GenISys
Advancing the Standard

# BEAMER

## Training webinar

## Part 2: Optimization – Field Control

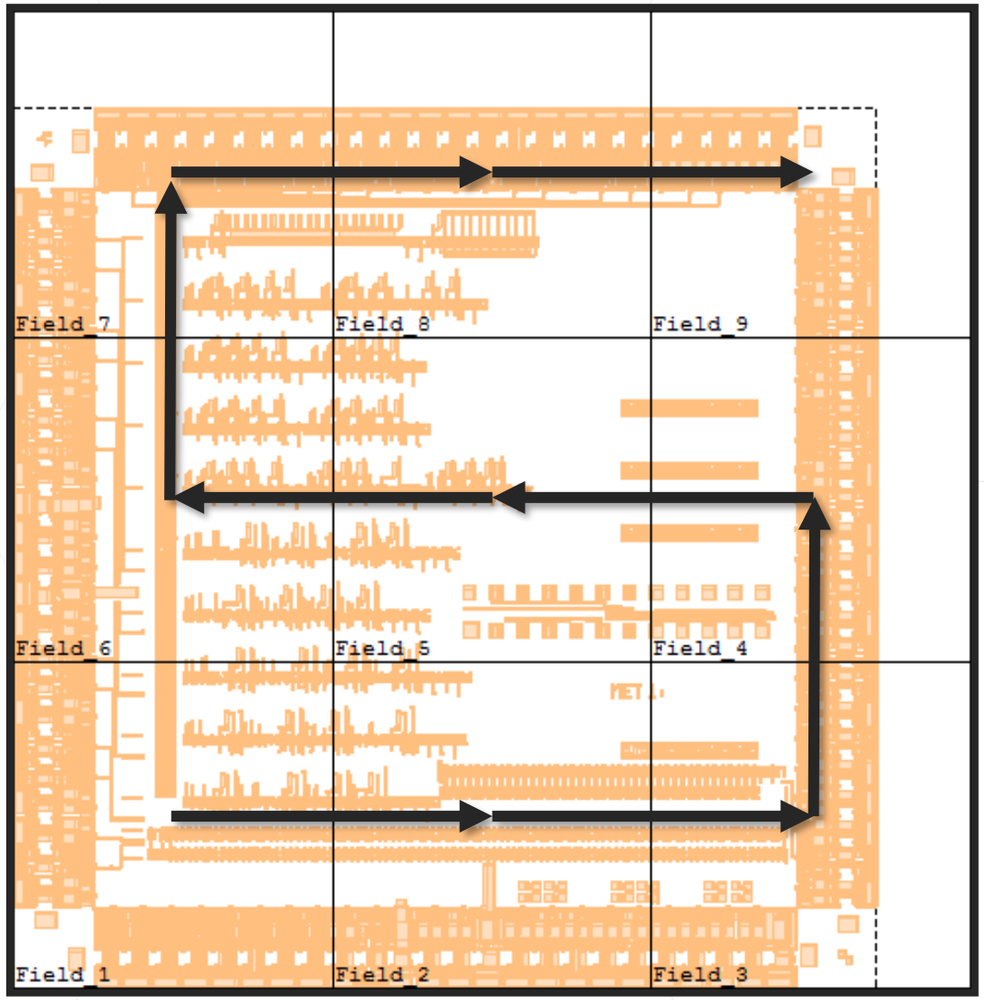
# Agenda

- Field Stitching
- Field Ordering
- Feature Exposure Order Control within the Field
- Summary
- Q&A

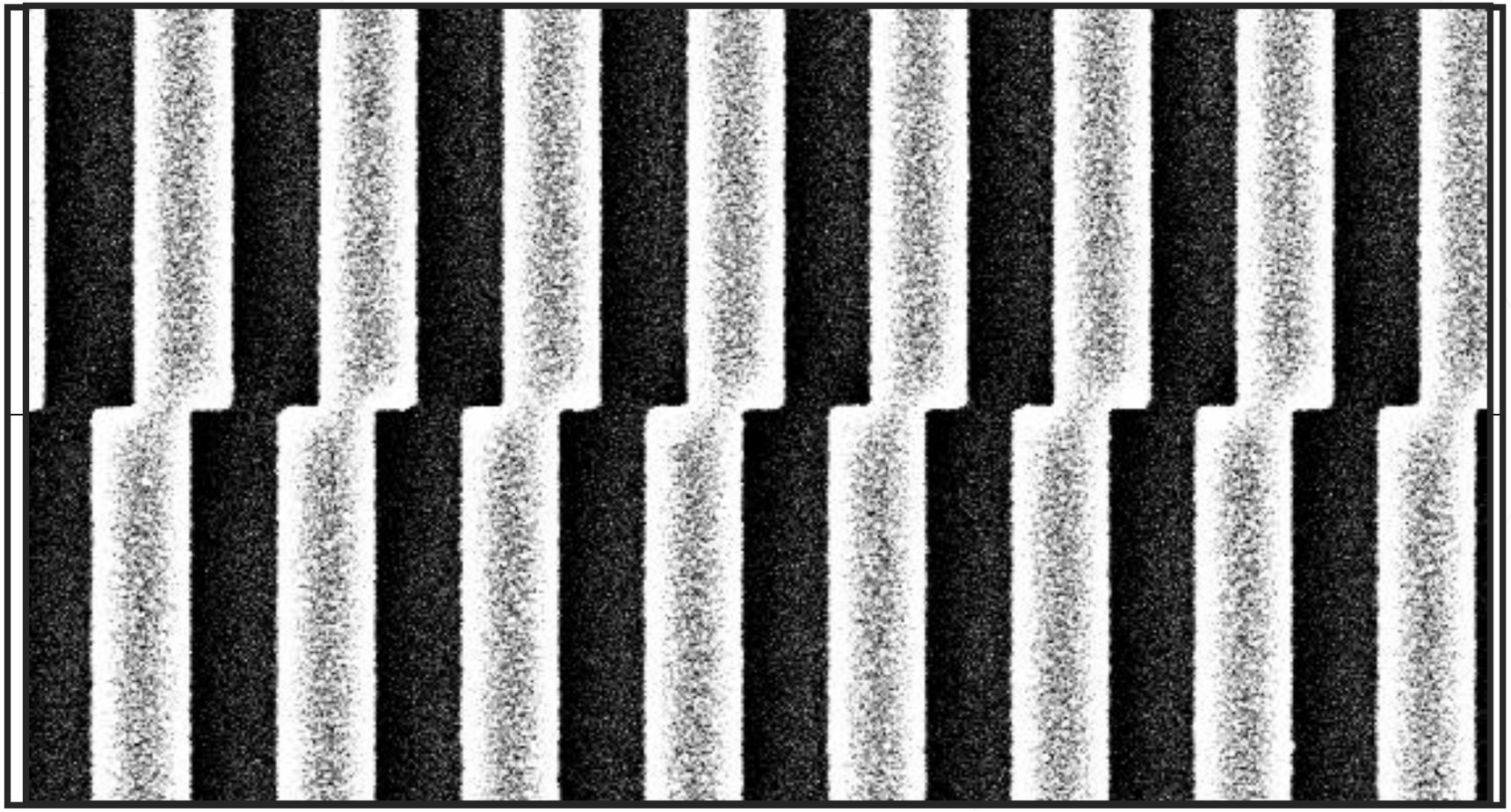
# E-Beam Exposure Fields

Since field size is limited, large layouts are tiled:

- Uniform tile size
- Start bottom or top left
- Meander filling



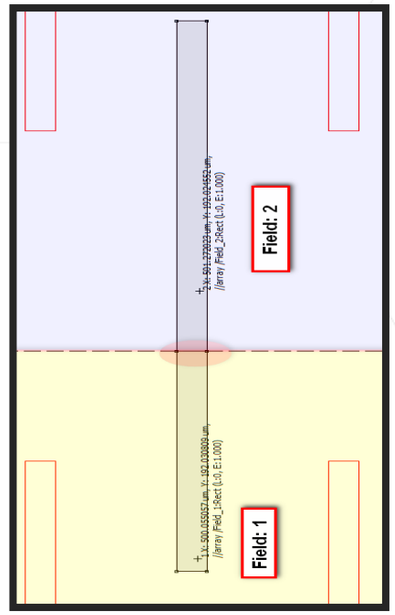
# Issues at Field Borders



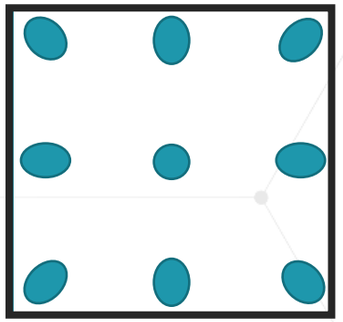
Courtesy: Nikolai Klimov, NIST

# Issues at Field Borders

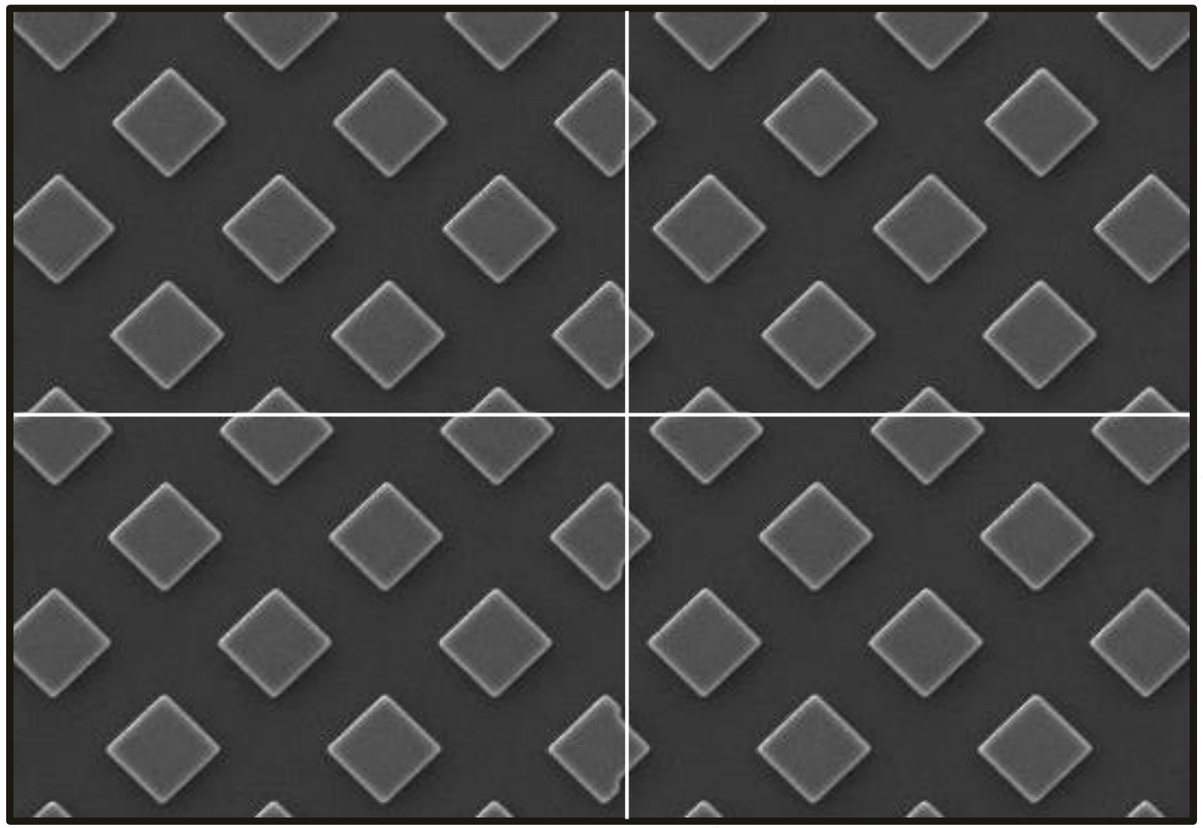
- Field Stitching:
  - Moving between fields requires a mechanical stage move.
  - Elements crossing the field border are split and exposed in two fields.

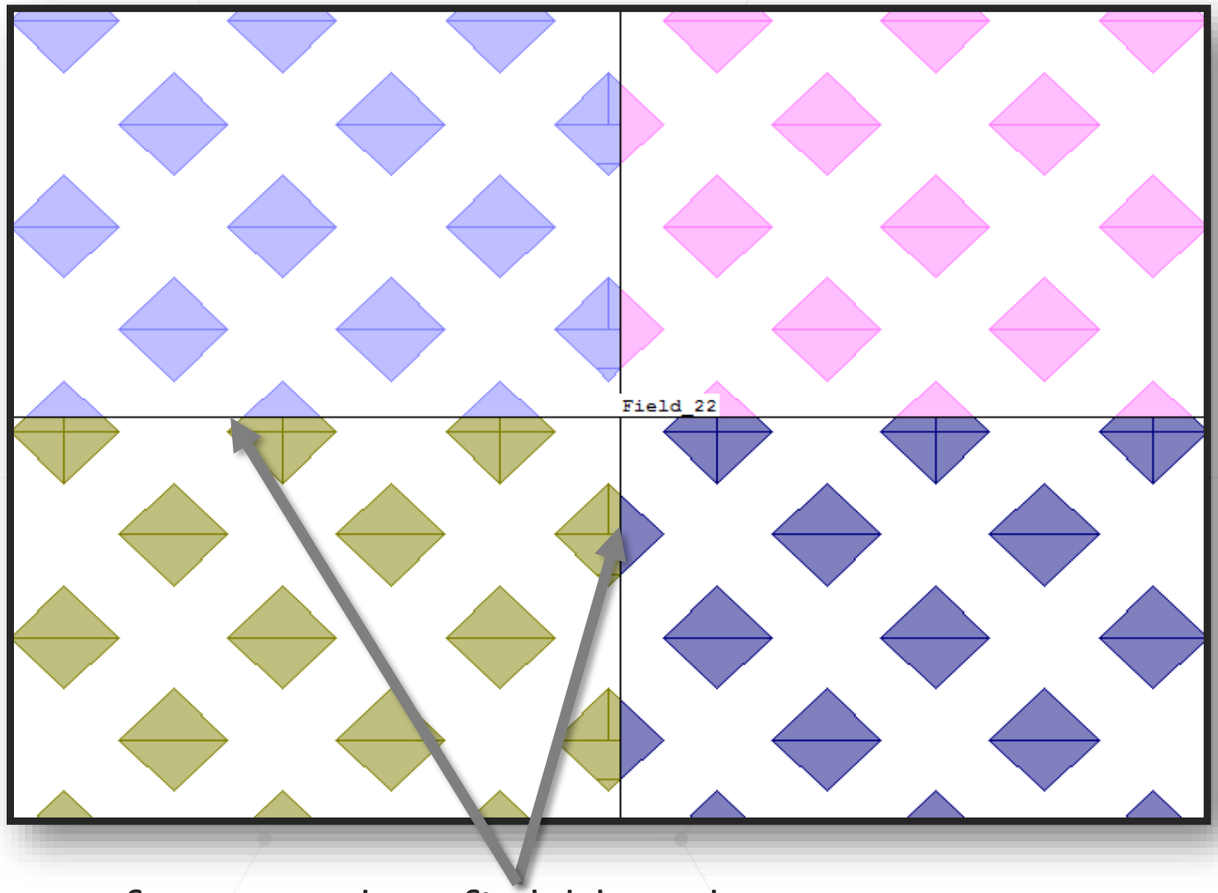



- Lower quality at field border because of aberration:
  - Field center has highest accuracy; field edges have lower accuracy.
  - Critical features should be positioned in center of the field.



# Field Stitching

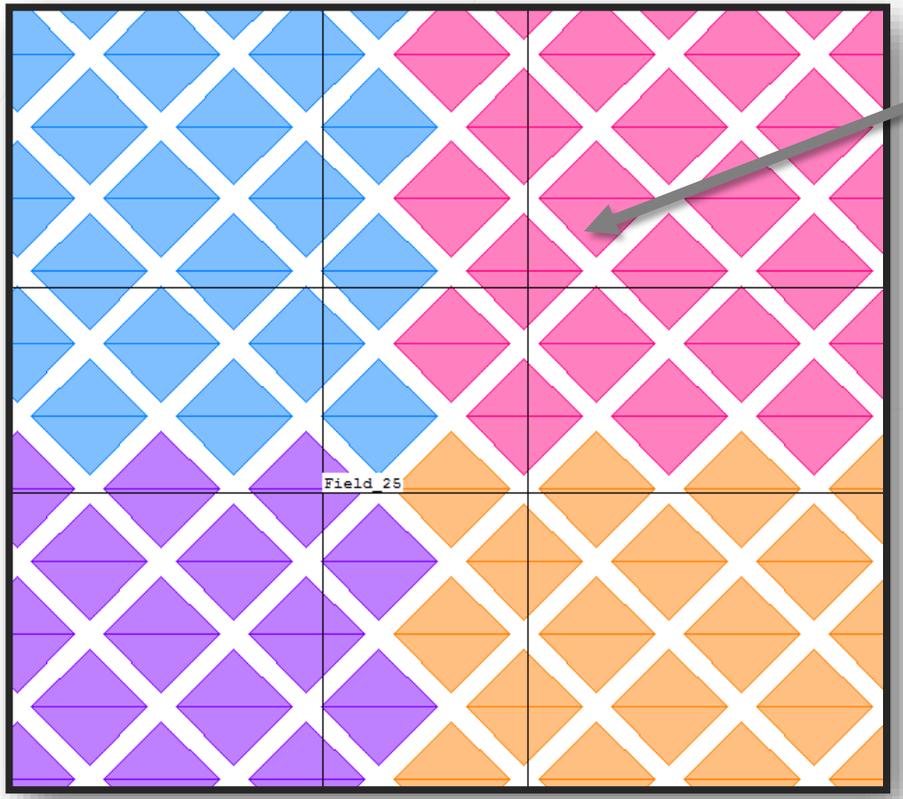


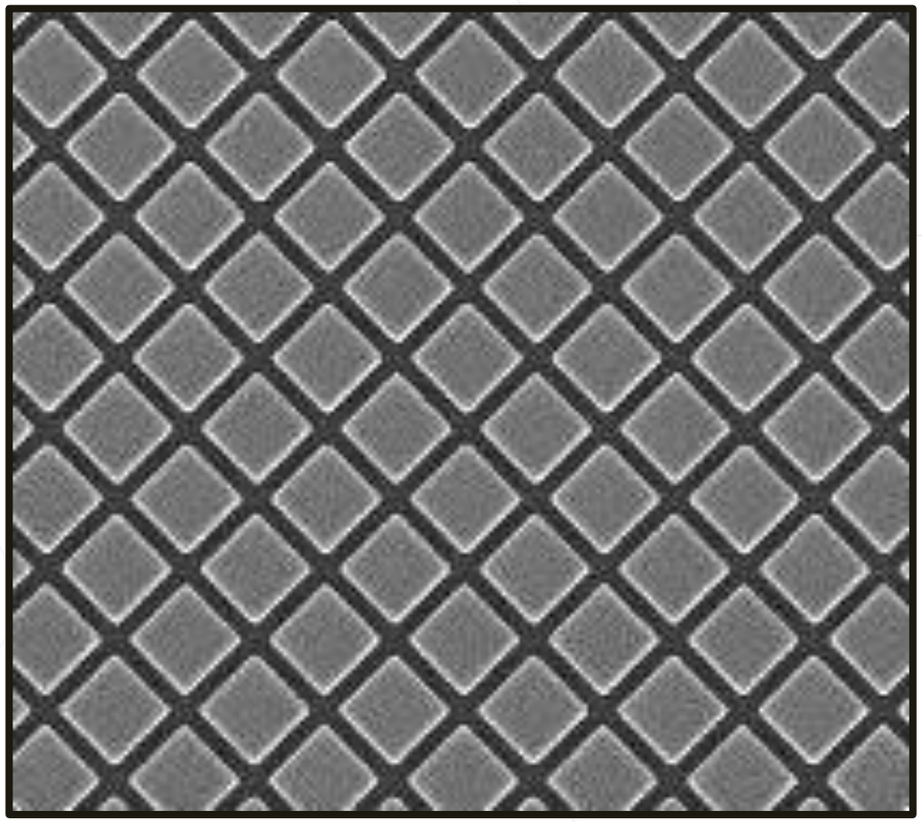



Figures get fractured at field borders.
Therefore, data must be within a field

# Software Solution: Overlapping Fields

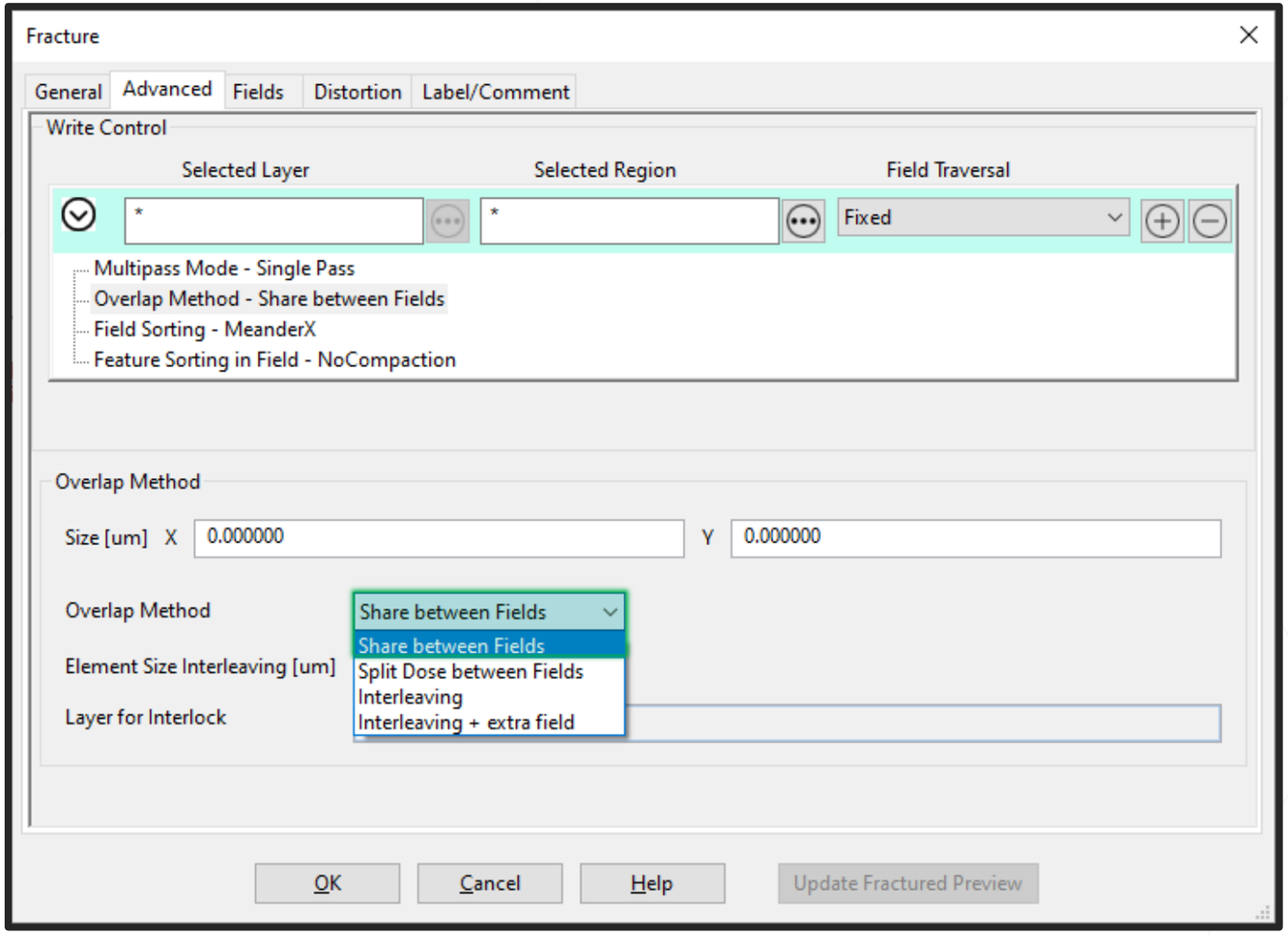
Allows Data < Overlap to be completely within a field

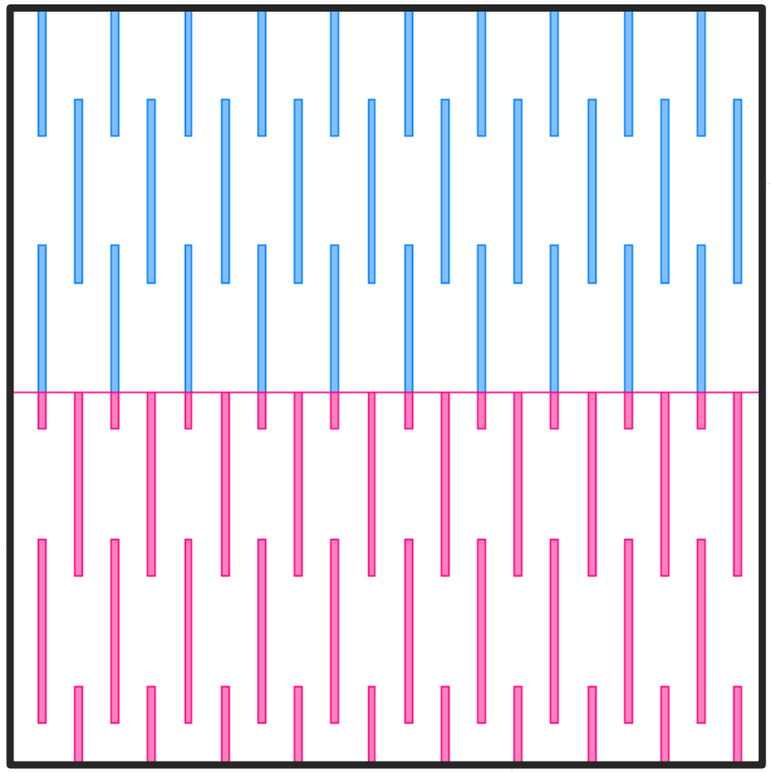


# Live Demo: Field Overlap

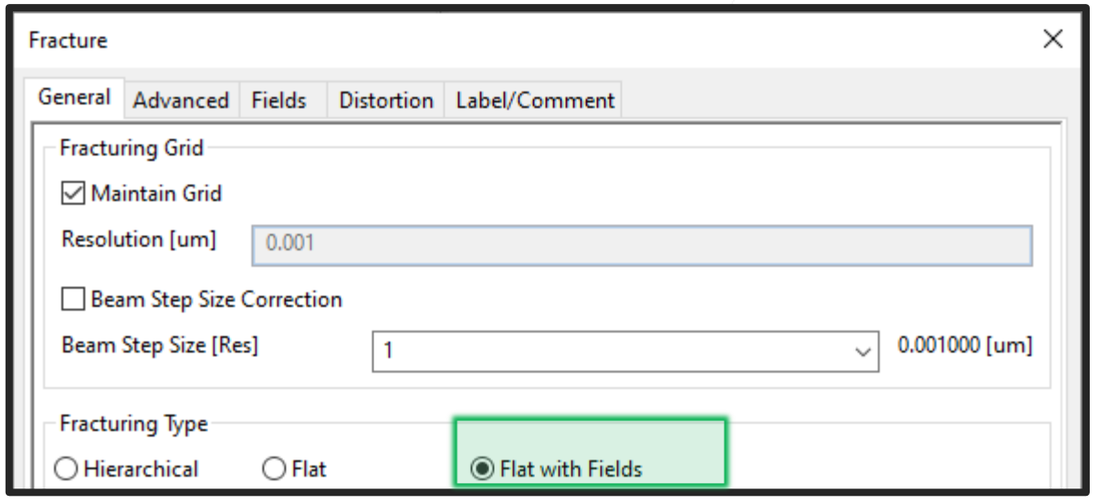
## Field overlap

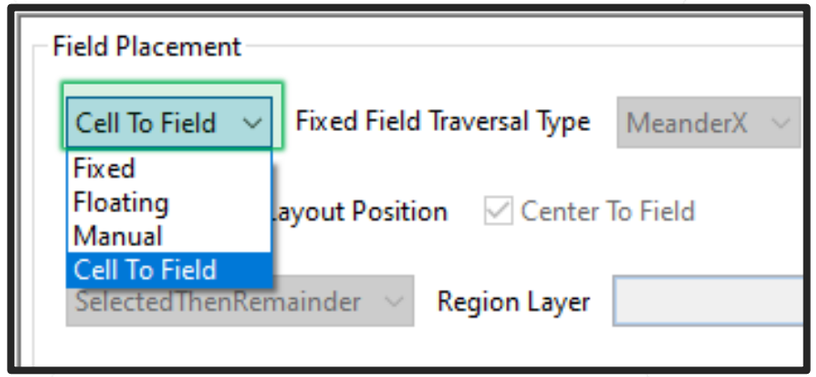


# Field Fracture

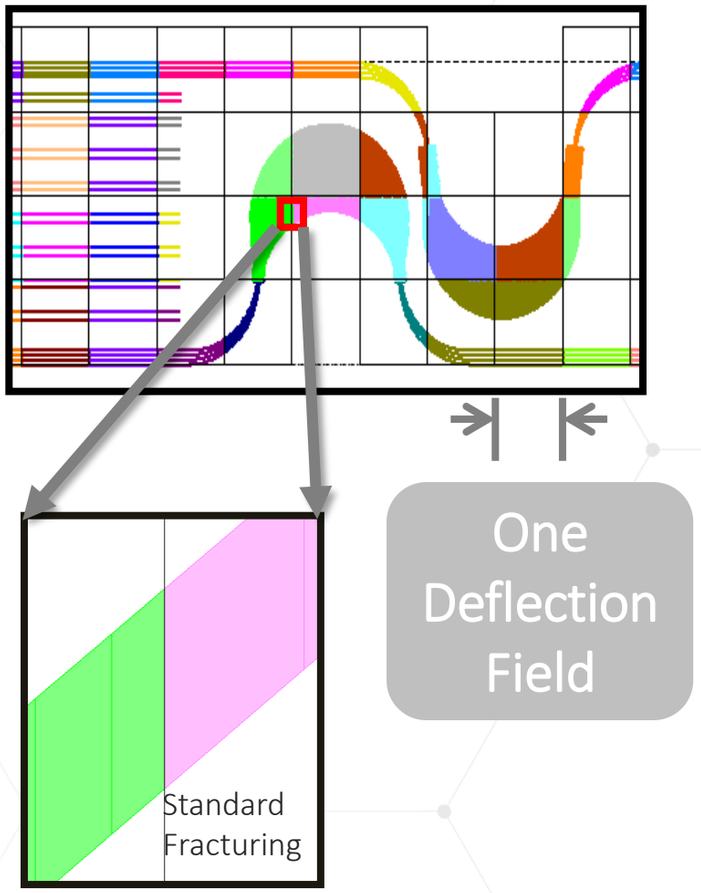
- The live demo of the field fracturing is using Fracture module with the “Flat with Fields” mode.
- To keep the field fracturing, which is done by Fracture module, the export to tool specific format needs to be set to be “Cell to field”.



# Large Element

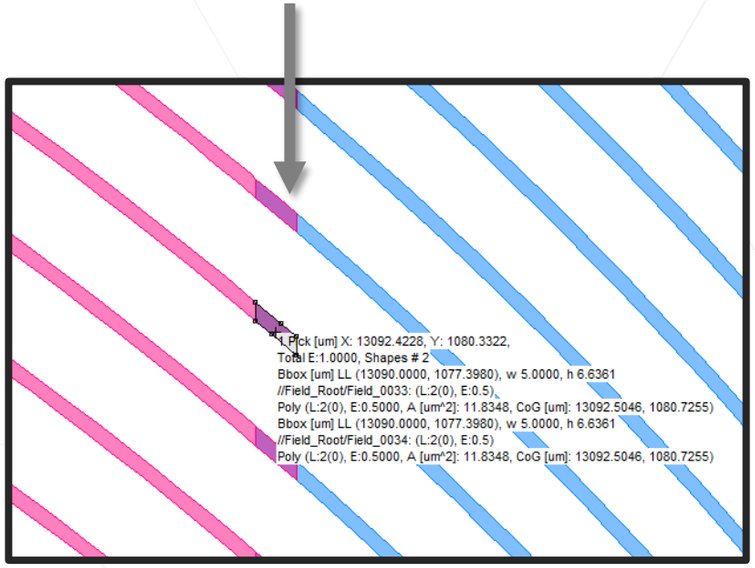
- Patterns such as large waveguides can be challenging:
  - Shapes are unavoidably broken at field boundaries.
  - Lithographic effects of broken shapes significantly affect the waveguide performance.

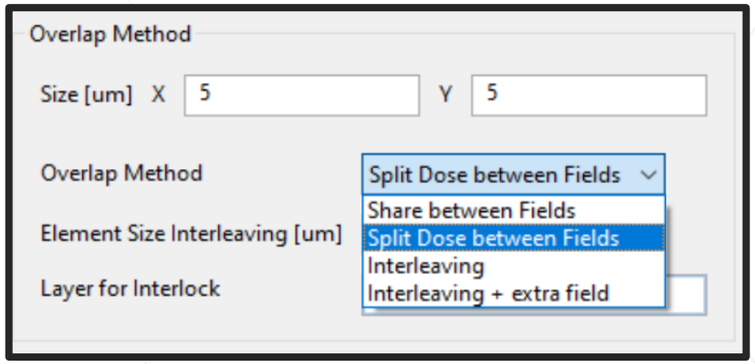


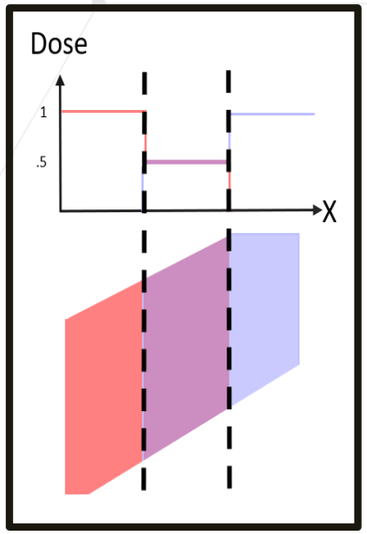
# Dose Splitting

- Patterns such as large waveguides can be challenging:
  - Shapes are unavoidably broken at field boundaries.
  - Lithographic effects of broken shapes significantly affect the waveguide performance.
- Solution 1:
  - The elements that span over the whole overlap region are exposed in two fields with 50% dose for each.

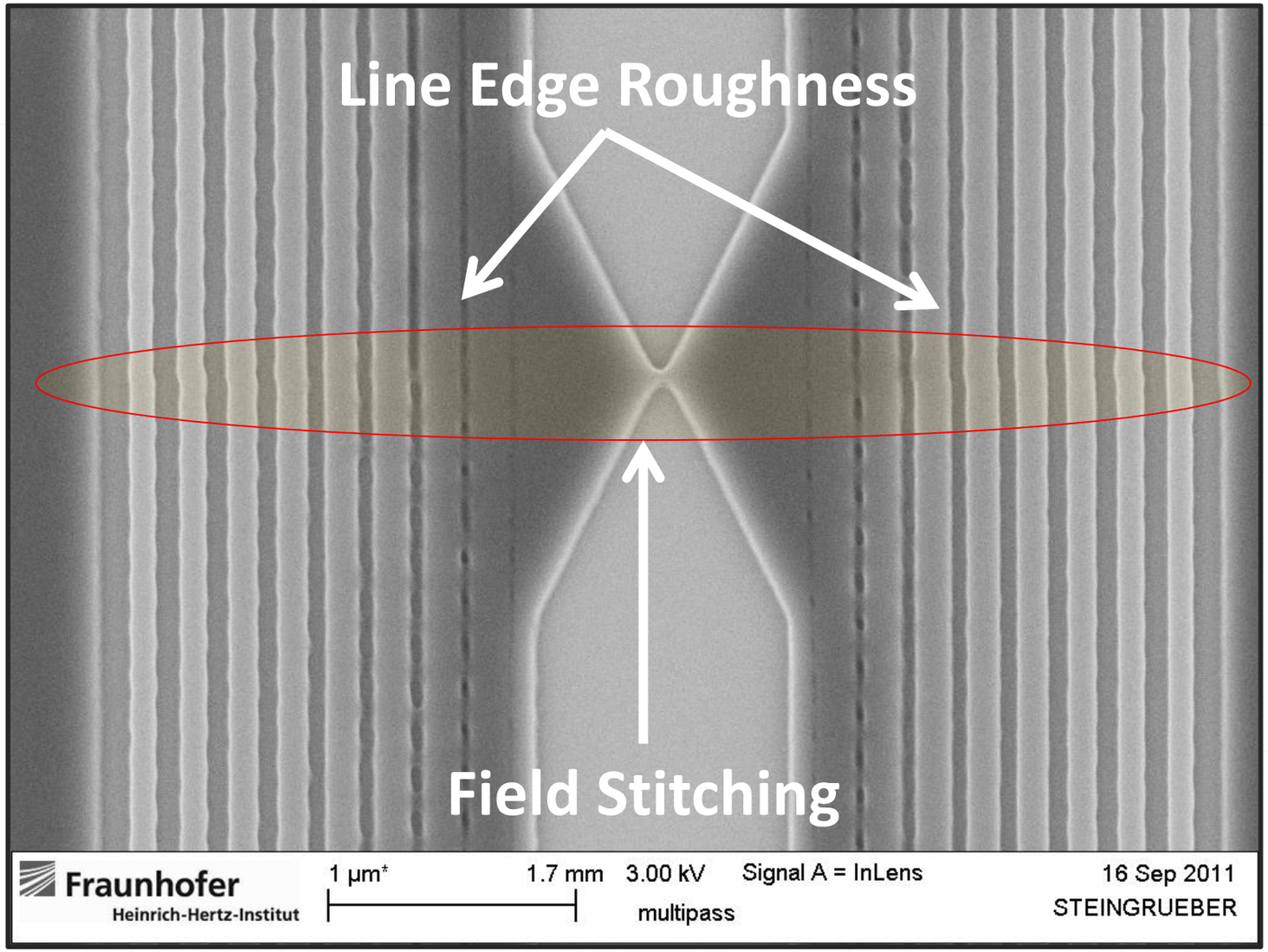
Exposed in two fields with dose 50%



# Problem: Stitch Error



# Multipass: Theory of Operation

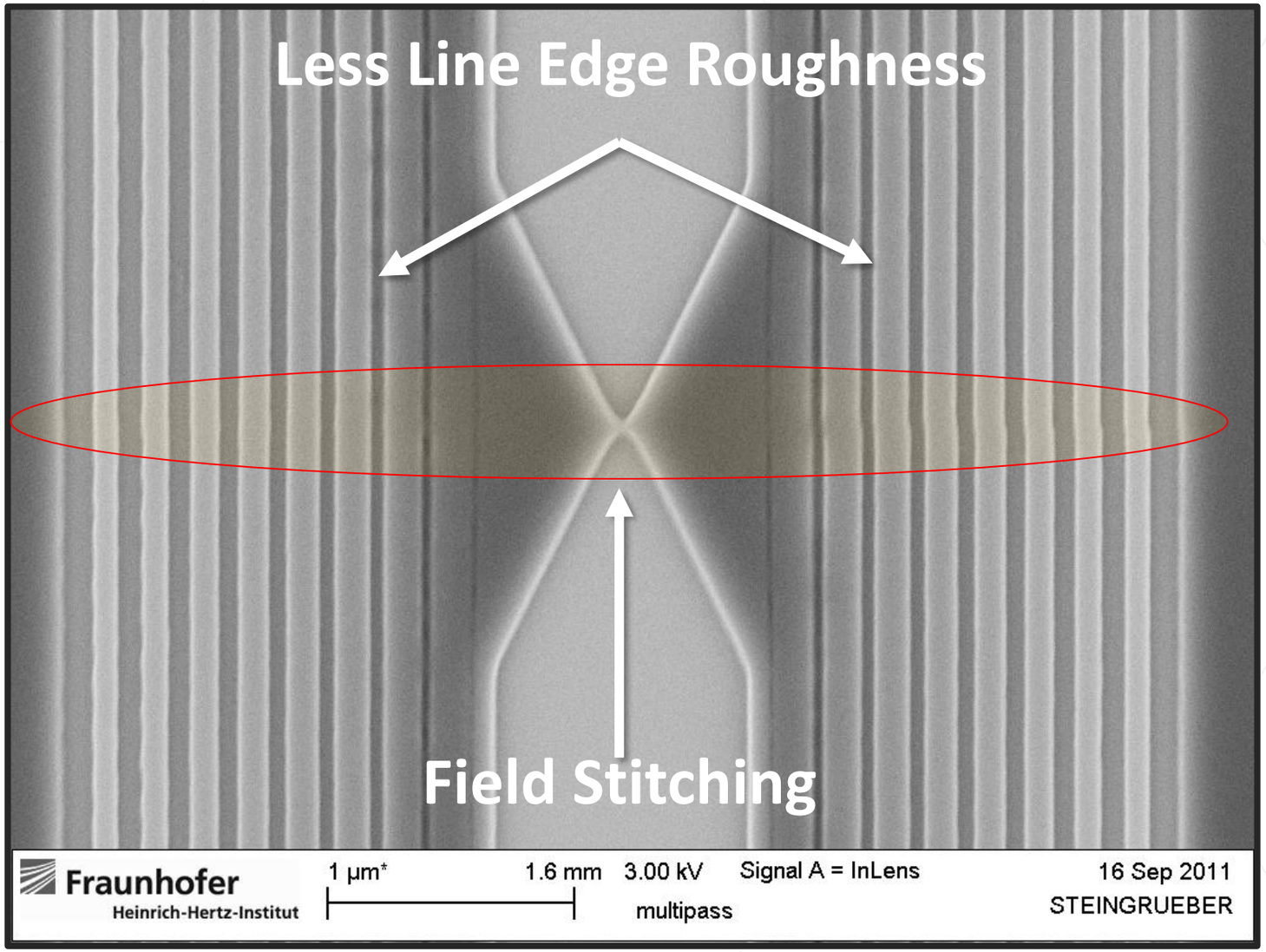
Writing Errors are either **systematic** or **statistical**

- Systematic errors include
  - Field Distortion and Field Aberration
  - Scan Non-Linearities
  - Shutter Effect
  - X/Y asymmetries due to speed in X axis..
- Statistical Errors include
  - Beam Current Fluctuations
  - Beam Noise (line edge roughness) and Drift
  - Stage Position Errors, mechanical vibrations, …

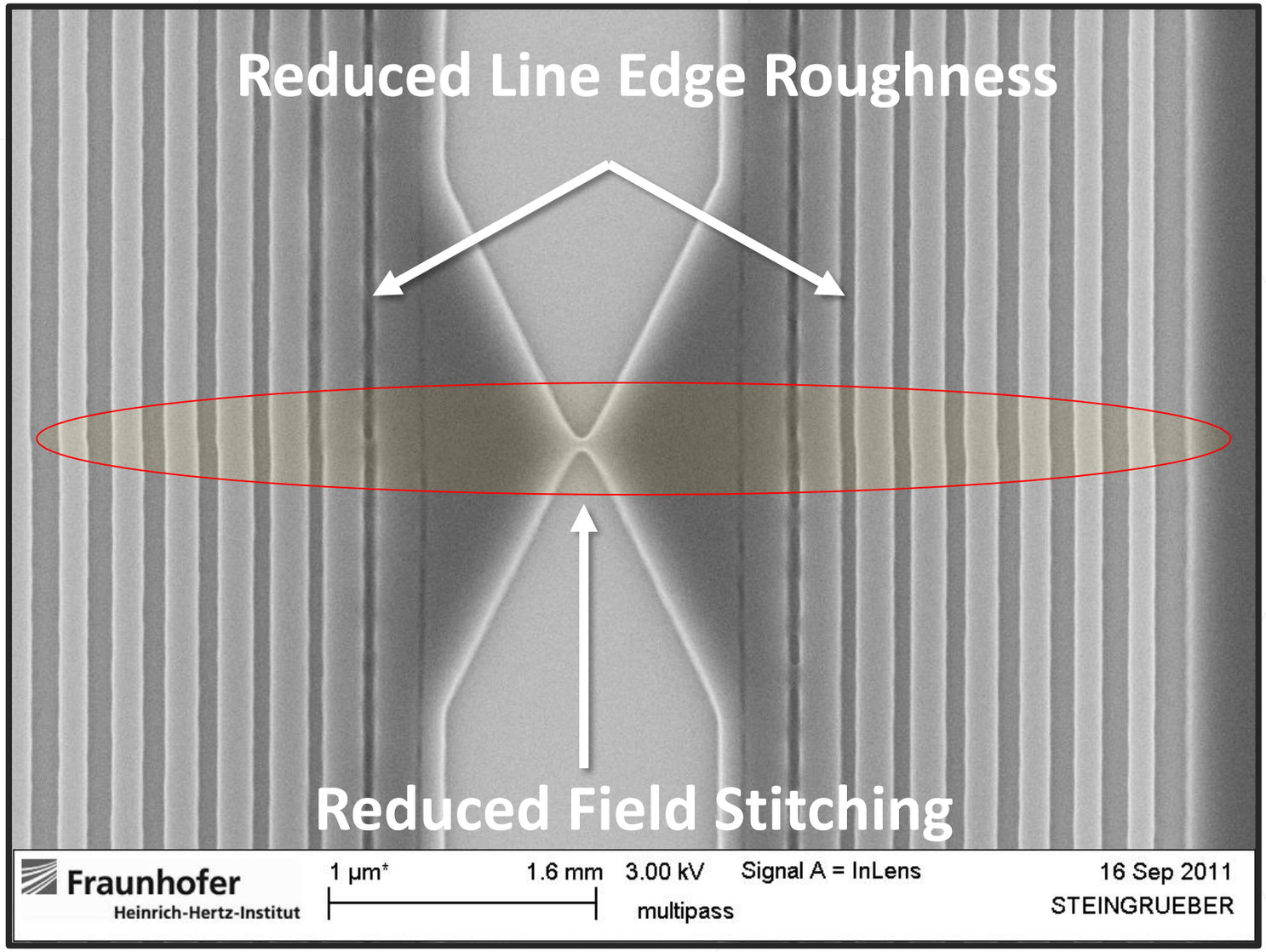
**Multipass reduces both type of errors**

- Statistical errors through averaging
- Systematic errors by using offset strategies

# 4x Pass w/o Shift at 100µC

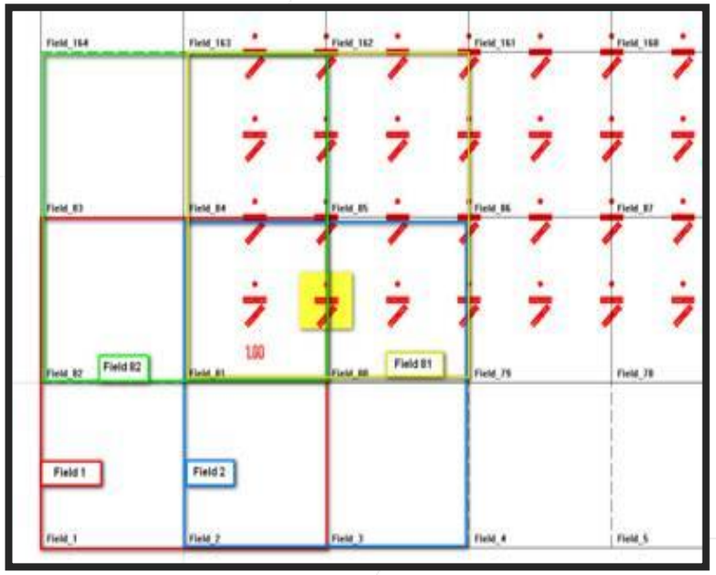


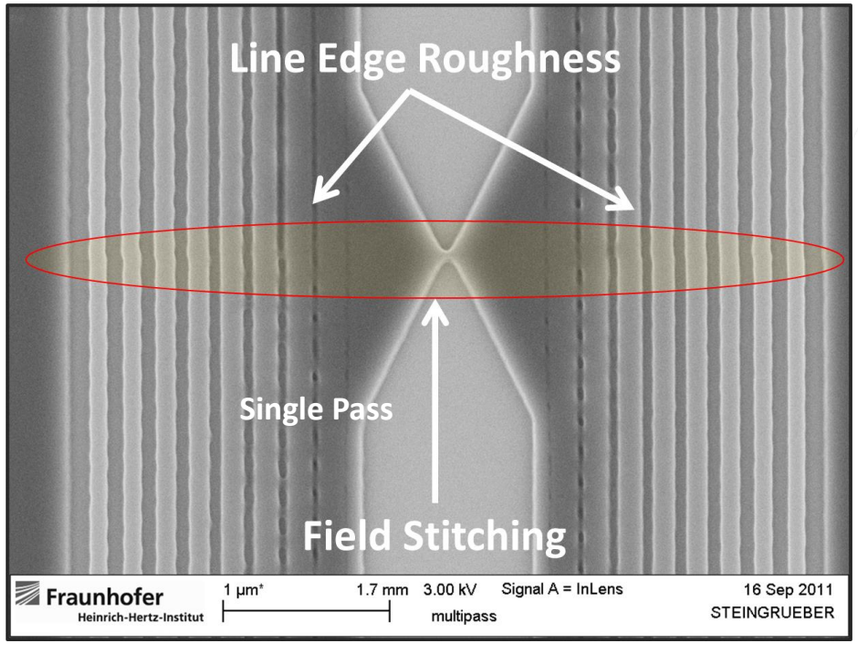
# 4x Pass with Shift at 100µC

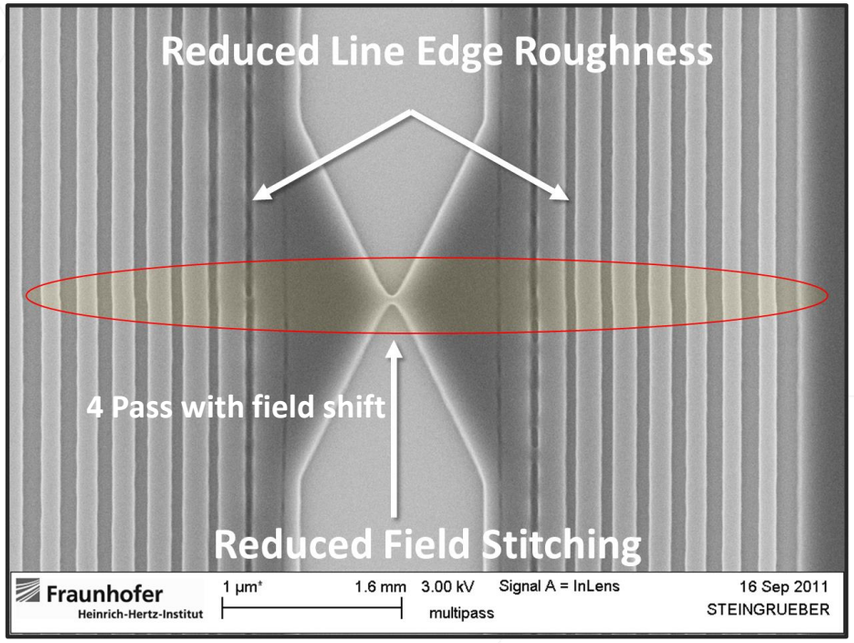


# Multipass with field shift

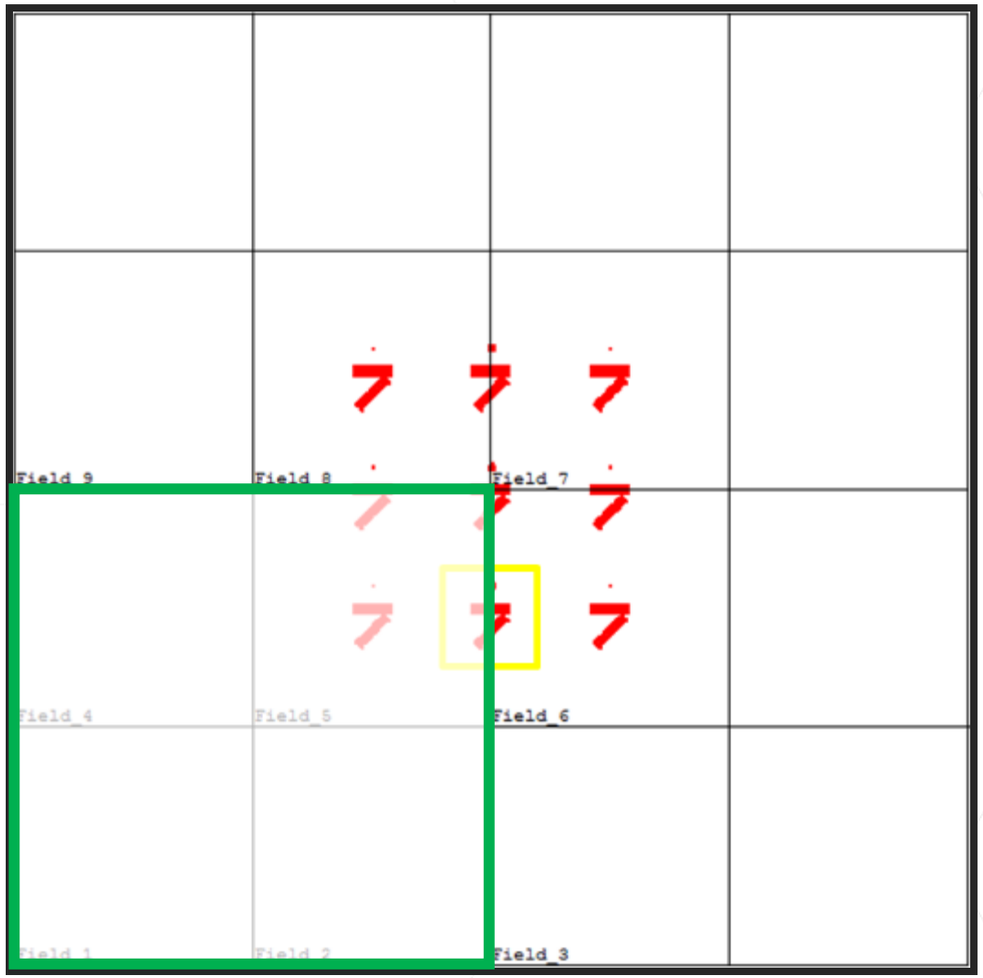
- Multi-Pass reduces LER and improves resolution
- Field-Shift helps to mitigate stitching errors
- Sub-field shifts help to improve shape uniformity



# 4X Pass with ½ Field Shift in X/Y



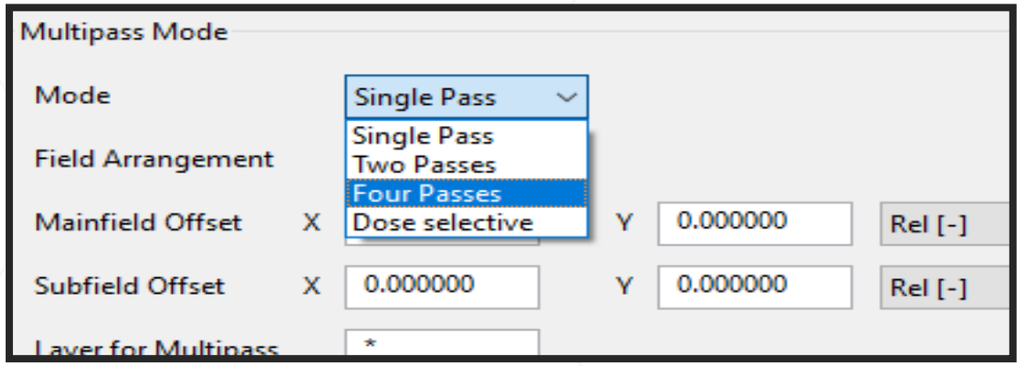

Left half of Yellow area exposed

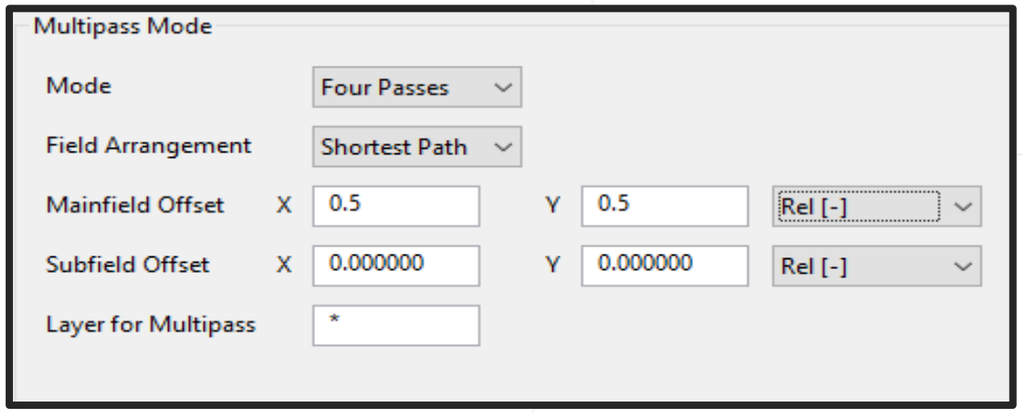
4th time

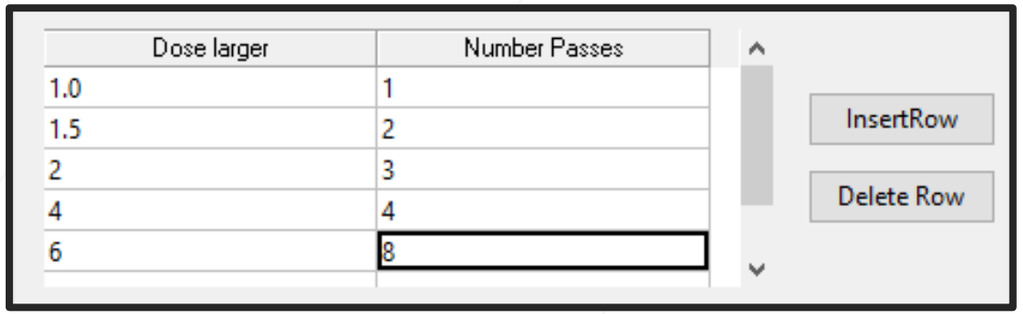
One E-Beam Exposure Field

# Live Demo: Multipass

- Multipass Mode
  - 1 – writing with a single pass
  - 2 – every element is written twice
  - 4 – every element is written quadruple times
  - Dose Selective – For each defined dose value the number of passes can be specified
- Mainfield offset
  - Defines the shift of a field against another
- Subfield offset
  - Defines the shift of a subfield against another
- Layer for Multipass
  - Applies multipass only to specified fields



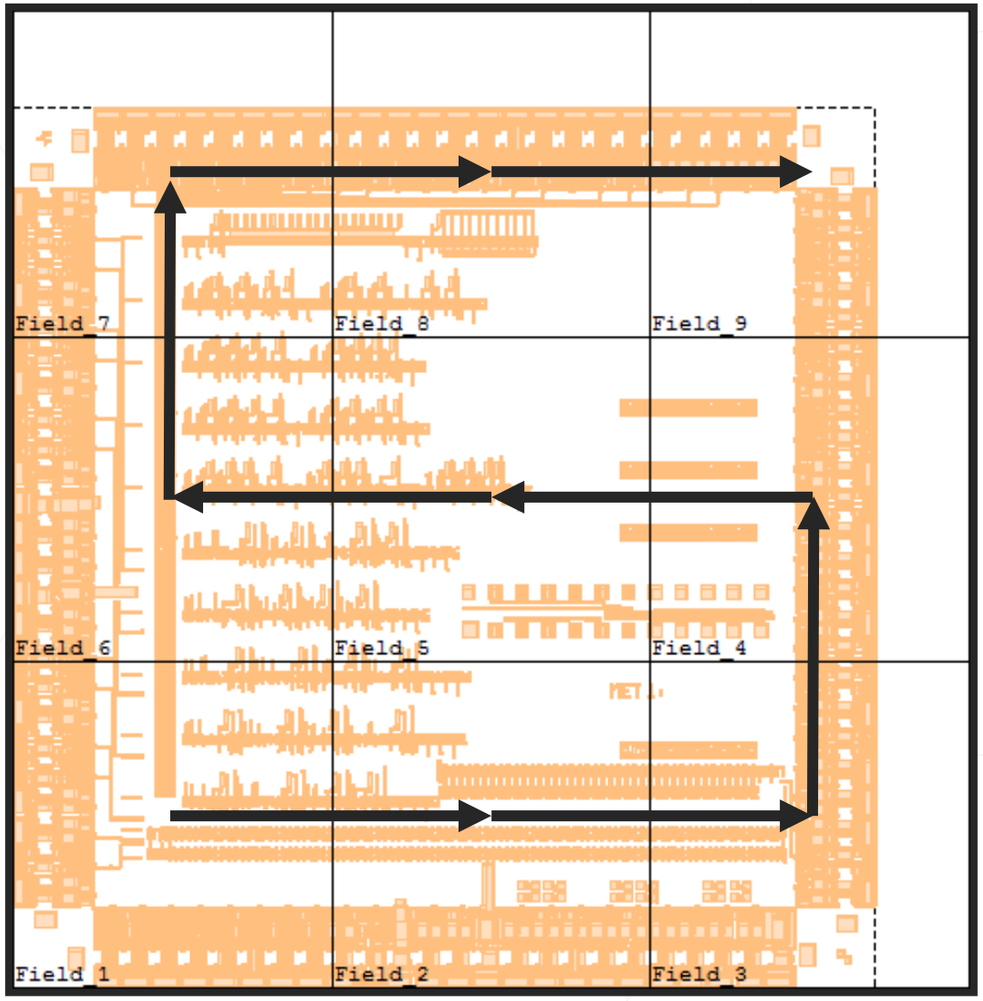



# Agenda

- Field Stitching
- Field Ordering
  - Fixed Fields
  - Floating Fields
  - Fields follow geometry
  - Manual Fields
  - Re-ordering
- Feature Exposure Order Control within the Field
- Summary
- Q&A

# Fixed Field Ordering

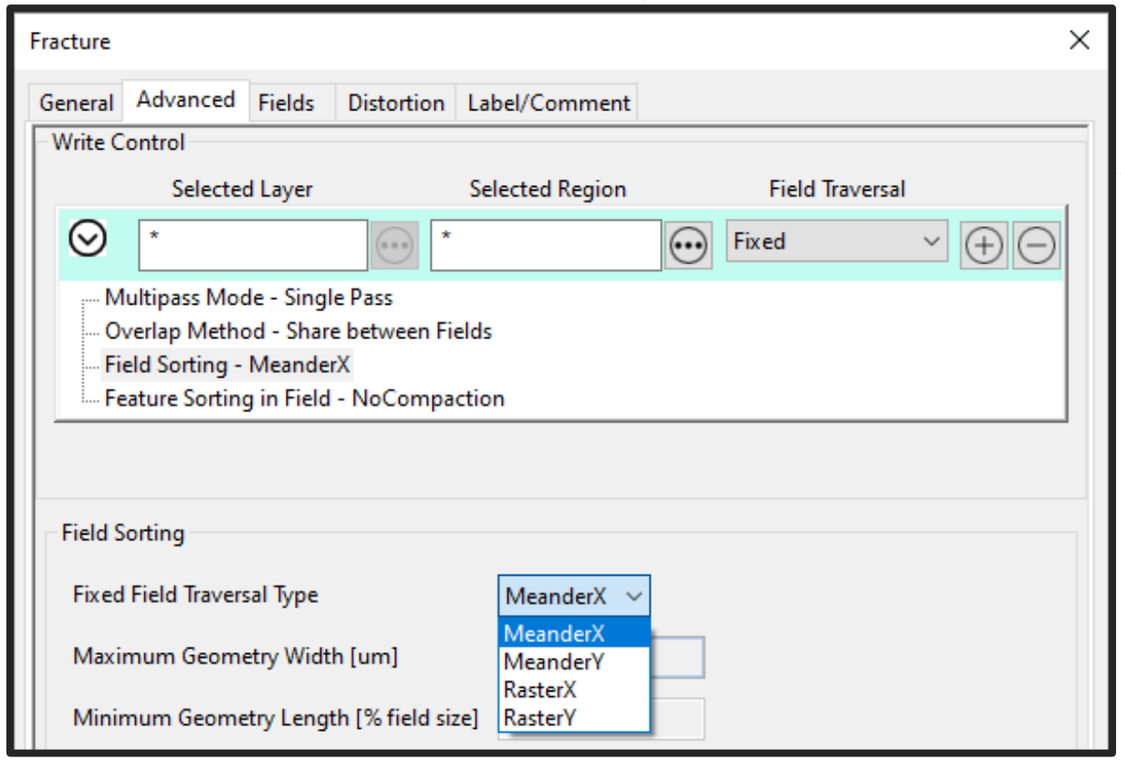
## Fixed field ordering – recommended with overlap

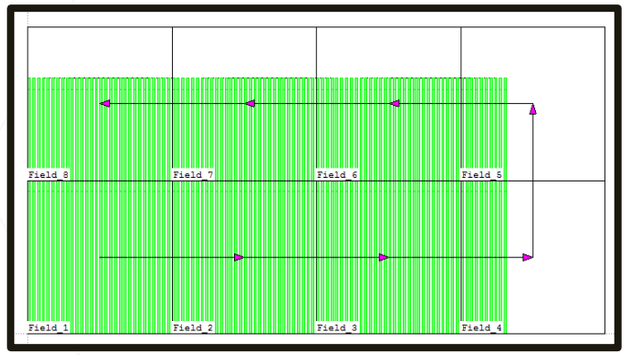


# Fixed Field Ordering

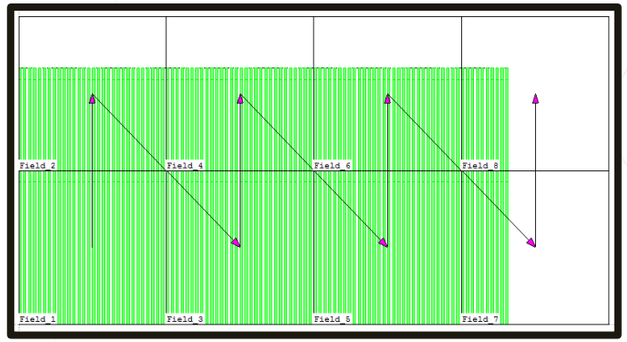
Field ordering affects the time delay between writing of adjacent fields

- For example: MeanderX is not a good choice for a Y-oriented gratings
- Raster Y Field ordering enables grating lines to be written in immediate sequence




Meander X

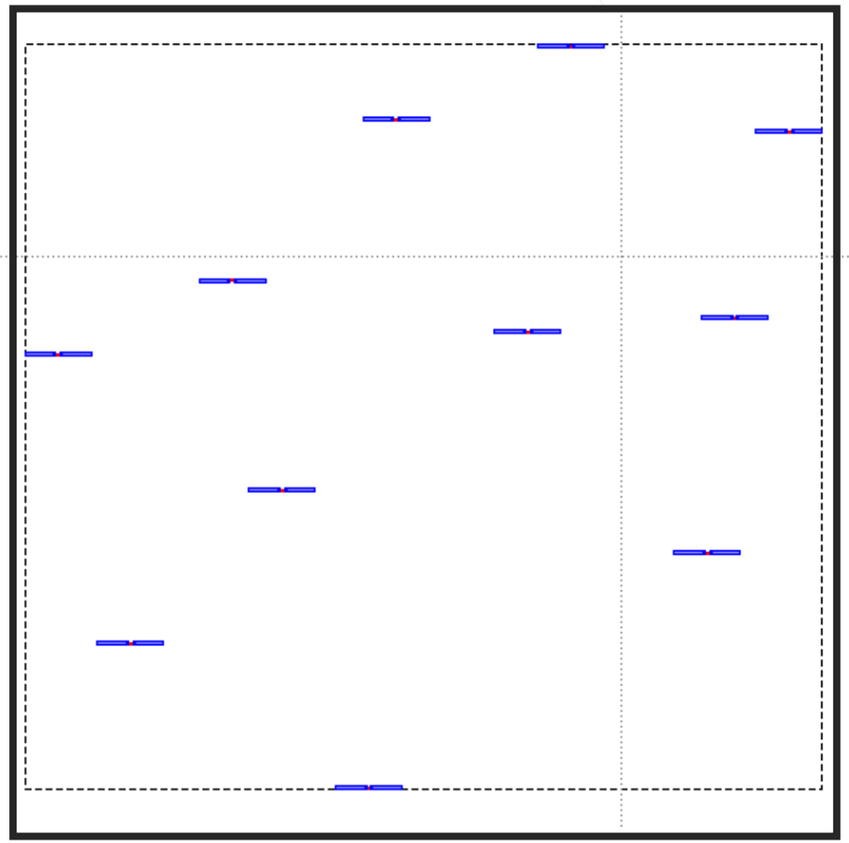



Raster Y

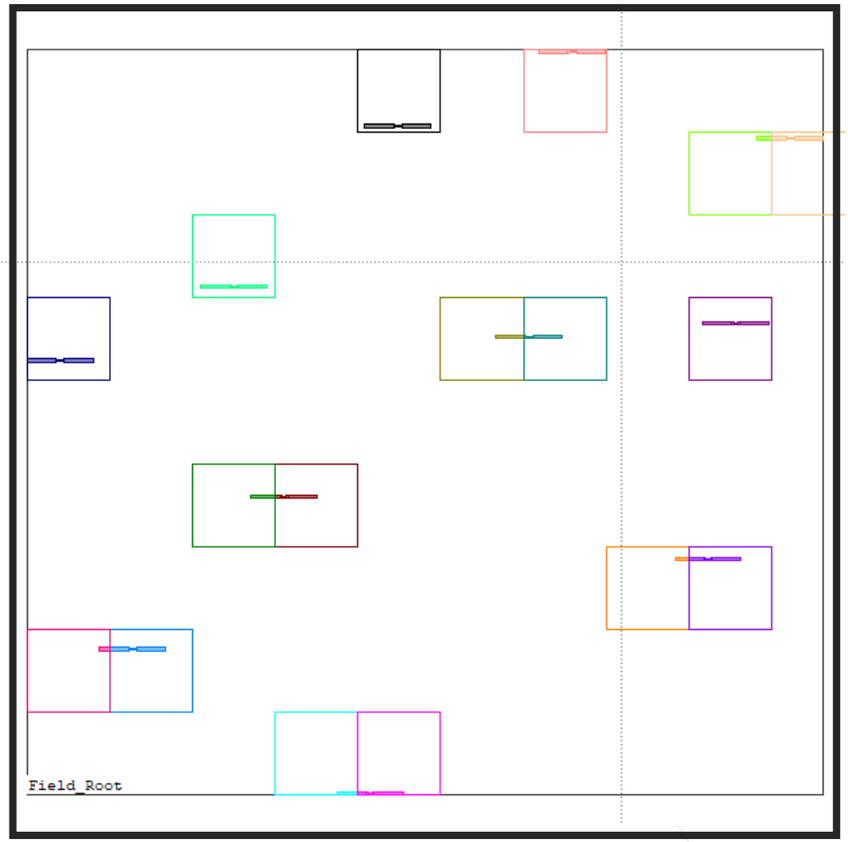
# Field Ordering

Pattern dependent field ordering is intended to

- Enhance the exposure quality
- Reduce the writing time by reducing the stage movement and minimize the field number



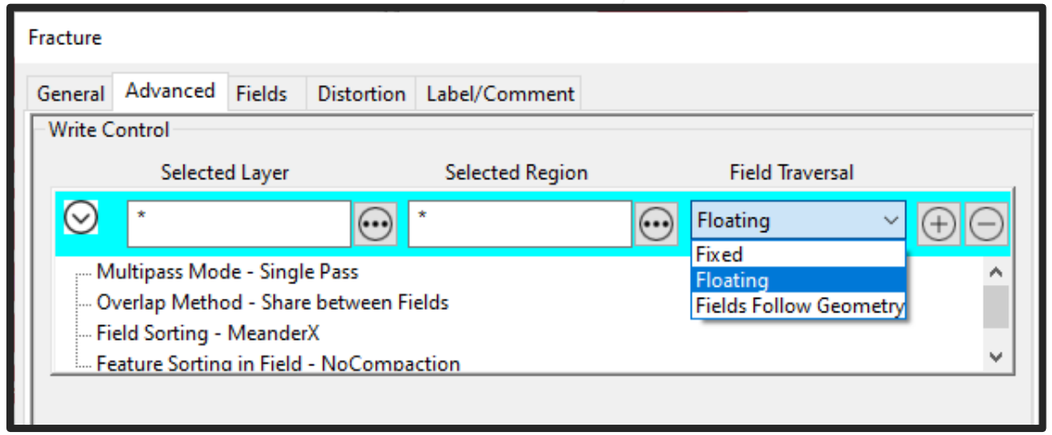
Fixed field

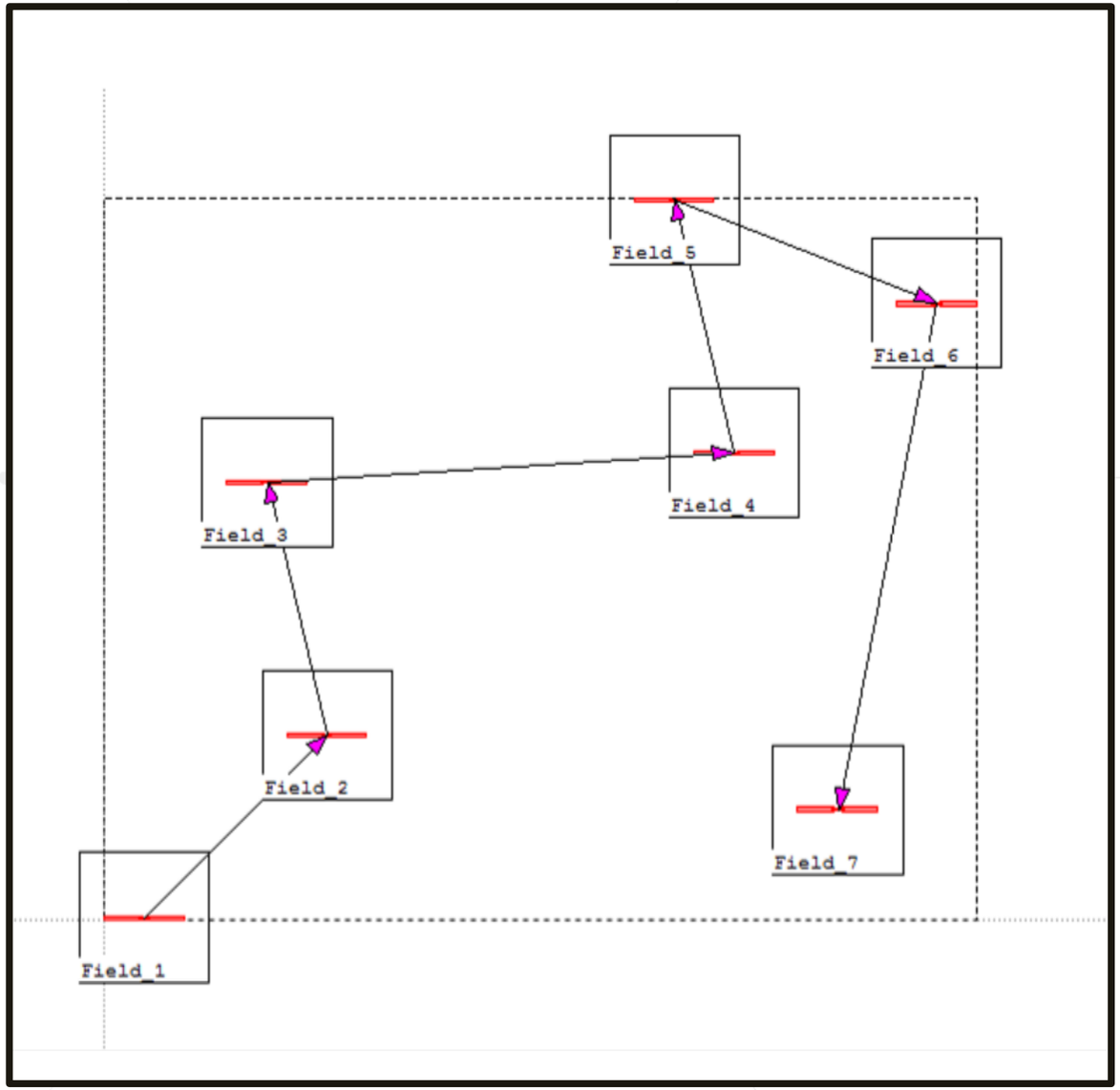


# Live Demo: Automatic Floating Fields

## Automatic Floating Fields

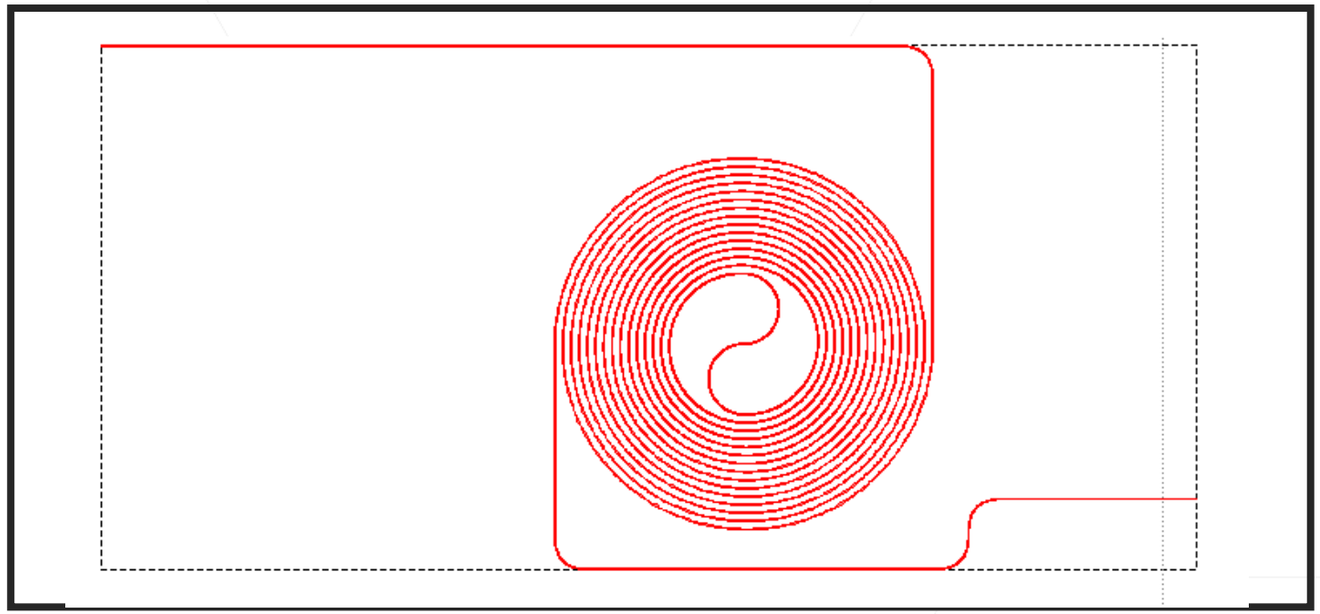
- Places the fields around the data
- Attempts to position in the middle of the field.
- Optimizes the number of fields and minimizes stage travel



# Long Waveguide Pattern

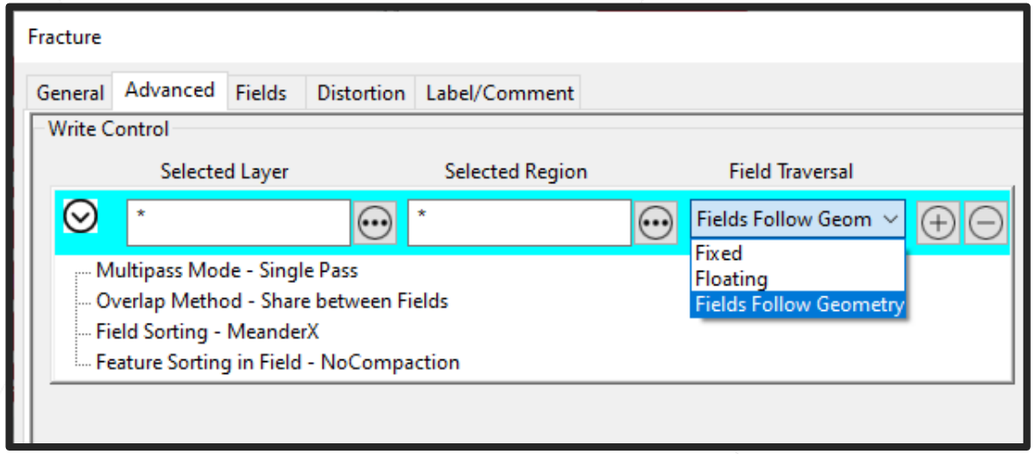
How to improve the optical performance of waveguide?

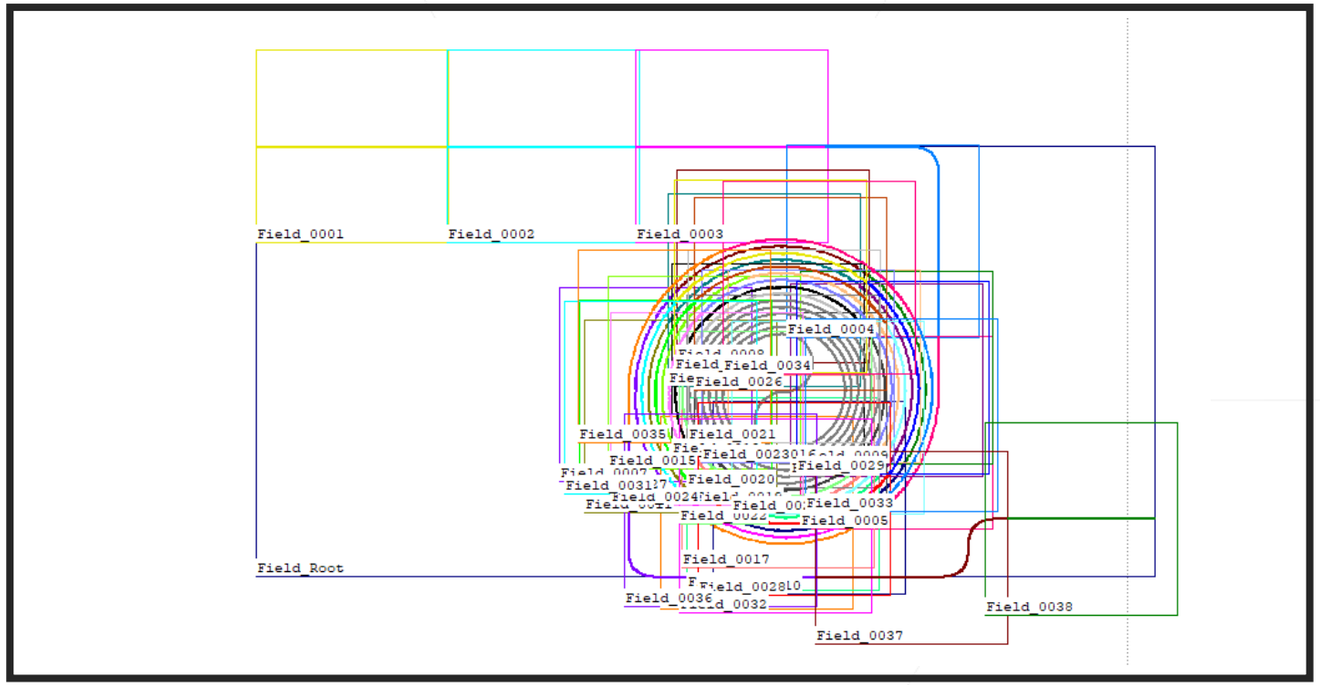


# Live Demo: Fields Follow Geometry

## Fields follow geometry

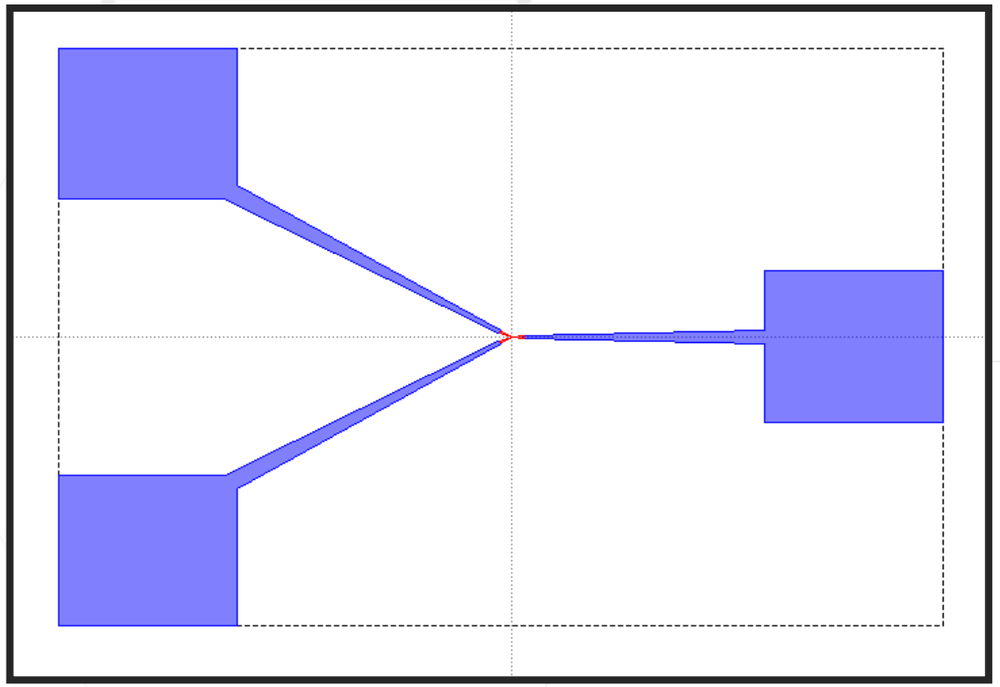
- Allows fields to be placed and ordered to follow long contiguous structures, e.g. waveguides, Microfluidics…



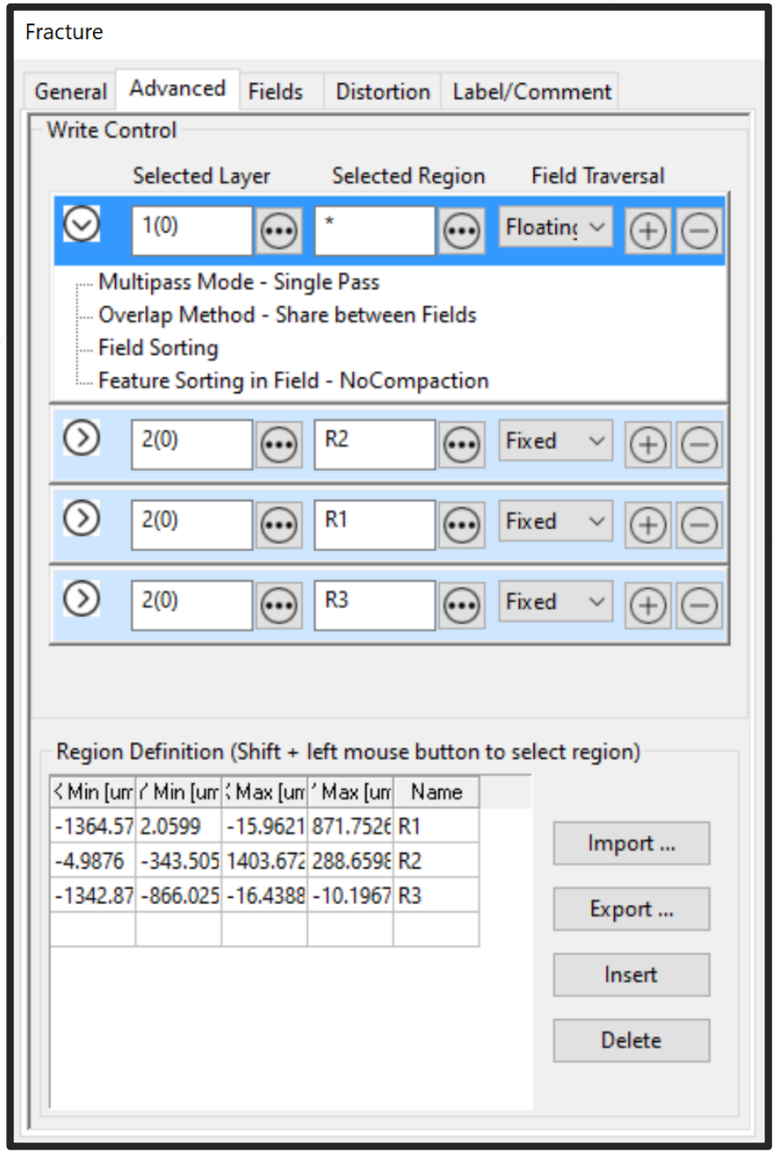
# Spider Pattern

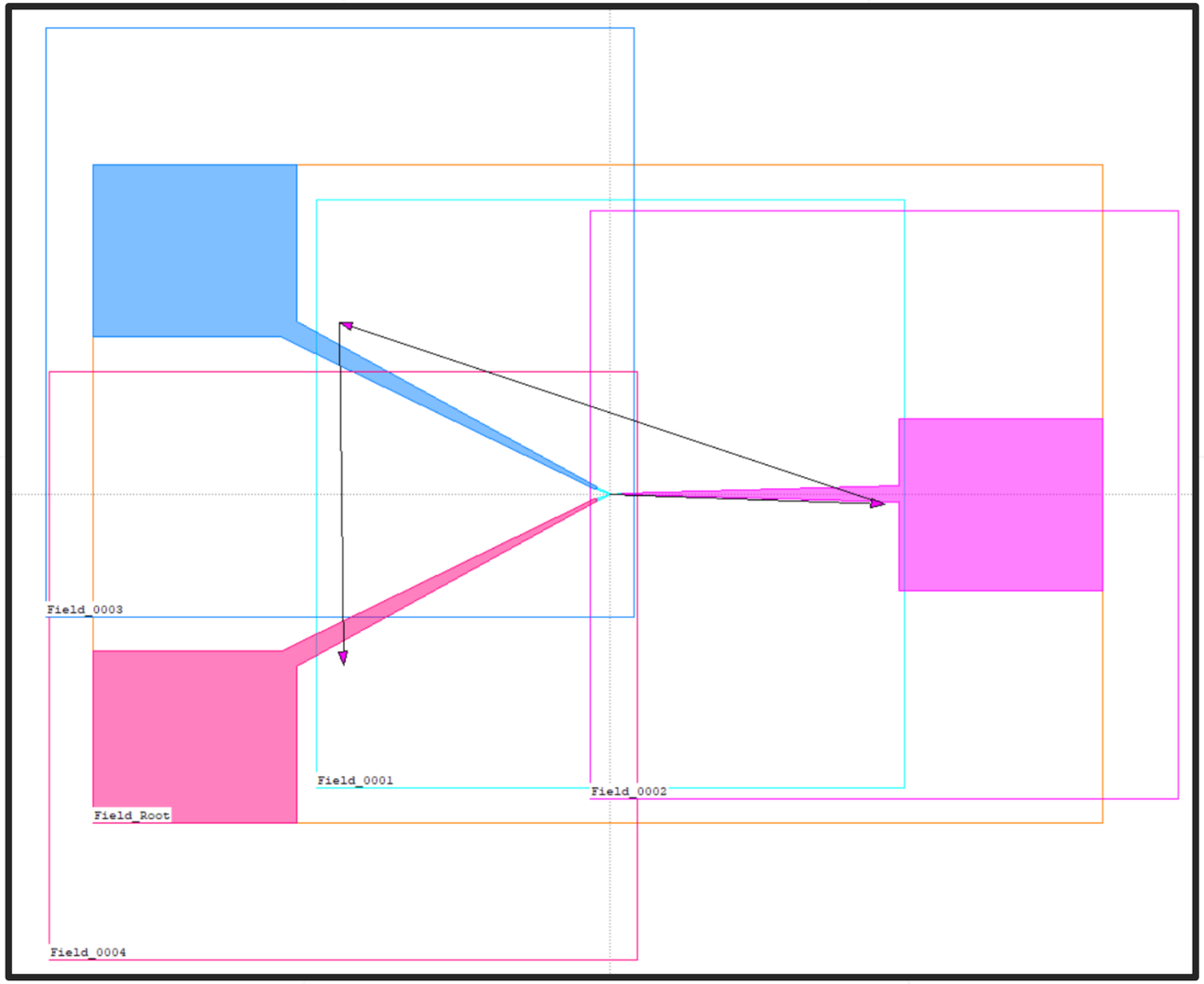
- Spider Pattern:
  - The critical pattern (red) is at the center.
  - The pad (blue) has less requirement for the quality control.



- Solution: Manually control different parts of the pattern.
  - Separate the pattern by layers.
  - Place the critical part at the field center.

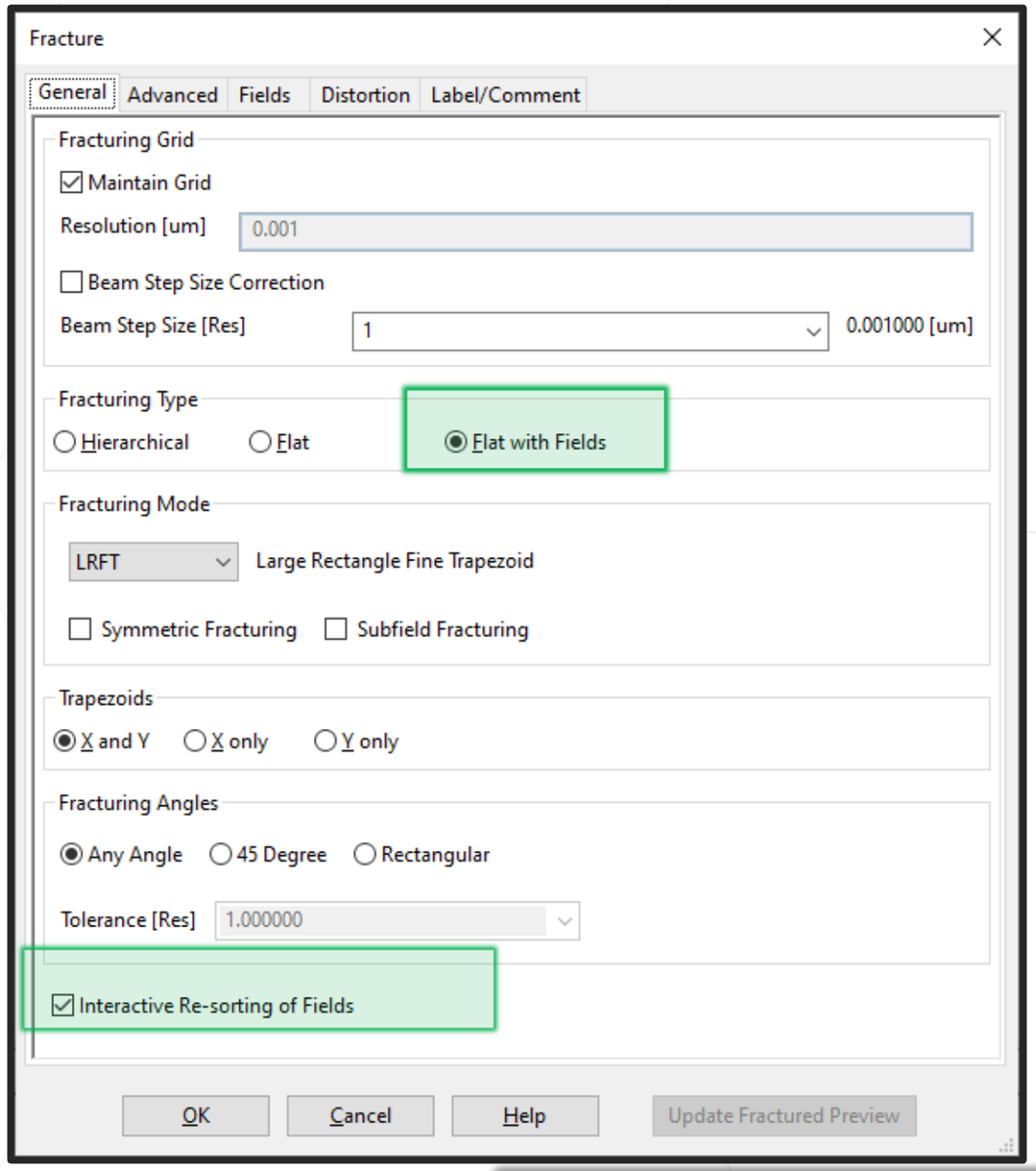
# Live Demo: Manual Field



# Live Demo: Interactive Re-sorting of Fields

- The order in which fields are exposed can be re-defined.
- Individual fields can be unchecked and therefore not exposed.



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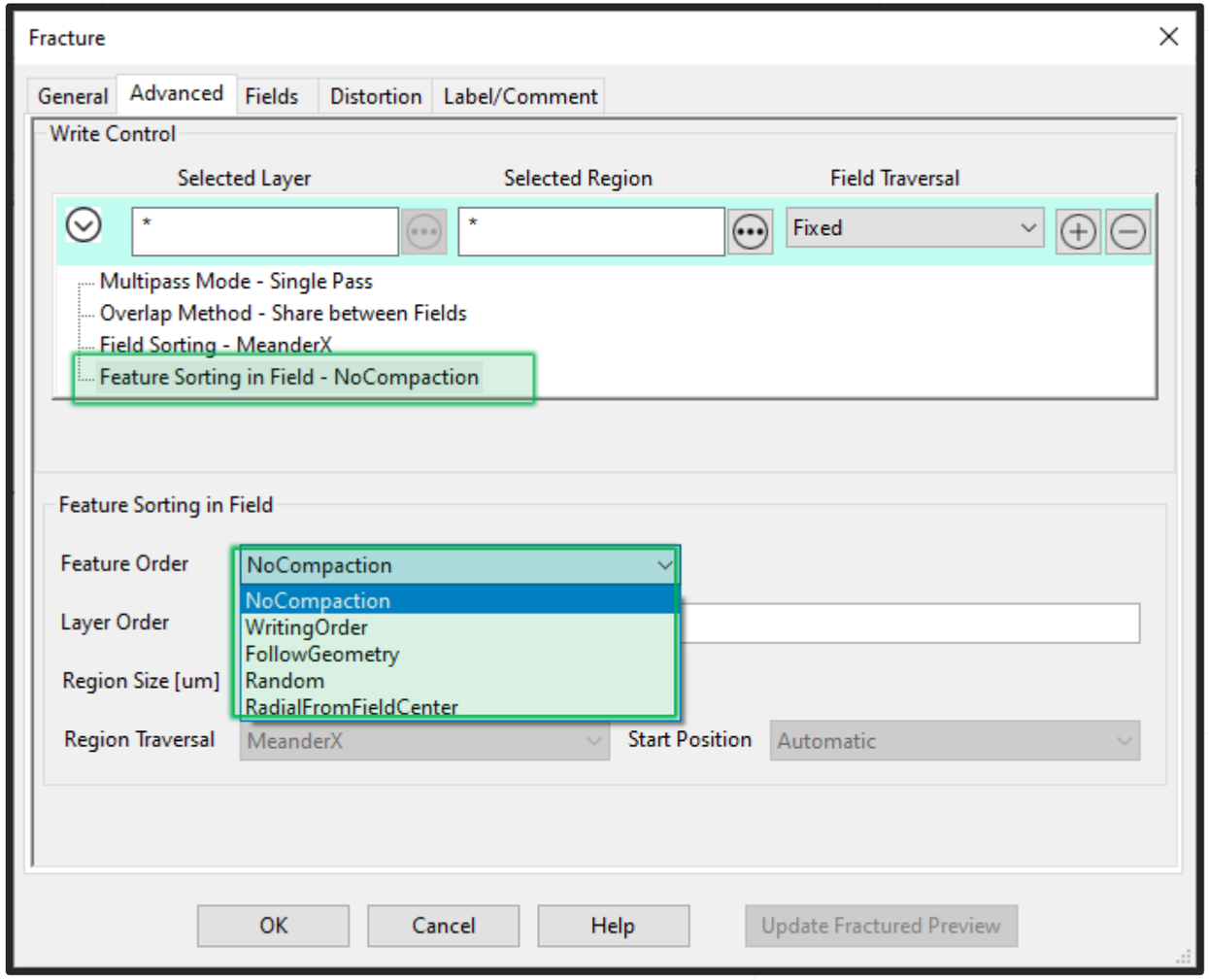
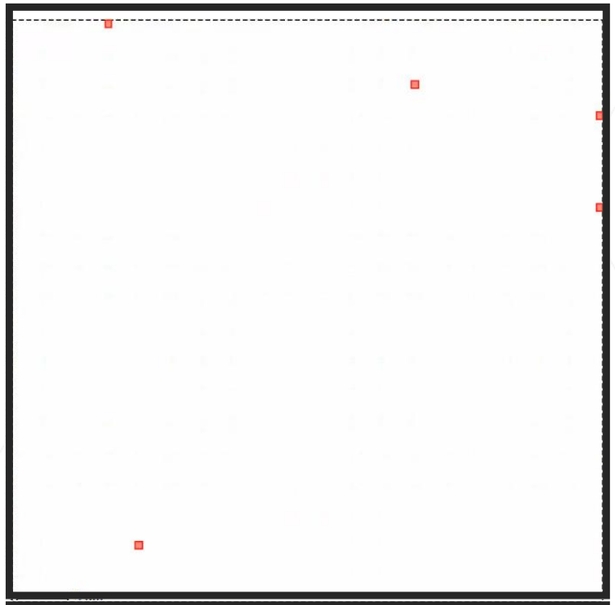
# Feature Sorting in Field

Feature sorting in field applies to features within an exposure field.

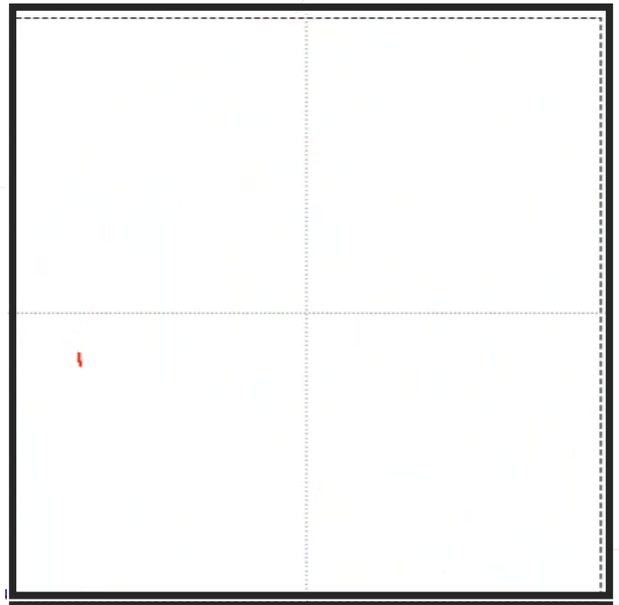


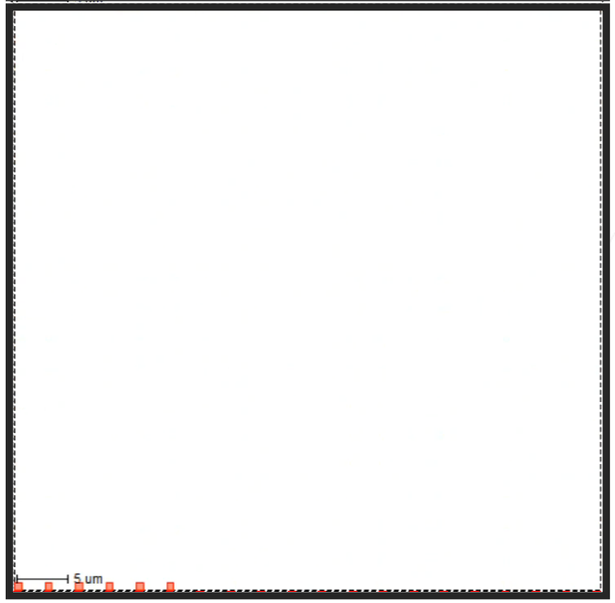
# Feature Sorting in Field



No Sorting

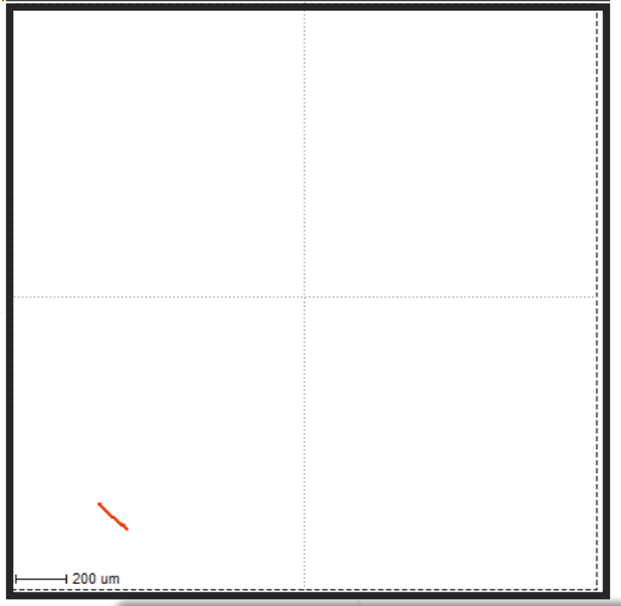
No Sorting



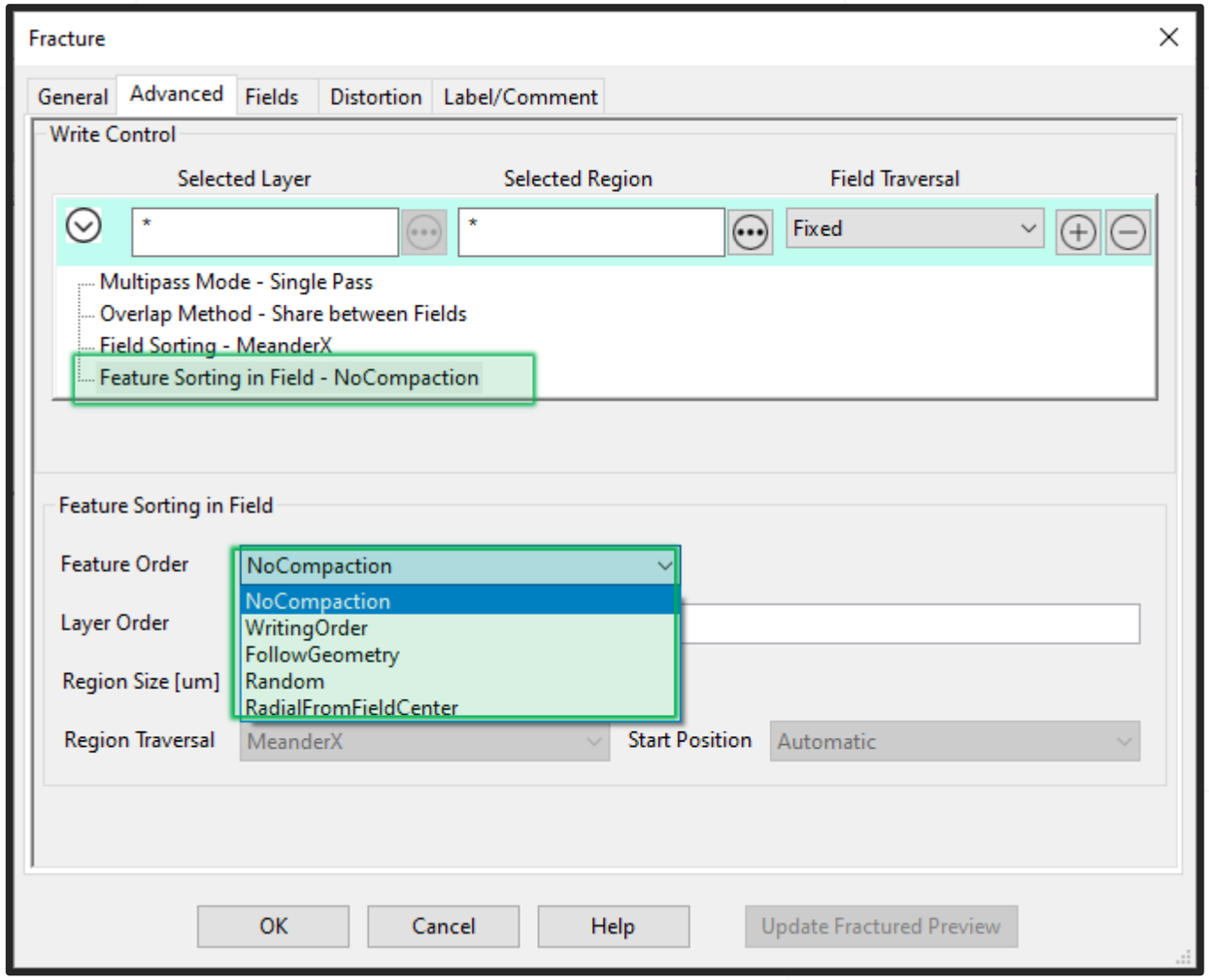



Writing Order

Follow Geometry



# Live Demo: Feature Sorting



# Agenda

- Field Stitching
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# Summary

BEAMER provides different techniques to improve the exposure strategy.

- Field stitching
  - Field overlap, to reduce the impact of field stiching
  - Multipass reduces system errors by averaging and by clever offset strategy.
- Field order optimization
  - Fixed fields
  - Floating fields/Fields follow geometry/Manual fields
  - Pattern dependent, to optimize exposure quality
- Feature sorting within the field
  - Writing order optimization within the field
  - Pattern dependent, to enhance the exposure quality.

# Outlook

## BEAMER training webinar part 3: Layout Operation

- Basic Layout Operation
  - Boolean operations/Bias/Transform/Bulk-sleeve application
  - Modification of existing patterns intelligently
- Grid Module
  - Layout vertex optimization
- Extraction from Layout
  - Extraction/Merge

# Thank You!

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