Calibre 2024.2 Release Highlights

Calibre Semiconductor Manufacturing Solutions

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Notes 1

Table of Contents

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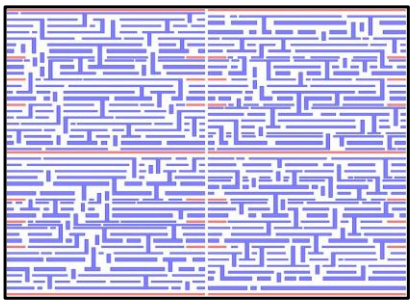
Notes 2

Calibre LSG DRM-Mode Accelerates Process Ramp-up and Design Enablement

- Calibre LSG DRM-Mode enables quick initial set-up and fast response to design rule revisions.
- Calibre LSG DRM-Mode elevates its constraints syntax to the familiar DRM-style language of Physical Design, removing the previous time-consuming effort to translate constraints to a different constraint paradigm.
- To invoke Calibre LSG DRM-Mode from Linux, enter the command line as follows:

```
$MGC_HOME/bin/calibre -lsg -DRMmode LSG_drm_options_file
```



Increase User Productivity 10x

- ✓ Configuration set-up using familiar DRM-Style constraints
- ✓ Fast LSG Kit development
- ✓ Update DR/technology revision in minutes

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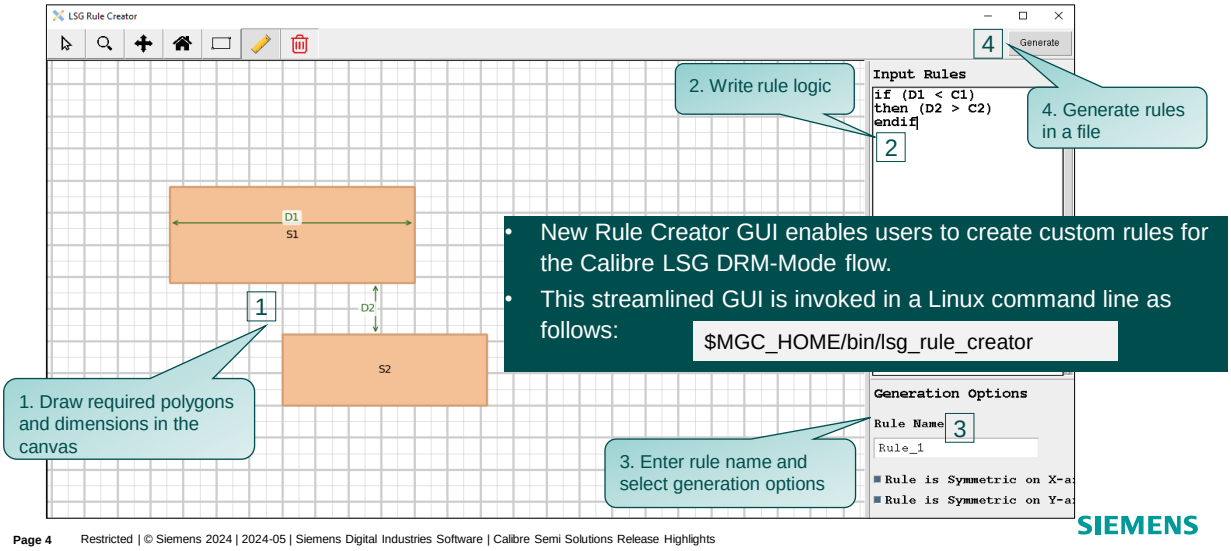
New Calibre LSG DRM-Mode enables fast and easy LSG configuration, delivering quick results to accelerate process development, test chip generation and DRC runset QA. LSG DRM-Mode elevates its constraints syntax to the familiar DRM-style language of Physical Design, removing the previous time-consuming effort to translate constraints to a different constraint paradigm. It provides a direct flow that assists technology development teams to quickly react to technology and design style changes.

To invoke Calibre LSG DRM-Mode from Linux, add –DRMmode into the command line while invoking Calibre LSG. The output from Calibre LSG DRM-Mode are the generated random layout clips in OASIS format. The clips are DRC-clean and created using the configuration options, DRC constraints, and design style topologies from user-defined design specifications.

New Rule Creator GUI Supports Custom Rule Development for Calibre LSG DRM-Mode Flow



- New Rule Creator GUI enables users to create custom rules for the Calibre LSG DRM-Mode flow.
- This streamlined GUI is invoked in a Linux command line as follows: $MGC_HOME/bin/lsg_rule_creator

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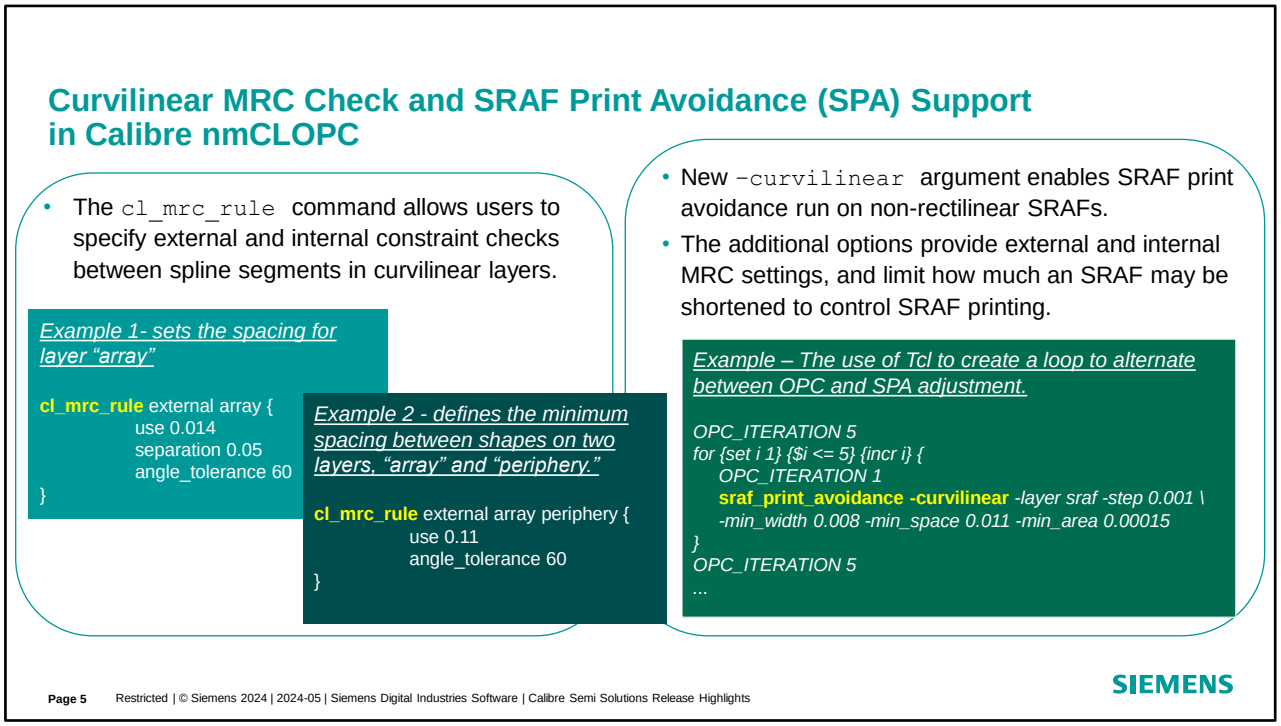
The new rule creator GUI provides a drawing canvas for creating layer shapes along with a coinciding rule entry pane. Entering or modifying a custom rule for your layout clips can be facilitated through intuitive syntax. When the rule entry is completed, a custom DRC constraint file is generated from the Rule Creator GUI that can be specified in your LSG DRM-Mode options file. Also, The output rule file from the Rule Creator GUI is encrypted by default.



cl_mrc_rule command can now specify precise MRC rules for spacing and width checks on the output from spline_opc. The check can be within a single layer or between two layers. Nearest neighbor spline segments are always ignored by the check.

The -curvilinear argument enables sraf_print_avoidance on non-rectilinear SRAFs. The additional options provide external and internal MRC settings, and limit how much an SRAF may be shortened to control SRAF printing.

-min_width is an optional argument that specifies the MRC internal value. Features which are narrower than this width are cut to prevent MRC violations.

-min_space is an optional argument that specifies the MRC external value. Gaps caused by sraf_print_avoidance cutting an SRAF are at least -min_space wide to prevent MRC violations.

Enhanced Anchor Points Creation and Curvature Aware Curvilinear OPC

- All anchor points are initially given equal priority when `spline_opc` tries to achieve the best edge placement or resolve MRC conflicts. With `POINTSET_WEIGHT`, users can reduce the priority of some anchor point sets so that conflict resolution favors the non-weighted sets.

Example - To meet the EPE specification for critical anchor points, first create an anchor point set containing them.

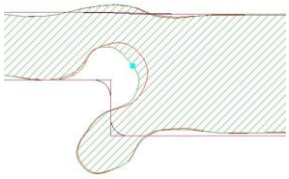
```
POINTSET all L1.smooth -out all_points
POINTSET topological not_inside L1.smooth L1 -out critical_points

POINTSET_WEIGHT all_points 0.7
POINTSET_WEIGHT -remove critical_points
```

- `anchor_point_layer` creates anchor points for use with the `spline_opc` and `POINTSET` commands. This command is updated with new `–inorder` option for creating implicit anchor points.

- Optional `-radius_of_curvature` argument is added in `spline_opc` to ensure the corrected mask is smoothly curved.

Red : without Curvature check
Green : with Curvature check



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The spline_opc algorithm minimizes EPE by shifting the Bezier curves controlled by the anchor points, simulating the result, and optionally correcting for MRC violations. In 2024.2 release, there are new options for creating anchor points and to ensure the corrected mask is smoothly curved.

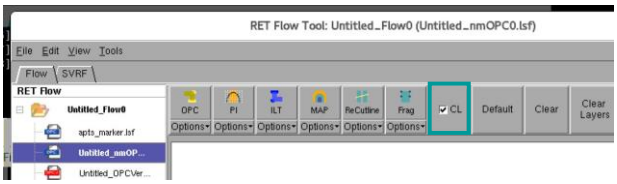
There is a new command, POINTSET_WEIGHT, for adjusting the priority of groups of anchor points. It allows to adjust the relative priority of anchor point sets so that more important areas achieve the best possible EPE. Users can now set a lower weight on the anchor points that are less important so that the more critical anchor points are given priority when resolving conflicts. User is required to specify the name of a set of anchor points that the command applies to and the weight value (priority).

anchor_point_layer creates anchor points for use with the spline_opc and POINTSET commands. This command has updates for creating implicit anchor points. The -rippleinside and -rippleoutside options available prior to 2024.2 are no longer supported. The new –inorder option causes implicit anchor points to be inserted in the order listed in anchor_point_layer. When -inorder is not specified, implicit anchor points are inserted after all other anchor points.

By default, spline_opc does not check the curvature. Starting from 2024.2, the spline_opc command adds the optional -radius_of_curvature argument to ensure the corrected mask is smoothly curved.

Calibre RET Flow Tool (RFT) Enhancements

- The Calibre RET Flow Tool has been updated to include a CL checkbox to allow curvilinear sessions (nmCLOPC, nmCLBIAS, CL OPCverify) to be created within the tool and SVRF files with curvilinear options to be exported.



- The Calibre RET Flow Tool has been updated with a Pre-OPC checkbox to output preopc anchor points from spline-based nmCLOPC flows.

- The Calibre RET Flow Tool has been updated to include an Etch Image Grid option in the Simulation Settings panel.

- The Calibre RET Flow Tool has been updated to output debug layers for a Calibre nmOPC flow that includes SRAF Print Avoidance.

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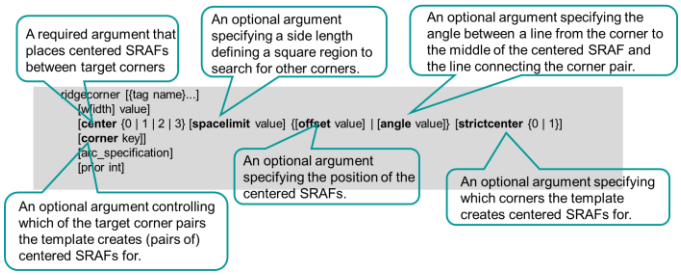
The Calibre RET Flow Tool has a new checkbox to allow users to quickly create curvilinear sessions in Calibre RFT such as a session for nmCLOPC, for nmCLBIAS, or for curvilinear post OPC verification. The SVRF files with curvilinear options can be easily exported. The Calibre RET Flow Tool has also been updated with a Pre-OPC checkbox to output preopc anchor points from spline-based nmCLOPC flows. This option is useful for anchor points optimization when developing nmCLOPC recipes.

The Calibre RET Flow Tool has been updated to include an Etch Image Grid option in the Simulation Settings panel. The Calibre RET Flow Tool has also been updated to output debug layers for a Calibre nmOPC flow that includes SRAF Print Avoidance.

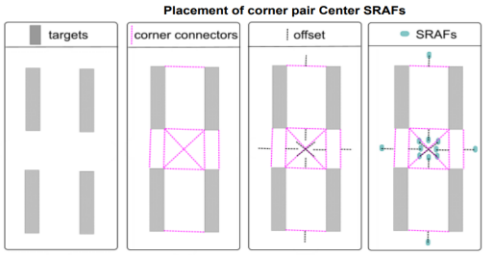
Updated nmSRAF Template for Centered SRAFs Placement

- Calibre nmSRAF `ridgecorner` template has new arguments to allow the placement of centered SRAFs in regions between target corners.



ridgecorner tag long1 w 0.01 center spacelimit 0.2 offset 0.04 corner pair

This template generates center SRAFs, with a width 0.01 um, for any tagged edge corner with another corner within the 0.2 um search box. The process of placing the center SRAFs is shown in the figure:



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The ridgecorner template can be used to create small centered SRAFs for proximate corners. In 2024.2, this template is updated with new arguments for centered SRAFs placement.

The new arguments include “center” argument which is a required argument for placing centered SRAFs between target corners. Users can optionally specify the spacelimit value, offset value, as well as the angle value for placing centered SRAFs. There are also options to select which corners and which of the target corner pairs the template creates centered SRAFs for.

In the example, the layout is a group of four rectangular polygons. The dotted pink lines indicate the connections between eligible corner pairs. The dotted black lines show the specified 0.04 um offset. The template places center SRAFs at the end of each of the black lines. For the diagonal corner pairs, the template creates a pair of center SRAFs.

New Defaults and Updates in Calibre nmSRAF/ MATE

New Defaults in nmSRAF and MATE

- The `lineendmergeangle` keyword in Calibre nmSRAF has a new default value of 150 degrees.
- Several default MRC values used by Calibre (CL EUV) MATE have been updated:

MRC Parameter	Pre-2024.2 Value	Post-2024.2 Value
minarea	0.000225	0.000025
minlength	0.025	0.005
minsquarearea	0.000125	0.000025
minsquarelength	0.010	0.005
minwidth	0.008	0.005

Calibre MATE Updates

- Calibre CL MATE is now able to reuse test patterns for multiple extraction directions for some symmetries, reducing the size of SRAF pattern library directory.
- Calibre MATE now automatically assigns priority values at the end of template generation, preventing duplicate values from occurring.
- The `--converge` argument in `mate_config` command now also causes the coverage calculations to be written to the log file `coverage.log`

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Lineendmergeangle is a Calibre nmSRAF keyword which sets a lower limit on the angle between curvilinear SRAFs for which line-end merge is performed. In 2024.2 release, the default value has been changed to 150 degrees. The default value of 150 degrees prevents sharp bends in SRAFs and the unintended merging of SRAFs associated with different target edges. Users can specify the keyword globally or by priority.

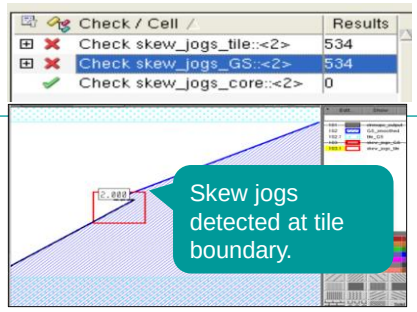
getSrafInfo is a script used by Calibre MATE to generate the final cnsraf recipe based on the extracted SRAFs and MRC constraints. As of release 2024.2, several of the default MRC values used by Calibre (CL EUV) MATE have been updated. The default change can be found from the table.

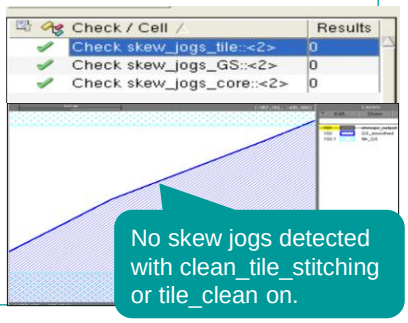
New OPCverify Command for Eliminating Tile Boundary Contour Jogs

- Tile boundary contour jog is not a problem when the contour is checked within the same OPCverify run. However, it may be a problem for specific applications when the contour is output and used as an input for another litho run.
- A new command is implemented to clean up/smooth image contour kinks located near tile boundaries.

  clean_tile_stitching [**max_displacement** length]
- `contour_options` command has been updated with `tile_clean` argument in 2024.1 release to clean artifacts on contours near tile boundaries.

  contour_options….. **tile_clean { on | off }**





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Calibre OPCverify has a new command which cleans up image contour kinks located near tile boundaries.

Contour layers created with Calibre OPCverify operations that perform simulation (such as image) often have small kinks on tile boundaries. These are caused by numerical noise during the simulation. These kinks are invisible to Calibre OPCverify checks, because the checks work at the tile level and the kinks are created later when the tiles are merged. However, the kinks can cause problems when the layers are used by downstream operations.

A new command clean_tile_stitching is implemented to clean up these contour kinks. Users can optionally specify the max_displacement value to direct Calibre OPCverify to only fix kinks on tile boundaries that can be done by moving edges of a layer less than or equal to the specified value. We recommend setting max_displacement to a value about the size of the contouring pixel, or about the length of a typical edge in layer.

Please note that we have also updated contour_options command with tile_clean argument in 2024.1 release to clean artifacts on contours near tile boundaries.

Open Frame Intensity Optimization for Throughput-Aware Obscuration in High NA EUV Source Mask Optimization

- Calibre SMO supports throughput-aware obscuration usage, which optimizes dose and minimizes amount of light blocked by the obscuration, for balancing between lithographic quality and scanner throughput.
- New commands are available to apply to EUV processes to optimize light energy losses due to obscuration.
  - `open_frame_intensity` can be used to activate open frame intensity optimization at the nominal process condition while keeping acceptable lithographic quality.
  - Users can also specify a target value for the optimization of open frame intensity by using `target_open_frame_intensity` and `target_open_frame_intensity_weight`.

Example 1- Open frame intensity maximization

```
....
job 4 polish
   pw_select nominal_1.0  pw1 pw2 pw3 pw4
   iterations 500
   open_frame_intensity_weight 300
```

Example 2 - Example - Open frame intensity optimization to a target of 0.75 with weight 300

```
....
job 4 polish
   pw_select nominal_1.0  pw1 pw2 pw3 pw4
   iterations 500
   target_open_frame_intensity 0.75
   target_open_frame_intensity_weight 300
```


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One of the key features in Calibre High NA EUV Source Mask Optimization (SMO) is throughput-aware obscuration for balancing between image quality and through put. Starting from 2024.2, Calibre SMO is updated to support throughput optimization through open frame intensity (OFI) optimization.

Open frame intensity is used in the scanner to measure the dose with sensor at the wafer level. Maximizing the energy transmission through the open frame can help to improve throughput. Adjustment of the weight between Dose/OFI and lithographic component help to find the balance between throughput and lithographic quality. New commands are available to apply to EUV processes to optimize light energy losses due to obscuration. Do not specify open_frame_intensity_weight with target_open_frame_intensity or target_open_frame_intensity_weight.

Calibre nmModelflow New Options

New argument to select the mode for plotting cm1 terms

- New `cm1term` argument is added in `mdf plot grid` to select the mode for plotting specific cm1 terms.

New argument to write the grid information to disk

- New `-savetextgrid` and `-savegrid` arguments in `mdf plot grid` write the grid information to the disk in either text or binary format.

New option to change how normalization is calculated for CM1 model analysis

- `mdf cutline cm1_model_terms` has a new option, `-normalize`, which changes how normalization is calculated for CM1 model analysis.
  - `-normalize 1` involves summation of absolute term values computed over all gauges or sites.
  - `-normalize 2` involves summation over only a specific gauge or site.

Updated `mdf param_set_and_build` command

- `mdf param_set_and_build` now accepts contours as input data; previously it only worked if gauge data was included in the inputs.

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There is a new cm1term argument in mdf plot grid to select the mode for plotting specific cm1 terms. It uses the following parameters. “-scale” specifies whether the cm1 term grid is scaled by the cm1 term coefficient. “-name” specifies plotting a CM1 grid around a gauge only for the named CM1 term. “-index” specifies an index number for CM1 terms that use them.

mdf plot grid command is updated with two new arguments. -savetextgrid and -savegrid arguments are available now to write the grid information to the disk in either text or binary format, respectively. The filename used depends on the simulation mode chosen.

mdf cutline cm1_model_terms now has a new option to change how normalization is calculated for CM1 model analysis. “0” calculates non-normalized terms instead of normalized terms. “1” calculates normalization such that the term value at the crossing point is divided by the sum of the absolute term values, computed over all gauge and site crossing points and terms. This is the default value. “2” calculates normalization such that the term value at the crossing point of a gauge or site is divided by the sum of the absolute term values, computed at the crossing points for only that specific gauge or site.

Prior to 2024.2 release, mdf param_set_and_build only worked if gauge data was included in the inputs. Starting from 2024.2, this command now accepts contours as input data.

Calibre nmModelflow GUI Updates

Updated optimization settings for CM1 length parameters

- The optimization settings for certain CM1 length parameters have been changed so the upper bound is set to “auto” instead of a fixed value in order to handle values higher than 100 for DUV and to automatically set a value of 100 for EUV.
  - This change primarily affects Modelforms 29, 50, and 99.

New Compare Layouts button in Calibration Jobs Compare dialog

- It allows users to create a new job that combines selected layers from the compared jobs into a single layout.

New default group by group plots in Calibration Job window

- For calibration jobs that contain groups, the following Group by Group plots are selected by default in the Calibration Job window > Plots > GaugesSimStats entry:
  - Weight vs SimErr, Meas vs SimErr, SimErr vs Drawn, CtrErr vs SimErr, SimErr vs. Group

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New Commands in Calibre RET Modeling

New Command to Compute Akaike Information Criterion (AIC) for an Etch Model

- Calibre nmModelflow has a new command to compute the Akaike Information Criterion (AIC) for an etch model.
  - Akaike Information Criterion (AIC) is an information-theoretic approach to model selection that seeks to minimize over-fitting risk.
- The model with the lowest AIC is output to the terminal.

```
mdf check aic
```

New Command to Split CM1 Linear Optimizer Input Data into Training and Verification Sets

- Calibre nmModelflow has a new command to split CM1 linear optimizer input data into training and verification sets.
- This is used during MOGA calibration to improve verification objectives and test for overfitting.
  - Users have options to specify the fraction of the enabled data to be used as verification data and the method used to select the verification data subset from the enabled data.
  - Users specify the seed value to be used if type is set to random. Users are allowed to switch back to unsplit data if needed.

```
mdf optimize verify set [-fraction val -type random | first | last -seed val] | unset
```


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Akaike Information Criterion (AIC) is an information-theoretic approach to model selection that seeks to minimize over-fitting risk. AIC considers the goodness of fit, number of parameters and gauges to determine the best model based on a weight. AIC is an additional metric to compare calibrated models. AIC is blind to overall fitness and should be used to check for over-fit risk and make a final decision between candidate models. Starting from 2024.2, Calibre nmModelflow has a new command to enable AIC computation for an Etch model.

There is also a new command to split CM1 linear optimizer input data. Users can use this command to split the input data into training and verification sets. This can be used during MOGA calibration to improve verification objectives and test for overfitting. Several keywords are available to set this new command. Users specify the fraction of the enabled data to be used as verification data. Users can choose to split the data randomly. If so, the seed value needs to be specified. If not provided, the number of enabled data points is used as the initial seed value for randomization. Users can also set the first or the last few data points as verification data. If needed, the unset keyword can be used to unsplit data.

More Updates in Calibre RET Modeling

New Option for Kernel DDM Training

- `kernel_ddm_train` has a new argument, `-linear_feature_size`, to select training features linearly across a size range.

Changes to the EUV-Related Model Formats

- In the Black Border Model File Format, the `dose_ring` parameter now supports negative dose values.

Changes to the VEB Model

- The default consistency value for `average_bias` has been changed to 3 to align with current best practices.

New Warnings

- As of version 2024.2, runs that load any VT5 models exit with a message “VT5 resist model not supported with GPU.”

New Default for Maximum Grid Shift

- The `mdf simulate gridshift` command has a new default value for the maximum grid shift. The new default value is 1.

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By default, linear selection is deactivated and the tool selects training features using a random selection method across a size range. Starting from 2024.2, users can use the new argument, `-linear_feature_size`, to select training features linearly across a size range.

Prior to the 2024.2 release, the tool issued a warning message if a negative dose value was specified, and no black border contribution was added for that cell. Starting from 2024.2, the negative dose value is supported. So, if a negative dose value is specified, then the black border contribution cell is added, even though it is negative.

There is a default change for VEB modeling. The default consistency value for average_bias has been changed from 1 to 3.

VT5 models does not support GPU acceleration. Starting from 2024.2, runs that load any VT5 models exit with a message “VT5 resist model not supported with GPU.”

There is default change in mdf simulate gridshift command. Prior to 2024.2, the default for maximum gridshift is 0.5. It has been changed to 1.0 to better align with current best practices.

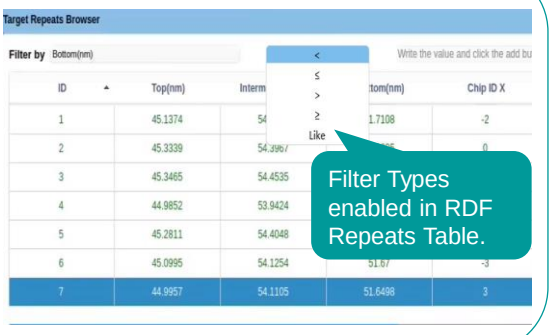
New Features in Calibre SEMSuite

Updates in Contour Data Flow Tool

- New option in the Contour Data Flow (CDF) tool Settings Pane to activate running auto setup tuning on MTflex.

Updates in the Raw Data Filtering (RDF) Tool

- The Target Repeats Browser has enhanced filtering function in repeats table.
- Gauge file generation now uses the drawn CD value to calculate the location coordinates of the target if target validation succeeds.
- The decision results files have ImageScore and CD information columns added.
- There is a runtime improvement to the validation step.



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From the Contour Data Flow (CDF) tool, there is a Settings gear icon to display and configure settings values. The settings values include Default Setup File, Results Directory, Input Layout Path and Layer, Output Precision, Analysis Precision, Threading, and MTFlex activation for auto setup tuning. Mtflex (For auto setup tuning only) specifies the filepath to a remotes script file for running auto setup tuning with MTflex enabled.

In the Raw Data Filtering (RDF) tool, the Target Repeats Browser has filtering function enhanced in repeats table. Gauge file generation now uses the drawn CD value to calculate the location coordinates of the target if target validation succeeds. If target validation fails, the measured CD value is used to calculate the location coordinates. There are two new columns added in the decision results files. Users can now read Image score and the CD information from the decision results files. Lastly, there is a runtime improvement to the validation step in the RDF tool.

New Kernal Type and Automatic Chunk Size Adjustment in Calibre SONR

Non-uniform Tophat Kernel Support for Model Generation

- Users can now generate lookup table models using “tophat_gauss” kernel type which specifies to use a ring-shaped gaussian kernel.

```
sonr --feature --density_file kernel name
TYPE tophat_gauss outer [ inner ]
```

Automatic Chunk Size Adjustment for Low Memory Runs

- Users have a new option to adjust the chunk size automatically based on available memory in both `sonr --cluster` and `sonr --tree` commands.

```
sonr --cluster --lowmem
sonr --tree --lowmem
```

Density Kernel Types Supported in Calibre SONR			
1.	Circular Gaussian distribution	4.	Standard Gaussian distribution convolved with a rectangle of length and height.
2.	Tophat, or uniform, kernel	5.	Standard Gaussian distribution convolved with a tophat kernel. New!
3.	Elliptical Gaussian distribution with different spread along the x-axis and y-axis.		

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sonr --feature application creates lookup table models which provide dynamic density and optical information. Starting from 2024.2, users can now generate lookup table models (lutmodels) using a non-uniform tophat kernel. The new “tophat_gauss” kernel type specifies to use a ring-shaped gaussian kernel. It is a standard Gaussian distribution convolved with a tophat kernel.

sonr --cluster creates clusters of feature vectors, which can be used to select representative features or generate a sonr model. sonr --tree creates a prediction tree using a previously trained cluster model. Starting from 2024.2, both commands is implemented with “--lowmem” option which can set the chunk size automatically based on the available memory when the run starts.

New Features for Creating Scatterplots and Heatmaps in Calibre SONR

New argument to specify the number of bins for coverage check

- Users have a new optional argument to determine how many bins are used in calculating coverage.
- This can be useful for verifying that representative vectors have not omitted any zones of the design.

sonr --scatter --coverage **[{-b | --bin} number]**

Updated argument in `sonr --scatter` for clarity

- The "`--reference`" argument in `sonr --scatter` command is now "`--sample`" for clarity.

sonr --scatter { –s |**--sample }**

- Example below combines the input (A.db+B.db) and does two comparisons, (A.db+B.db) versus 1.db and (A.db+B.db) versus 2.db.

-i A.db -i B.db -s 1.db -s 2.db

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sonr --scatter application creates scatterplots and heatmaps. It can calculate how well a subset of feature vectors represent the overall database. There are a couple of updates in 2024.2 release.

First of all, the coverage check can now specify the number of bins. The effect of this option depends on whether number is a floating point or integer. If the number is an integer (for example, 100), it specifies the number of bins; that is, the granularity. If the number is a floating point (for example, 100.0), this number specifies the size of the bins in microns.

Secondly, the --reference argument in sonr --scatter command has changed to --sample argument. This is a required argument for Usage 1 (scatterplots) and an optional argument for Usage 2 (Coverage checks) that specifies a second database to compare. Multiple data files can be treated separately like showing in the example.

Updates in SONR Model Evaluator

- Users have a new "`--with_fe_after`" option in SONR model evaluator to run `sonr --fe` immediately after evaluating a model. This ranks the features in the model for relative importance to results.
  - `sonr --fe` command analyzes data to determine the features with the strongest effect on the objective and plots the Shapley values.

`--a` is an optional argument that plots the Shapley analysis in an abstract bar plot.

`--e` is an optional argument that generates a dependence plot for each feature other than the one being analyzed.

sonr --model_evaluator **–with_fe_after [--a] [--d] [--e] [--o directory]**

`--d` is an optional argument that plots the Shapley analysis as a density distribution.

`--o` directory is an optional argument that creates a new directory by the specified name.

- Users are now required to specify "--n" argument to identify the value assigned to non-hotspots.

sonr --model_evaluator **–n** number

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sonr --model_evaluator command enables the evaluation for a SONR machine learning model. There is a new optional set of arguments that runs sonr --fe after model evaluation finishes. The default behavior is to not perform this step. The other update is that the –n argument which specifies the value of the label column that identifies non-hotspot ("good") data has changed from an optional requirement to a required argument.

New Functionality in Calibre Cluster Manager (CalCM)

New command to specify include files in the job configuration file

- Users can now specify include files at the job level in the `job.conf` configuration file with the new "`JOB RUNINCLUDE filename`" command.

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New option to submit interactive jobs

- Users can now specify `calcm_submit_job -i` to use interactive mode, which prints the Calibre log to stdout after the job is launched.

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New enhancement to share the cluster page by using the Share Page button

- By clicking the Share Page button, it copies the unique URL of the current Cluster page with its current settings to the clipboard.

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Users can now specify include files at the job level in the job.conf configuration file with the new "JOB RUNINCLUDE filename" command. The calcm_run script sources the specified file after sourcing those in the Job Queue application's RUNINCLUDE argument, overriding that setting for the job.

Users can now submit interactive jobs in CalCM. Simply specify calcm_submit_job -i to use interactive mode, which prints the Calibre log to stdout after the job is launched. Users can also add -k to allow killing the submitted job with Ctrl+c.

Users can now click the Share Page button and copy the unique URL of the current Cluster page with its current settings to the clipboard. The URL preserves the following from the current Cluster page: Time range; Threshold function; Selected metrics; Selected hosts; "group by" value; "filter by" selection along with the filter option value; Customize ( ) options settings; Plot zoom state

Thank You!

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