Exposure Strategies for Optimised Writing

This Application Note details the different exposure strategies that can be used in a single layout. Among the alternatives, BEAMER allows powerful modifications to the field-ordering and feature-sorting. Particularly, two methods are demonstrated: using multiple *Export* modules and using the *Fields* module.

INTRODUCTION

The increase in speed and performance of incoming technologies are dependent on miniaturising the unit elements called chips. This shrinking of devices pushes tool resolution to its limit, which challenges the design and fabrication process of devices. Particularly, preparing an optimized exposure strategy is straightforward with patterns with simple characteristics. However, exposing patterns with complex or mixed characteristics can be challenging and may require breaking up into multiple exposures. To make the exposure job creation easier, less error-prone, and efficient, it can be preferred to process the entire pattern in one exposure file.

Multiple options for fracturing, sorting or field control within a single exposure file leads to optimal results for complex layouts. In this document we show examples for mixed exposure strategies for different layouts. This technique can be accomplished with two methods: (1) using *multiple export modules* and merging those results, and (2) using the full feature set of the *Fields module* to order the data. There is no limit to the number of exports that can be combined into one exposure file. This approach is very useful to improve lithography results by choosing the best strategies and saves time by single file exposure.

MULTIPLE EXPORT MODULES

The *Export* module integrated into BEAMER gives various options to control lithography-tools writing throughput. Here, we explore 3 layouts that benefit from the multiple export features.

1. COMBINING RASTER X & RASTER Y FIELD SORTING

Figure 1 shows two gratings, one x-oriented (red) and one y-oriented (blue). In this layout, each grating can be exposed to follow the grating trend minimizing distortion at the field edges.

Figure 2 shows a flow that works to achieve the mentioned tool criteria. The layout is imported into BEAMER. Then, the *Extract* module is used to select either layer 1(0) or 2(0) as the layer of interest (to explore other options in the *Extract* module go to Appendix A). Afterwards, the *Export* module
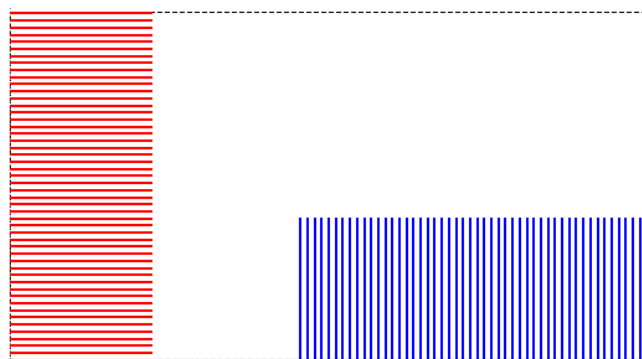

Figure 1. Layout compound with an x-oriented grating (red) and y-oriented grating (blue).

is used to set a *Fixed Field Placement*. For this, in the *Advanced* tab, the *Fixed Field Transversal Type* is set
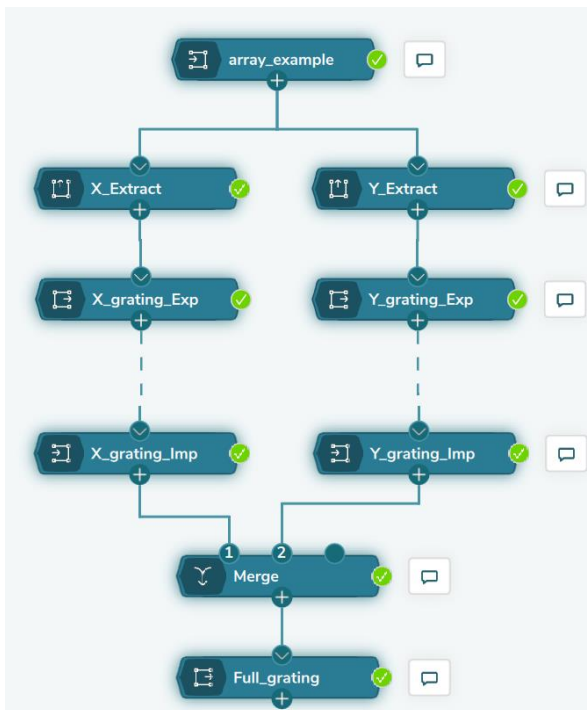

Figure 2. BEAMER flow to extract the two regions of interest, export them, re-imported and merge to export a single exposure file.
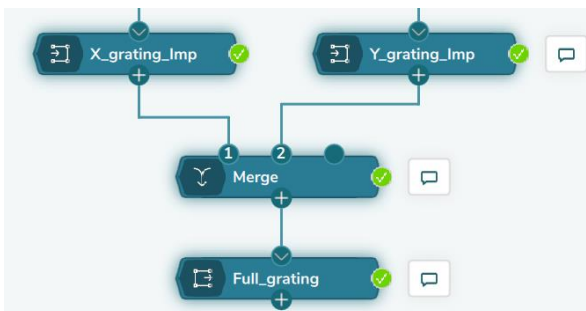
Figure 3. Re-import of the exported gratings, then merged and exported together.

to *Raster X* (for red)/*Raster Y* (for blue) according to the layout to modify. Once the gratings are exported separately, they are re-imported and merged (see Fig. 3).

Finally, the merged layout is exported selecting the specific tool format to use during the lithography patterning. Importantly, to preserve the separate X and Y writing orders, in the *Advanced* tab, the *Field Placement* is set to *Cell To Field* (see Fig. 4). The exported file results in a layout that is exposed following the two selected writing orders. Accordingly, the *Raster X* and *Raster Y* methods are patterned in a single exposure file (see Fig. 5).
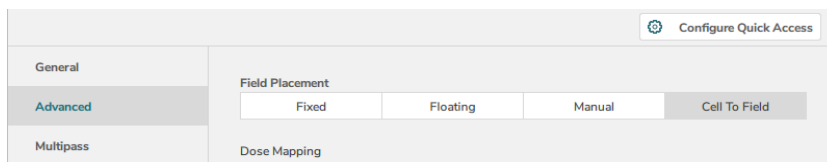

Figure 4. Advanced Export settings set to 'Cell To Field' field placement.
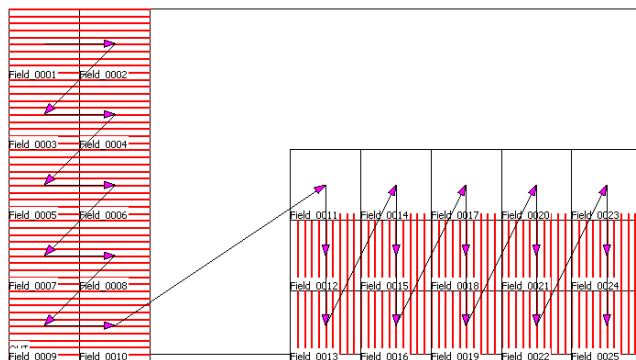
Figure 5. Resulting exposure file with two writing strategies.

2. COMBINING FLOATING AND OVERLAPPING FIELDS

Figure 6 exhibits a layout that includes scattered data (blue) and dense region data (red). In this layout, the region with sparse data is optimised centring the writing fields in every feature. Alternatively, in the dense region, the fields need to overlap to avoid stitching.
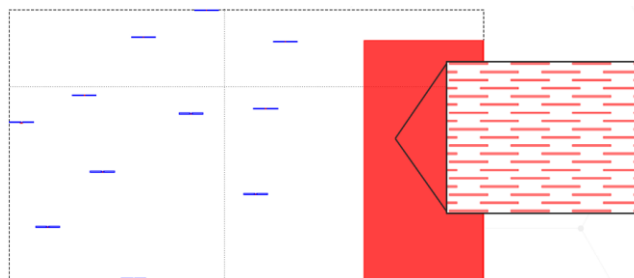
Similarly, to the previous example, the *Extract* module is used to individually take each region and modify it separately (see

Figure 6. Mixed layout with scattered features (left) and dense region (right).

Appendix A for details on the *Extract* module). Once the sparse and dense regions are separated, the *Export* module is used to apply the respective field control options. Figure 7 shows the required settings to export the file for the scattered region. Here, the *Field Placement* is set *Floating*, as such that the fields are centred in every feature (see Fig. 9).
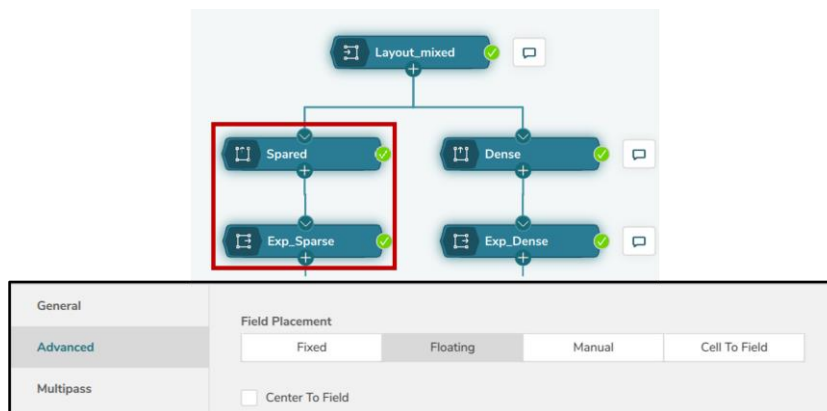

Figure 7. BEAMER flow and export settings set to Floating Field Placement for the sparse region of the layout.

Figure 8 shows the settings to export the dense region. Here, the *Field Placement* is set tobrie *Fixed*, which enables the *Field Overlap* options in the *Multipass* tab. *Size XY* defines the overlap between the fields in X and Y, respectively.
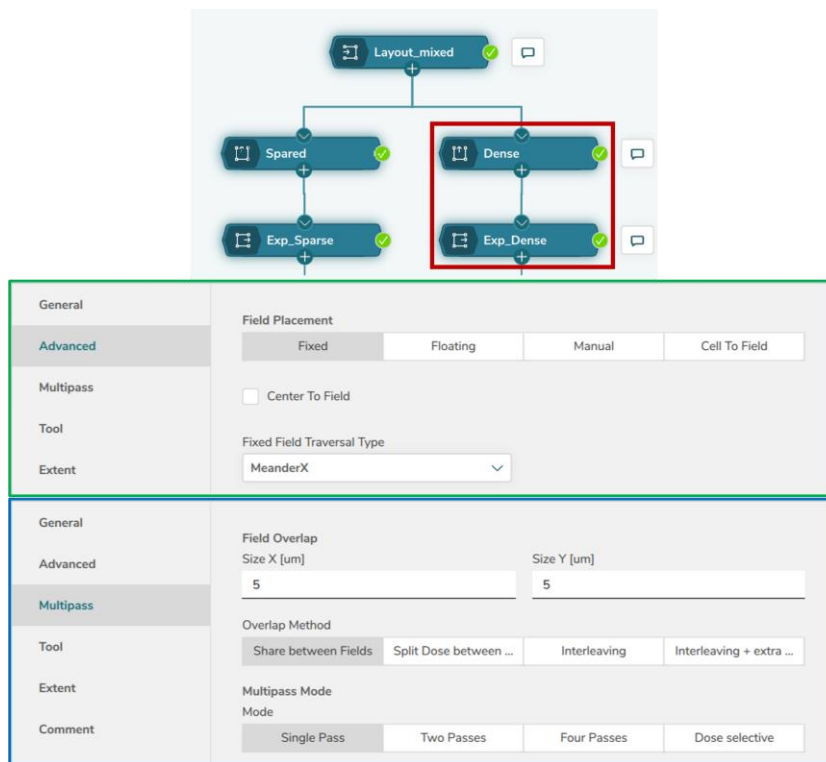

Figure 8. BEAMER flow and Advanced export settings set to Fixed Field Placement for the dense region of the layout. Moreover, Field Overlap is fixed to 5 um in the Multipass tab.

Finally, both files are re-imported, merged, and exported once more. As before, the final *Export* module needs to preserve the settings for the separate regions. Therefore, the *Field Placement* is set *Cell To Field*. Figure 9 shows the corresponding fields sorting for each region.
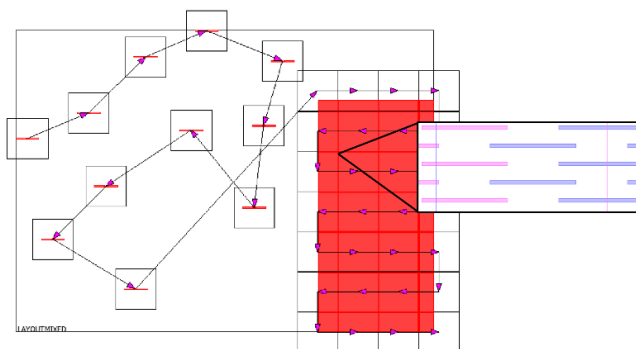

Figure 9. Mixed layout with floating field placement (left) and fixed field placement (right).

3. DRIFTING TEST – MULTIPLE EXPORT MODULES

A common design to quantify tool drift, it is a layout that starts and finishes patterning in the same area. Figure 10 shows a blue grating (pattern of interest) and a red with yellow boxes (patterns to track tool drift). To run such a test, the red box is patterned at the beginning, followed by the grating writing and finally the yellow box.
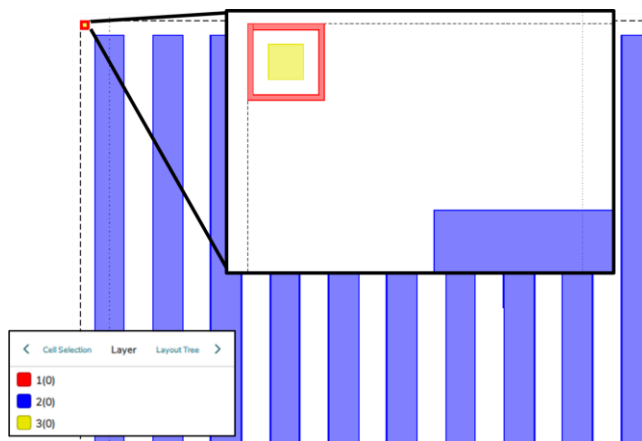

Figure 10. Layout to quantify drift suffered during exposure.
Includes a box in a box marker and the pattern of interest.

As in previous examples, each of the regions are extracted separately. Afterwards, the regions are exported, re-imported, merged, and finally, a file containing the three regions are exported (see Fig. 11).
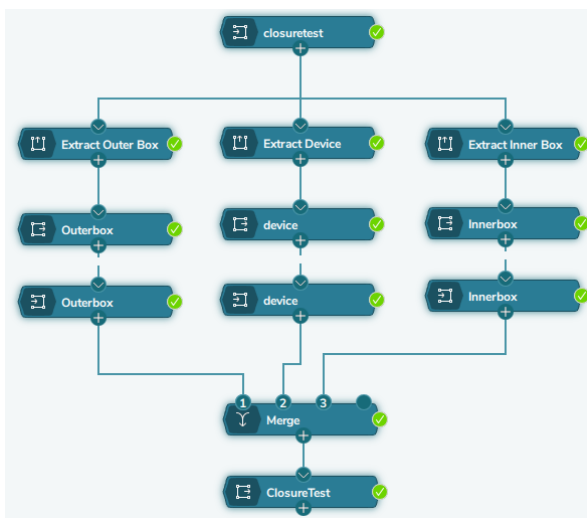

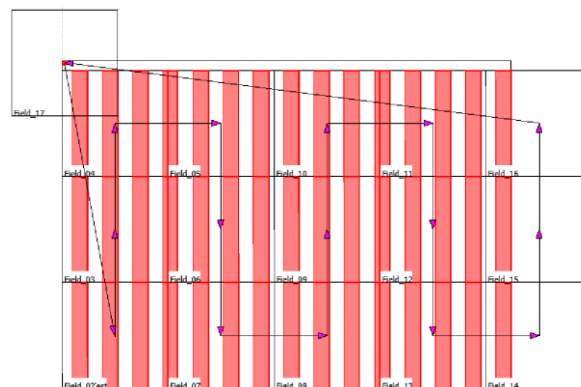*Figure 11. BEAMER flow to obtain an exposure file for a pattern used in drift tool testing.*

Figure 12. Final exposure file showing with arrows the writing path.

Following this process, the red box is exposed first. The pattern of interest is exposed second, and the yellow box is exposed last (see Fig. 12).

FIELDS MODULE

The *Fields* module (see Fig. 13) is a tool that prepares specific regions, layers, or cells of a layout without the need for an *Export* module. This module has the advantage of keeping the modifications within BEAMER allowing further corrections without exporting and re-importing the data.
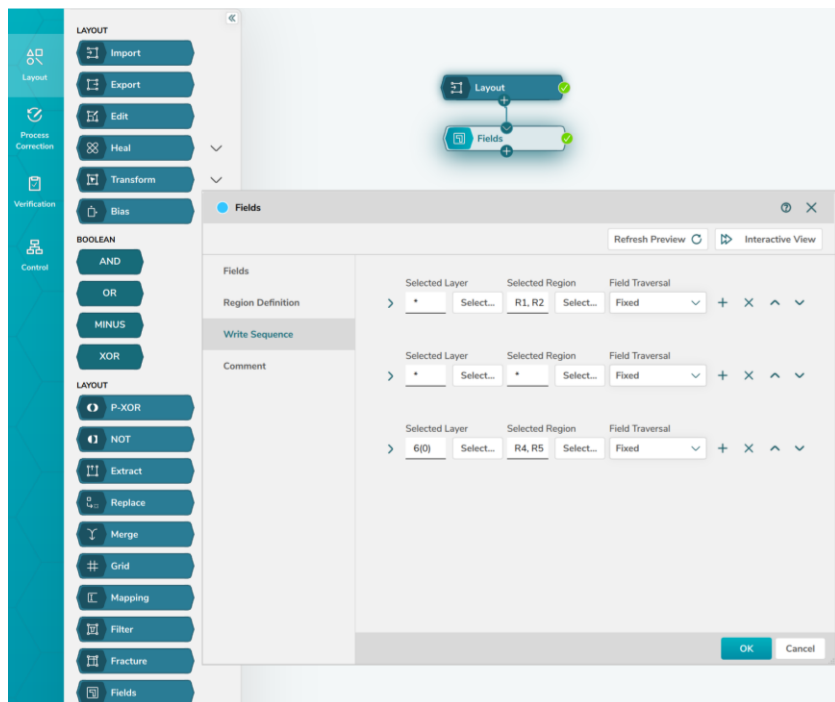

Figure 13. Fields module located in the Layout tab in BEAMER and settings showing the Write Sequence options.

The flow and the use of the *Fields* module is described briefly for two different waveguides, followed by two examples explained in detail.

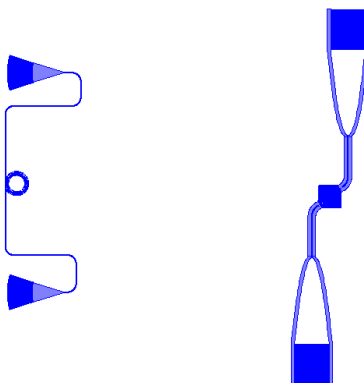Initially, the layout is imported into BEAMER (see Fig. 14).

Figure 14. Waveguides imported into BEAMER.

Afterwards, define the *Region Of Interest* (ROI) and the field sorting for each of them (see Fig. 15).
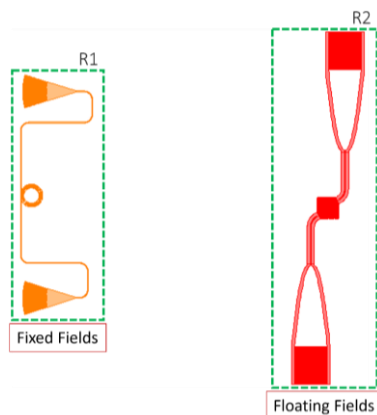

*Figure 15. Region Of Interest (ROI) defined by the
green rectangles and setting of the field sorting.*

Finally, the ROIs are processed and combined into a single output layout (see Fig. 16).
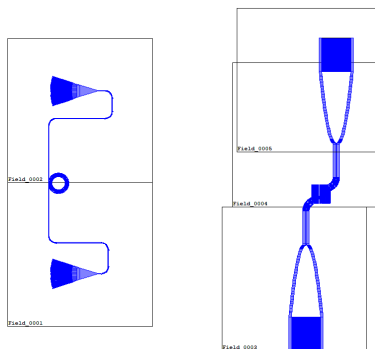

*Figure 16. Exposure file using the correspondent field sorting
for every ROI. Fixed (left) and Floating (right) sorting.*

1. CMOS FIELD ORDERING

A single layout can be composed of a wide variety of geometries with different grades of importance. Accordingly, controlling the writing order is paramount to optimising a device. An example of this is shown in Fig. 17. The layout called CMOS, is a sensor where the critical regions need to be patterned first (green), the rest of the sensor second (yellow) and the markers last (red).
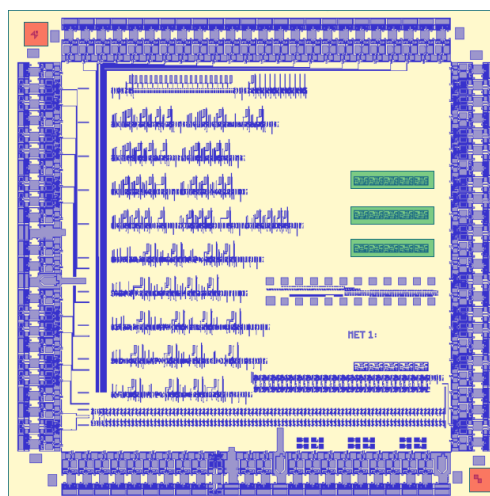

*Figure 17. Layout of a CMOS sensor. Critical regions
(green), general (yellow) and markers (red).*

Within the *Fields* module, and similarly to the *Extract* module, the mentioned regions are defined in the *Region Definition* tab (see Fig. 18)
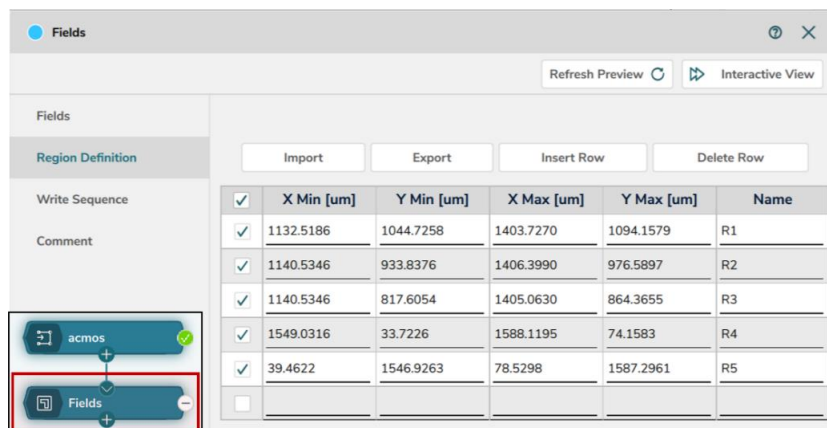

Figure 18. Flow with the Fields module connected to the CMOS layout. The regions are defined in the Region Definition tab within the Field module.

Later, in the *Write Sequence* tab, the region-specific settings are indicated (see Fig. 19). In the *Selected Region* box (green), the critical regions are chosen (R1, R2 and R3). In the *Field Transversal* box (blue), it is possible to choose among the *Fixed*, *Floating*, and *Fields Follow Geometry* options. Finally, the keys (purple) for adding or removing enable more regions to modify or to remove, respectively, while the moving upwards and moving downwards arrows allow to decide a patterning sequence. As is shown in Fig. 19, critical regions (R1 – R3) are patterned first, then the rest of the sensor, and finally the markers (R4 and R5).
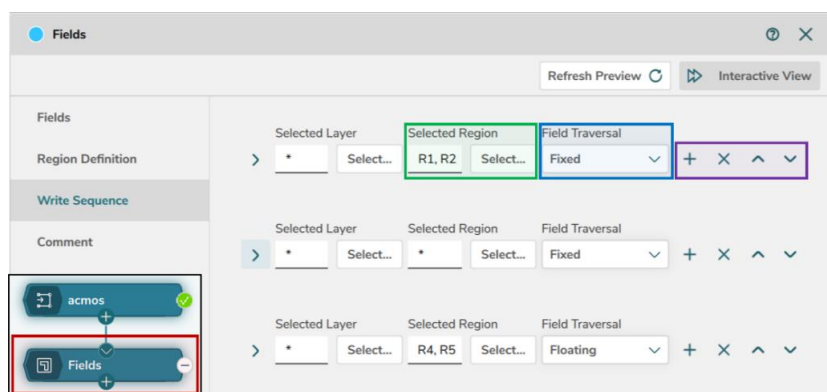

Figure 19. Write Sequence tab within Fields module. Selected Region enables choosing the ROI (green), Field Transversal allows choosing among Fixed, Floating and Fields Follow Geometry (blue) and keys to add, remove or select sequence (purple).

Importantly, in the second *Selected Region* the '*' stands for 'all the remaining regions' which are not explicitly defined individually.

Finally, the data is exported to any tool specific format setting the *Field Order* to *Cell To Field*, which preserves the control instructions from the *Fields* module (see Fig. 20).
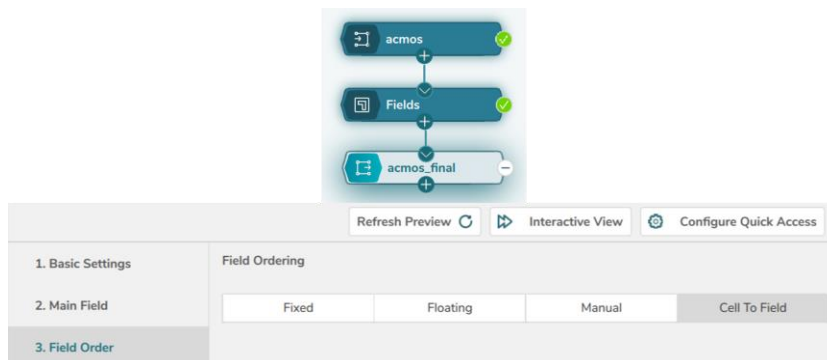

Figure 20. Export module attached to the Fields module (top) and Field Order set to 'Cell To Field' to preserve Fields module configuration (bottom).

2. DRIFTING TEST – FIELDS MODULE

For the layout shown in Fig. 10, the *Fields* module is set to obtain the same result as using multiple *Export* modules. Here, the three regions are differentiated by their layer name; therefore, the fields ordering are set according to the layer name. Figure 21 exhibits the *Write Sequence* tab where each layer has

Figure 21. Write Sequence set in the Fields module for the layout in Fig. 10. Layers name is used to define the Field Transversal condition.

Floating or *Fixed* field sorting. Moreover, the sequence is established as such that layer 1(0) is patterned first (red box in Fig. 10) and layer 3(0) is patterned last (yellow box in Fig. 10).
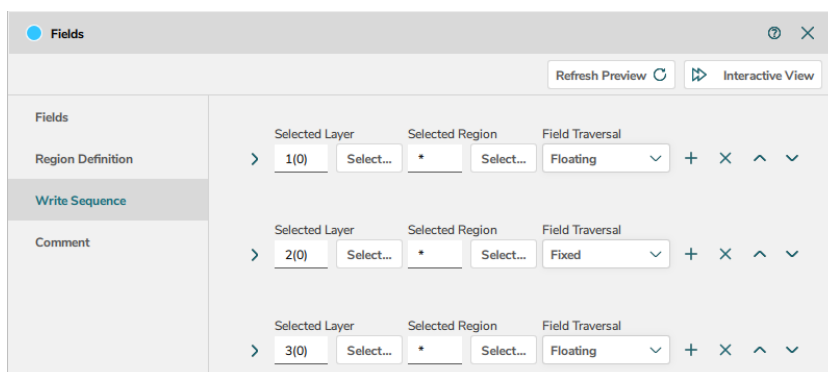
Comparatively, Fig. 22 shows the difference when using a flow with multiple *Export* modules (left) against a flow applying the *Fields* module capabilities (right).
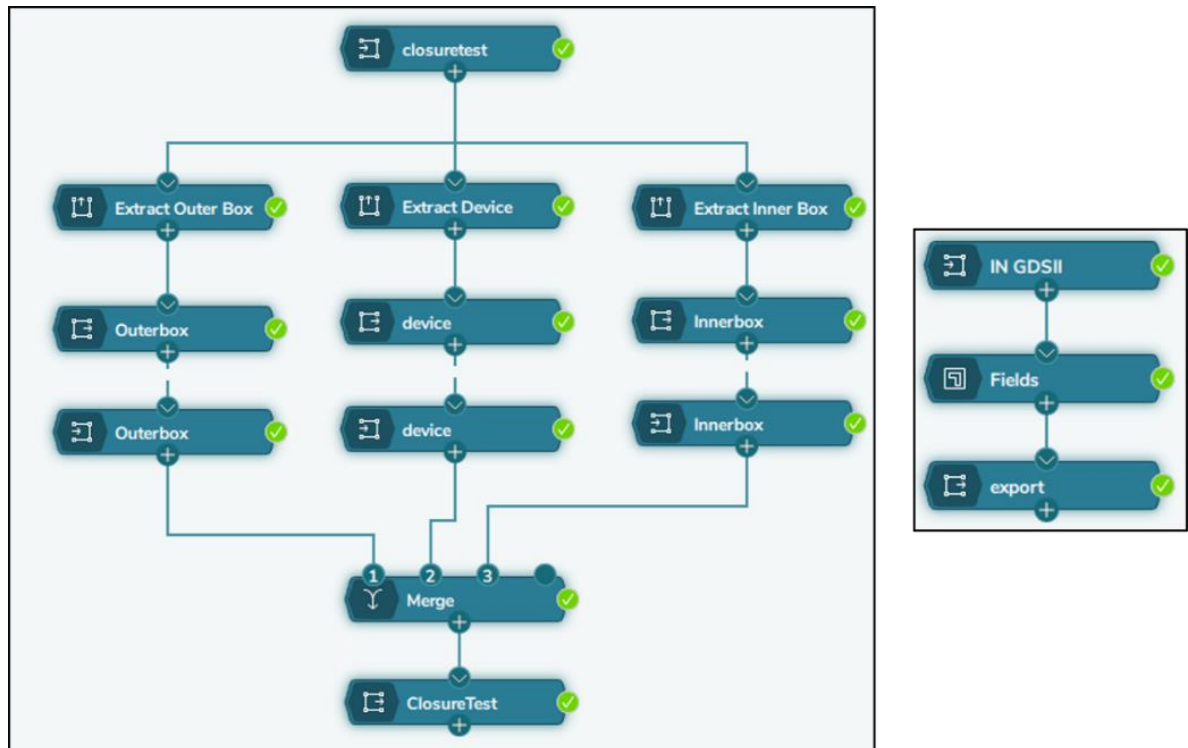
Figure 22. Flow using Multiple Export Modules to set the Field ordering to three different regions (left) and flow using the Fields module to set identical conditions to the same three regions (right).

SUMMARY

- Using BEAMER, it is possible to create a single exposure file that uses multiple field control enabling other export options.
- The *Cell To Field* option in the final *Export* module preserves different writing strategies.
- This general technique can be used for challenging layouts that require mixing overlapping fields and floating fields, multi- pass and floating, feature writing orders, and many more.
- The *Multiple Export Modules* and *Fields Module* methods result in the same exposure file; however, the *Fields* module is often faster.

Appendix A

The *Extract* module allows to select areas of interest by selecting the *Extraction Type* according to the entire layout, cell instances, cell definition and by regions.
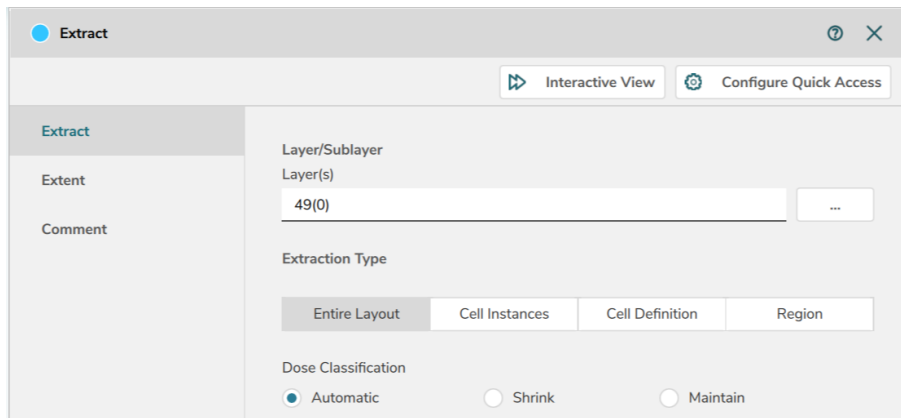

Fig. A1

When the layout is defined by layers, selecting the *Entire Layout* option plus the layer of interest is sufficient.
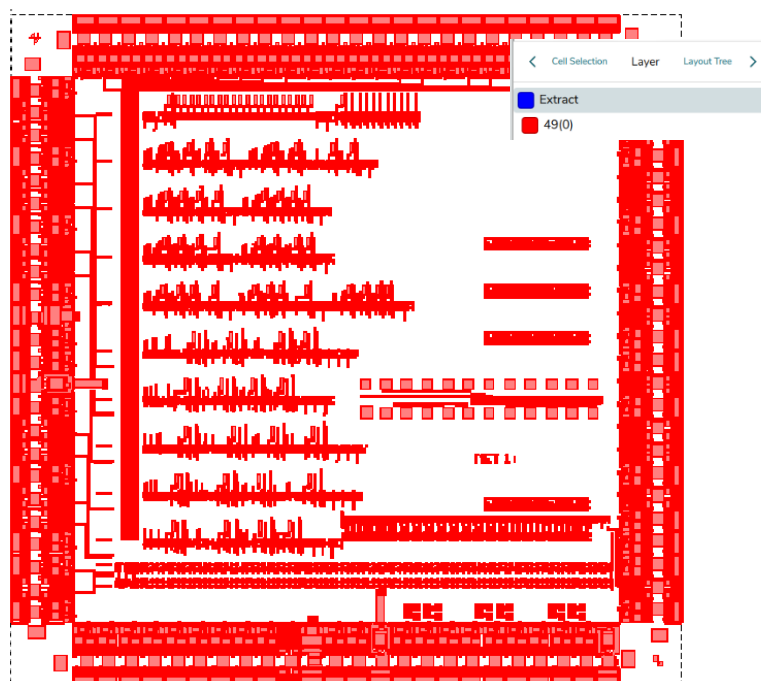

Fig. A2

Alternatively, if the layout is compound by cells, the corresponding name is choosen by pressing the 3-dots button (works for both: *Cell Instances* and *Cell Definition*).
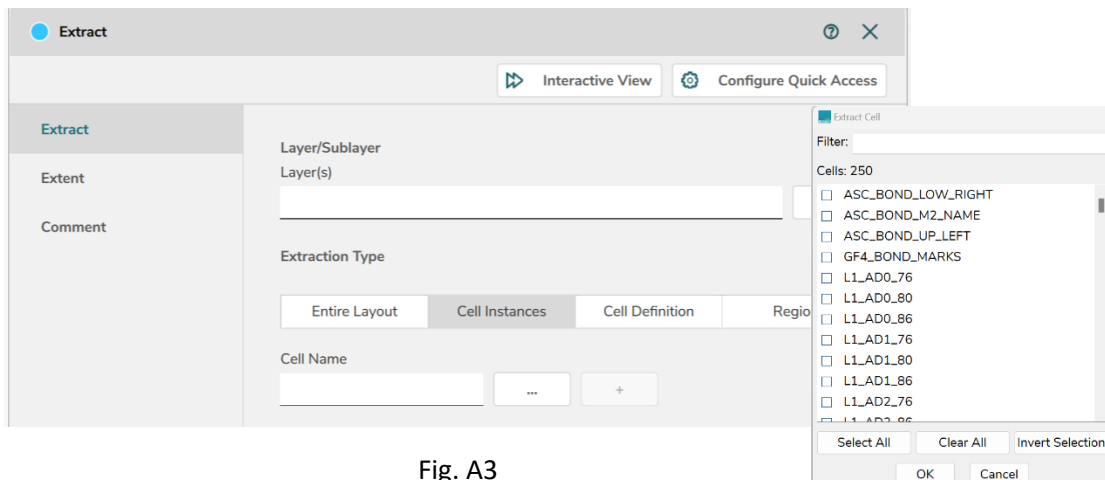
Fig. A3

Finally, the *Region*-type allows you to manually draw a bounding box to the area of interest. To create a bounding box, press the key *Shift* plus left-mouse click. Drag the mouse to cover the area to extract and left click again.
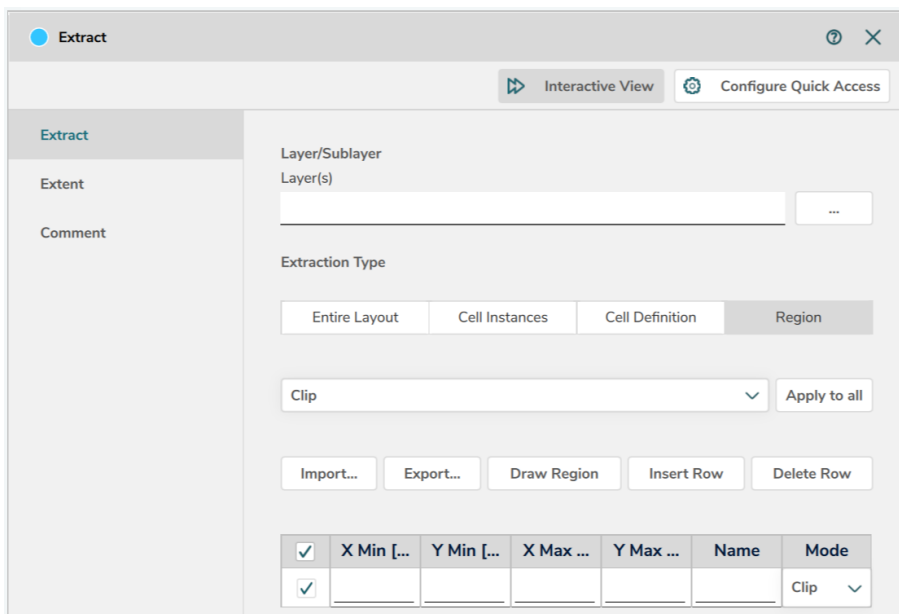

Fig. A4

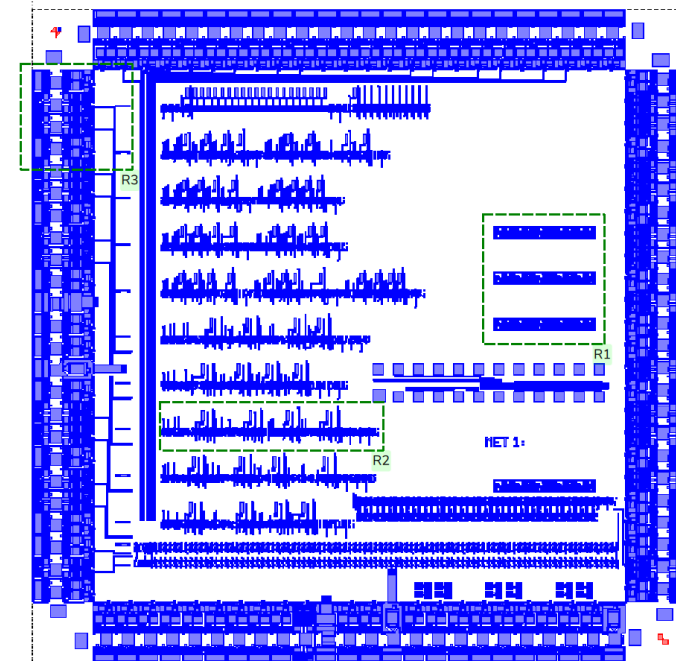This process leads to a green box labelled with *R#* where '#' increases depending on the number of boxes created.

Fig. A5