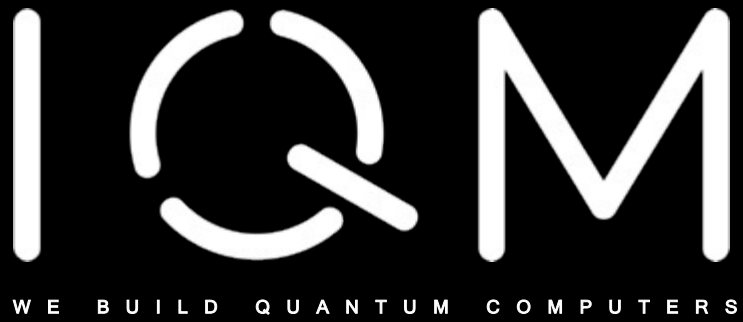
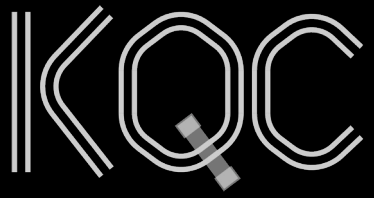
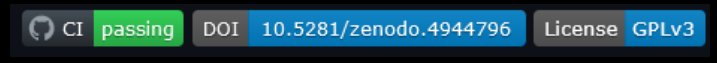


Winter School

Superconducting quantum processor design with KQCircuits®



github.com/iqm-finland/KQCircuits



Schedule

Monday	Tuesday	Wednesday	Thursday	Friday
Caspar & Pavel	Alessandro	Alessandro	Niko & Eelis	Caspar
Introduction to QPU design Installing KQCircuits First look around	Introduction to designing Create a custom qubit element	Design a custom chip	Finite element simulations	Mask export Composite waveguides GUI

Mask export

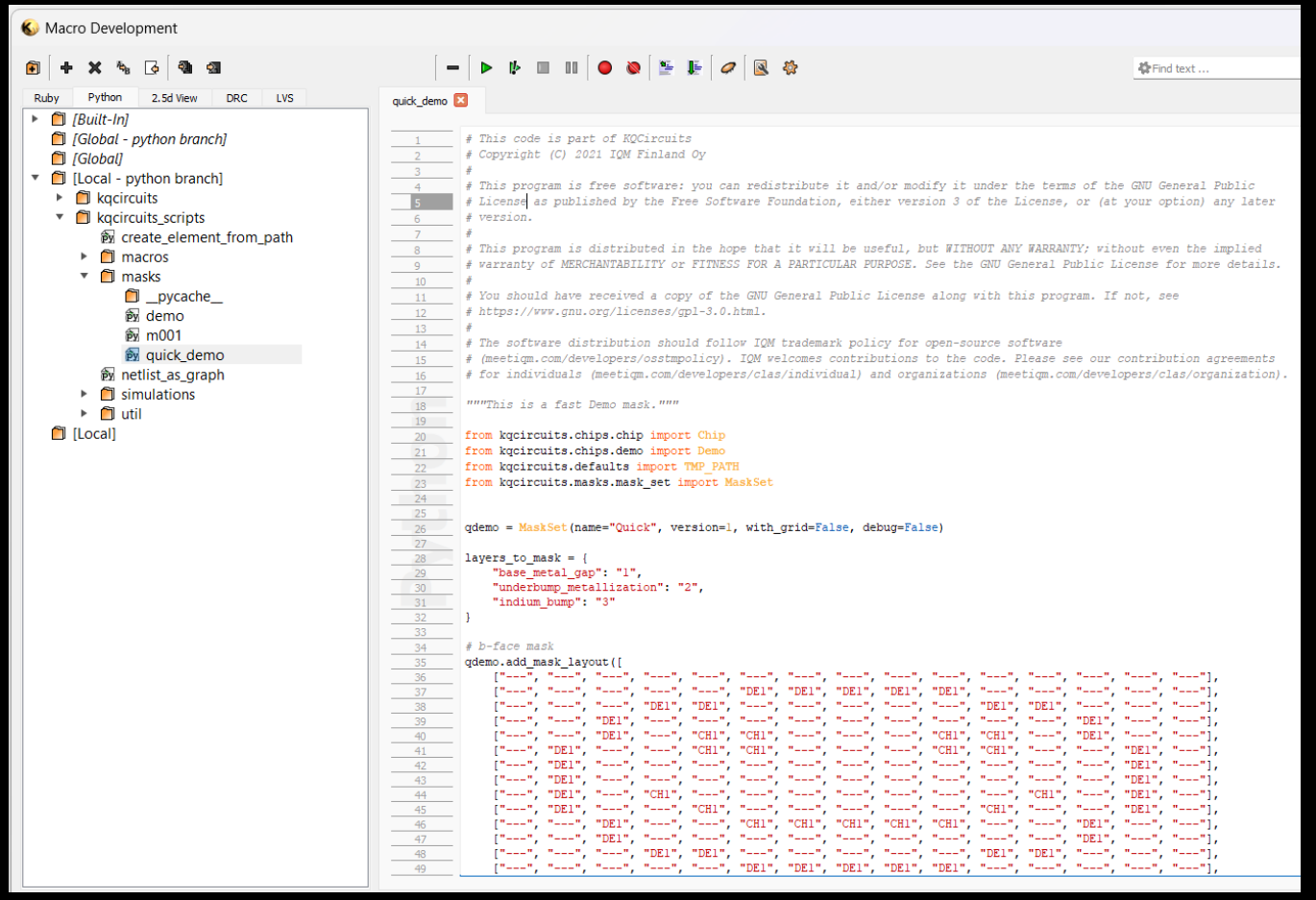
Purpose of KQCircuits mask export:

- Merge metallization layers
  - Turn `base_metal_gap_wo_grid`, `ground_grid` and `base_metal_added` into `base_metal_gap`
- Generate masks for wafer-scale lithography
  - Adds alignment markers
  - Configurable which layers are exported to a mask
  - Optionally invert layer polarity
- Export individual chips and related files

Mask export

In the KLayout Macro editor (F5):

- Open kqcircuits_scripts/masks/quick_demo.py
- Run with 
- Files are exported to KQCircuits/tmp folder



Mask export script

Create a `MaskSet` with the name, version, and optional ground grid setting

```
qdemo = MaskSet(name="Quick", version=1, with_grid=False, debug=False)
```

Define the chip map to place different chips or variants – give each variant a three-letter code

```
qdemo.add_mask_layout([
    ["---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---"],
    ["---", "---", "---", "---", "---", "DE1", "DE1", "DE1", "DE1", "DE1", "---", "---", "---", "---", "---"],
    ["---", "---", "---", "DE1", "DE1", "---", "---", "---", "---", "---", "DE1", "DE1", "---", "---", "---"],
    ["---", "---", "DE1", "---", "---", "---", "---", "---", "---", "---", "---", "---", "DE1", "---", "---"],
    ["---", "---", "DE1", "---", "CH1", "CH1", "---", "---", "---", "CH1", "CH1", "---", "DE1", "---", "---"],
    ["---", "DE1", "---", "---", "CH1", "CH1", "---", "---", "---", "CH1", "CH1", "---", "---", "DE1", "---"],
    ["---", "DE1", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "DE1", "---"],
    ["---", "DE1", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "DE1", "---"],
    ["---", "DE1", "---", "CH1", "---", "---", "---", "---", "---", "---", "---", "CH1", "---", "DE1", "---"],
    ["---", "DE1", "---", "---", "CH1", "---", "---", "---", "---", "---", "CH1", "---", "---", "DE1", "---"],
    ["---", "---", "DE1", "---", "---", "CH1", "CH1", "CH1", "CH1", "CH1", "---", "---", "DE1", "---", "---"],
    ["---", "---", "DE1", "---", "---", "---", "---", "---", "---", "---", "---", "---", "DE1", "---", "---"],
    ["---", "---", "---", "DE1", "DE1", "---", "---", "---", "---", "---", "DE1", "DE1", "---", "---", "---"],
    ["---", "---", "---", "---", "---", "DE1", "DE1", "DE1", "DE1", "DE1", "---", "---", "---", "---", "---"],
    ["---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---", "---"],
], "ltl", layers_to_mask=layers_to_mask)
```

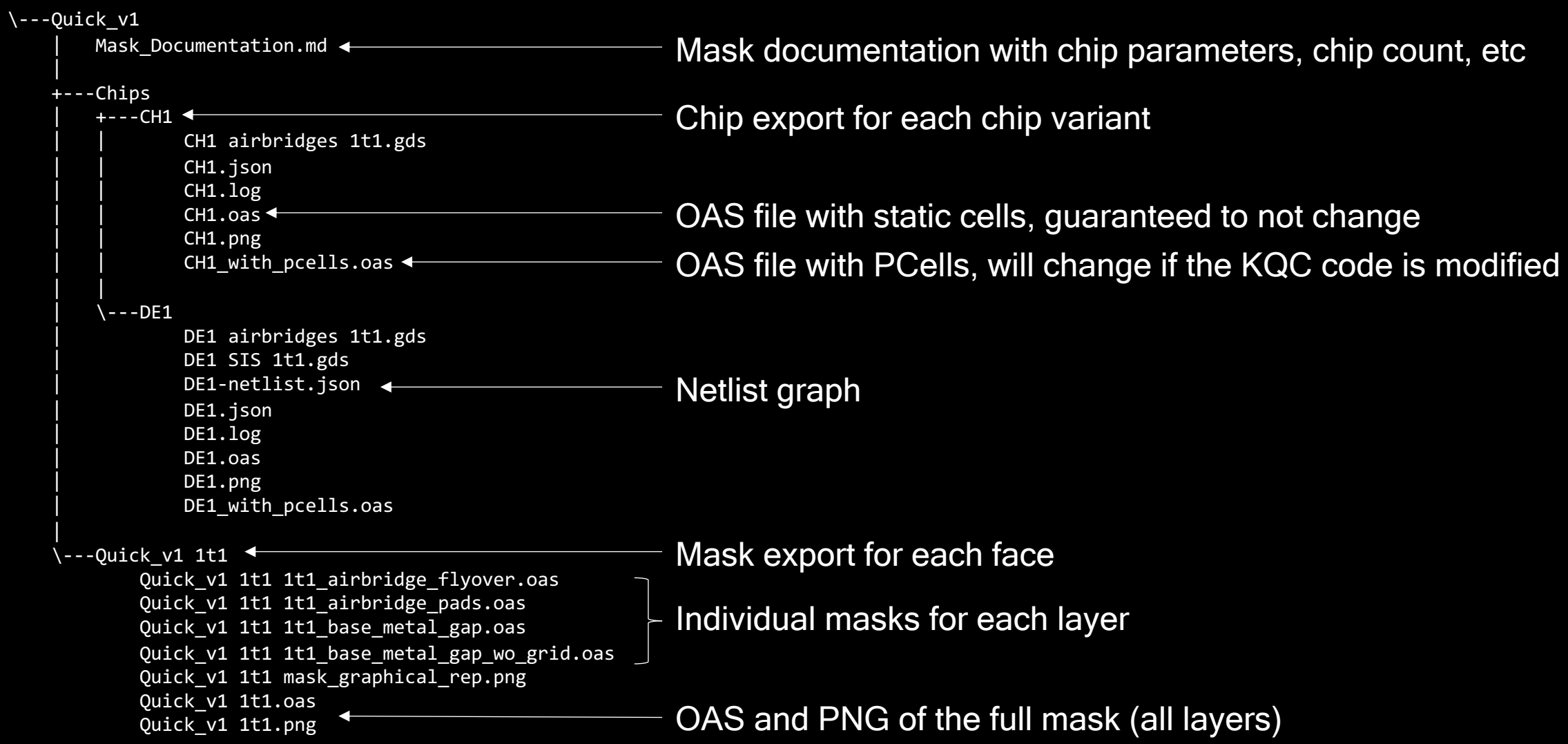
Add chip variants –specify the chip class and parameters

```
qdemo.add_chips([
    (Chip, "CH1"),
    (Demo, "DE1", parameter=value, ...),
], threads=2)
```

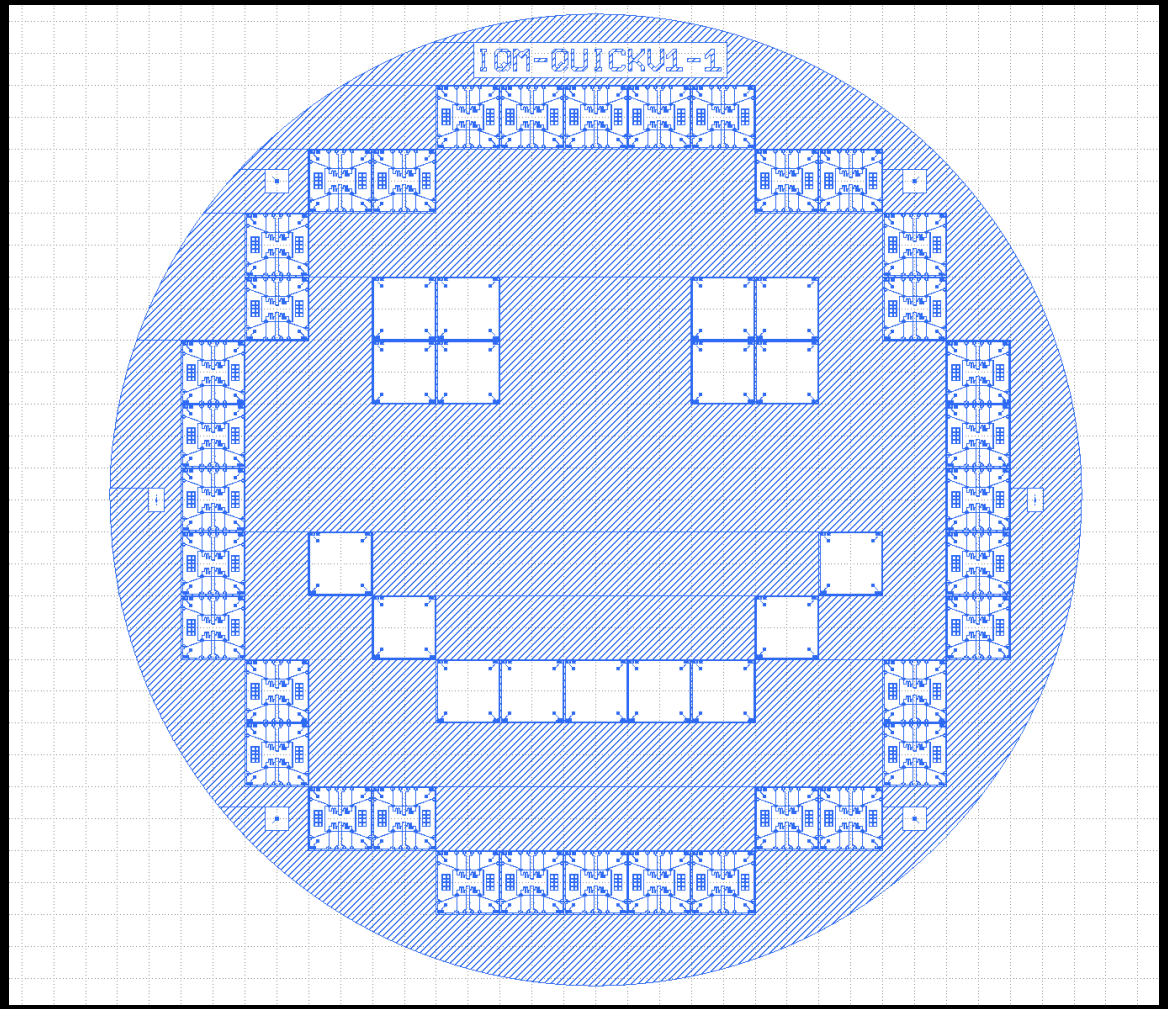
Build and export the mask

```
qdemo.build()
qdemo.export(TMP_PATH)
```

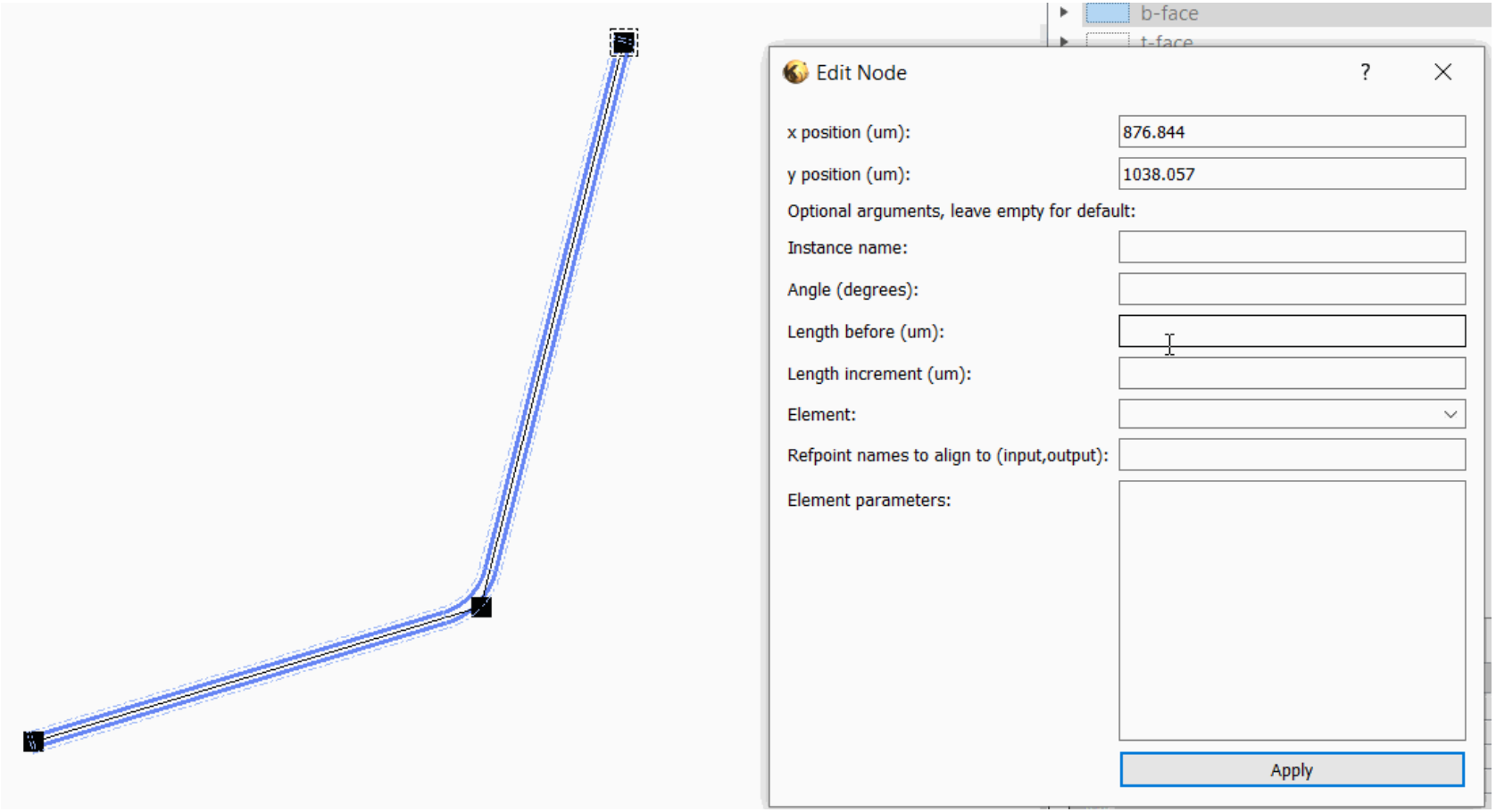
Exported files



Quick_v1 1t1 1t1_base_metal_gap.oas



GUI editing

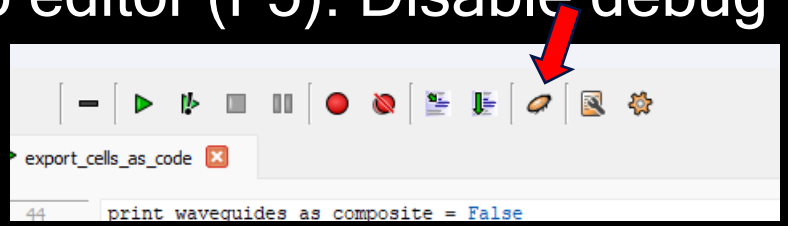

b-face
t-face
Edit Node
x position (um):
876.844
y position (um):
1038.057
Optional arguments, leave empty for default:
Instance name:
Angle (degrees):
Length before (um):
Length increment (um):
Element:
Refpoint names to align to (input,output):
Element parameters:
Apply

Configure KLayout for GUI editing

Under *File* → *Setup* :

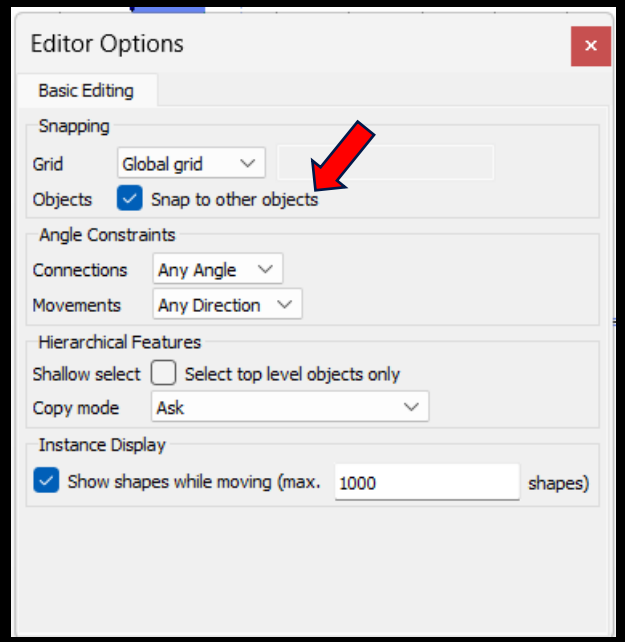
- *Application* → *Default Grids* : Add courser grid values, for example 10 and 100 um
  - While editing, select the grid you like under *View* → *Grid*.
- *Display* → *Cells* : Enable *Show PCell guiding and error shapes*.

Macro editor (F5): Disable debug mode

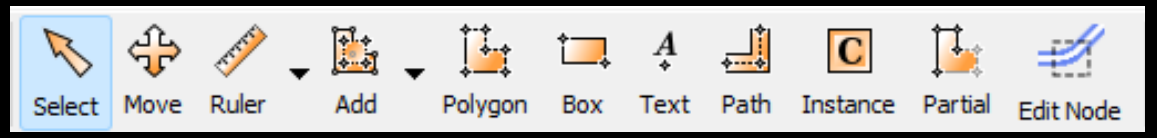


Editor Options (select *Partial* tool, then F3):

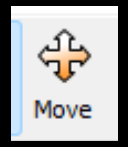
- *Snap to other objects* (optional)



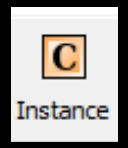
KLayout toolbar



Select: select cells, double click (Q) to change parameters

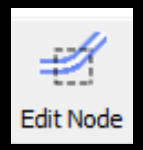


Move: move an entire PCell.



Instance: place a new PCell instance (or just drag from the library)

Partial: edit “guiding shapes”, includes routing waveguides

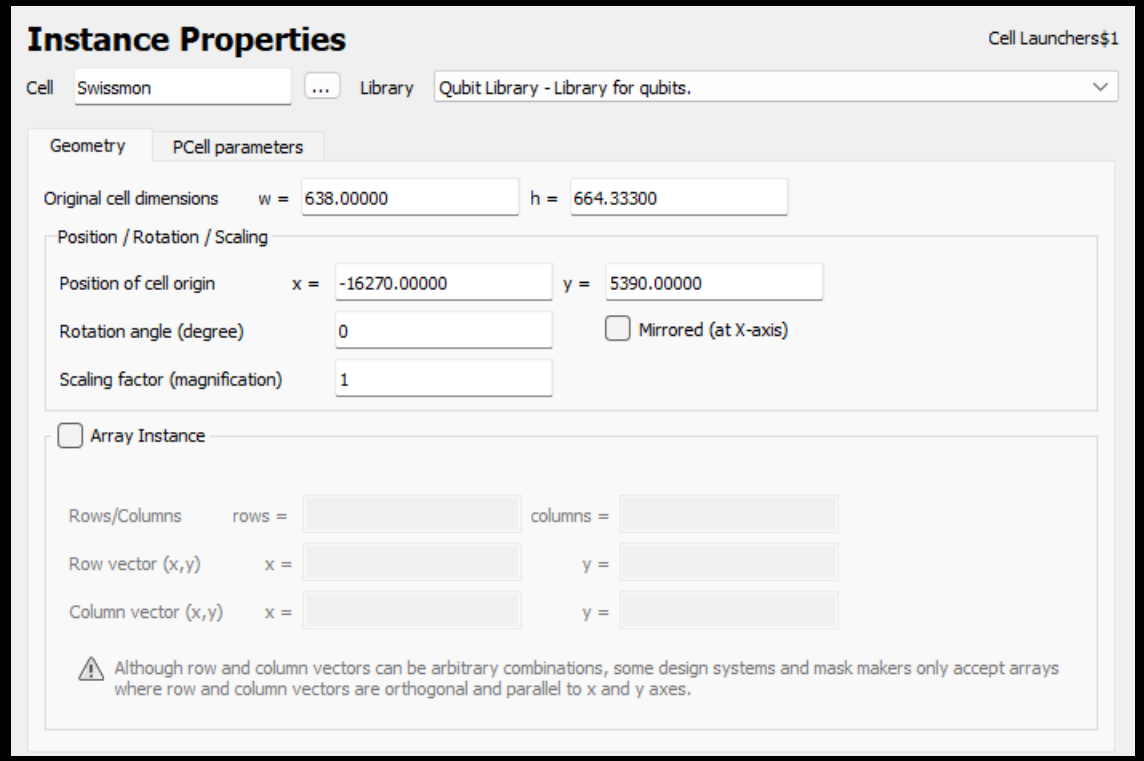


Edit Node: Edit advanced properties of a WaveguideComposite node

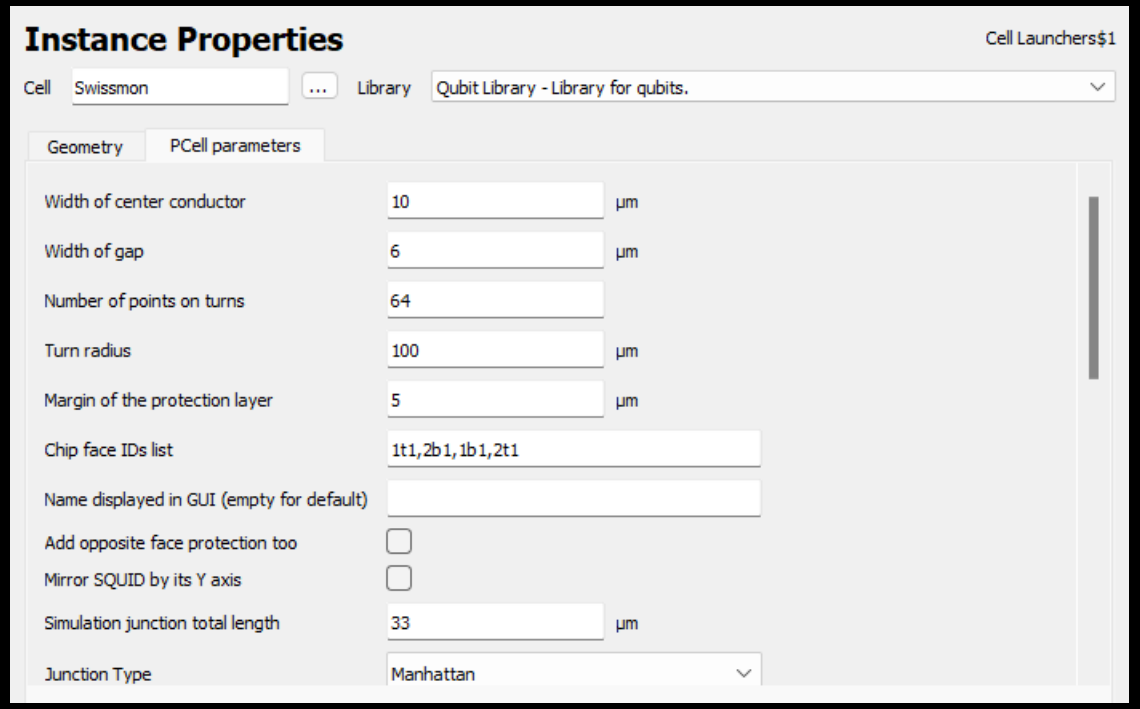
Editing PCell properties

Select cell, double click or press Q

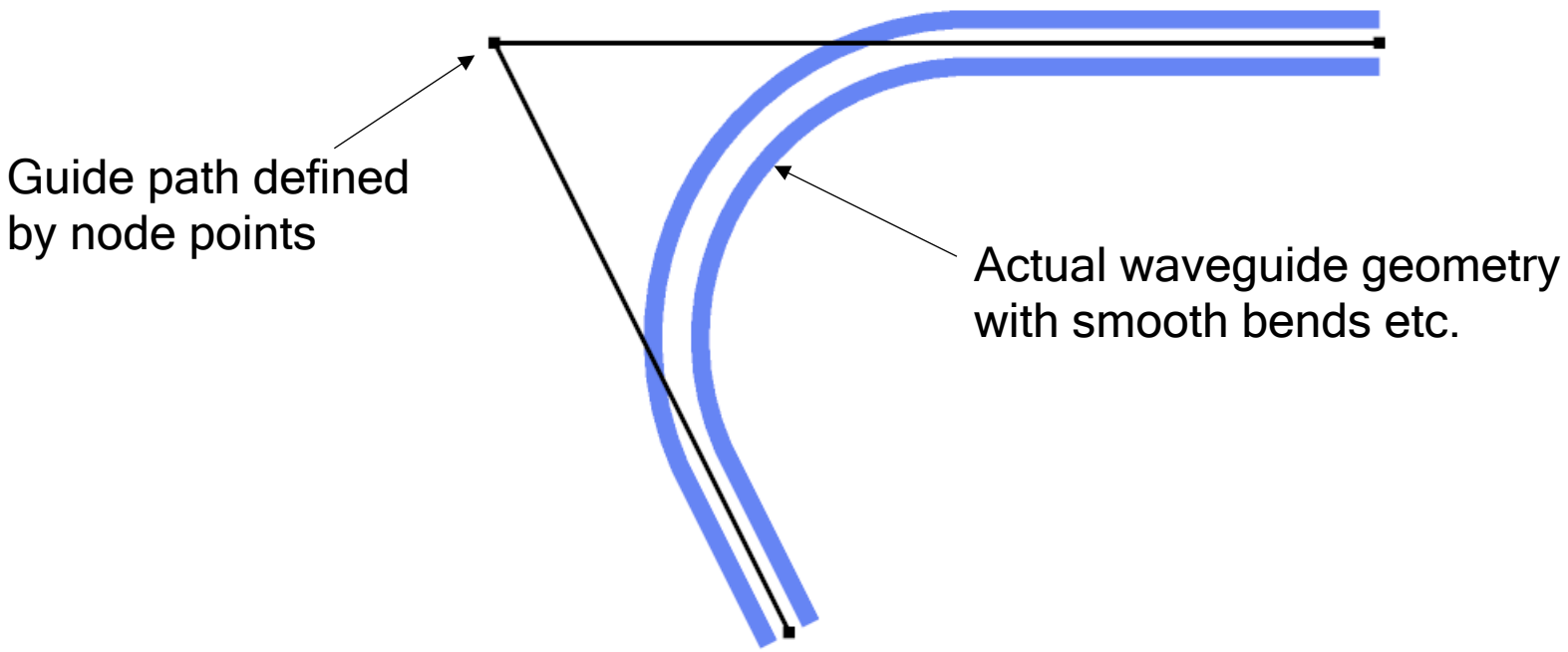
Geometry: position, scale and rotation



PCell parameters

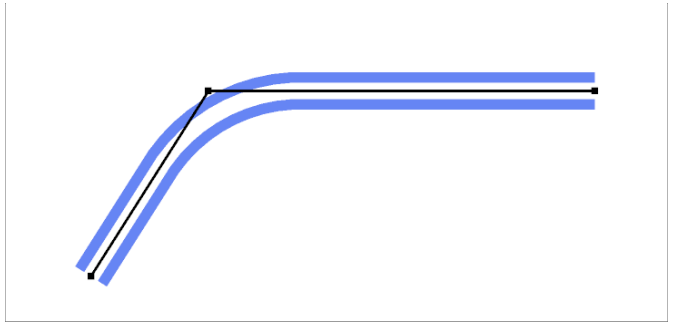


Editing waveguides

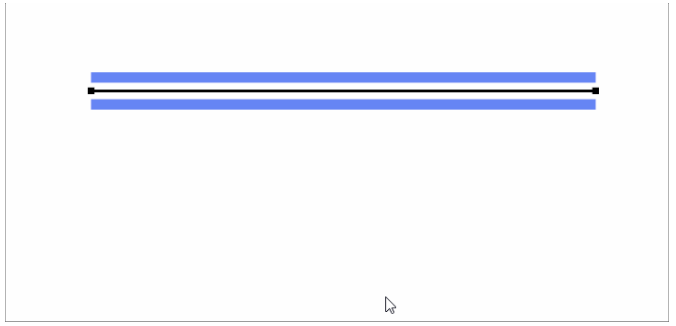


Use the Partial tool to edit the guide path

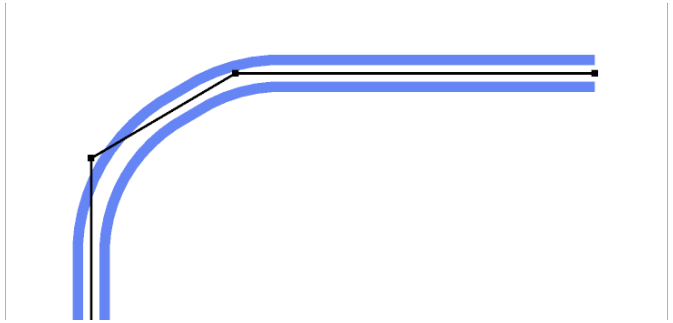
Editing with Partial tool



Click node, move, click
Move a single node

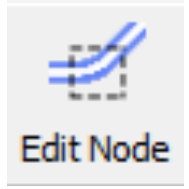


Double click: Add node
Click node, DEL key: Delete node



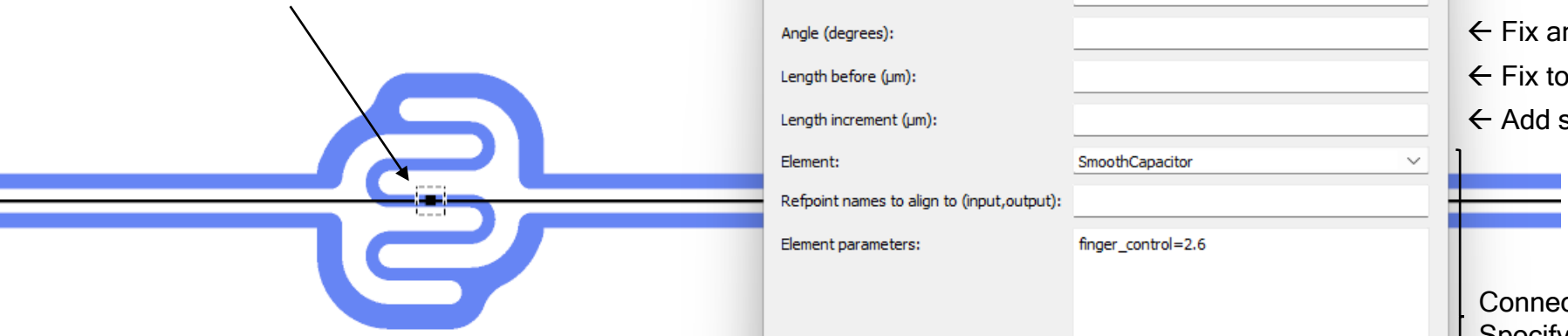
Click edge, move, click
Parallel move

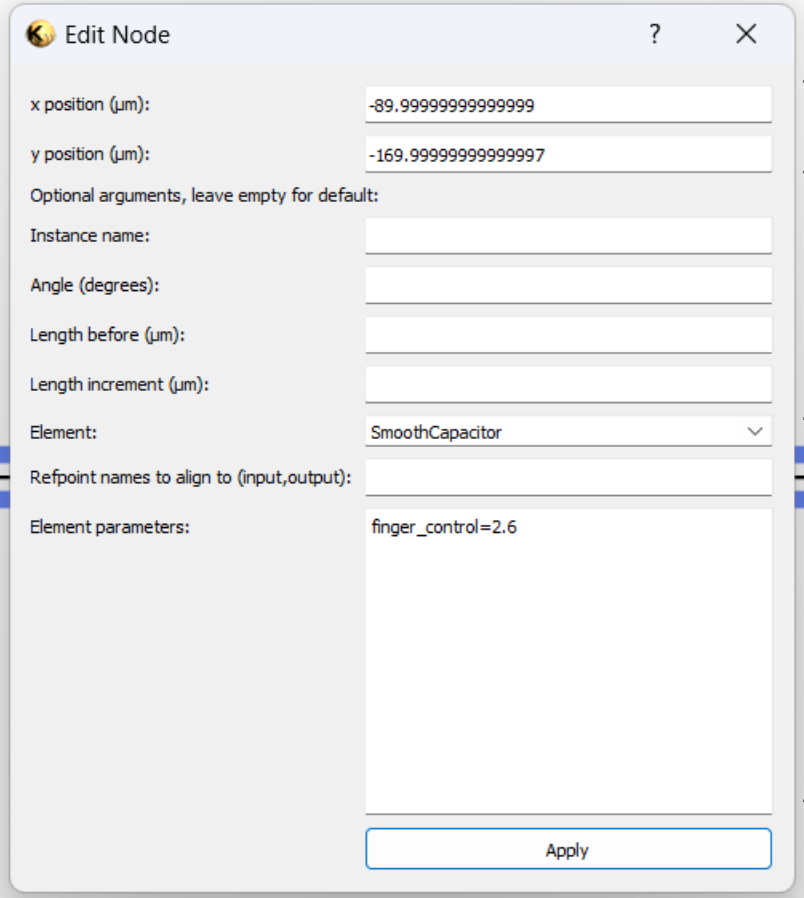
Edit Node tool



Only works on WaveguideComposite elements

Dashed box shows
Selected node





Node position

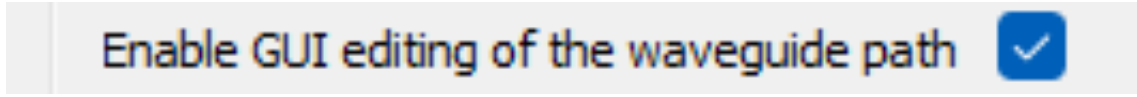
← Fix angle of the waveguide at this node

← Fix total length of segment before this node

← Add some amount of length w.r.t. straight waveguide

Connect inline element,
Specify inline element parameters as key=value pairs

WaveguideComposite parameters



Set to False for “code-only” waveguides to avoid guide path clutter

Defines how corners are made when connecting inline elements or using fixed node angles.

- `False` (default): turning point at one turn radius from the element - maximum corner angle 90 degrees.
- `True`: corners start turning as close to the element as possible – more flexible

GUI Editing with code generation

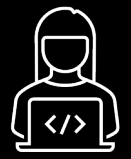
1. Place a chip in the layout
   - Use `Launchers` to start with an empty chip with only launchers
2. Convert the chip to a static cell and show as top
   - Select the cell, then *Edit → Cell → Convert Cell to Static*
   - Right click the cell, choose *Show As New Top*.
3. Edit or place elements
4. Export as code
   - Open the macro editor (F5)
   - Find `kqcircuits_scripts/macros/export/export_cells_as_code`
   - Adjust options (e.g. `output_format = “insert_cell+chip”`)
   - Copy the code to a new chip file, modify as needed.

Thank you for participating!

What to do next?

Switch to the main GitHub repository: https://github.com/iqm-finland/KQCircuits

Keep the discussion going in the Discord: https://discord.gg/4wP8WAeWuJ



Contribute with bug reports, feature requests and code!

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- Quantum physics and design calculations.
- Electromagnetic field simulations, including finite element and lumped circuit modeling.
- Numerical modeling and optimization.

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