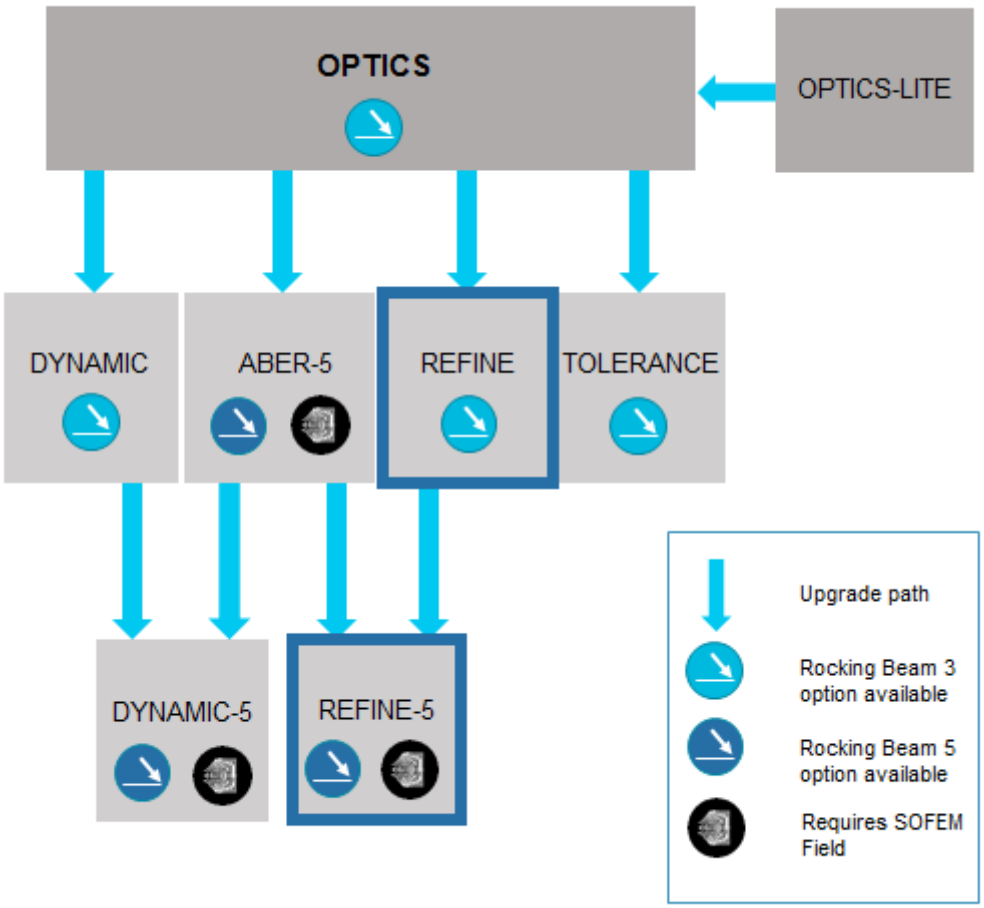
REFINE & REFINE-5

Column optimisation

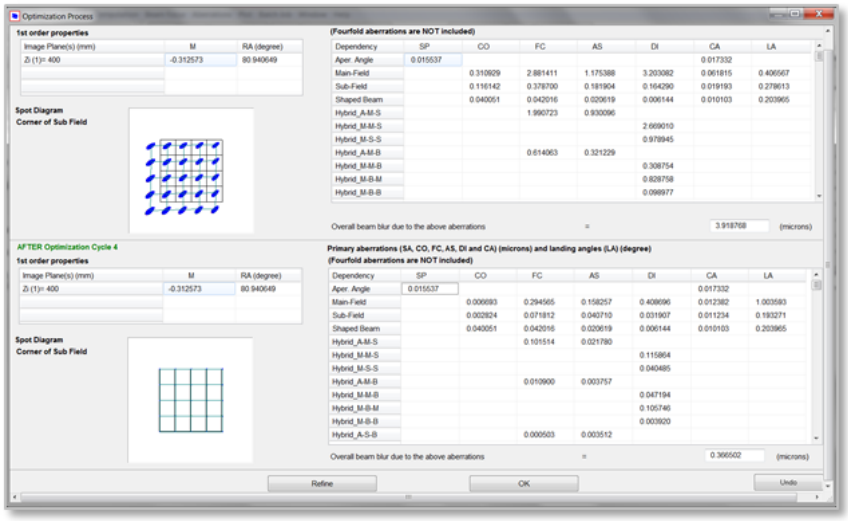


Overview

REFINE and REFINE-5 take the initial design of an electron or ion beam column, and interactively refine the design to optimise the performance by minimising the aberrations.

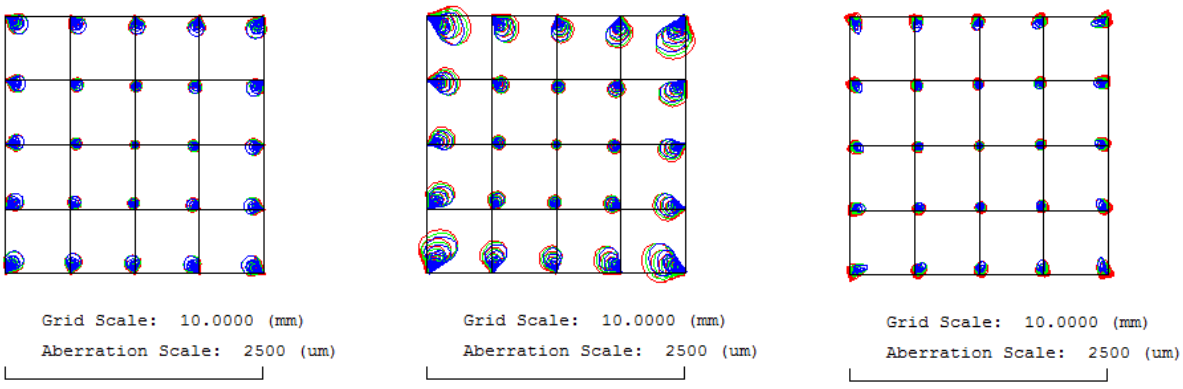
In a particle beam column there are many design parameters that can be varied. A large number of aberrations depend on the variable parameters therefore the overall aberration is a complicated non-linear function of the variable parameters. In such situations, the use of an optimisation procedure is useful, and generally yields designs with significantly better properties than those found by trial and error.

The REFINE-5 module extends the functionality of REFINE to allow optimisation of the aberrations up to 5th- order terms. Additional interfaces are provided which allow the user to control the 5th- order terms that are to be minimised by specifying weighting factors for each group of 5th—order aberrations. The variable parameters of the system (also specified interactively by the user) are adjusted to minimise the weighted sum of the aberrations. The weighting factors can be specified for any combination of 3rd- order and 5th- order aberration terms.



Optimisation Process Window.

The user has significant control over the optimisation process, including interactive control over the weighting factors assigned to each aberration and constraints on the range over which each variable parameter is allowed to change. Variable parameters are axial position, size and relative strength of each lens and deflector, and the rotation angle of each deflector. The quantity to be minimised is a weighted sum of squares of all the individual aberrations. Starting from an initial design, the program alters each variable parameter by a small amount, and re-computes the aberrations. This yields the partial derivative of each aberration with respect to each variable parameter. A least squares equation is then solved, to find the change in each variable that would minimise the weighted sum of squares of the aberrations in the "least squares" sense, if the partial derivatives were to remain constant. To ensure stability, a positive damping factor is introduced into the principal diagonal elements of the least squares matrix. The calculation is repeated for several values of the damping factor, and the damping factor which minimizes the target function is selected using a one-dimensional binary search. This constitutes one optimization cycle. The entire cycle is repeated several times, until a local minimum is reached.



Spot diagrams for a sample system. Left: 3rd order aberrations for system before optimization; Middle: 3rd-order+5th-order aberrations for system before optimization; Right: 3rd-order+5th-order aberrations for system after optimization of all aberrations up to fifth-order