Distortion Correction using Beamer from GeniSys

With Metrology on the Heidelberg DWLs

A method to match lithography across different classes of tools

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Search

LAB USERS PORTAL

GETTING STARTED HIGHLIGHTS EDUCATION AND OUTREACH MEDIA EQUIPMENT ABOUT US

Microns

10 µm

Make it at the CNF

Start a New Project

Join an Existing Project

Remote Process Work

Acknowledging CNF

Dress Code

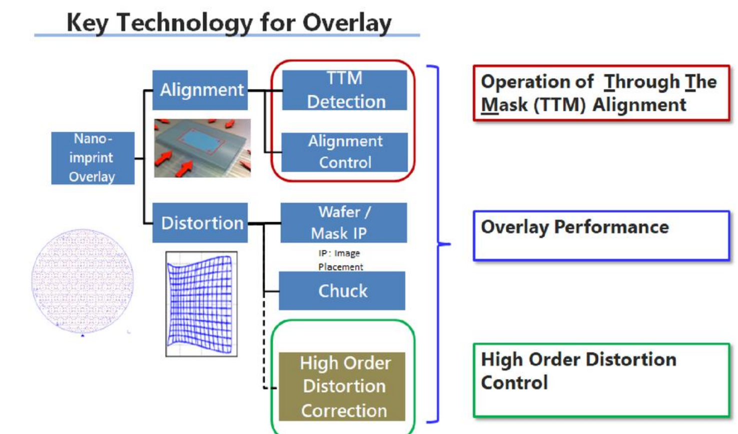
Equipment

Explore the broadest range of user scenarios on the toolset – Get the most out of the tools

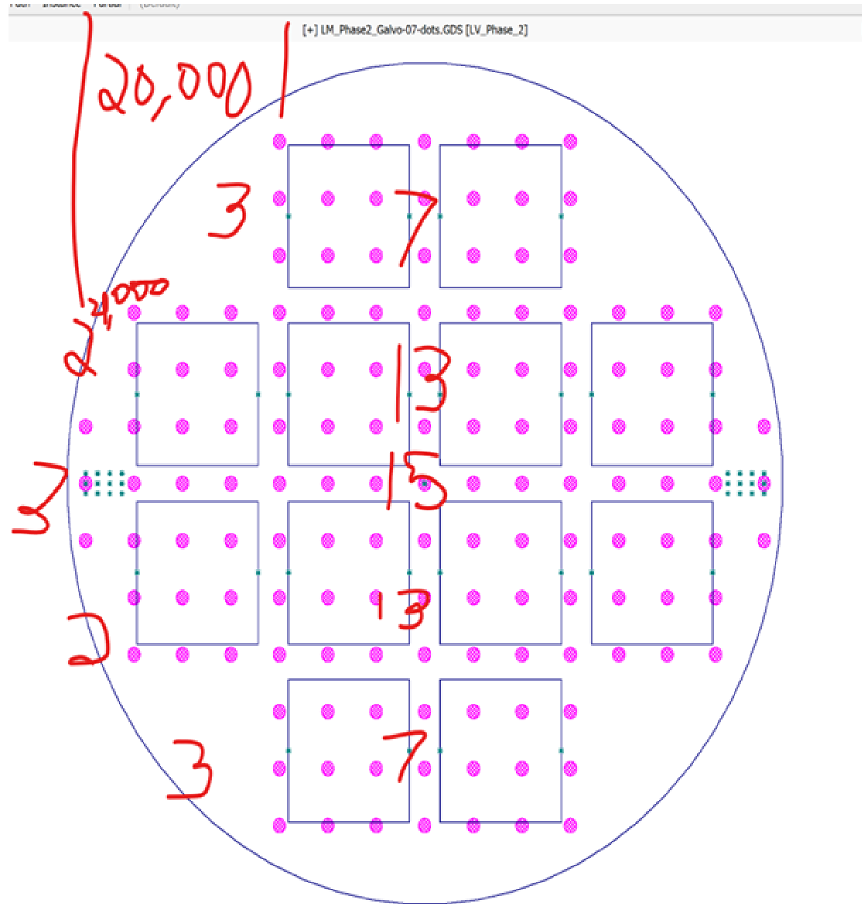
Distortions in patterning systems

- Systems and Causes
  - Optical lenses (LCD, Steppers)
  - Electron beam columns
  - **Galvo systems – Deflection-based systems**
  - Nanoimprint
  - Roll-to-roll
- Application and Motivation
  - New materials ...
  - ...allowed in etchers
  - ...no recipe in RIE
  - ... low ion mill rate

- Systematic -> Distortions (Reproducible)
  - Path-ray non ideality (optical, magnetic..)
  - Non-orthogonality, Magnification, Keystone
  - Histeresis
- Stochastic -> Error (Non-reproducible)
  - Noise (EMI, vibration)
  - Mechanical (e.g., backlash,etc..)
  - Interference (e.g. sensors, ..)
- Environmental -> Drift (Measurable)
  - Temperature
  - Magnetic
  - ...
- Material
  - Bowing
  - Stress
  - ...



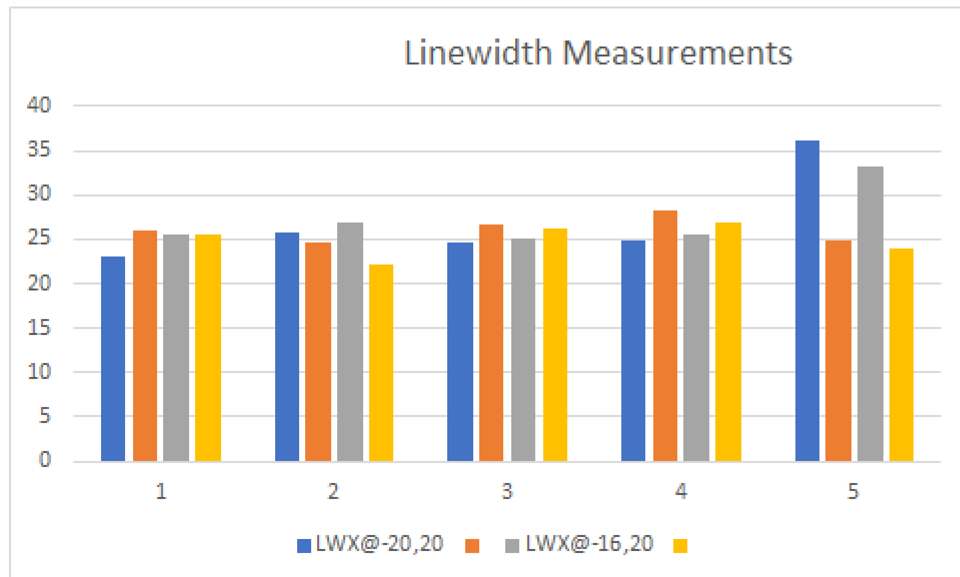
The Problem: Pre-patterned high-value wafers



- Pre patterned Device Layer would not match photomask
    - Distortion was present
- GeniSys has Distortion Correction Module
- Heidelberg DWL metrology
- Solution -> Distort GDS to match distorted device (milestone need)

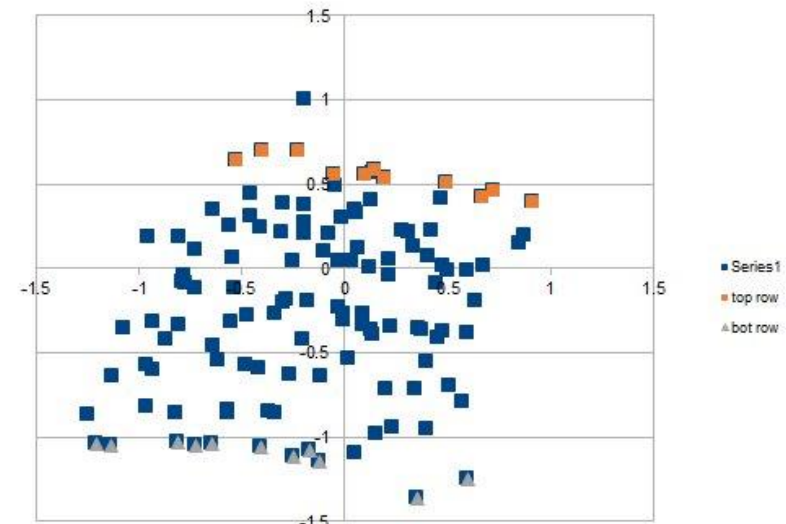
Heidelberg DWL66 Metrology

- Measure routines
- Location, Linewidth, Overlay
- Die-by-Die or Routine
- Parameter optimization
  - Field Alignment Method



- **Scatter of “as-measured” data**
- **Rotated data (numerical processing)**

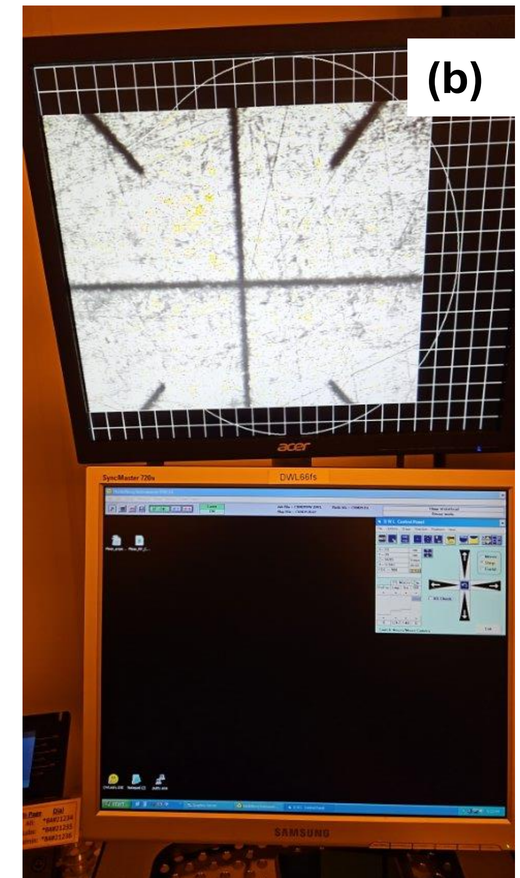
Gold Mask – Reference (DWL2000)



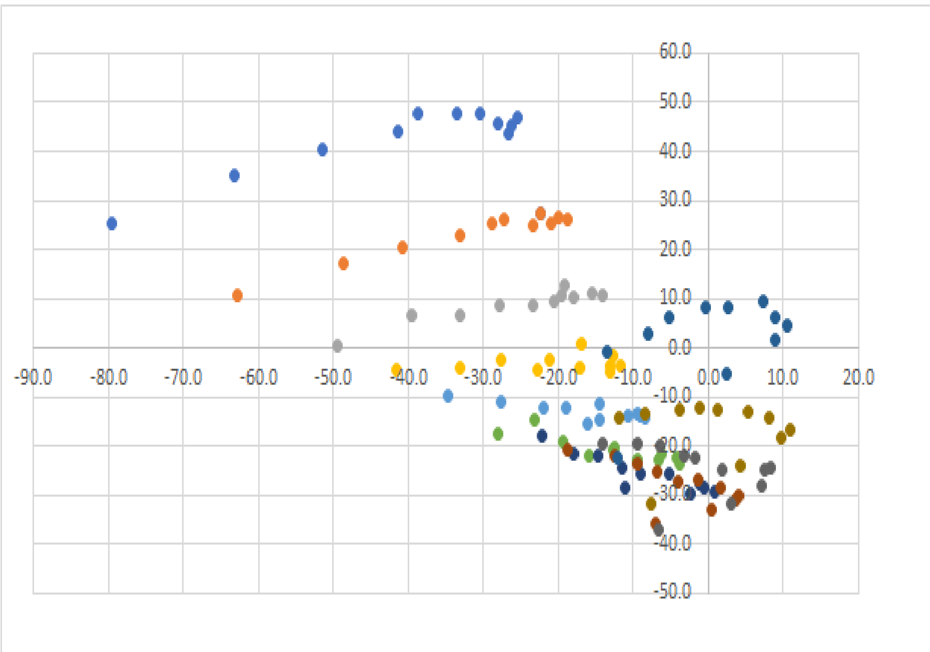
Heidelberg DWL Mark Location

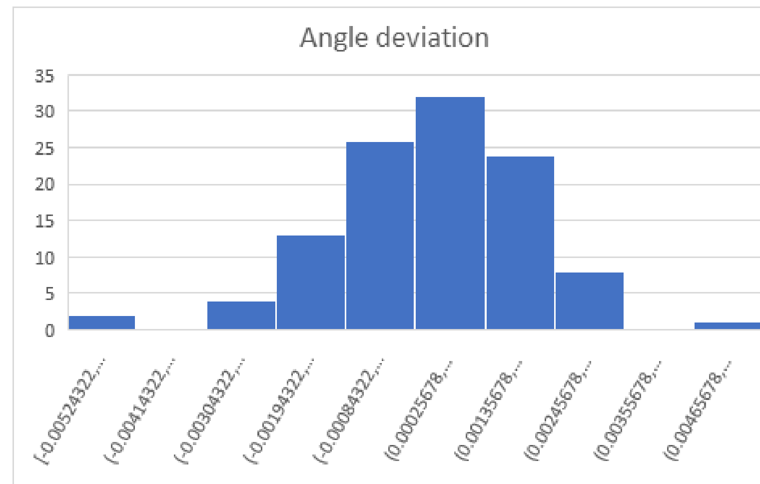
- Video system metrology
- Calibration with interferometric stage
- Dual camera system (micro and macro)
- Detect
  - Cross, Pattern, Lines
- Measure
  - Position, Linewidth
  - Overlay (box-in-box)

- On these wafers, reproducibility was +/-0.5um

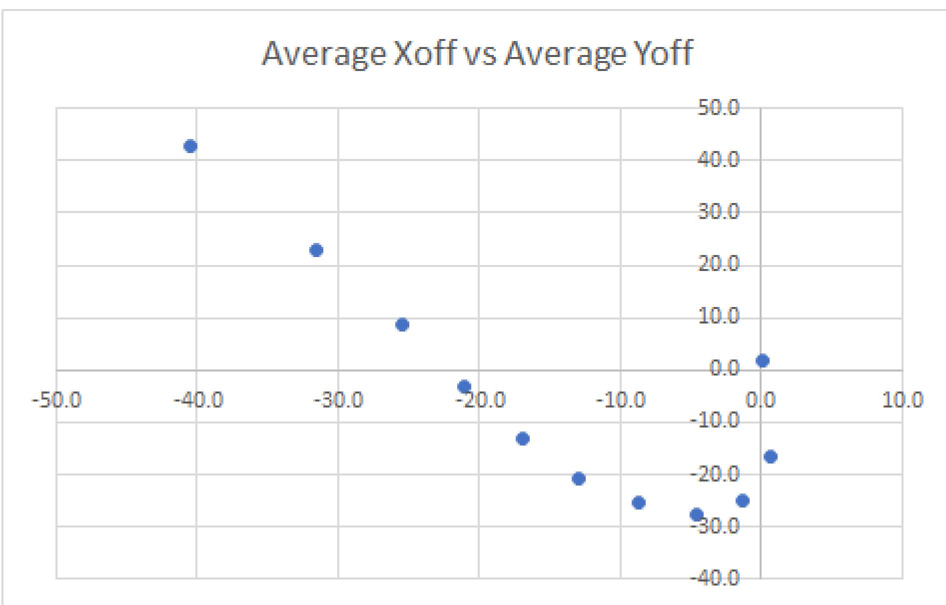


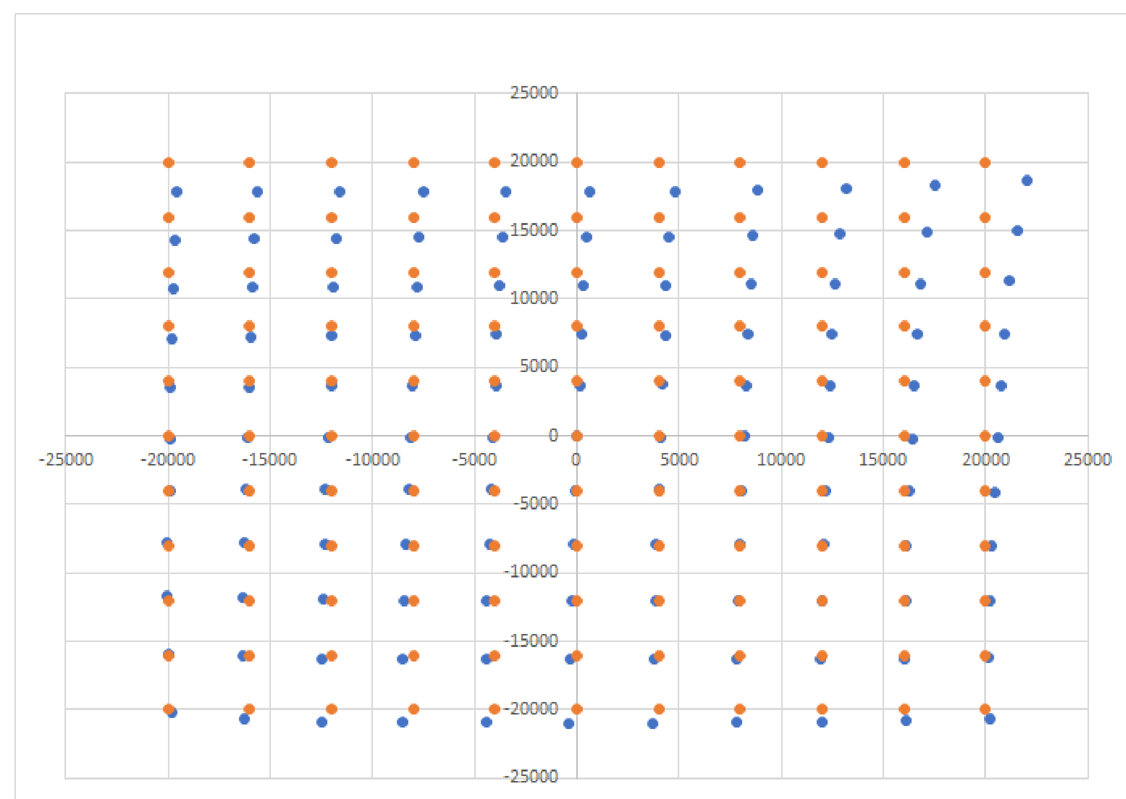
(a) lower limb measured in red box – Micro camera; (b) Macro view of center cross and DWL66 control





- Translation: $\begin{vmatrix} x' \\ y' \end{vmatrix} = \begin{vmatrix} x \\ y \end{vmatrix} + \begin{vmatrix} tx \\ ty \end{vmatrix}$
- Rotation: $\begin{vmatrix} x' \\ y' \end{vmatrix} = \begin{vmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{vmatrix} * \begin{vmatrix} x \\ y \end{vmatrix}$
- Scaling: $\begin{vmatrix} x' \\ y' \end{vmatrix} = \begin{vmatrix} Sx & 0 \\ 0 & Sy \end{vmatrix} * \begin{vmatrix} x \\ y \end{vmatrix}$

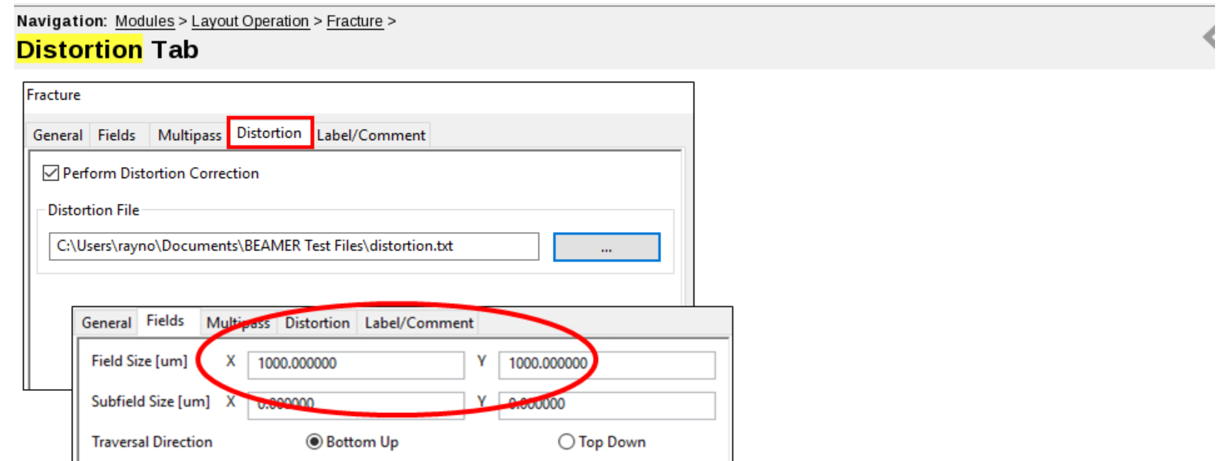


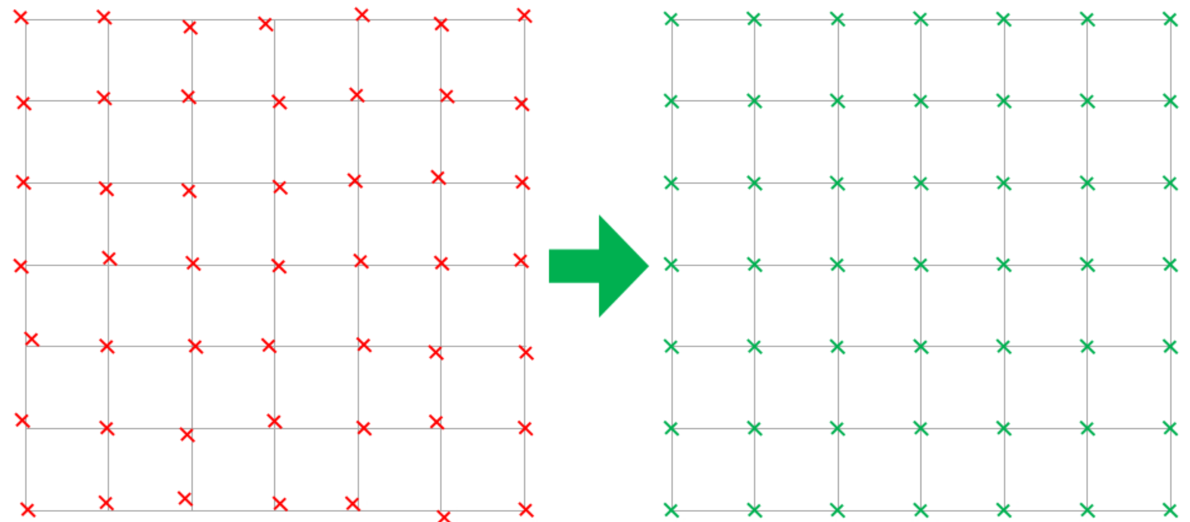


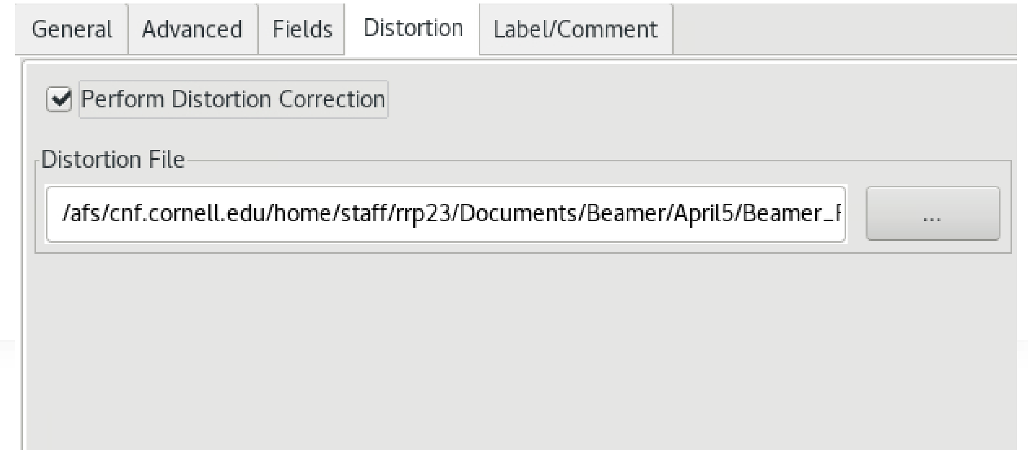
Beamer – Pre-distortion of CAD

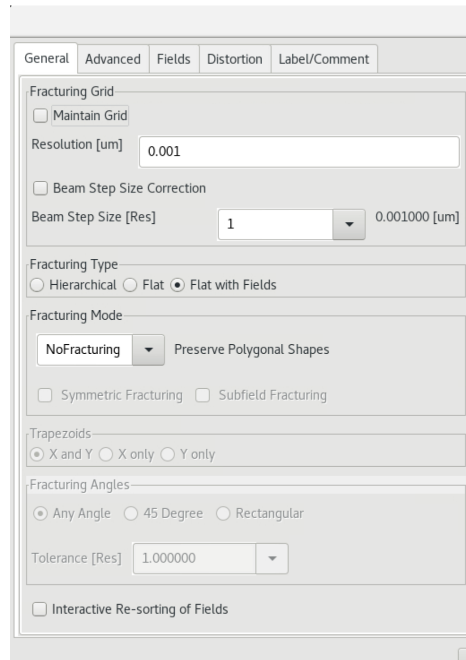
GeniSys – Distortion Correction with Beamer

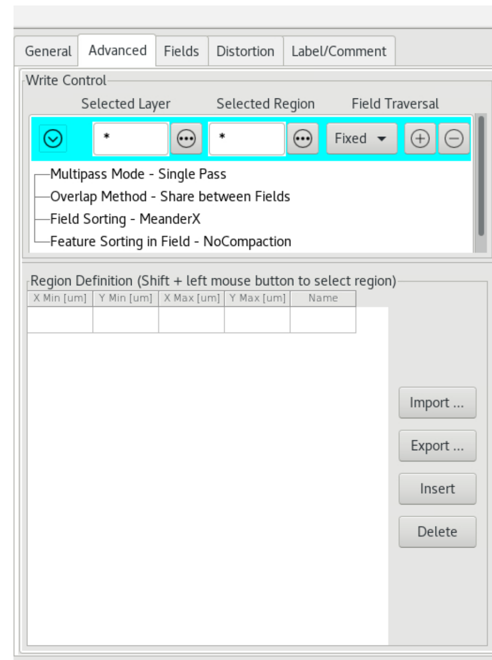
- Distortion correction will apply a position dependent correction of geometries in a pattern.
- Fracture module
  - 'Flat with Fields' option in the general tab.
  - Set the field size in the Fields tab to match your final export.
  - A map of field distortions is applied as shown above, and based on this, the pattern edges are shifted to compensate for these distortions.
  - Currently the distortion file can only be imported but not displayed/edited.
  - The distortion file uses a pre-defined format.
  - The distortion correction shifts each vertex of a polygon according to the distortion map.

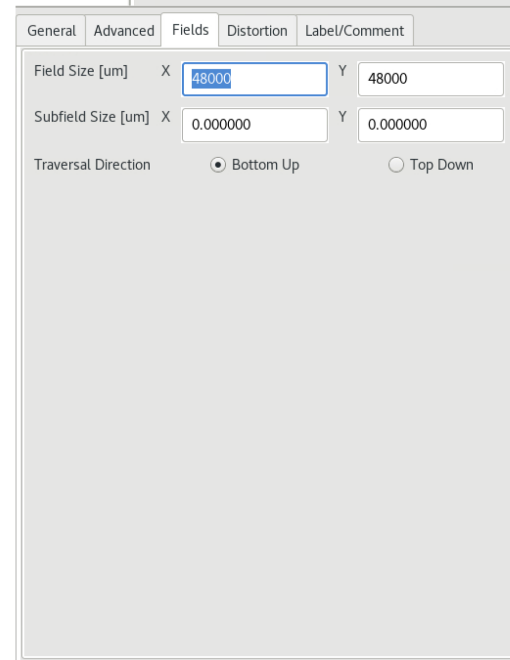





General
Advanced
Fields
Distortion
Label/Comment
Perform Distortion Correction
Distortion File
/afs/cnf.cornell.edu/home/staff/rrp23/Documents/Beamer/April5/Beamer_F
...


General
Advanced
Fields
Distortion
Label/Comment
Fracturing Grid
Maintain Grid
Resolution [um]
0.001
Beam Step Size Correction
Beam Step Size [Res]
1
0.001000 [um]
Fracturing Type
Hierarchical
Flat
Flat with Fields
Fracturing Mode
NoFracturing
Preserve Polygonal Shapes
Symmetric Fracturing
Subfield Fracturing
Trapezoids
X and Y
X only
Y only
Fracturing Angles
Any Angle
45 Degree
Rectangular
Tolerance [Res]
1.000000
Interactive Re-sorting of Fields


General
Advanced
Fields
Distortion
Label/Comment
Write Control
Selected Layer
Selected Region
Field Traversal
Fixed
Multipass Mode - Single Pass
Overlap Method - Share between Fields
Field Sorting - MeanderX
Feature Sorting in Field - NoCompaction
Region Definition (Shift + left mouse button to select region)
X Min [um]
Y Min [um]
X Max [um]
Y Max [um]
Name
Import ...
Export ...
Insert
Delete


General
Advanced
Fields
Distortion
Label/Comment
Field Size [um]
X
48000
Y
48000
Subfield Size [um]
X
0.000000
Y
0.000000
Traversal Direction
Bottom Up
Top Down

VIEWER - Distortion (on korat.cnf.cornell.edu)

File View E-Beam Properties Help

90 or 45 degree | Drawing Speed: 64x

Layer | Tree | Doses

- Distortion
- 1(0)

Field_Root

Field_0001

All | Hide | Show

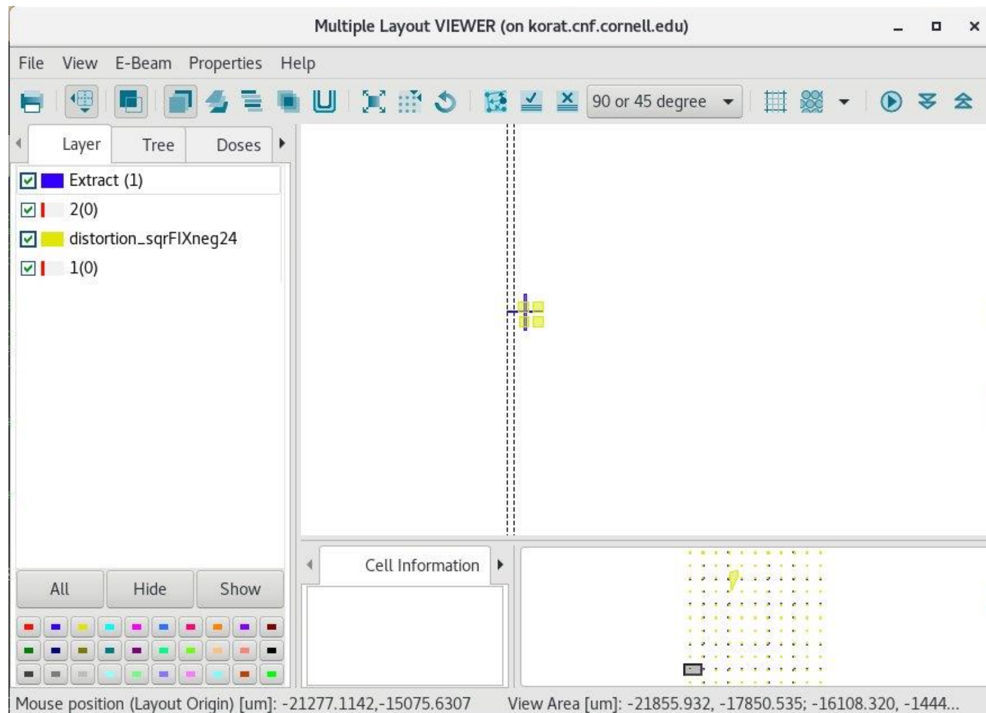
Cell Information | Measurement Info | Pick Data Info

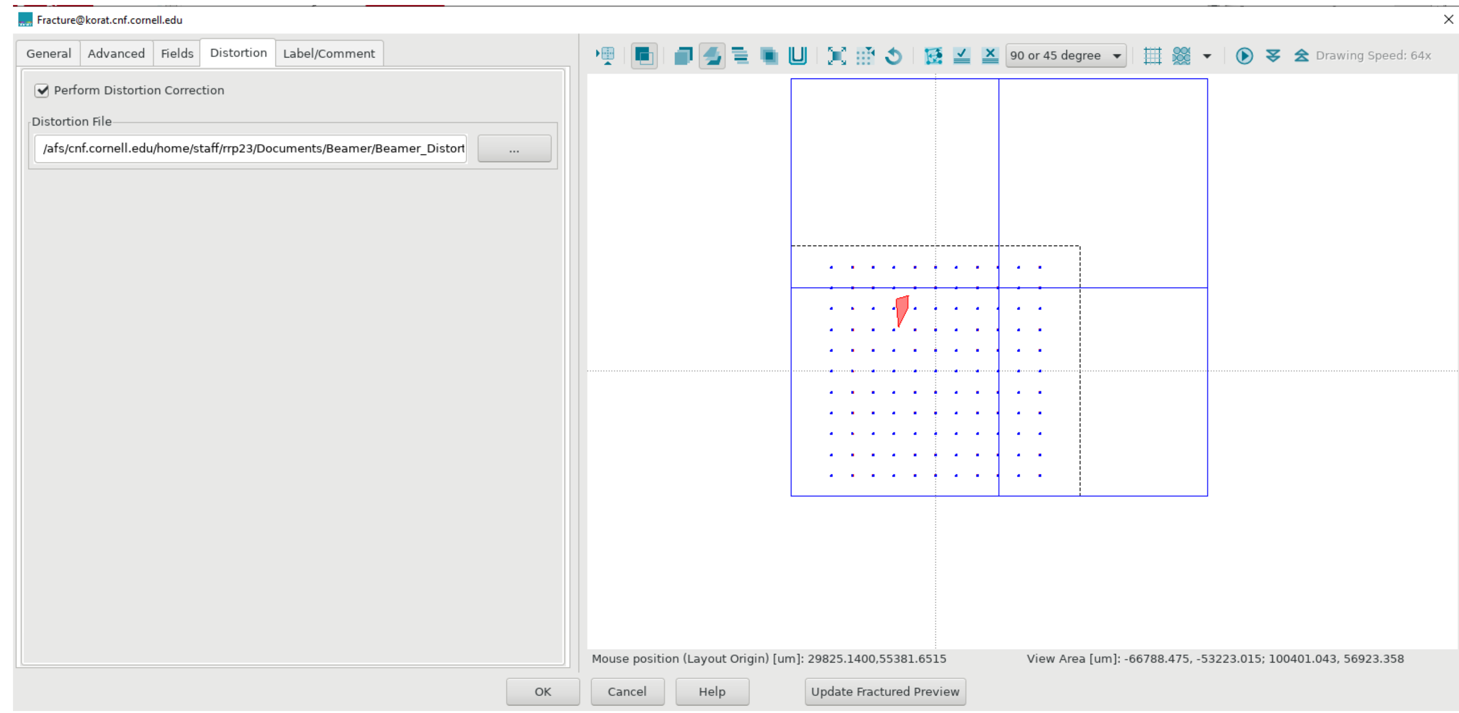
```
File Name:
   Layout Bbox[um]            : (-24000.000000, -24000.000000), (24000.000000,
   Database Units [um]        : 1.000000e-3
```

Mouse position (Layout Origin) [um]: -35820.4547,12233.5043

View Area [um]: -44660.724, -24020.530; 44724.223, 24109.826

Beware of Mismatch in Field Size
-> Multiple fields used to Fracture -> *FAILURE!*





Example Distortion File

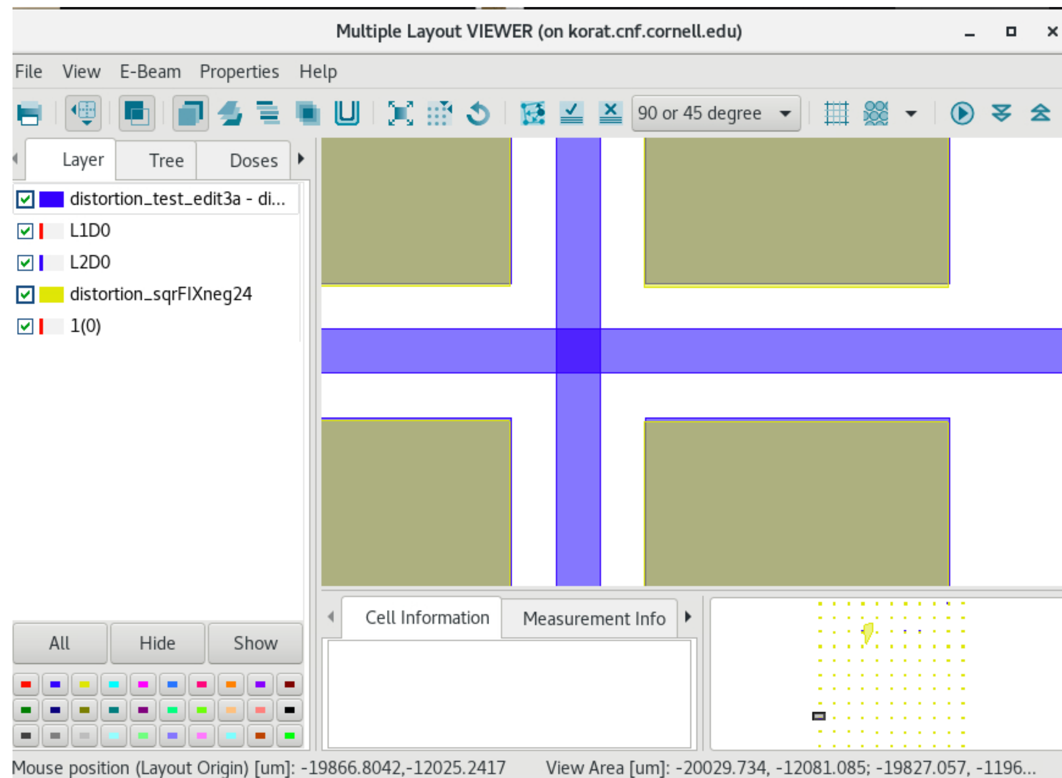
```
BEAMER FRACTURE DISTORTION FILE v1.0
[FieldSize]
X=48000
Y=48000
[MeshSize]
X=4000
Y=4000
[DistortionVectors]
#   @24000  @-20000  @-16000  @-12000  @-8000  @-4000  @0  @4000  @8000  @12000  @16000  @20000  @-24000
@24000  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),
@20000  (0|0),  (-10| 17),  (-9| 21),  (-2| 25),  (0| 28),  (7| 30),  (7| 32),  (10| 33),  (14| 31),  (11| 28),  (1| 24),  (-13| 14),  (0|0),
…
@4000  (0|0),  (-18| -4),  (-12| 0),  (-8| -0),  (-4| -2),  (-2| -2),  (2| -2),  (5| -2),  (7| -1),  (9| 0),  (5| 0),  (-4| 3),  (0|0),
@0  (0|0),  (-21| 5),  (-15| 4),  (-12| 3),  (-7| 3),  (-10| -5),  (-1| 2),  (1| 4),  (4| 3),  (7| 4),  (3| 10),  (-4| 13),  (0|0),
……
@-24000  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),  (0|0),
```

```
=TRANSPOSE(I51:I61)

=ROUND(B2,0)&"| "&ROUND(B15,0)
    =INT(B2)&"| "&INT(B15)

=CONCAT("(",O2,")",",")
```

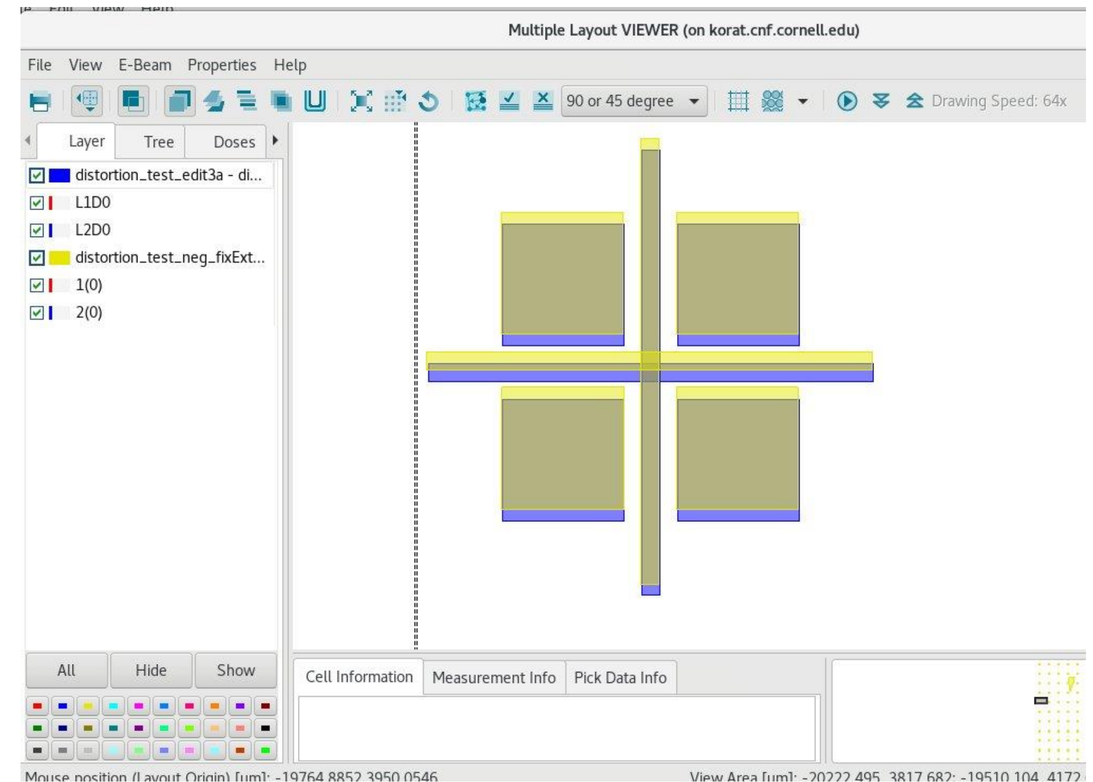
Validate with measured data

Create CIF from Actual Locations

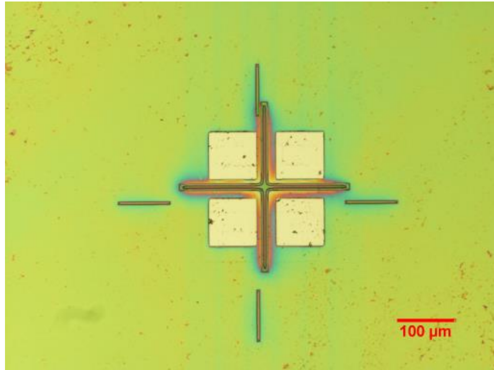
Distortion Matrix matches Measurement

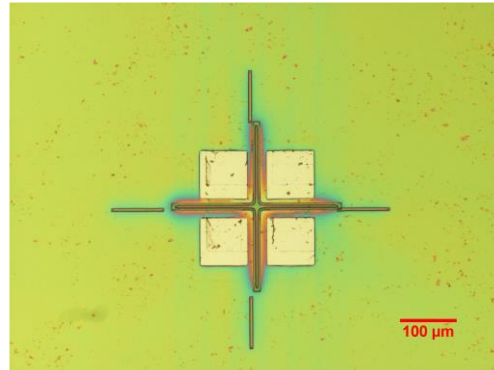


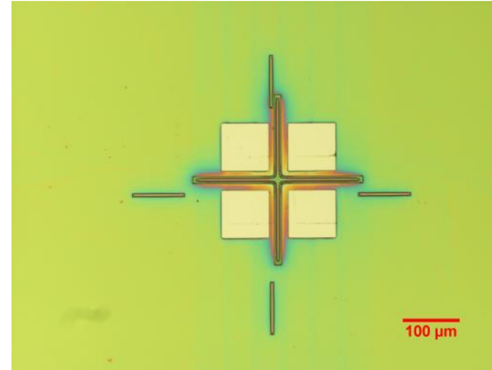
Glitch in Transposing Measurements

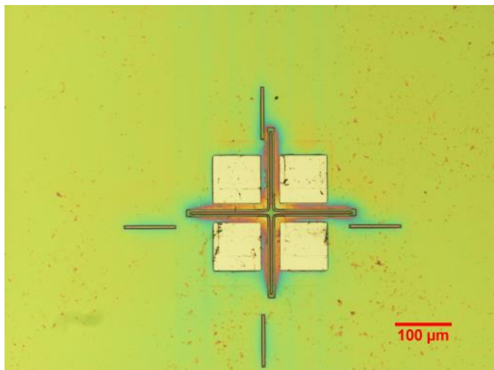


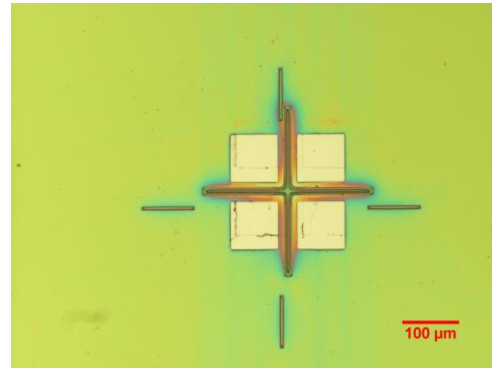
Distortion Corrected Exposure results











- Aligment of squares to cross field
- Crosses from measured data
- Squares from converted ideal pattern with Beamer
- Note
  - Extra limbs show problem with Distortion Matrix generation

Summary and Recommendations

- Beamer Distortion Correction applied to large distortions successfully
- Interpolation is linear
- Distortion Matrix format is text format – easily assembled
- Can create mathematical interpolations using any distortion model

- Ability to distort pure paths is highly desirable
  - Had to convert to polygon
  - Preserve cell hierarchy (e.g. box-in-box)
- Import, Create, Manage
  - Distortion Matrices
  - Interaction with tools (DWL, ProSEM)
- For "developers",
  - Extraction of distortion type, and
  - Parametrization of model distortions

Acknowledgements

- LUX
  - https://www.luxsemiconductors.com
- CNF
  - cnf.cornell.edu/
- NSF's NNCI
  - https://cnf.cornell.edu/about/nnci
- https://www.nano.upenn.edu/
  - https://research.gatech.edu/node/19319
- GeniSys
  - *https://www.genisys-gmbh.com*
- Heidelberg
  - DWL66 @ CNF
  - https://www.cnfusers.cornell.edu/node/39
- https://research.gatech.edu/
  - https://www.nano.upenn.edu/equipment/ipg-photonics-ix200f-2/

National Nanotechnology
Coordinated Infrastructure