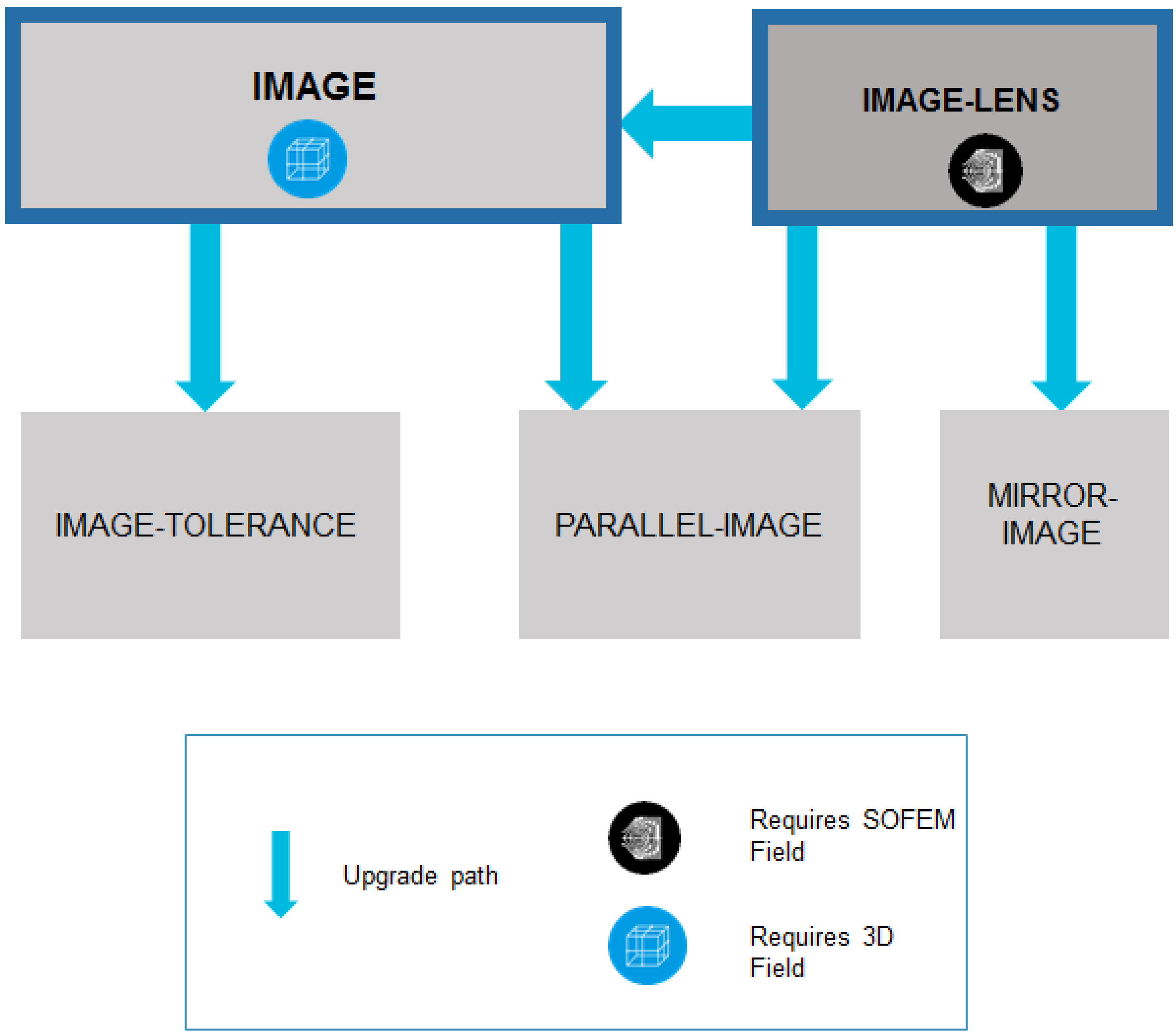
IMAGE & IMAGE-LENS

Simulation of aberrations and discrete Coulomb interactions.

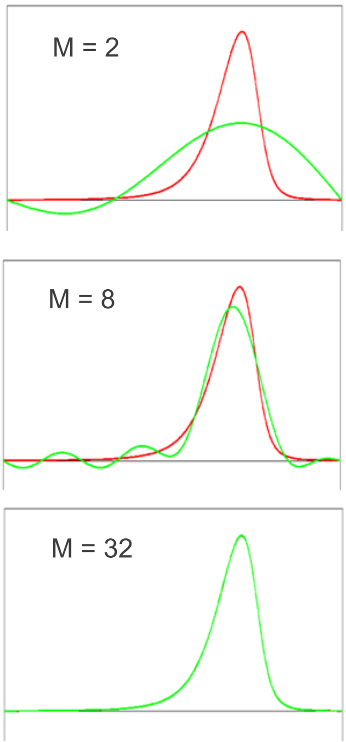


Overview

IMAGE-LENS allows the analysis of systems containing round lenses only. Accurate direct ray tracing eliminates the need to use conventional aberration theory, and the method is therefore applicable to systems with aberrations of any order. The software computes and plots the total blur including both aberrations and coulomb interaction effects. Post-processing facilities are included, for plotting point spread functions (with systematic or random initial conditions) and through-focal series of edge blur diagrams.

The IMAGE software extends the capabilities of IMAGE-LENS to allow the analysis of a wide range of systems which, in addition to round lenses, can include combinations of multipole lenses, deflectors, stigmators and Wien filters.

In order to analyse a system, suitable field computation software such as SOFEM Field or 3D Field must first be used to compute the axial field function of each element.



Fourier series fits to the axial field function of a magnetic lens with asymmetric pole-pieces. Fits are shown with 2, 8 and 32 terms of the Fourier series. 32 terms gives an excellent fit.

The axial field function of each optical element is fitted with a set of orthogonal analytic functions. Two sets of fitting functions are provided: Fourier series and Hermite series. Fourier series are suitable for electrostatic potential distributions, while Hermite series are convenient for magnetic lenses and deflection fields, since these are generally of finite axial extent, and can usually be fitted well with a few terms of a Hermite series.

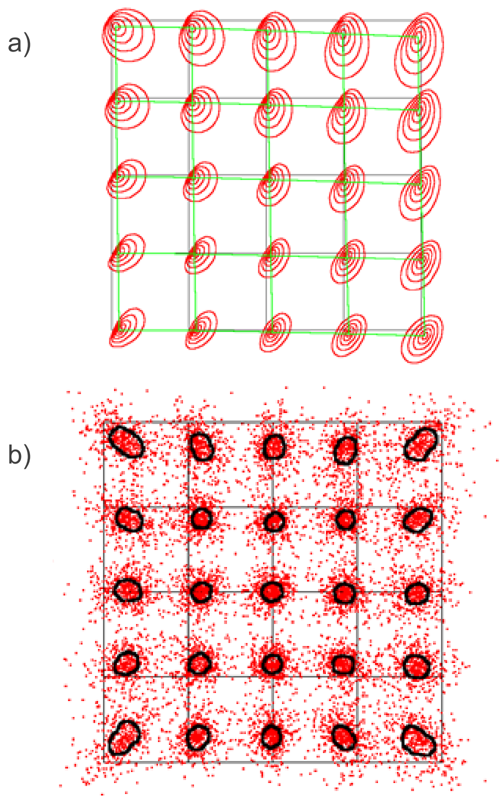
After fitting the axial fields by exact analytic functions, the off-axis fields at any point are obtained very accurately by radial power series expansions. The software can compute these expansions to the 11^{th} power of the off-axis distance (r^{11}), for all multipole field components up to dodecapole (12-pole) fields. Thus the software can handle the aberrations of all types of optical element likely to be encountered in practice. The analytic representation of the fields for each optical element means they are all exact solutions of Laplace's equation, suitable for use in direct ray-tracing.

The paths of electrons or ions are traced through these analytic fields by direct ray-tracing, using a fifth-order Runge-Kutta formula, with adaptive step size for automatic error control. This ray-trace algorithm typically gives an accuracy of better than 1 picometereover a column length of 1 metre.

In the ray tracing, a whole ensemble of particles can be traced down the column simultaneously. This makes it possible to include the Coulomb fields between the N particles in the ensemble, on each time step. The N-body Coulomb fields can be computed in two ways: either directly, in a pair-wise fashion, for the $N(N-1)/2$ discrete interactions, or using a fast hierarchical tree-code algorithm, that enables the inter-particle fields to be computed in $O(N\log_2 N)$ operations. This enables the discrete Coulomb interaction effects (both stochastic and global) to be included, and for their effects to be combined with the geometrical and chromatic aberrations of the imaging elements in a unified and rigorous way.

The fact that the electrons and ion paths are calculated directly, as functions of time, means that there are no restrictions on the imaging conditions. In particular, there are no limitations on the magnitudes of the ray slopes relative to the axis, and there are no restrictions on the particles reversing their axial direction.

Post-processing facilities are included, for plotting point spread functions (with systematic or random initial conditions) and through-focal series of edge blur diagrams.



Computed point spread functions for a projection system. (a) Spot diagrams of geometrical aberrations, for a system with a deflected sub-field, with systematic initial conditions. (b) Spot diagrams for an on-axis sub-field, showing combined effect of aberrations and discrete Coulomb interactions.

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