Research on three-dimension current density distribution of a 30kV focused ion beam with Coulomb interactions

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Key words: Coulomb interactions; three-dimension current density; optimization

High resolution focused ion beam (FIB) systems have developed with various application since the late 1970's. Coulomb ion-ion interactions play an important role in the beam current density distribution and the final full wide at half maximum (FWHM) of the FIB. Much attention was paid to Coulomb interactions in the Ga LMIS[1-2] and the FIB column[3]. Influence of Coulomb interactions on current density distribution at the image plane has been obtained. However, the beam current density of the whole column is ignored, which makes it more difficult in designing the real apertures, the liner tube and the beam-blanking plate. In this paper, three-dimension focused ion beam current density distribution is obtained through N-body Monte Carlo method with Coulomb interactions being considered.

Firstly, the principle of N-body Monte Carlo simulation on all aberrations and Coulomb interactions was researched in detail. Bunches of charged particles are created near the Ga LMIS with random initial positions, directions, kinetic energies and distributions as listed in Tab.1. Secondly, three-dimension beam current density distribution is simulated by solving the Newton-Lorentz equation of motion of all ions, where the electric field includes the lens field, the dynamic corrected deflection filed and Coulomb interactions among ions. The spatial field of the lenses is obtained by second order finite element method and Hermite interpolation[4-6] with high precision. The spatial dynamic corrected deflection field is calculated by Mebs software[6], as shown in Fig.1. The number of particles per bunch(N) affects both the Coulomb interactions and the whole computation time, so we choose it by minimizing the ending effects of the bunch. Finally, ion trajectory of the FIB column(listed in Tab.2) is traced by fifth-order Runge-Kutta algorithm to get the three-dimension beam current density distribution, as shown in Fig.2. The three-dimension beam current density distribution from the ion source to the specimen can lay foundation for the FIB mechanical design. The research is support by NSFC (Grant No 11205012)

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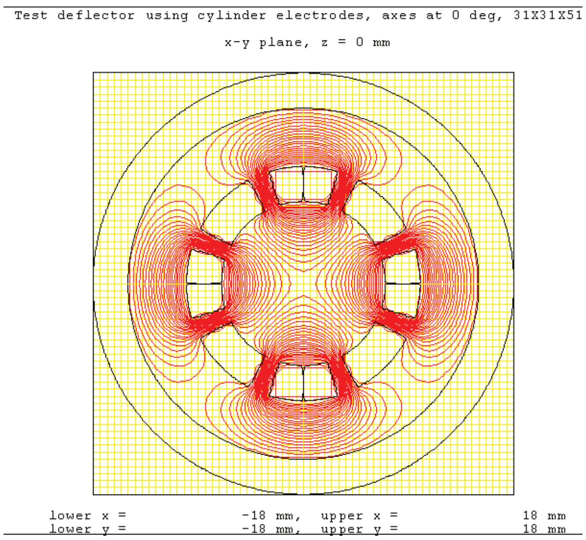
[5]Projection Software User Manual (Version 3.2) (Mebs Ltd Publications, London 2001).
[6]Image Software User Manual (Version 3.2) (Mebs Ltd Publications, London 2001).

Tab. 1 Original parameters of 0.1μA Ga LMIS

Class	Ga LMIS
Diameter of the virtual source	50nm with Gaussian intensity distribution
Energy spread	5ev, Gaussian distributions
Angular current density	30μA/sr, uniform distribution



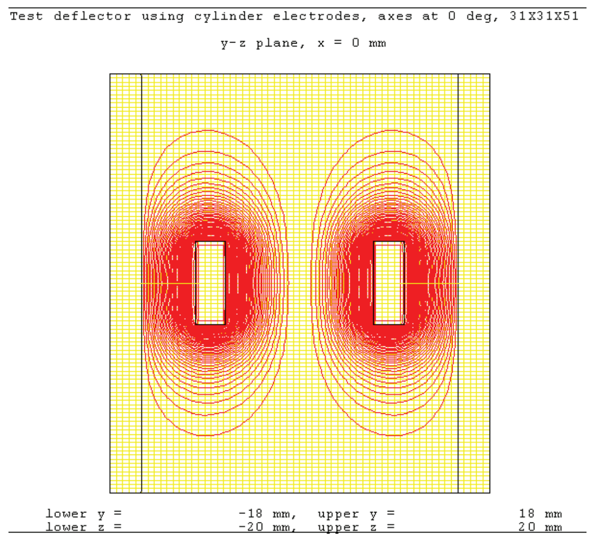


Fig.1 The dynamic corrected deflection filed

Tab. 2 Optical parameters of the pre-lens deflectors

Class	Deflection voltage (v)		stigmator voltage(v)	
	Deflector 1	Deflector 2	Deflector 1	Deflector 2
0.3mmX0.3mm deflection field	-273.9020	342.3775	3.4368	-4.2720

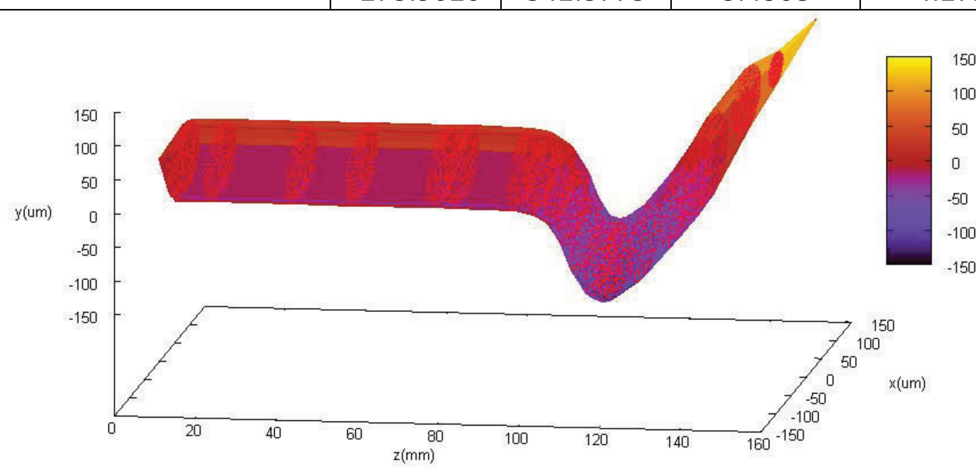


Fig.2 Three-dimension beam current density distribution of the FIB column