Modeling and Analysis of Aberrations in Electron Beam Melting (EBM) Systems

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Introduction: In EBM, a technology pioneered by Arcam AB, mA currents of electrons are combined with kV voltages to melt 100 µm sized metal grains. The focusing and deflection systems were proven to cause aberrations in 1936 [1]. They therefore impose a limit on the size and resolution of what the EBM machine can build.

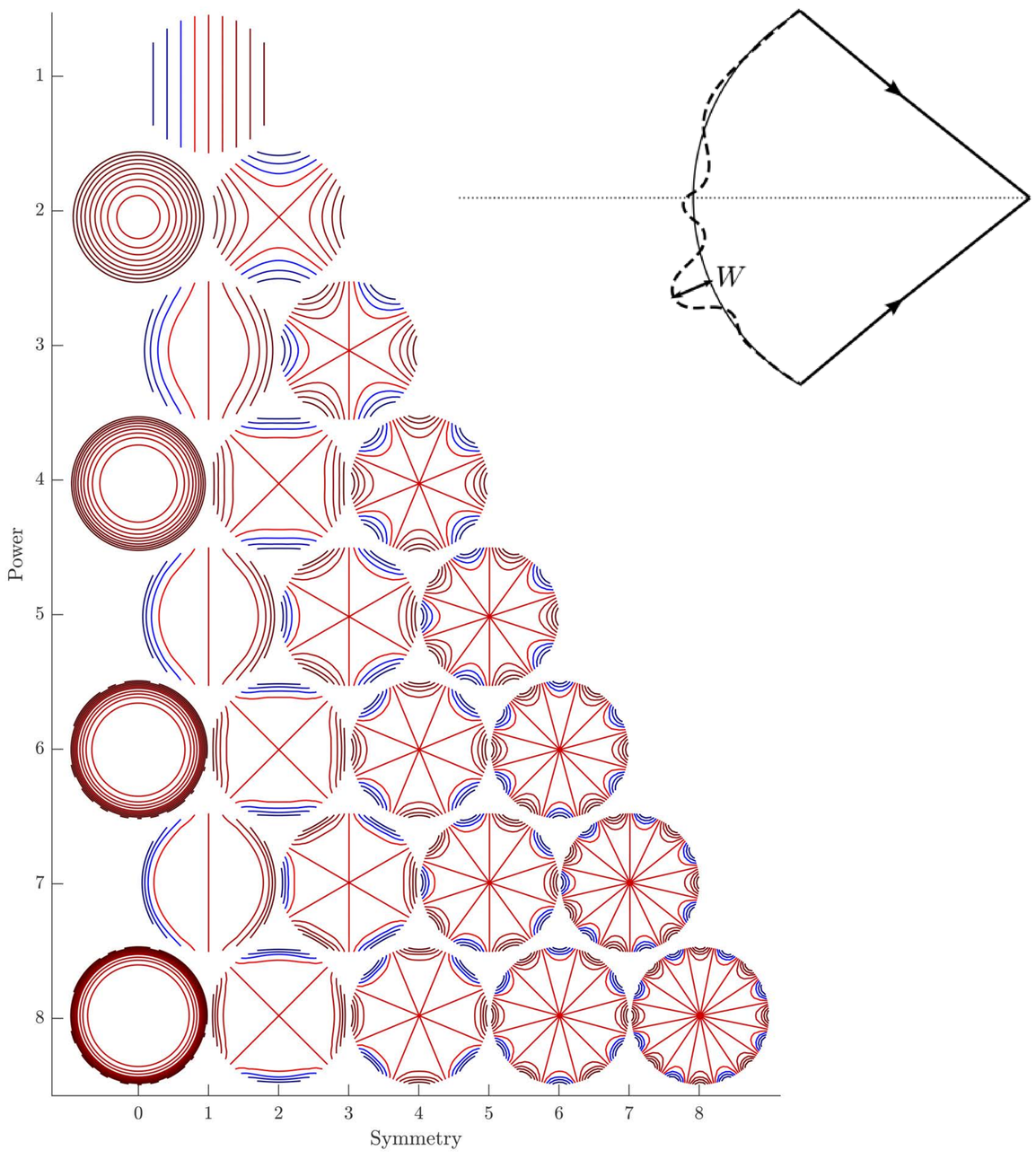

Figure 1. Aberration basis functions (left) and aberrated wavefront (right).

Model Geometry and Components:

- 1 m long vacuum cylinder with grounded walls
- A focusing solenoid after 20 cm
- A superposition of magnetic multipoles after 30 cm.

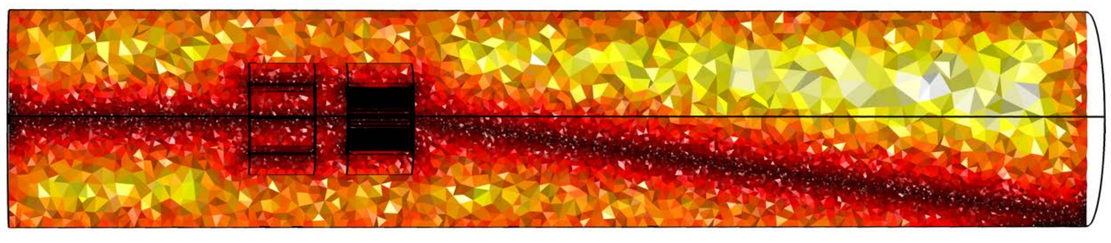

Figure 2. Model meshed for a deflected beam

Implementation:

- AC/DC Module
- Particle Tracing Module
- Livelink™ for MATLAB®
- Extensive scripting
- Up to 2 M elements.

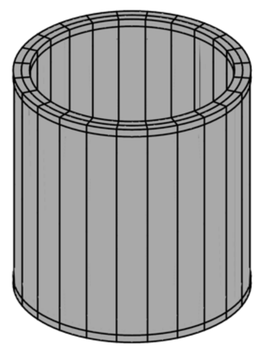

Figure 3. Geometry of superposition coil

Results: Magnetic fields of multipoles with up to 24 poles were simulated. For beams Parametric studies of focal length, spot size and deflection angles were run.

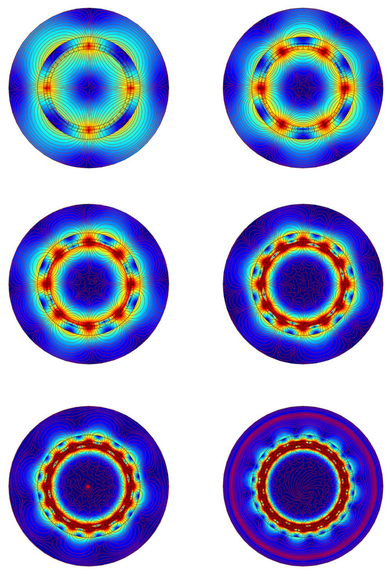

Figure 4. Multipole fields from 4, 6, 8, 12 and 24 poles.

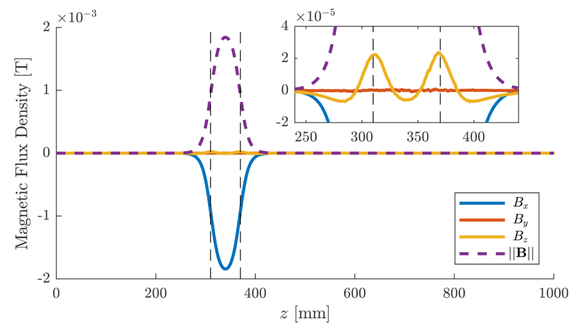

Figure 5. Magnetic fields along z axis of single dipole lens used for deflection.

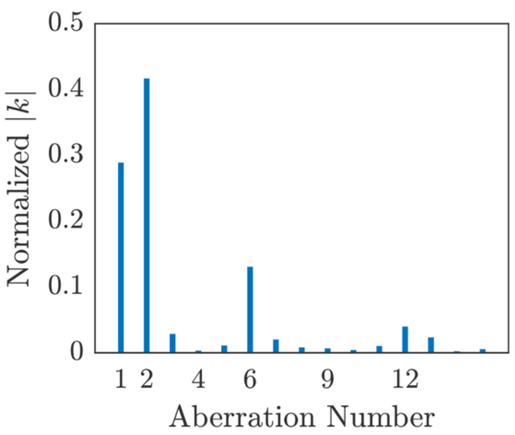

Figure 6. Aberration spectrum of beam in figure 7.

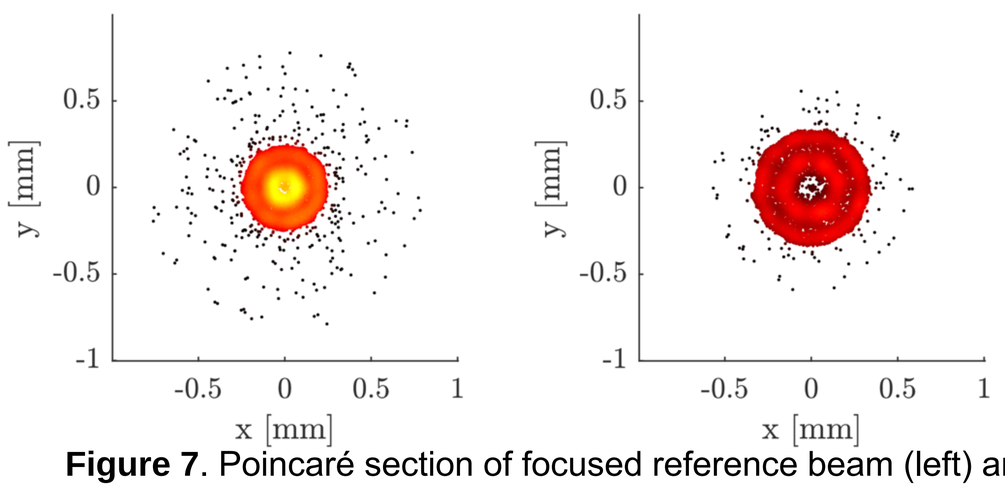

Figure 7. Poincaré section of focused reference beam (left) and one that has been defocused by 15 mm (right).

Conclusions: We have built a framework for simulating magnetic multipoles in a tight geometry with the COMSOL Multiphysics® simulation software. We have studied aberrations in EBM, with methods adapted from electron microscopy and substantial amounts of computation.

References:

1.O. Scherzer, Über einige Fehler von Elektronenlinsen, Zeitschrift für Physik, 101.9, pp. 593–603(1936).
2.A. Azhirnian, D. Svensson, Modeling and Analysis of Aberrations in Electron Beam Melting (EBM) Systems, Master's Thesis, Department of Physics, Chalmers University of Technology (2017).