflection

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



Effects of Substrate Height Variation

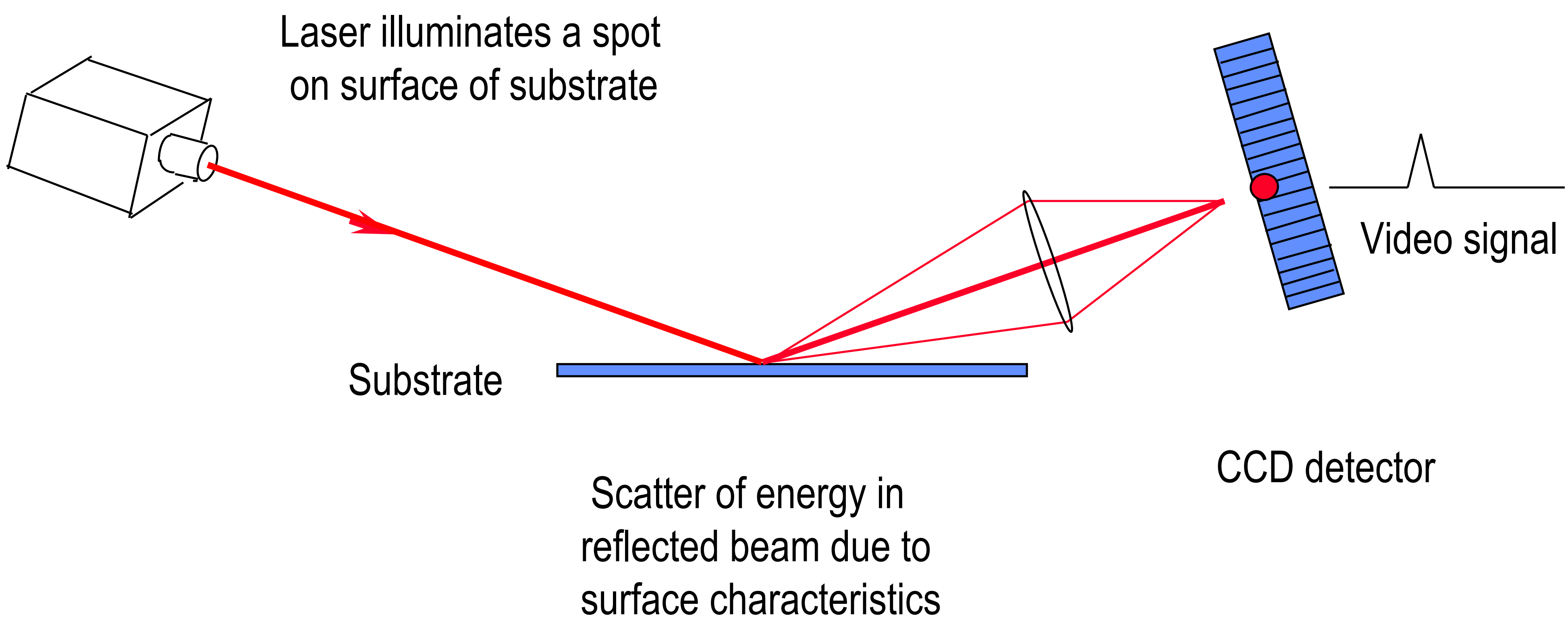


Changes in Substrate surface height relative to plane of the Calibration wafer result in

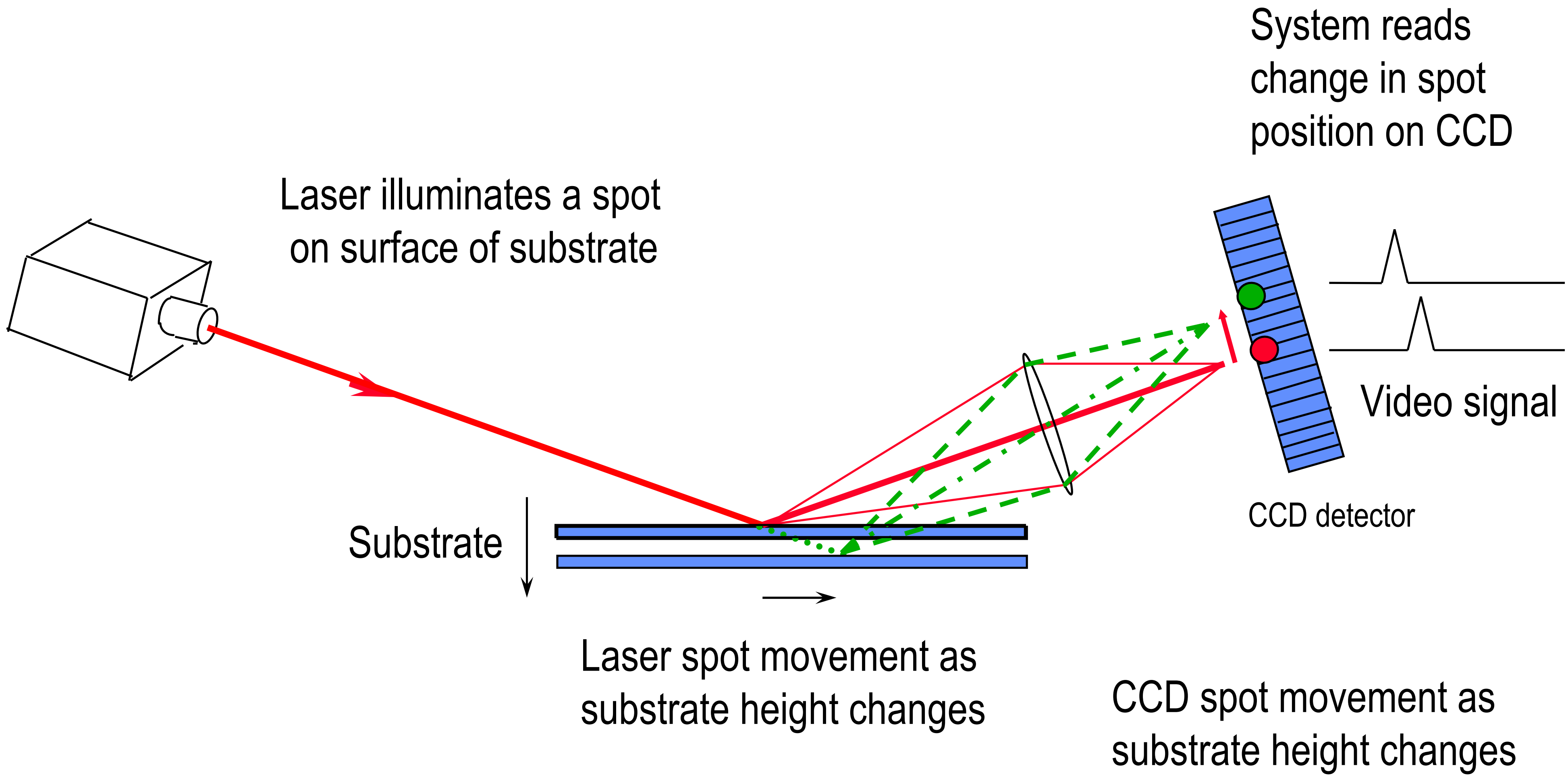
a) Incorrect Field size

b) Defocused beam

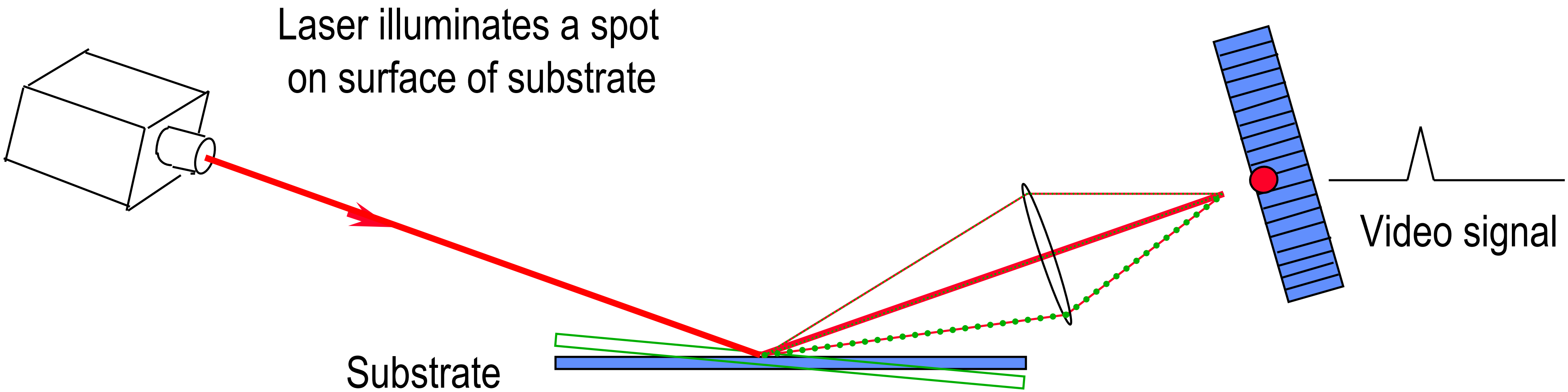
Laser Height Sensor



Laser Height Sensor



<u>Laser Height Sensor</u>



CCD detector

No laser spot movement as substrate tilt occurs

No CCD spot movement as substrate tilt changes

Height Dependant Corrections

After measuring the height , corrections are made to compensate for the height difference between the substrate surface and height of the calibration mark (FM) used for setting up the focus and deflection calibrations.

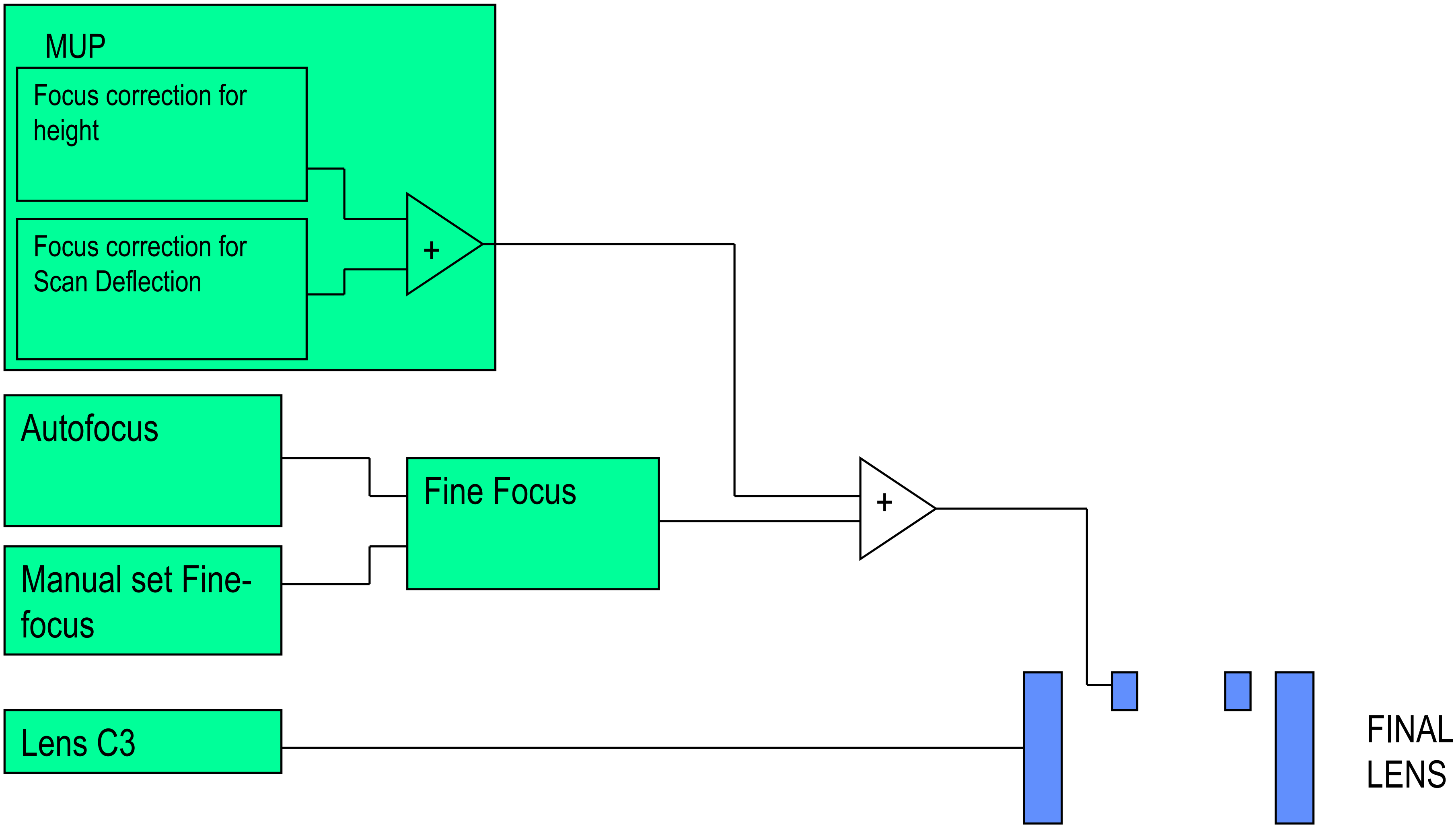
Corrections are calculated and applied for :

Focus (Fine Focus coil)

Deflection Scales - Main Field
- Subfield
- Beam Error Feedback

Deflection Rotation - Main Field
- Subfield
- Beam Error Feedback

Focus Control



Summary Pattern Generator

Functions

- Transfers the Pattern data from the Hard disk to the deflection ccts
- Fractures the pattern in real time
- Sorts the shape exposure sequence
- Controls the dose clock
- Controls the stage during pattern writing
- Adds the corrections to Main, Sub fields and BEF

- PGA temperature control is included & is needed.
- The Mainfield, SEM and BEF all use the same coil and driver
- The FAB display Oscilloscope monitors shows the Analogues
- The Pattern Generator has full control in the FAB mode.
- Correction calculations are very sophisticated.

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.

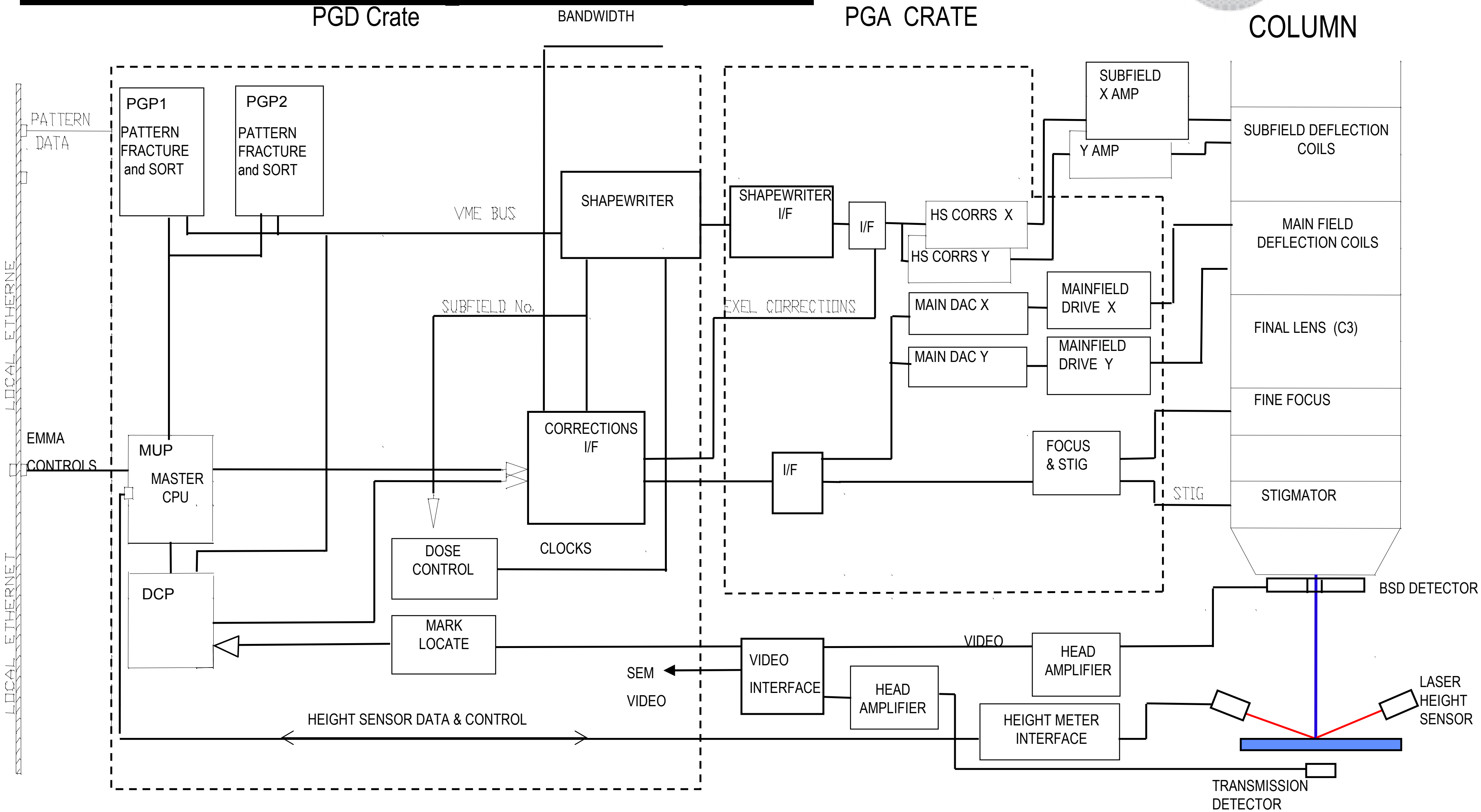
Height

- 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



SCALP (Stage, Chamber, Airlock and Plinth)

The SCALP functions include :-

Stage – Provides precision movement in X/Y axis

- Driven by two air-cooled Stepper-motors

Airlock – Enables fast loading and unloading of substrate from Chamber

Robot – Transfers substrate between Airlock and Stage

Vacuum Control

- Plinth Interlock Control System (PICS)
- Rotary Roughing pumps for Chamber and Airlock, the Column is pumped via the Chamber
- Turbo pumps for Chamber and Airlock
- Ion Pumps, LaB6 1 Gun and 1 Mid column. FEG 2 Gun, 1 Post Anode & 1 Mid column

Nitrogen bleed for system venting

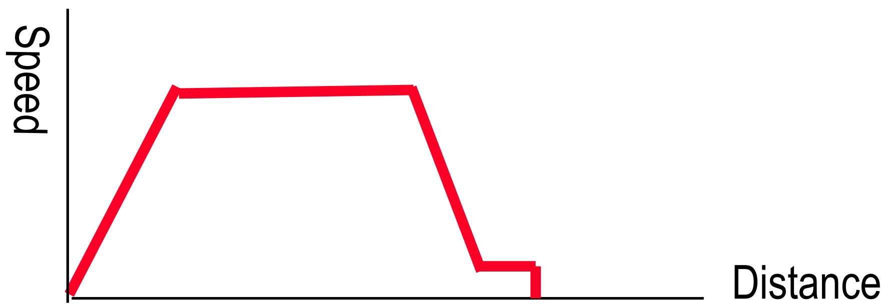
Mimic Panel control to Vent and Pump and monitor valve positions.

Temperature Control Systems

Stage Movement

Stage Movement and Position is achieved by precision controlled motors.

The stage can only be be positioned mechanically to within a few microns of the required position.



Stage Position Measurement is performed by laser interferometer
Depending on the e-beam model, measurement accuracy of 0.00061 micron (6/1000000 mm).

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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

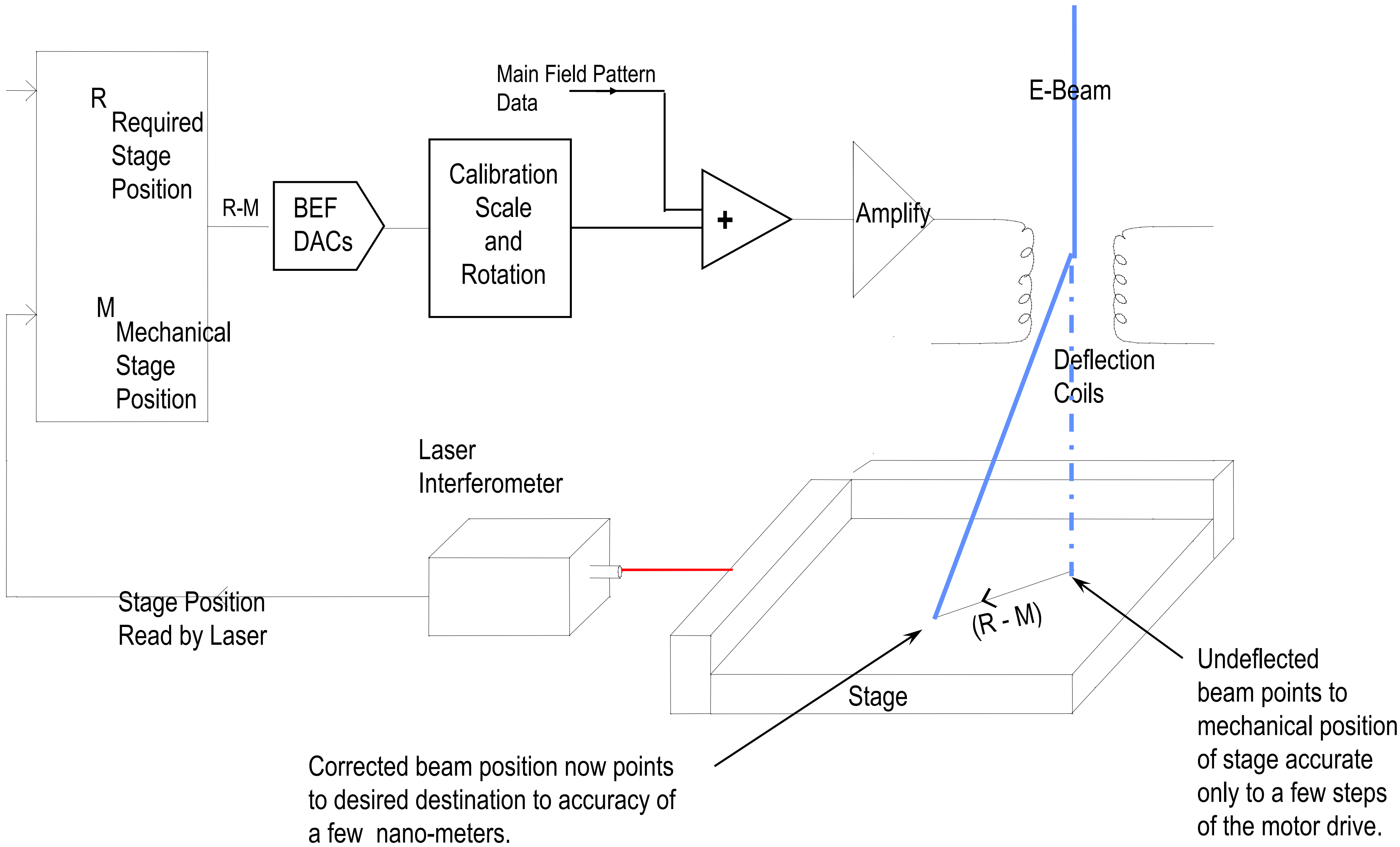
Continuous monitoring of errors measures subsequent position errors.

Continuous correction of variable errors by "Dynamic" Beam Error Feedback

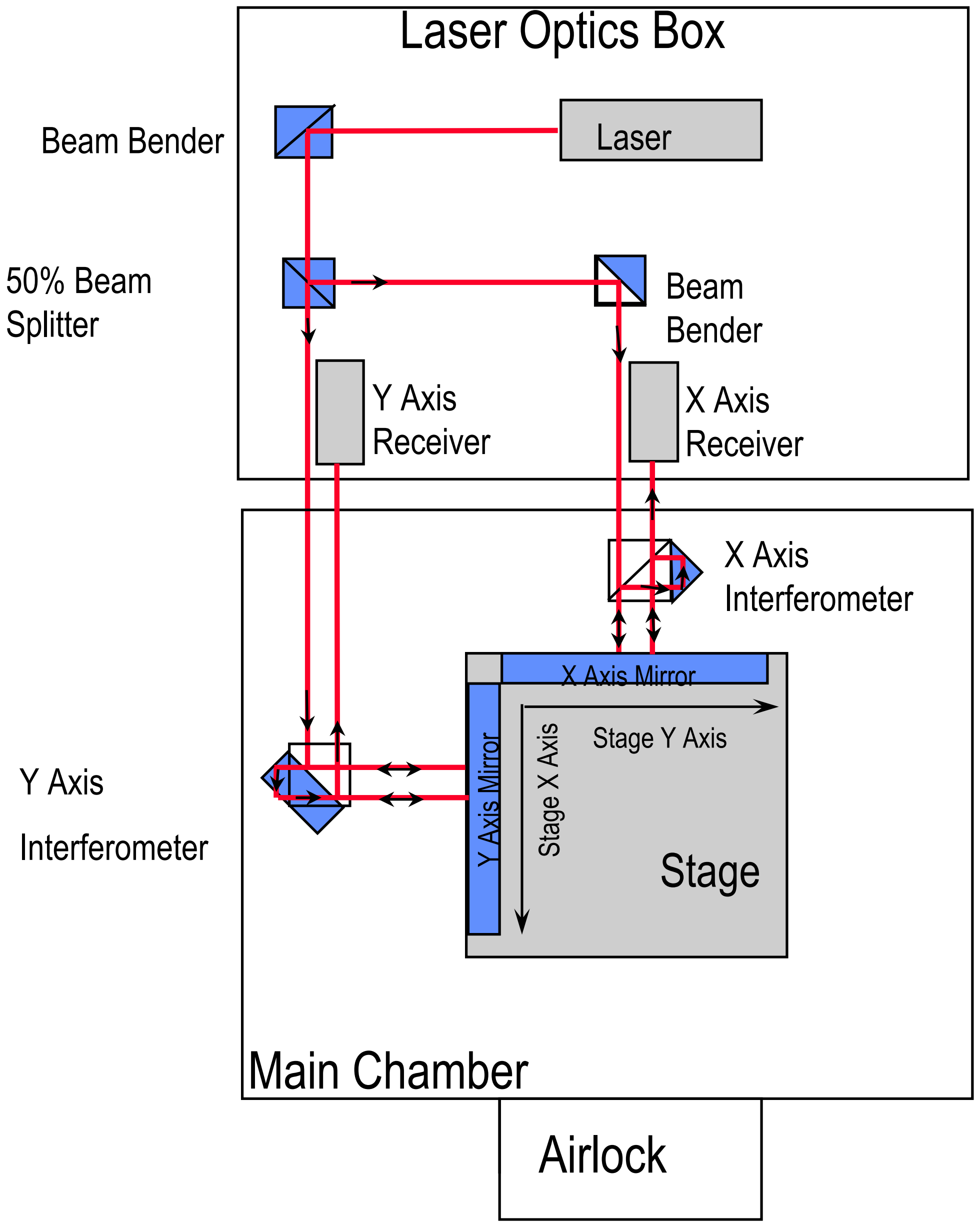
Range of Dynamic BEF = ± 5 microns

Continuous monitoring of the stage position ensures continuous correction for any subsequent position errors - positional drift or small vibrations.

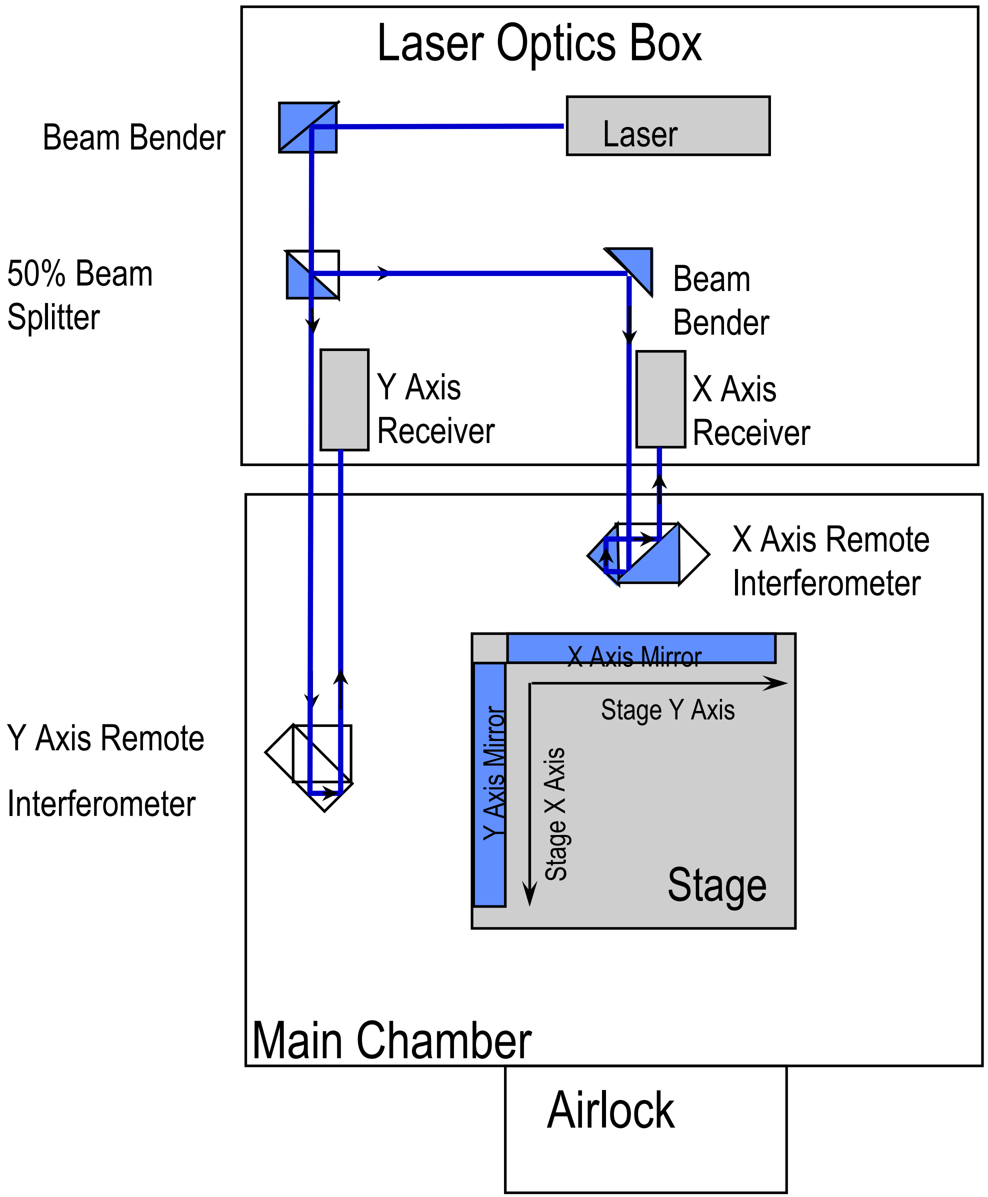
Elements of Beam Error Feedback



Laser Interferometer Optics



Laser Interferometer Optics



The Laser emits a second beam for each axis which is polarized at 90^0 to the first.

This beam travels through a different path as shown. It is reflected back to the Receiver by the Remote Interferometer optics and does not "see" the Stage.

This beam measures any changes of path length between the Laser and the Remote Interferometer units.

The measurements of the two beams are combined and the resultant signal output provides an accurate measurement of the position of the stage relative to the remote interferometer units.

Hence changes of room temperature affecting the path length in the Laser Optics Box do not affect the accuracy of the measurement of the Stage position.

Vacuum System

All vacuum system functions are controlled and continuously monitored by powerful software from an independent processor.

Automatic Bakeout control to obtain Vacuum level required by Cathode. (Requires 2 days)

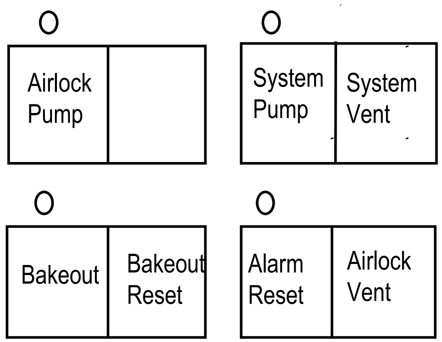
Simple user-friendly operator interface with comprehensive status display.

Vacuum System and Control

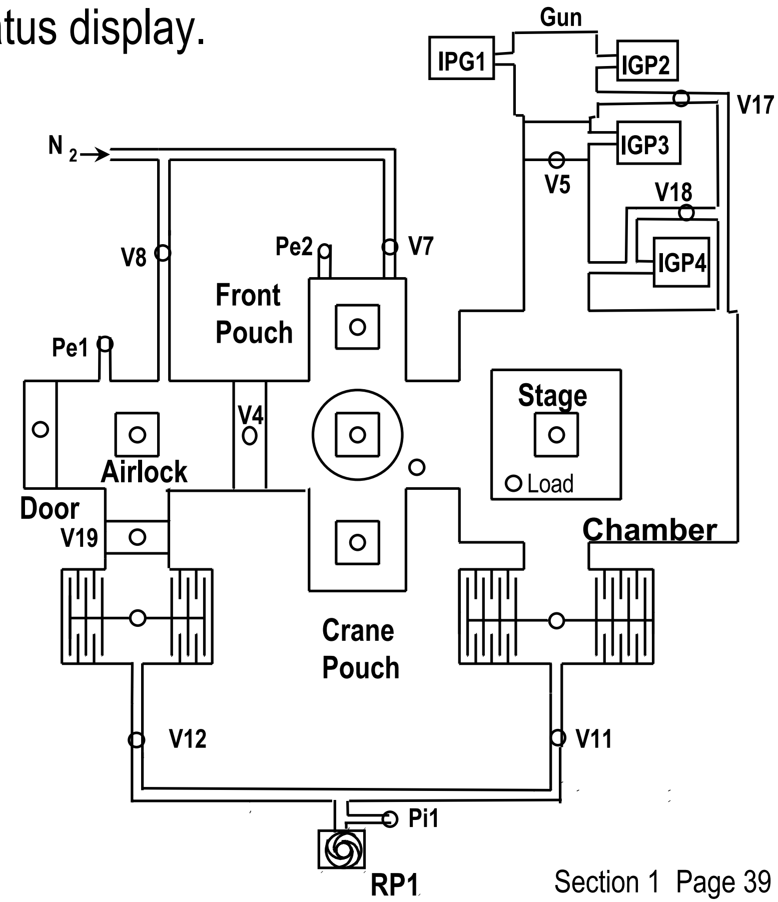
All vacuum system functions are controlled and continuously monitored by an independent processor using powerful “**PICS**”software (**P**linth **I**nterlock **C**ontrol **S**ystem).

Automatic Bakeout control to obtain Vacuum level required by Cathode. (Requires 2 days)

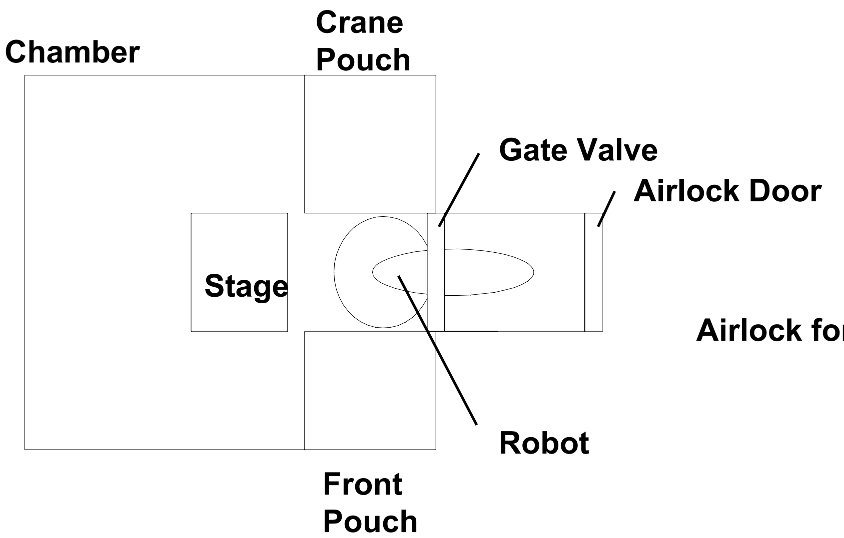
Simple user-friendly operator interface with comprehensive status display.



Vacuum operated from this simple push-button panel



Substrate Handling



Airlock for handling up to 10 substrate holders

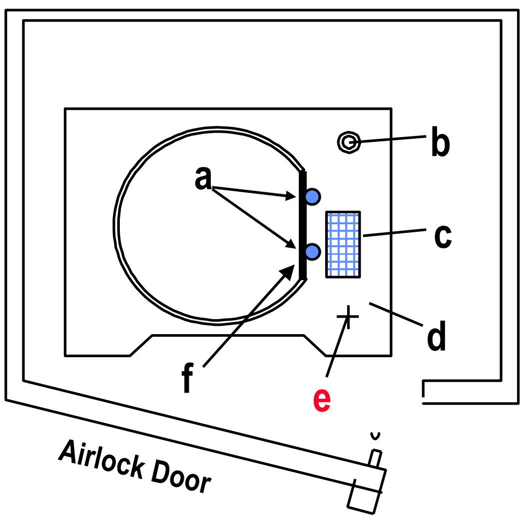
- Substrates can be moved between any source and destination - AL, FP, CP, CH.
- Hardware sensors allow software to determine legal moves.
- One pouch is used to condition the next substrate while the current one is being written.
- The other pouch may be used to hold a stitch plate for machine monitoring.

10 Chuck Airlock

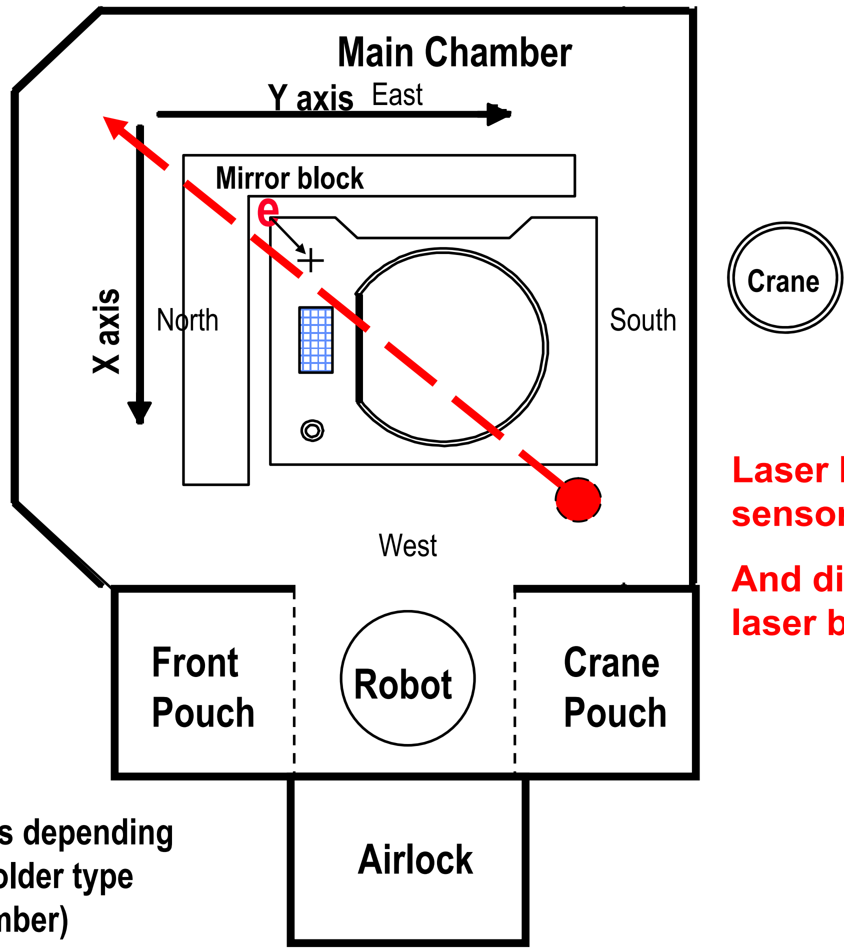
- Up to 10 Holders may be held in the Airlock
- Holders can be transferred from the Airlock to the Stage in any sequence and can be returned to any spare position in the airlock.
- Each holder has a unique serial number identified by a barcode which can be read by the airlock.
- The database HOLDER_TABLE.COM contains the information of every holder, its serial number, type, substrate size and important parameters.
- A database file CASPOS.COM contains the reference number and location of holders in the airlock.
- After loading a holder onto the stage the holder must be "initialized".
  Initialising loads all the parameters stored in the HOLDER_TABLE.COM database associated with the holder and makes a height check.

Holder alignment

Holder when correctly loaded into Airlock



Holder as viewed on the Stage



Laser height sensor Diode

And direction of laser beam

IDENTIFICATIONS.

a) Reference pins
b) Faraday cup
c) Calibration wafer, contains calibration mark (FM) gun emission target (GT) various other mark types
d) Molybdenum block
e) 0,0
f) Wafer flat - orientation varies depending on the specific substrate holder type (substrate size, type or number)

Temperature Control

The accuracy of the lithography created by the Vectorbeam system depends on the temperature control and stability of the chamber, stage, column and electronics.

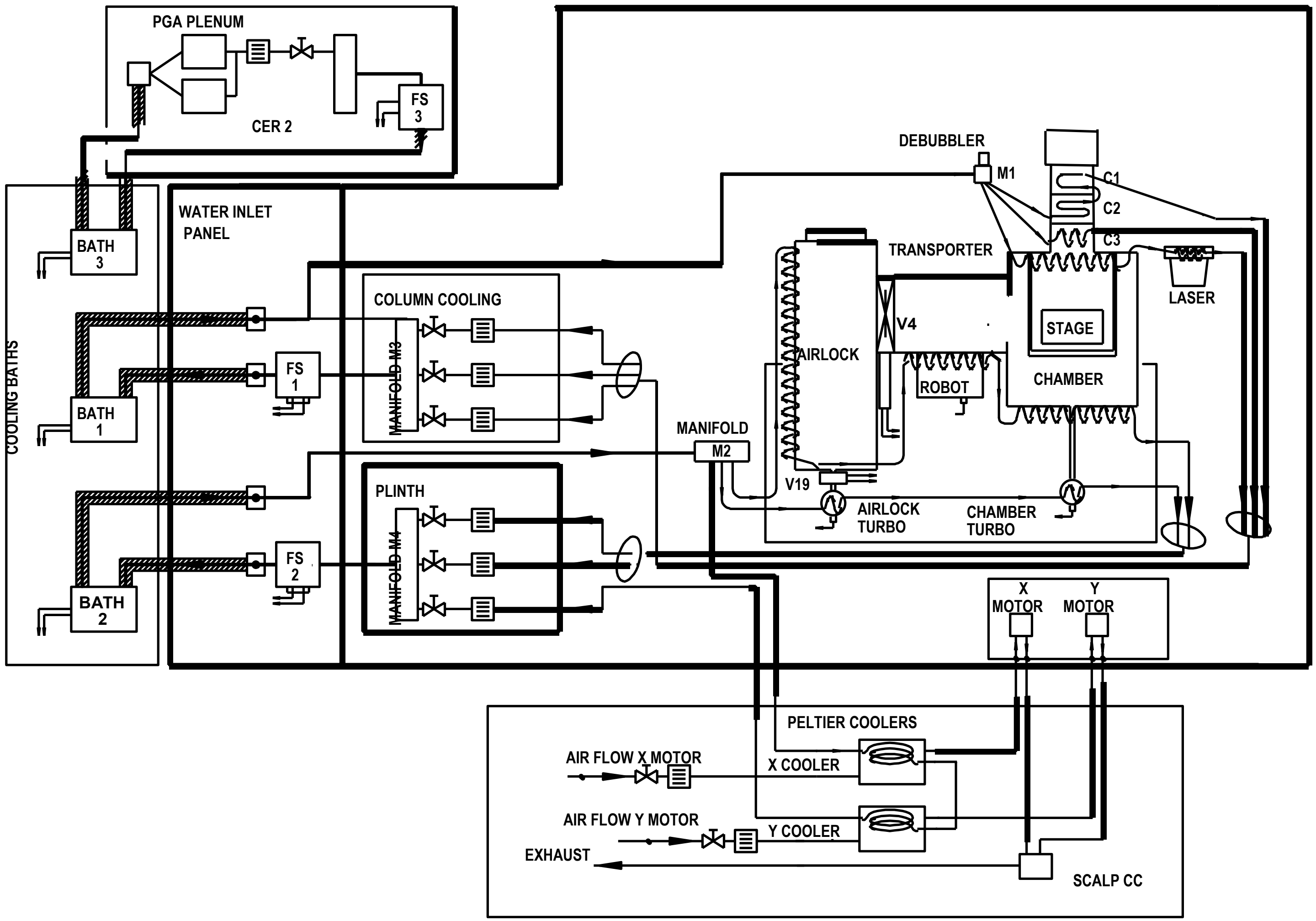
The water levels of the temperature baths need regular checking.
Typically, the water requires topping up at least once a week.

The stage motors are air-cooled by a sophisticated control mechanism requiring careful balancing of flow rates and temperature settings.

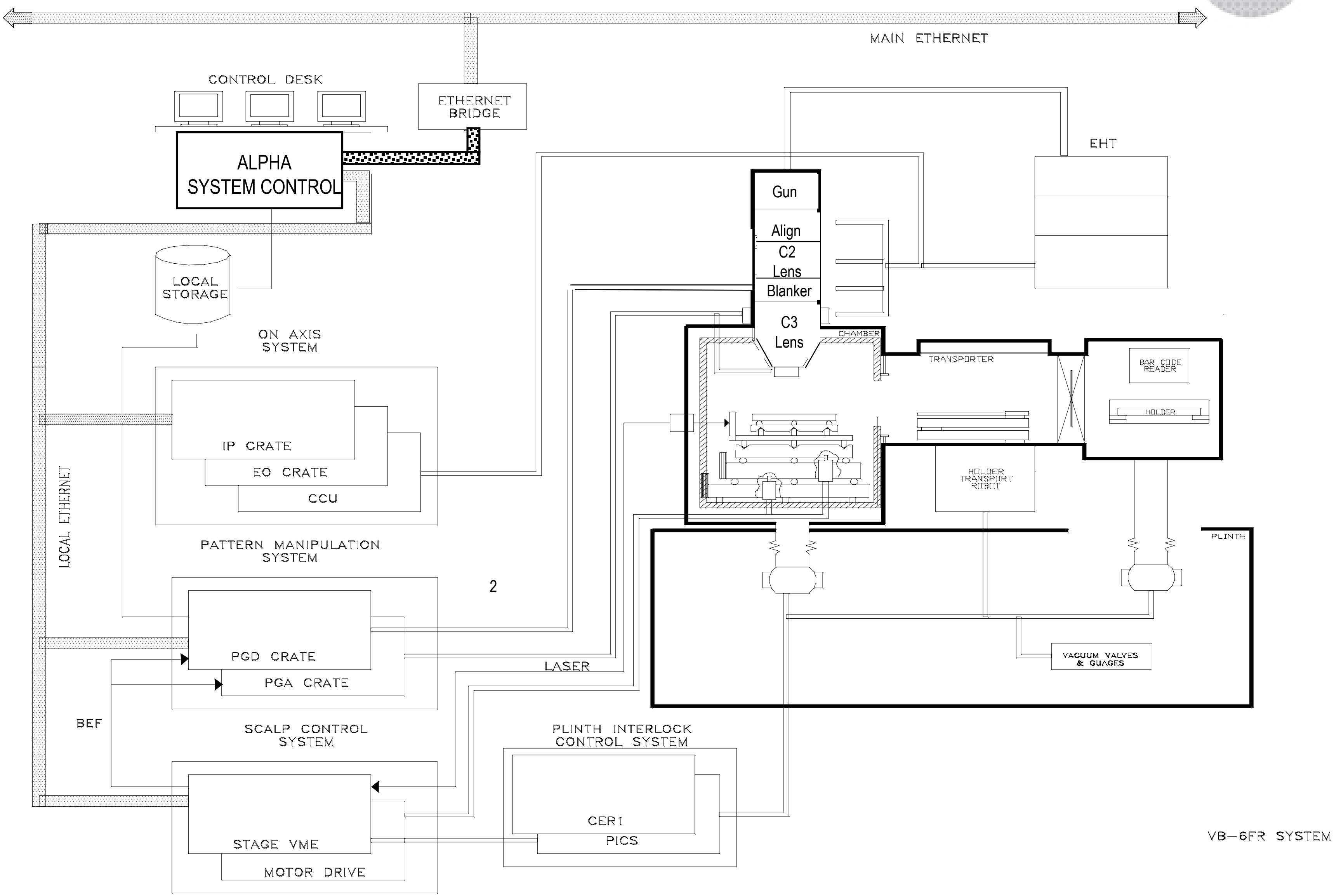
Comfirmation that the temperature control is functioning correctly should be made regularly.
This can be done by running the test jobfile HT_STAB.COM

NOTE: The water temperature baths require checking EVERY week and topped up with distilled or de-mineralised water.

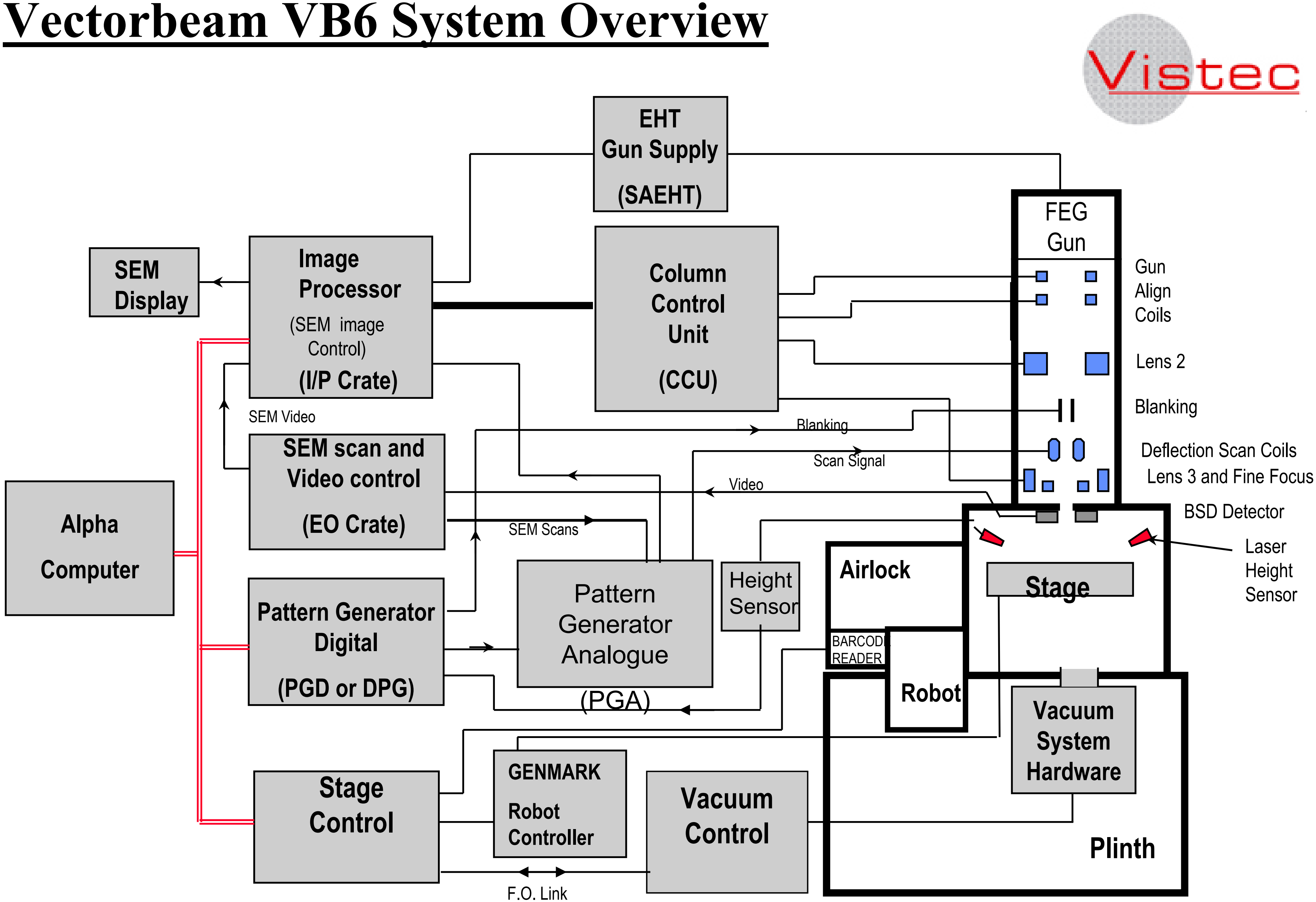
Temperature Control



Vectorbeam VB6 System Configuration



Vectorbeam VB6 System Overview



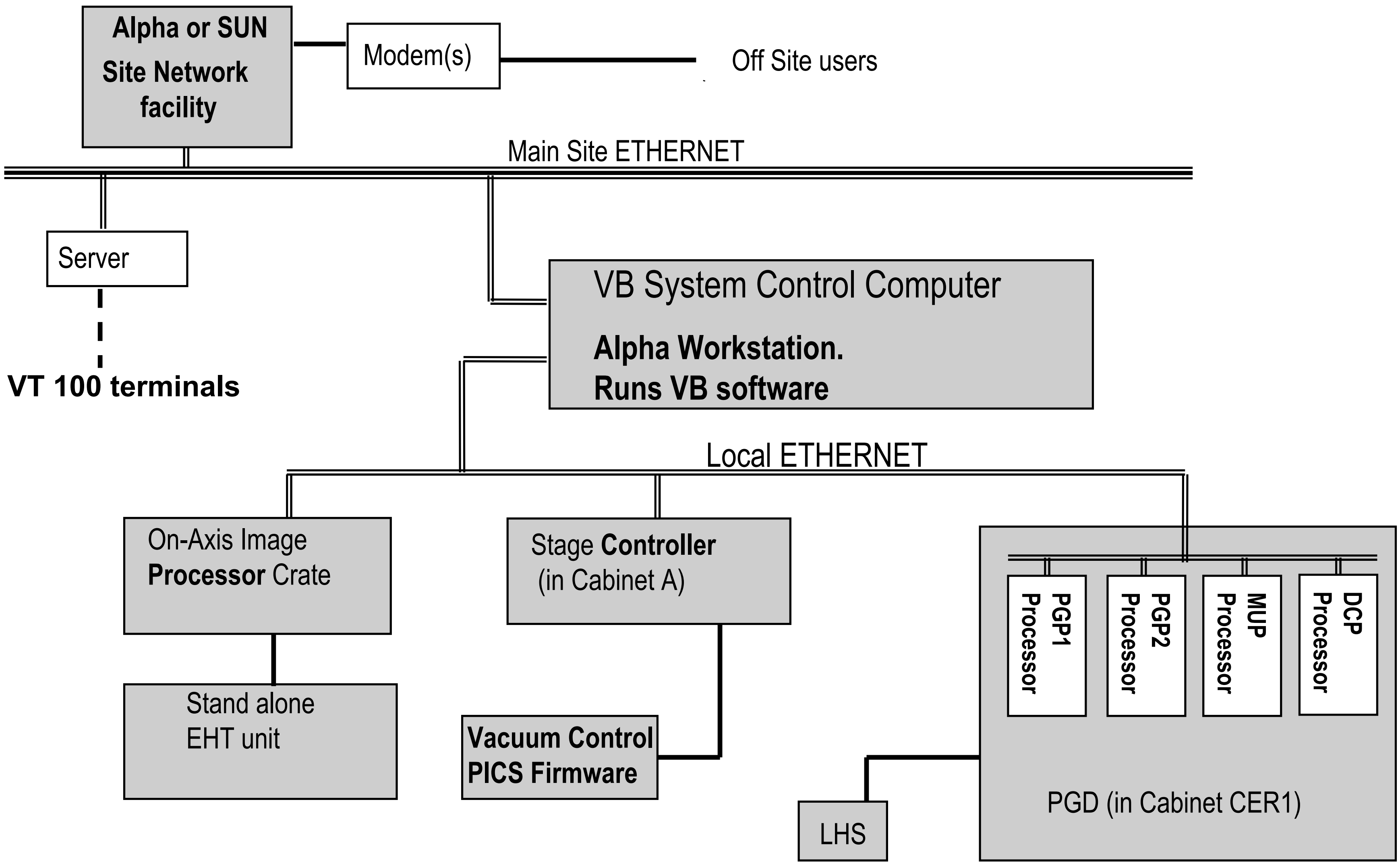
Power Supply

An Uninterruptible Power Supply (UPS) provides protection from brown-outs and voltage surges on the Mains.

Following a sudden mains power failure the UPS allows approximately 20 minutes of machine operation, during which the operator can safely run down the system.

The links from the UPS to the Vacuum control system will automatically shut down the Gun and vacuum system when the Battery supply runs critically low.

VB6 Processor Data Flow



EMMA Software Control
Brief Overview

System Control

An ALPHA computer communicates with all the Sub-systems via a LAN.
(Pattern Generator, Stage Control and Image Processor.)

The ALPHA runs under the VMS Windows Operating System

Most Vectorbeam functions are controlled by the EMMA software.

- by commands from the keyboard
- by commands within Command Files run on the ALPHA
- by operator actions within various interactive panels on the Display

The Vacuum System is controlled by PICS (Plinth Interlock Control System)

Operator Control

Booting the ALPHA and entering the Username and Password will produce the VMS "Operator" prompt :

VB_OPER>

When working with this logged-on session the user has normal "Operator" control of the system operation and functions. There can be only one system Operator.

Anyone logging on after this will be given the prompt

VB_SUPER>

Working in any of these logged-on sessions enables only limited access to the system. EMMA Display functions can be used but the EMMA panels cannot be displayed

Logging OFF by the Operator enables the next person to Log ON to become the Operator.

EMMA

EMMA commands run within the VMS operating system

Commands can be mixed with VMS commands

EMMA commands can use VMS functions - eg

- Symbols
- Logicals
- Lexicals

VMS can call EMMA commands

EMMA and VMS commands can be incorporated in Command files to create operation sequences, subroutines or databases.

Command files can use the VMS logic functions such as

- IF….Then
- Go To
- Loop

EMMA Vectorbeam Command Set

There are 12 sets of commands:

Each command starts with “Q” to differentiate the command from being a DCL command.

QINITIALISE	Connecting EMMA to the subsystems
QMOVE	Moving the Stage
QSUBSTRATE	Loading/unloading substrates
QSET	Setting a system parameters or status
QADJUST	Optimising various setup requirements of the system
QCALIBRATE	Calibration of deflection system
QEXPOSE	Exposing a pattern
QDISPLAY	Displaying system information
QMAP	Creating or entering “Mapped” modes
QLOCATE	Measurement of alignment marks
QMARK	Defining or displaying alignment mark parameters
QFILE	Saving and restoring of system parameter data-bases

EMMA Command Format

Long form - example to Calibrate Main field

qCALIBRATE MAIN /noalign/iter=10/acc=0.005/ cover=0.984 /diag

qCALIBRATE MAIN

Short form- example to Calibrate Main field

CMFI

- All three commands perform the same task.
- Commands are not case sensitive.
- When an option parameter is not specified a default value is automatically applied.
- The Short form can be assigned different default values.
- Some short form commands do not function when used in command files.
  (If in doubt, use the long form!)

Calibrate Functions

qCALIBRATE commands are used to calibrate the system

- Main Field deflection

  scaling and rotation
  deflection distortion
  deflection focus
  deflection astigmatism

- Subfield deflection

  scaling and rotation

- Beam Error Feedback

- Stage magnetic mapping

- Substrate height mapping

Adjust Functions

The **ADJUST** commands are used to optimise the set-up of a parameter or property of the system.

Some "Adjust" functions involve the use of data determined by previous calibrations.

ASTG

qADJUST STIGMATION

(Adjust the stigmation and focus to optimise the beam at the main scan field centre.)

The "Set" Functions

A **SET** command may be used to assign a limit or set a value to a system parameter (e.g. high voltage).

It can also be used to select a system function or state.

Examples:

SFOC 0.5

qSET FF 0.5

(This sets the current controlling the "fine focus" coil to the specified value.)

SSEM

qSET MODE SEM

(This sets the system into the SEM system facilities mode and allows mouse control of the column functions.)

Move Commands

MOVE commands are used for controlling the stage.

All stage move dimensions are in mm.

Example:

MVPO 50 23.1234567
qMOVE POSITION 50 23.1234567

(This moves the stage to the specified stage position)

The “Display” Function

The **DISPLAY** command can be used to display the value of a system parameter as currently stored.

When used with the **/READ** option the actual (real-time) specified parameter will be read before displaying the value. (without the /READ option the displayed value is either the last value read or the last value sent as the target, whichever is the most recent).

Example:

DVAC

qDISPLAY VACUUM

This displays the current vacuum system status and vacuum pressures for the individual pumped sections of the system.

EMMA Control Panels

Many functions of the Vectorbeam can be displayed and/or controlled with the mouse from Panels on the ALPHA screen.

Column control (Alignment, Lens, focus, stigmation)

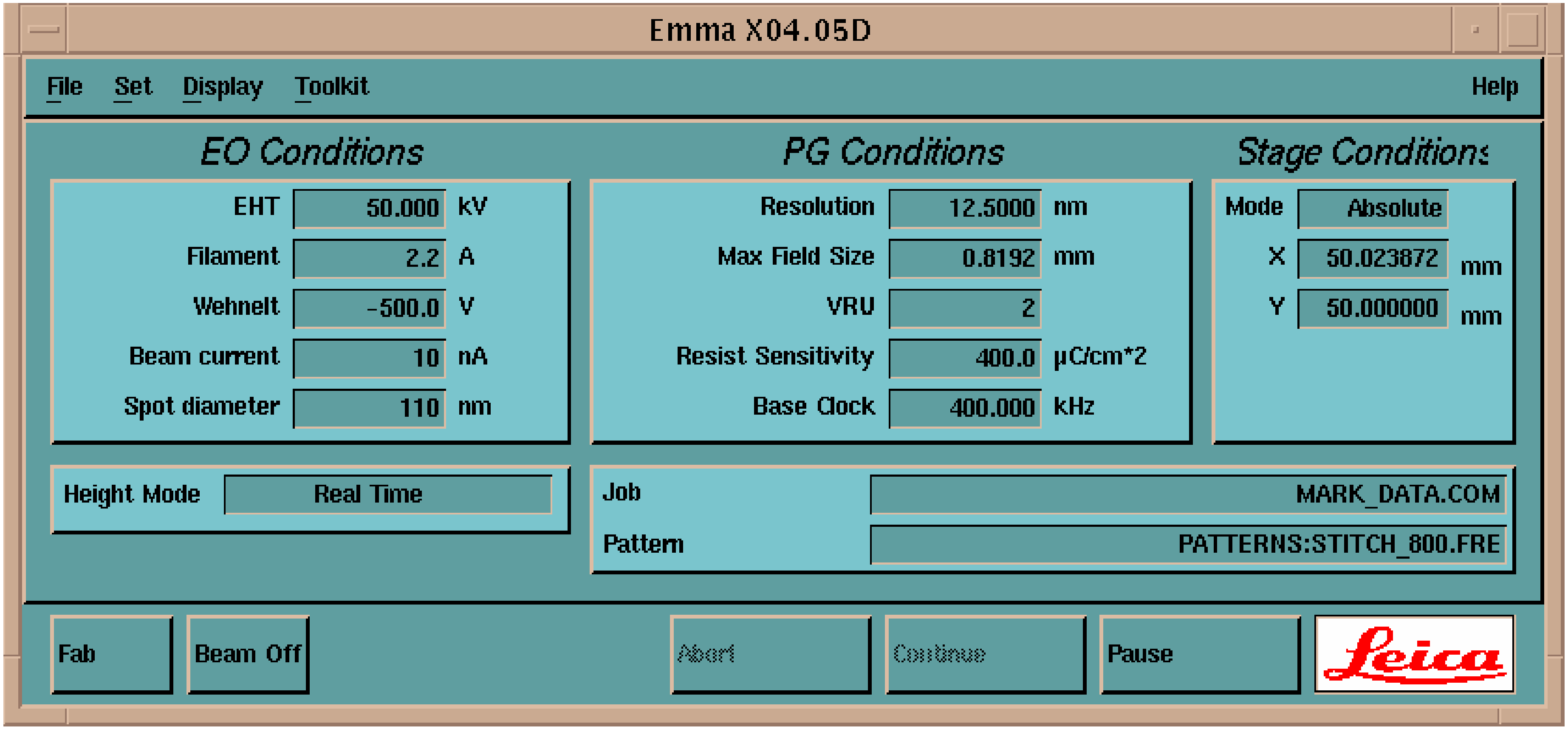
Stage movement

SEM functions

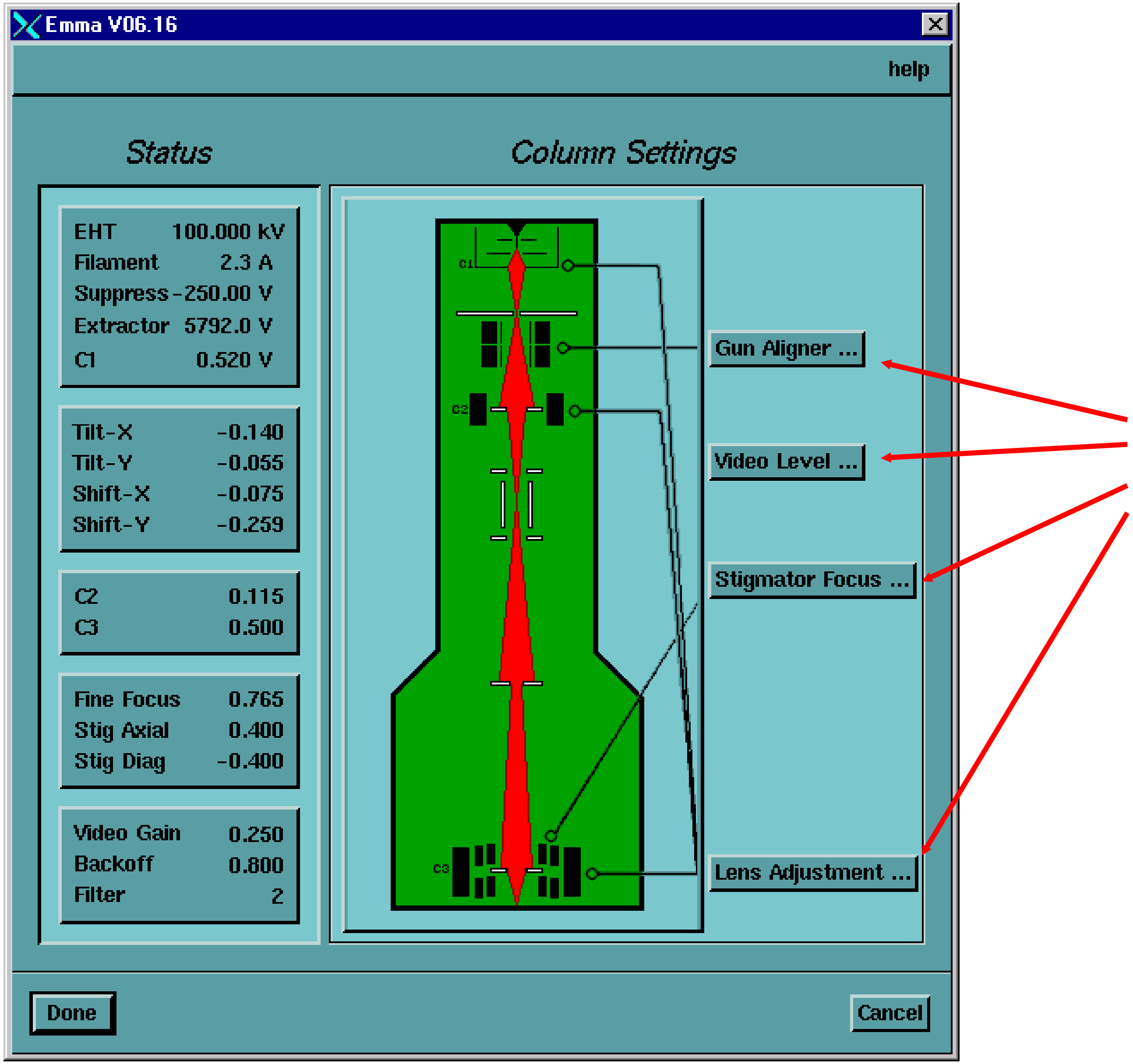
Pattern data information

Database information (System and Calibration coefficients)

Emma Status Panel

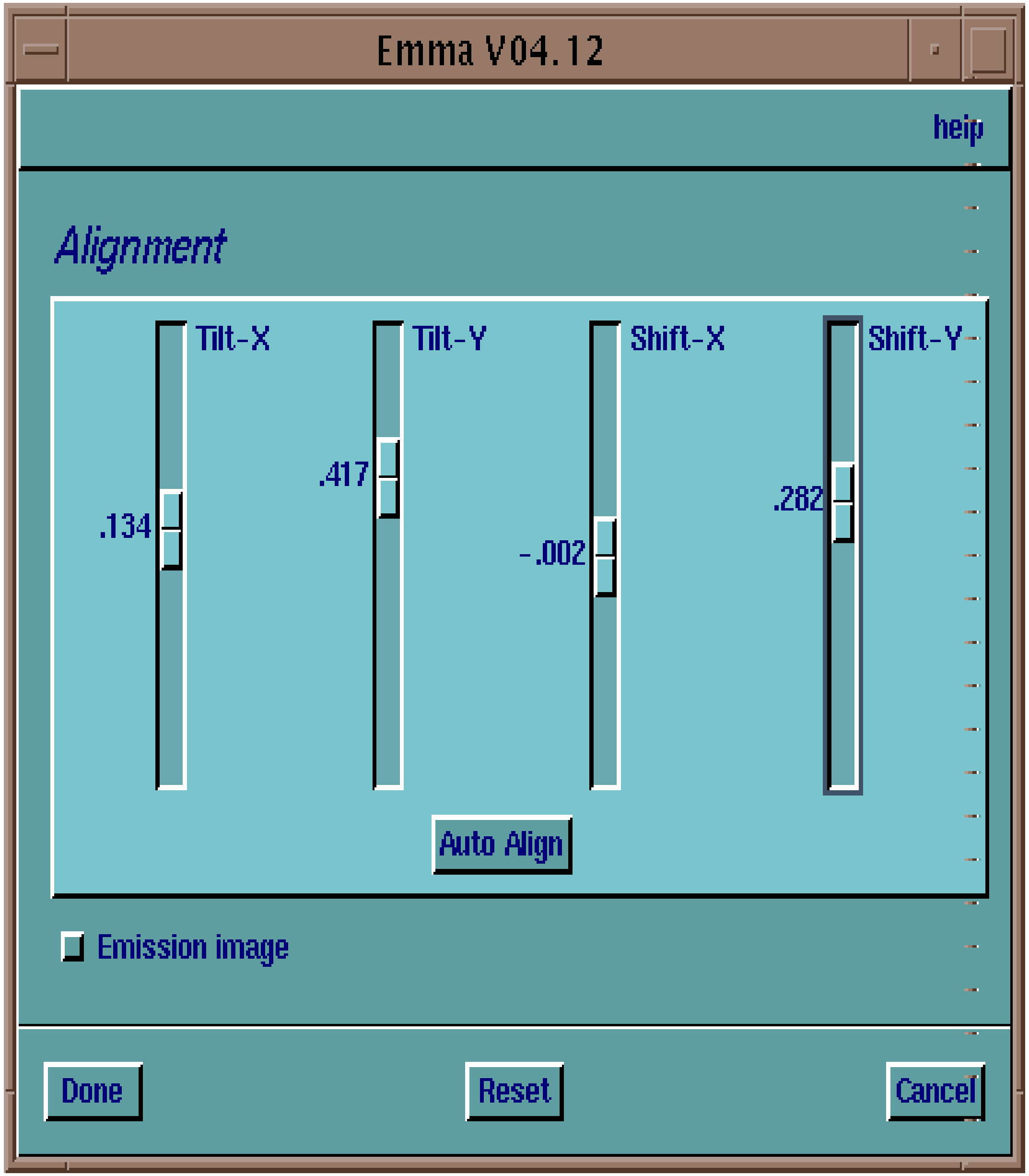


EMMA Display Panel

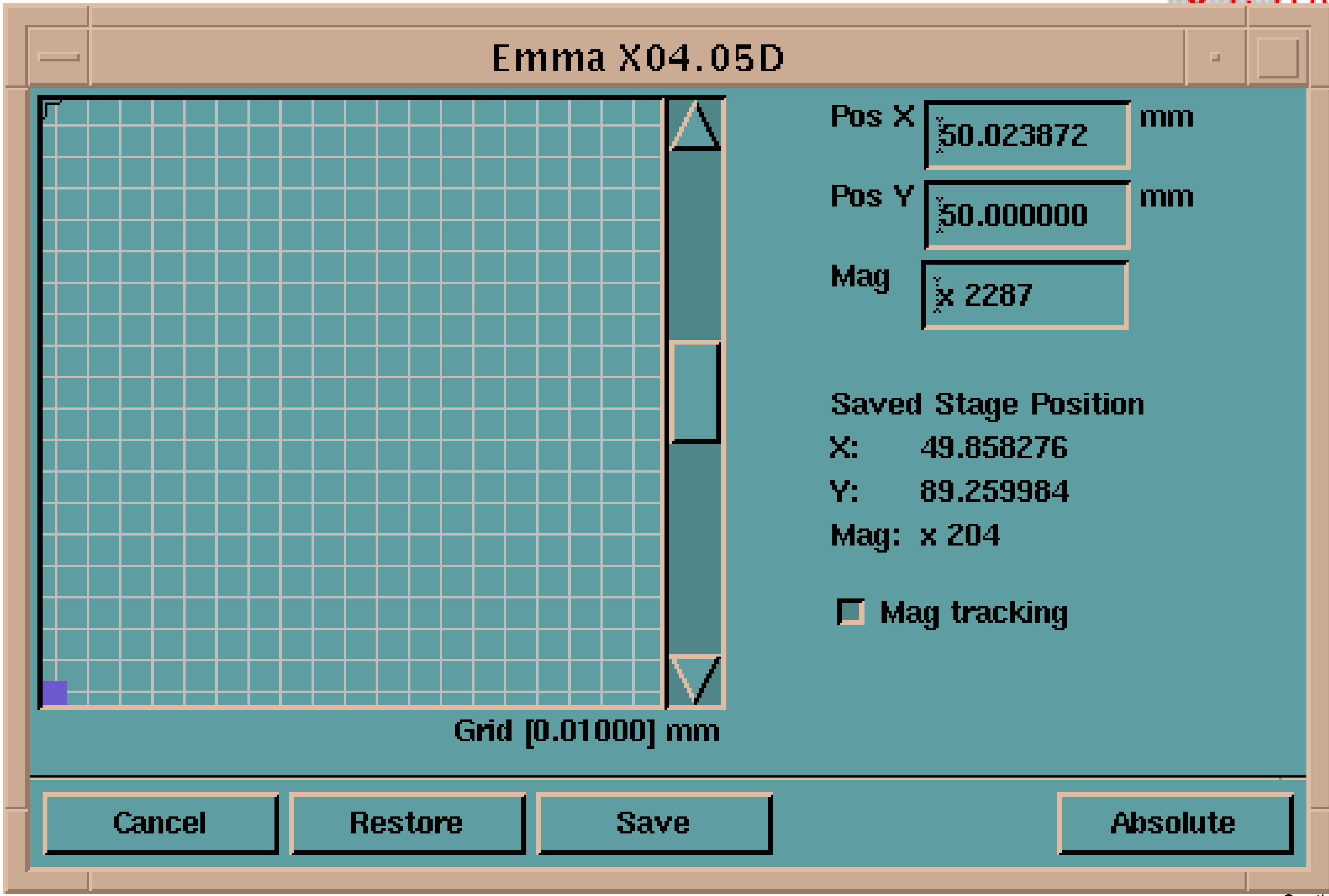


Click on these panels to obtain the panels for controlling the indicated functions.

Gun Alignment Control Panel



Joystick Mode Control of the Stage



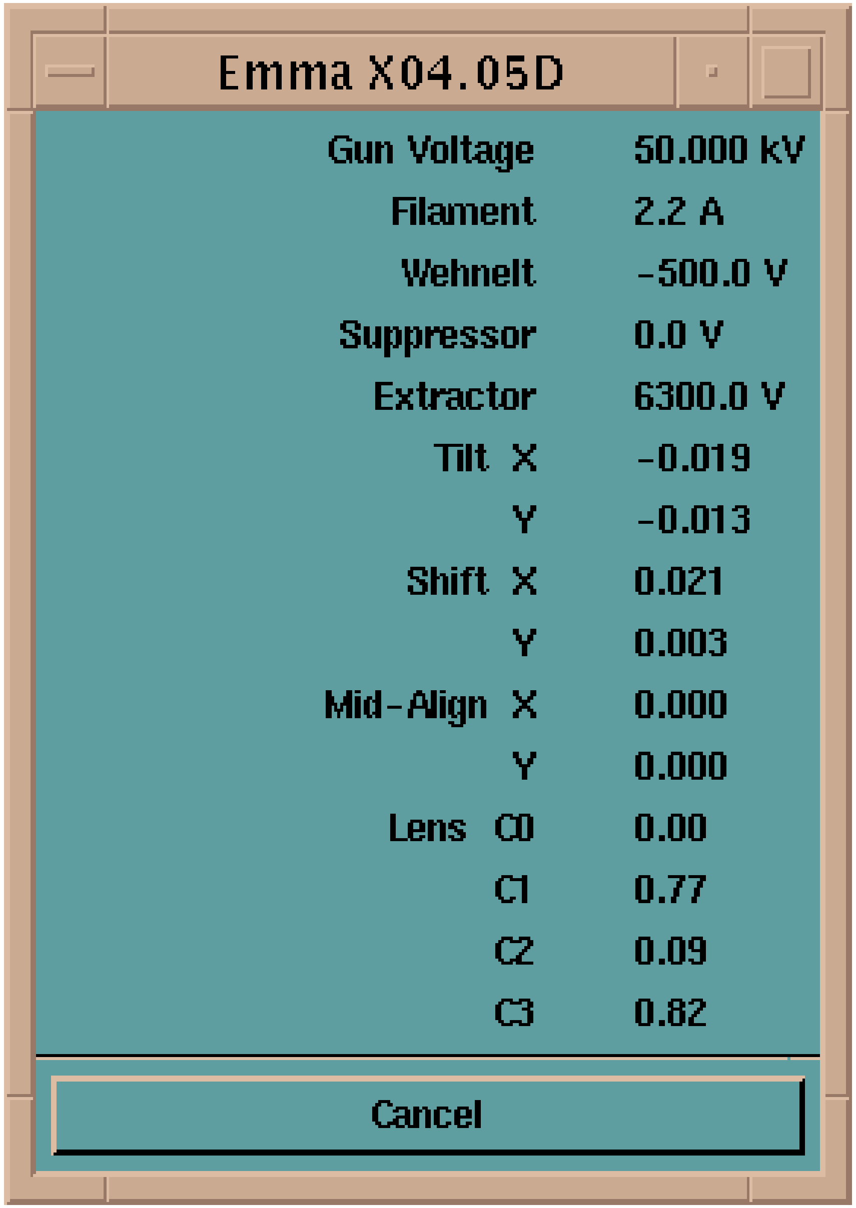
Calibration Data Display

Emma X04.05D

Main Field	2.18 A/mm
Bef Field	2.18 A/mm
Trap Field	14.18 A/mm
Main Pivot	40.80 mm
Trap Pivot	40.80 mm
Focus/height	0.008100
Rot/height	0.016730

Cancel

Column Control Data Display



EMMA Panel Functions - how to select

Function	Window Panel Selection	Pre - EMMA action
Stage movement	Toolkit … Joystick …(Stage move)	
All SEM functions	Toolkit … Joystick …(SEM mag)	
All SEM Screen graph mode,	Set ...Image Panel Set … Video Levels	mvsp gt
Check status before writing	Toolkit ...EO Monitor	
Adjust beam current	Set …Lens Adjust Set …Lens C1 &C2 Adjust	mvsp fc
Confirm pattern data	Display …database… Pattern	
Check gun align	Set …Gun aligner Set … Video Level	mvsp gt
Setting up the Video	Set …Video level	
Setting up the Stigmation	Set …Stig balance	mvsp fm
Check Column and beam current	Toolkit …EO Monitor	
Checking Gun Align	Set …Gunaligner Set	mvsp gt
Video set up	Set …Video level	mvsp fm
Expose pattern	Toolkit … Pattern Generator	