Magnetic Field Simulation Via Weak Form PDE For Multi-Beam Mask Writer Applications

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Abstract

Accurate magnetic field simulations are crucial in the design and optimization of advanced electromagnetic systems of the multi-beam mask writers (MBMWs). In MBMW systems, thousands of electron beams are focused with nanoscale precision within a small region close to the axis [µm], while the system domain is much larger [m]. Even minor inaccuracies or numerical noise in the calculated magnetic field within the beam region are compromising the reliability of the simulation results.

To address this challenge, we utilize the Weak Form PDE interface in COMSOL Multiphysics® to simulate static magnetic fields. This approach offers superior control over governing equations and boundary conditions, enabling a significant reduction in numerical noise close to the axis. We demonstrate this by introducing a magnetic vector potential, A=r·u(r,z), in a cylindrical coordinate system, which inherently improves noise characteristics at the axis, expressed as Br=−r·uz.

Furthermore, the weak form interface supports shape functions up to septic order in the discretization. This is a notable advantage over the standard Magnetic Fields (MF) and Magnetic Fields, No Currents (MFNC) interface, which supports up to cubic and quintic orders, respectively.

Our simulation results show that the weak form approach enhances magnetic field accuracy by micro-teslas (µT) and significantly reduces the noise close to axis compared to the standard MF interface (Figure 1). This improvement directly correlates to electron beam placement differences exceeding 1000 nm. Moreover, the observed reduction in the magnetic field noise translates to a fourfold decrease in electron beam placement noise as compared in Figure 2.

These findings underscore that the weak form method not only enhances simulation fidelity but also provides the essential precision required for the stringent demands of next-generation MBMW designs.

Figures used in the abstract

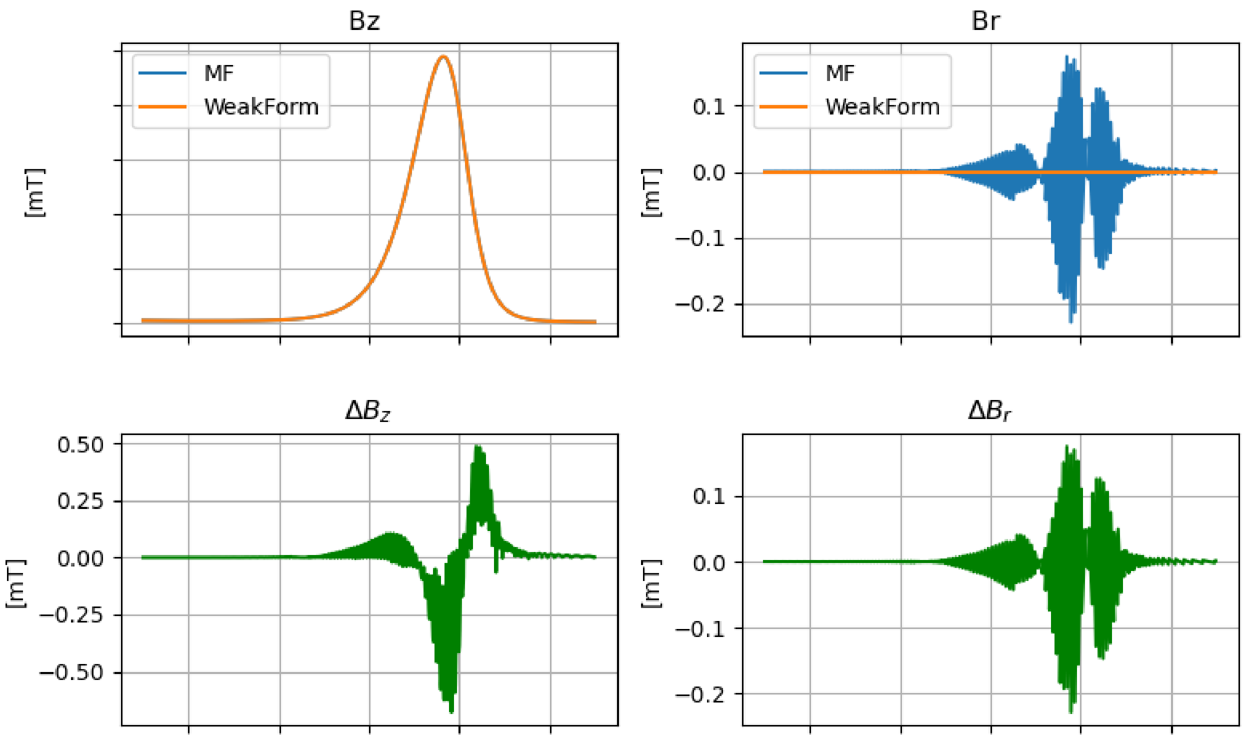

Figure 1 : Results of computed magnetic flux B at the axis. Top left: Bz; top right: Br; bottom left: difference of Bz between MF and weakform; bottom right: difference of Br between MF and weakform simulation.

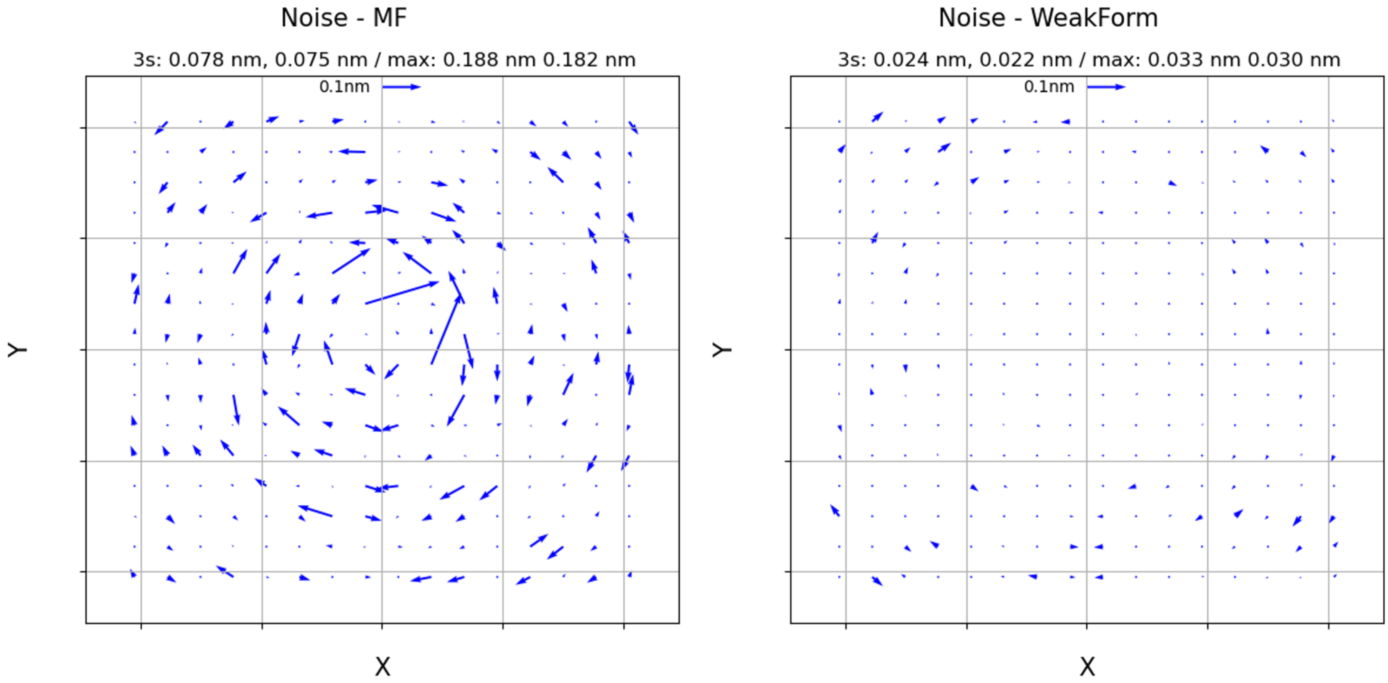

Figure 2 : Beam registration noise from MF (left) and WeakForm (right) computation.