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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 is 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.

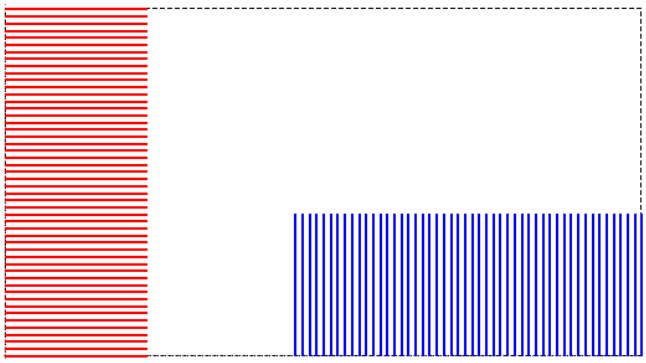
Multiple options for fracturing, sorting or field control within a single exposure file leads to optimal results for complex layouts. In this document we show examples for mixed exposure strategies for different layouts. This technique can be accomplished with two methods: (1) using multiple export modules 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

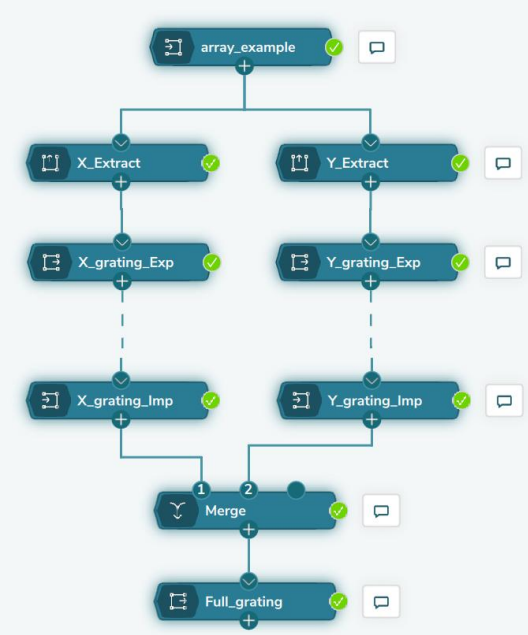
The *Export* module integrated into **BEAMER** gives various options to control lithography-tools writing throughput. Here, we explore 3 layouts that benefit from the multiple export features.

Combining Raster x & Raster Y Field Sorting

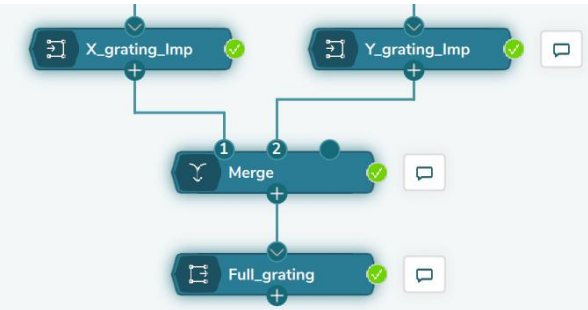
Below are two gratings, one x-oriented (red) and one y-oriented (blue). In this layout, each grating can be exposed to follow the grating trend minimizing distortion at the field edges.



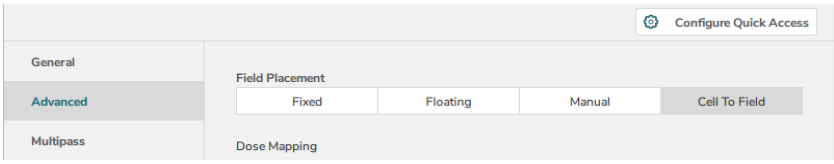
A flow that works to achieve the mentioned tool criteria is shown below. The layout is imported into **BEAMER**. Then, the *Extract* module is used to select either layer 1(0) or 2(0) as the layer of interest (to explore other options in the *Extract* module go to Appendix A). Afterwards, the *Export*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



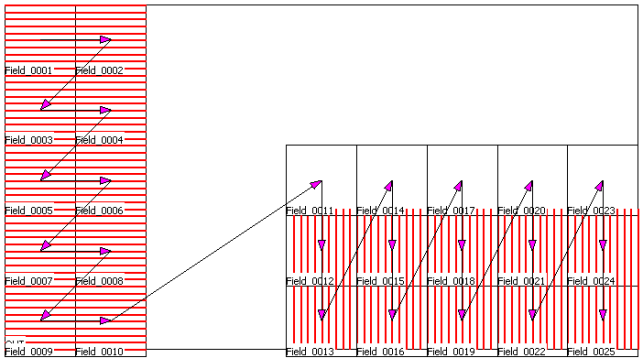
For this, in the *Advanced* tab, the *Fixed Field Transversal Type* is set to *Raster X* (for red)/*Raster Y* (for blue) according to the layout to modify. Once the gratings are exported separately, they are re-imported and merged.



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*.

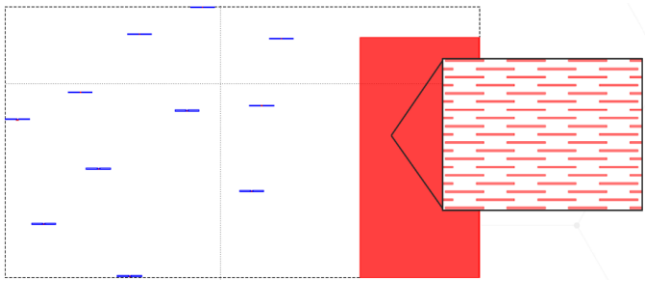


The exported file results in a layout that is exposed following the two selected writing orders. Accordingly, the *Raster X* and *Raster Y* methods are patterned in a single exposure file as shown below.

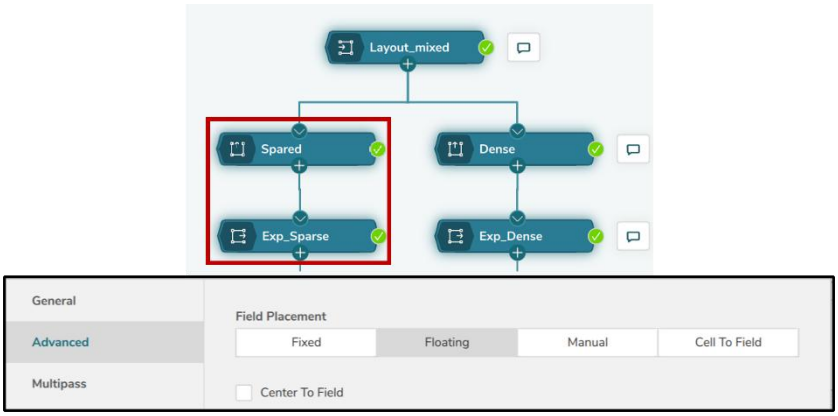


Combining Floating and Overlapping Fields

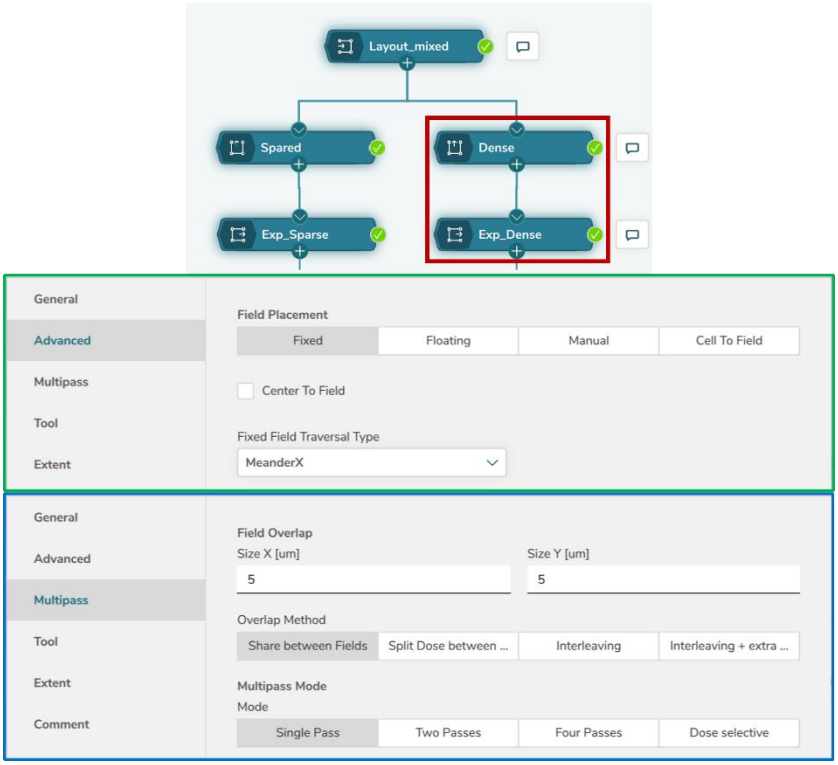
Below is a layout that includes scattered data (blue) and dense region data (red). In this layout, the region with sparse data is optimised centring the writing fields in every feature. Alternatively, in the dense region, the fields need to overlap to avoid stitching.



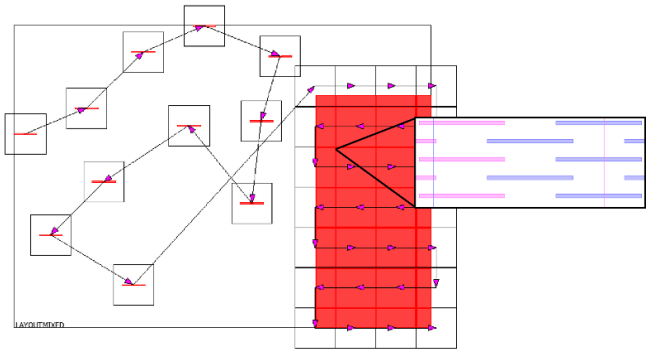
Similarly, to the previous example, the *Extract* module is used to individually take each region and modify it separately (see Appendix A for details on the *Extract* module). Once the sparse and dense regions are separated, the *Export* module is used to apply the respective field control options. The image below 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.



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

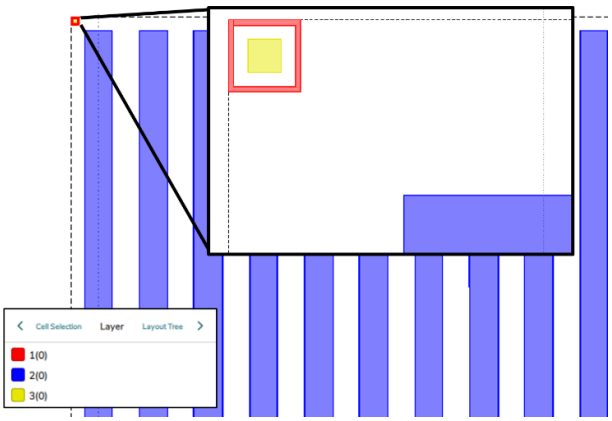


Finally, both files are re-imported, merged, and exported once more. As before, the final *Export* module needs to preserve the settings for the separate regions. Therefore, the *Field Placement* is set to *Cell To Field*. The image below shows the corresponding fields sorting for each region.

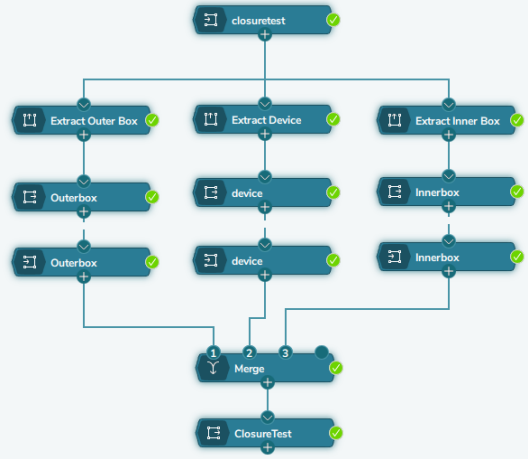


Drifting Test – Multiple Export Modules

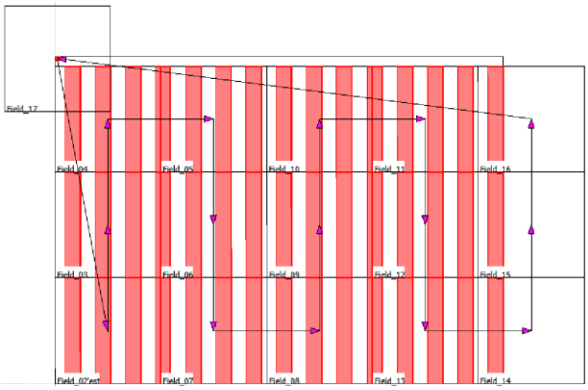
A common design to quantify tool drift, it is a layout that starts and finishes patterning in the same area. Below is a layout showing a blue grating (pattern of interest) and a red with yellow boxes (patterns to track tool drift). To run such a test, the red box is patterned at the beginning, followed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



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.



Following this process, the red box is exposed first. The pattern of interest is exposed second, and the yellow box is exposed last as shown below.

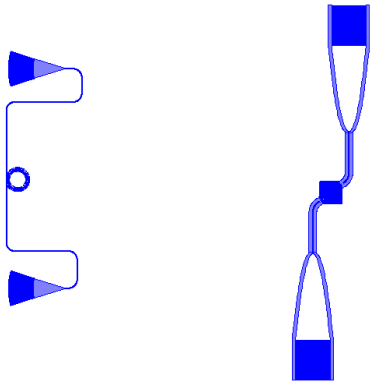


Fields Module

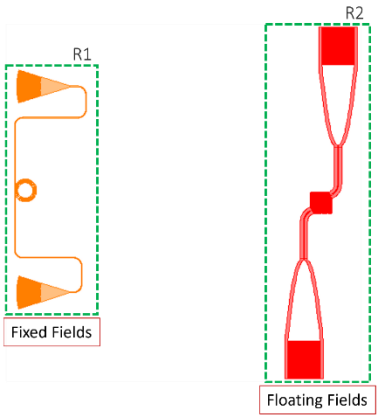
The *Fields* module is a tool that prepares specific regions, layers, or cells of a layout without the need for an *Export* module. This module has the advantage of keeping the modifications within **BEAMER** allowing further corrections without exporting and re-importing the data.

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

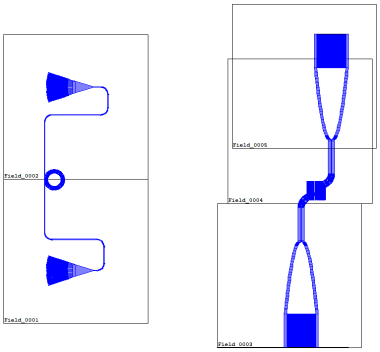
Initially, the layout (waveguides) is imported into **BEAMER**.



Afterwards, define the *Regions of Interest* (ROIs) using green rectangles and specify the field sorting for each of them.

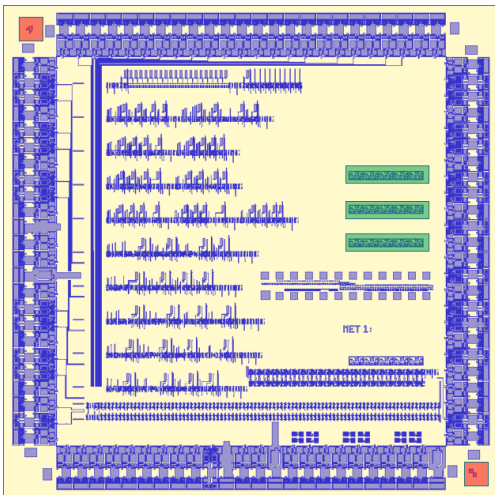


Finally, the ROIs are processed using Fixed (left) and Floating (right) field sorting and combined into a single output layout, as shown below.

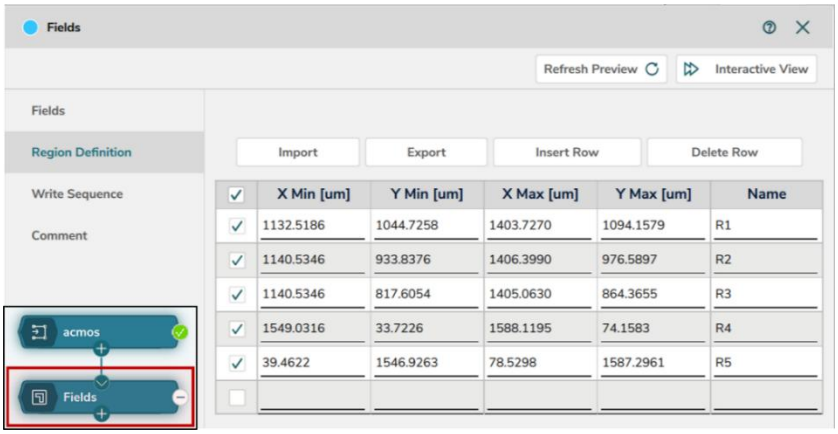


CMOS Field Ordering

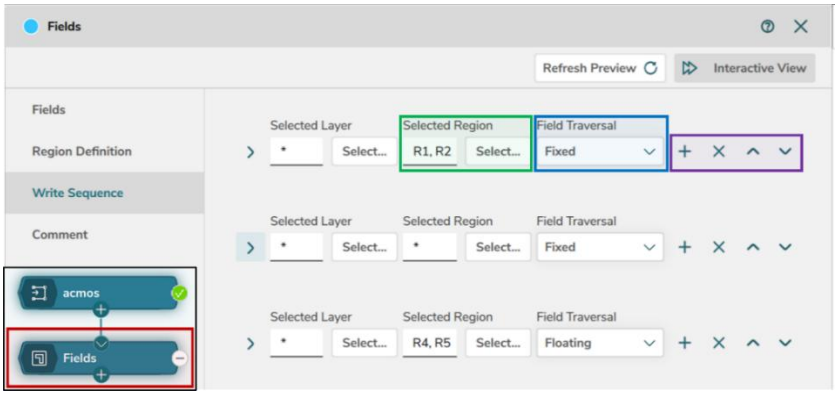
A single layout can be composed of a wide variety of geometries with different grades of importance. Accordingly, controlling the writing order is paramount to optimising a device. An example of this is shown in the image below. The layout called CMOS, is a sensor where the critical regions need to be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



Within the *Fields* module, and similarly to the *Extract* module, the mentioned regions are defined in the *Region Definition* tab.



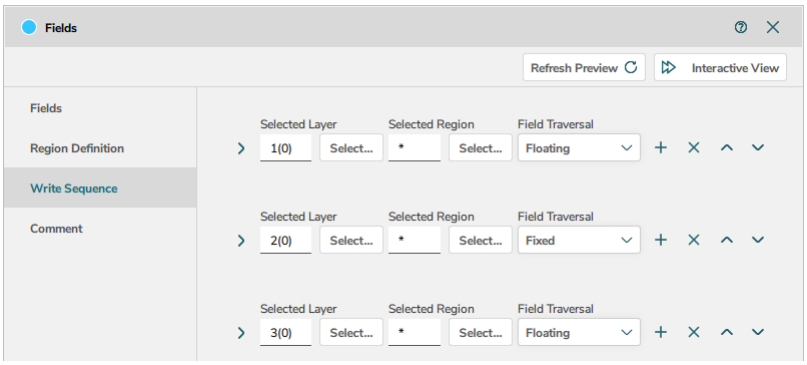
Later, in the *Write Sequence* tab, the region-specific settings are indicated as shown below. In the *Selected Region* box (green), the critical regions are chosen (R1, R2 and R3). In the *Field Transversal* box (blue), it is possible to choose among the *Fixed*, *Floating*, and *Fields Follow Geometry* 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 shown below, critical regions (R1 – R3) are patterned first, then the rest of the sensor, and finally the markers (R4 and R5).

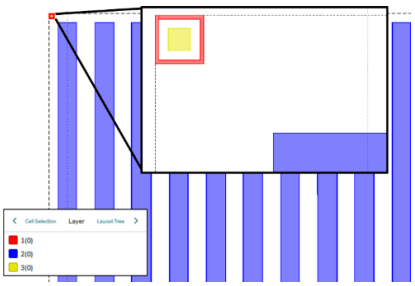


Importantly, in the second *Selected Region* the '*' stands for 'all the remaining regions' which are not explicitly defined individually. Finally, the data is exported to any tool-specific format setting the *Field Order* to *Cell To Field*, which preserves the control instructions from the *Fields* module as shown below.

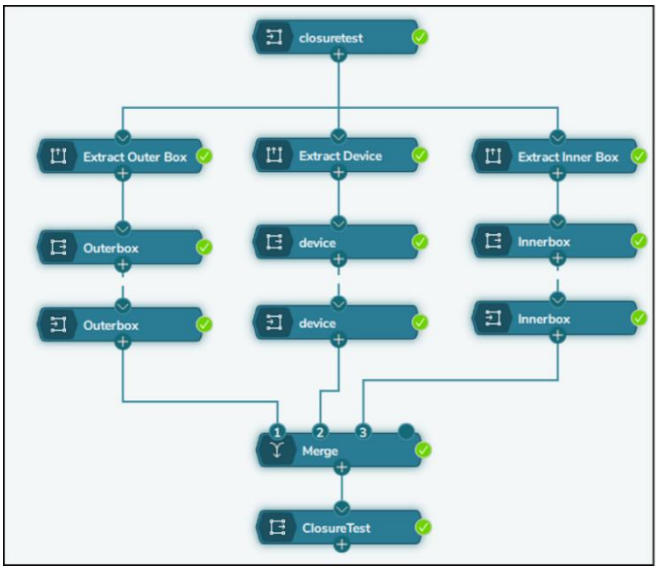
Drifting Test – Fields Module

For the previous drifting-test layout (shown again on the right below), the *Fields* module is configured to produce the same result as using multiple *Export* modules. Here, the three regions are differentiated by their layer name; therefore, the fields ordering is set according to the layer name. Below is the *Write Sequence* tab settings where each layer has *Floating* or *Fixed* field sorting. Moreover, the sequence is established as such that layer 1(0) is patterned first (red box in the layout) and layer 3(0) is patterned last (yellow box in in the layout).





Comparatively, the image below shows the difference when using a flow with multiple *Export* modules (left) against a flow applying the *Fields* module capabilities (right).

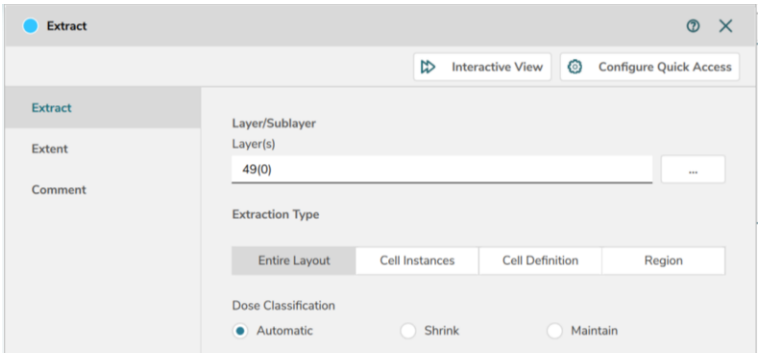


Summary

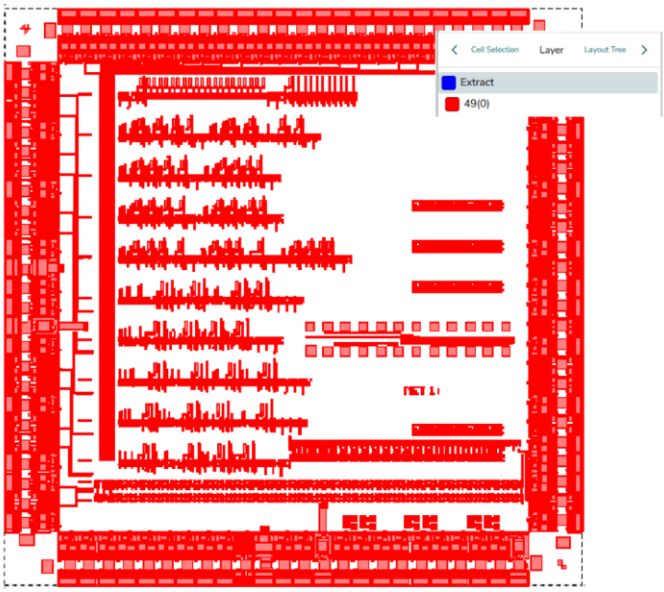
- Using **BEAMER**, it is possible to create a single exposure file that uses multiple field control enabling other export options.
- The *Cell To Field* option in the final *Export* module preserves different writing strategies.
- This general technique can be used for challenging layouts that require 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

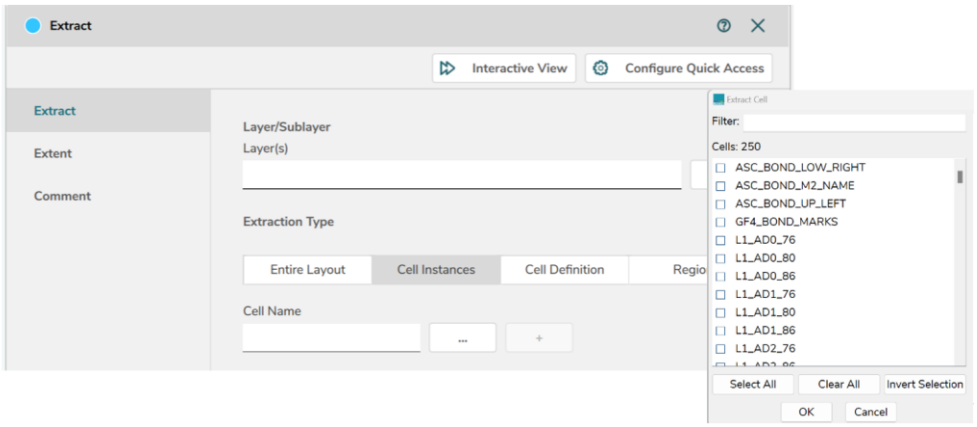
The *Extract* module allows to select areas of interest by selecting the *Extraction Type* according to the entire layout, cell instances, cell definition and by regions.



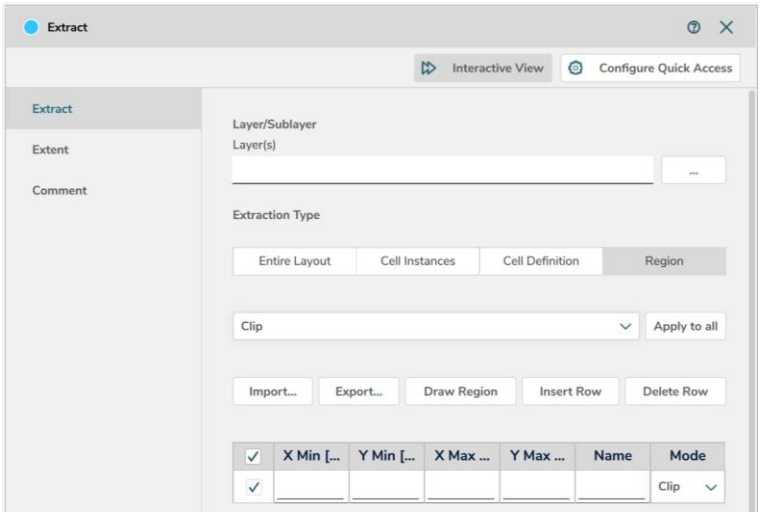
When the layout is defined by layers, selecting the *Entire Layout* option plus the layer of interest is sufficient.



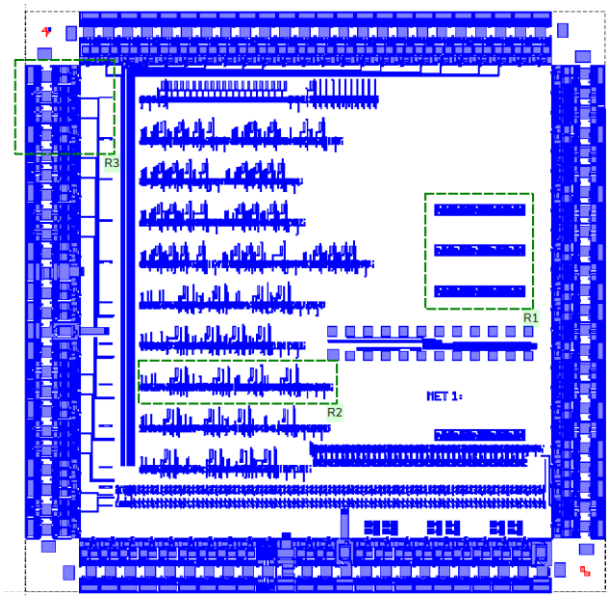
Alternatively, if the layout is compound by cells, the corresponding name is choosen by pressing the 3-dots button (works for both: *Cell Instances* and *Cell Definition*).



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.



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


R3
R1
R2
MET 1: