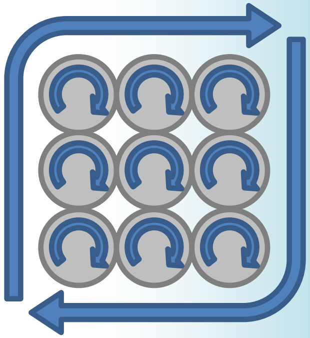
eRHIC High-Energy FFAG Magnet (49.5T/m) Analytic Model

Optimised to use less magnetic material

Magnetostatics with Magnetisation

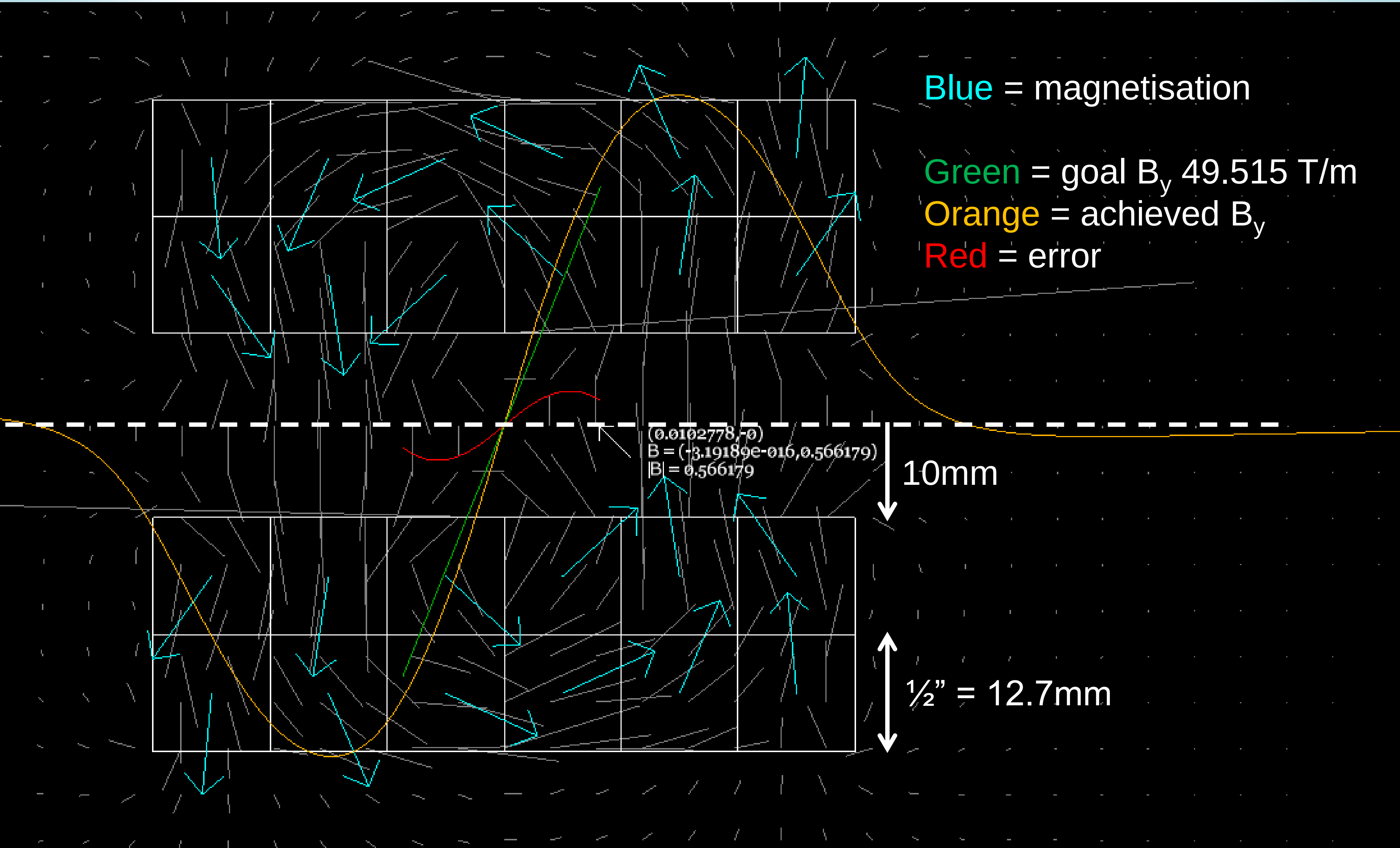
- $\nabla \cdot \mathbf{B} = 0$ as before
- $\nabla \times \mathbf{H} = \mathbf{J}$ + {time dependent term, ignore}
  - What is **H**? $\mathbf{H} = \mathbf{B}/\mu_0 - \mathbf{M}$, so rearranging gives:
- $\nabla \times \mathbf{B} = \mu_0(\mathbf{J} + \nabla \times \mathbf{M})$
- So magnetisation is like a fake current (the "bound current") equal to $\nabla \times \mathbf{M}$
- Actually from orbiting electrons:
  - So block of constant **M** = sheet currents



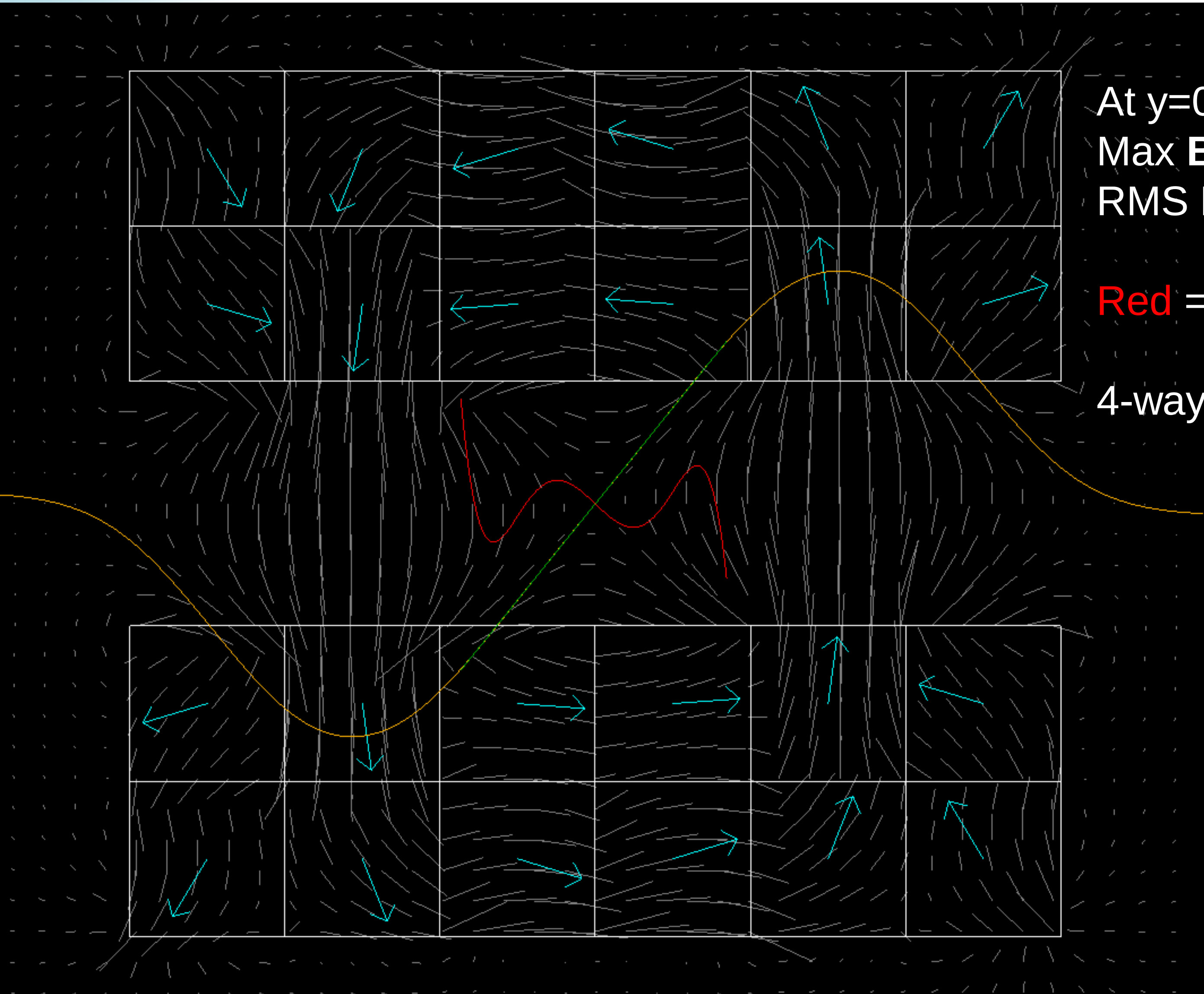
Field Model Parameters

- Consider a 2D problem
- Start with field of infinite wire: $|\mathbf{B}| = \mu_0 I_z / 2\pi r$
- This is analytically integratable into a infinite sheet of finite width (using atan and ln)
- $\mu_0\mathbf{M}$ has units of magnetic field (Tesla)
  - Also equal to $\Delta\mathbf{B}$ across an infinite plane boundary
  - This is the remnant field
- Used "SmCo" with 1.1T constant remnant field

Orientations = 2θ "Halbach" Law



Optimised for Min. RMS B Error

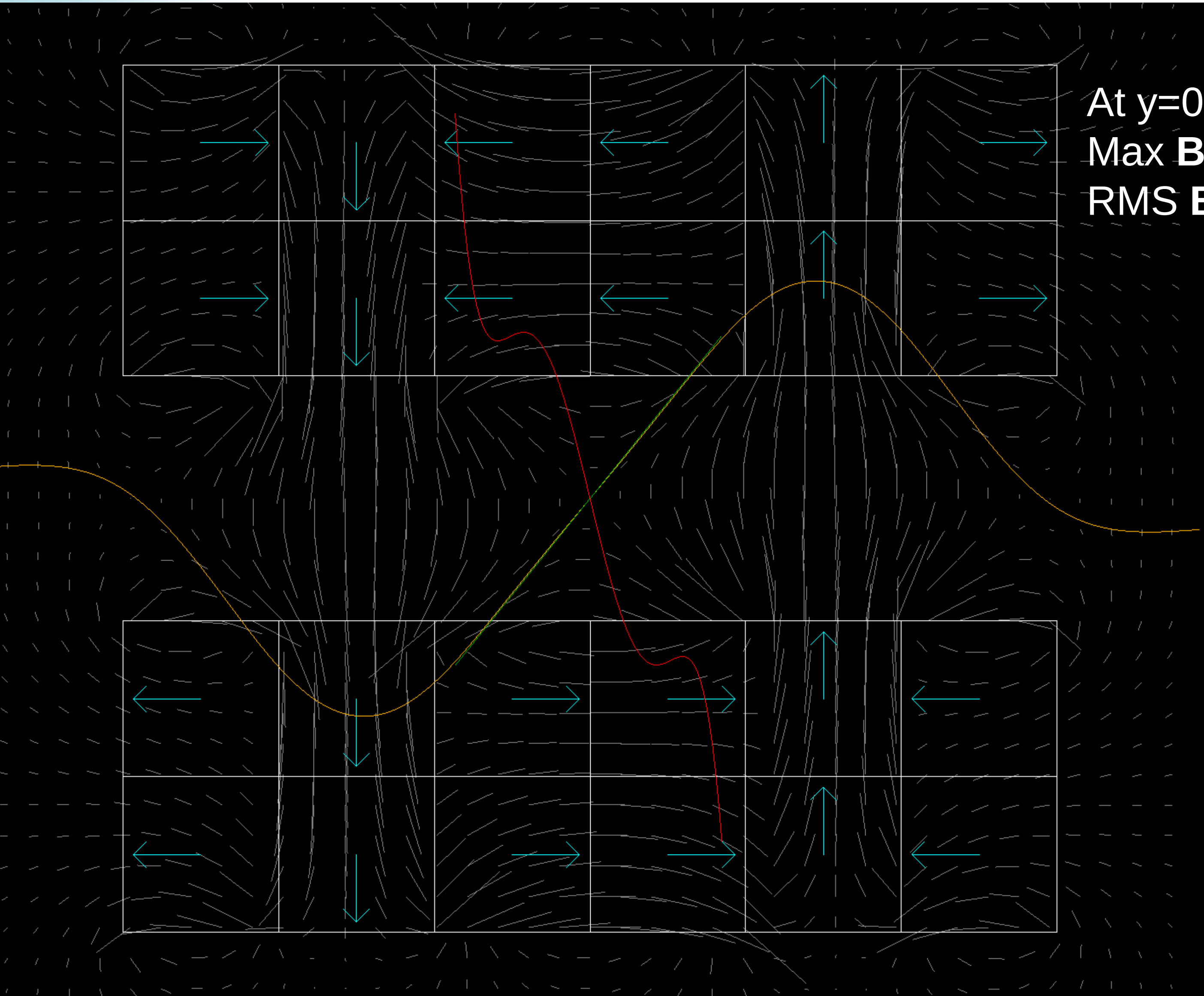


At y=0, |x|<11mm:
Max **B** error = 3.5mT (0.7%)
RMS **B** error = 0.9mT (0.2%)

Red = B_y error × 100

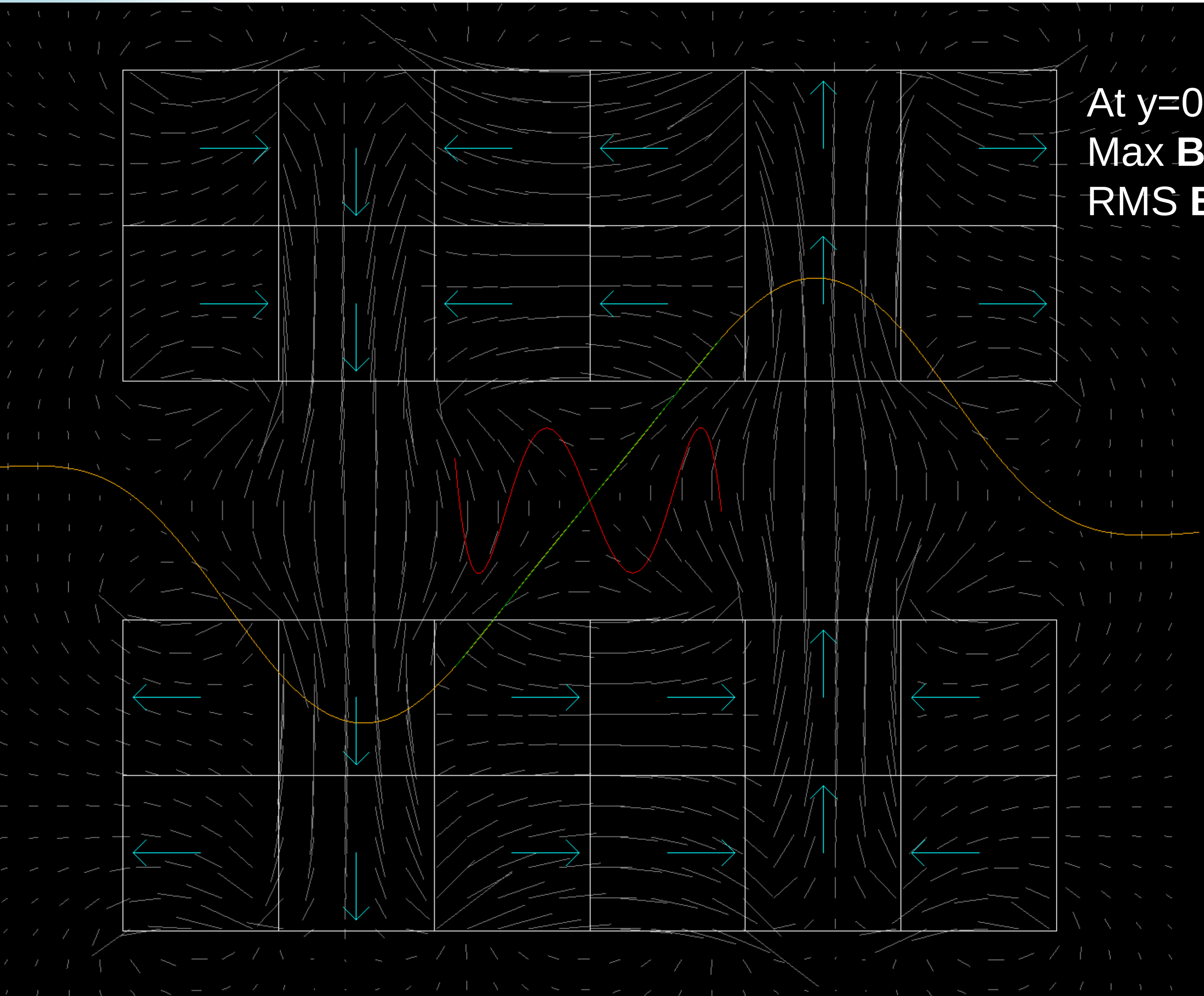
4-way symmetry enforced

Rounding Directions to 90°



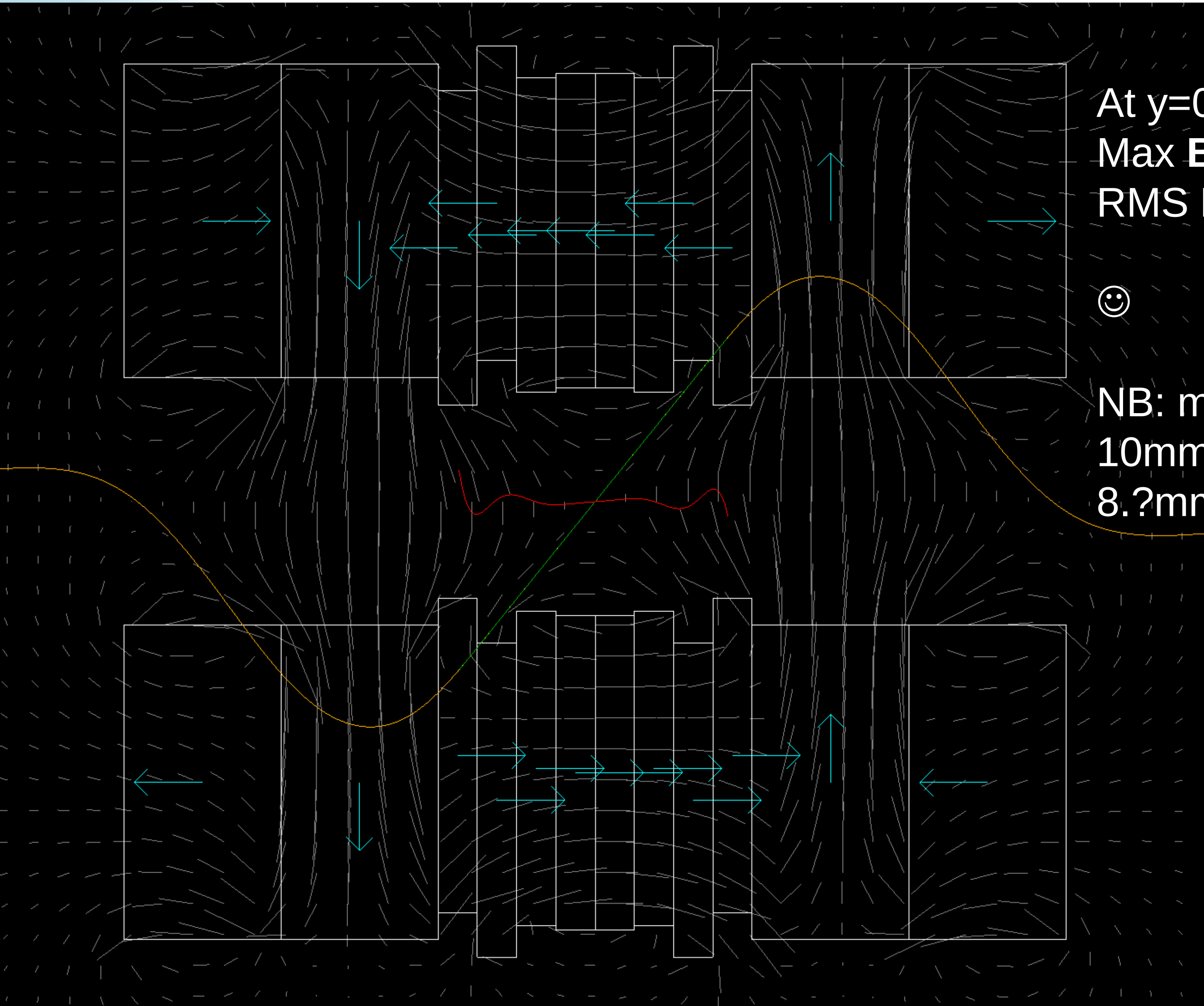
At y=0, |x|<11mm:
Max **B** error = 12.6mT (2.5%)
RMS **B** error = 5.6mT (1.1%)

Tune Slab Separation to 9.74mm



At y=0, |x|<11mm:
Max **B** error = 2.4mT (0.5%)
RMS **B** error = 1.7mT (0.3%)

Adding High Frequency Trim Blocks



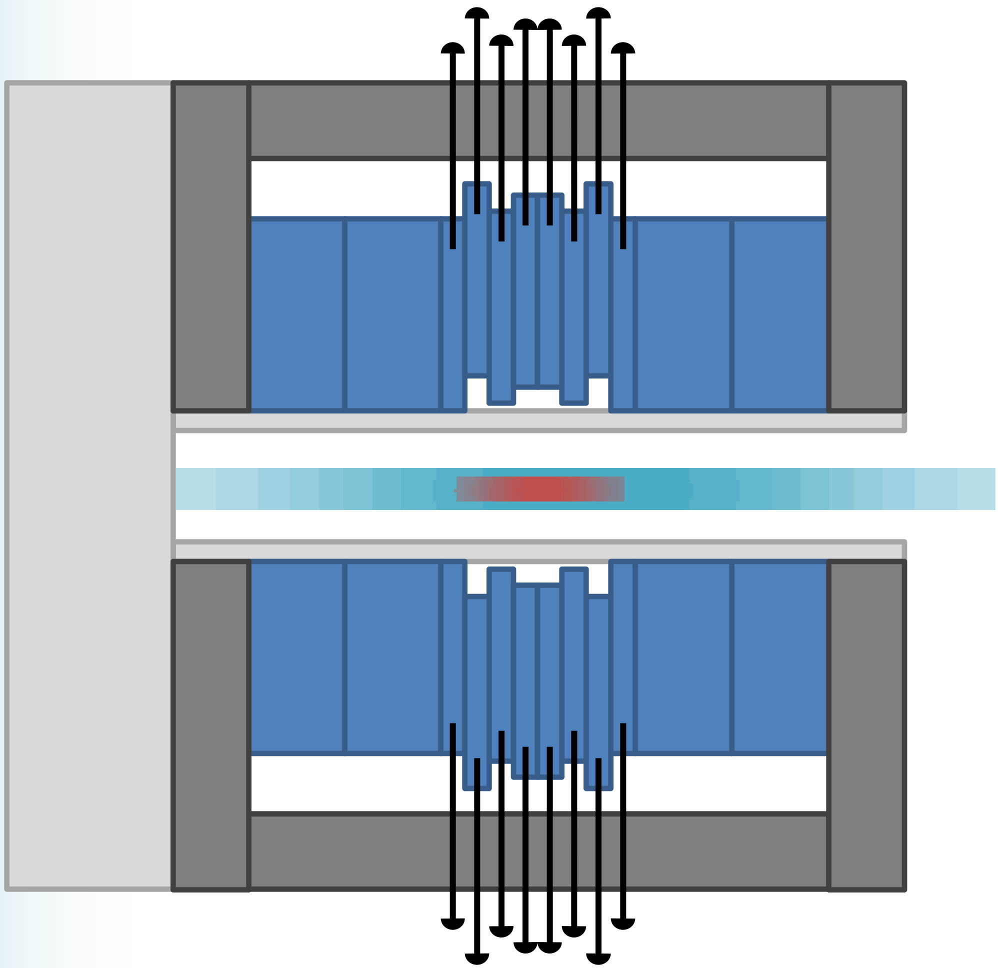
At y=0, |x|<11mm:
Max **B** error = 1.0mT (0.2%)
RMS **B** error = 0.2mT (0.04%)

☺

NB: main separation back to 10mm but some trim blocks at 8.?mm

(0.0619444,-0.0222222)
B = (-0.0496668,-0.0222796)
|B| = 0.054435

"Real-World" Version



Screws for vertical adjustments (not sure if you can tap threads into SmCo or need a connecting block)

Iron magnetic shield added to prevent field interference between the FFAGs

Non-magnetic steel or aluminium used to support and prevent magnets snapping together

Beam and SR light regions shown approximately

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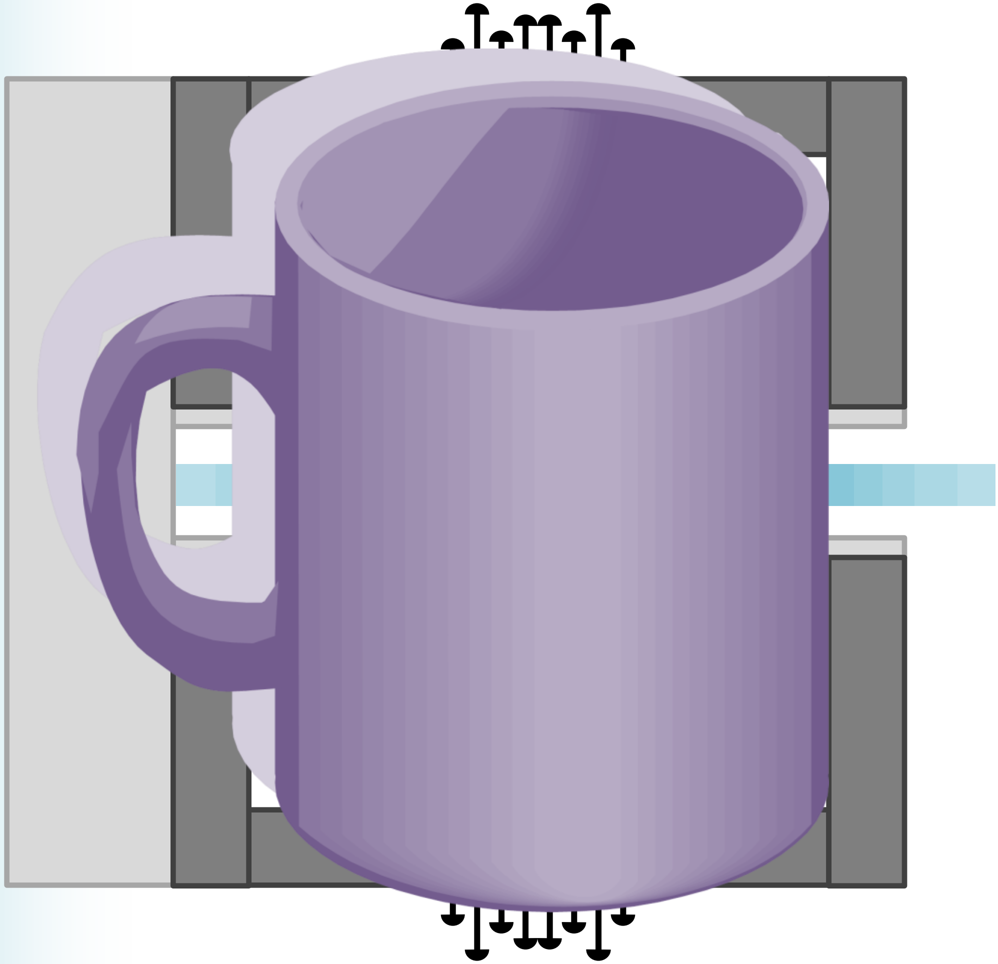

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eRHIC Magnet Future Work Plan

1. Verify this design with iron using a full-featured code (RADIA and/or SuperFish)
2. Build 20-30cm length test/tuning piece
   - Map the field using magnet division(?) equipment
   - Do the same for low-energy ring
3. Full-scale eRHIC magnet build
4. Two module (2 FFAGs, 2 cells = 8 magnets) test using AGS beam of proper rigidity?
   - Include corrector coils and position monitors