A Field Simulator for Permanent Magnet Applications

E. Ledwosinska, J. Gammel
Silicon Labs, Austin, TX, USA

Introduction:

Permanent magnets are ubiquitous in our world today, from refrigerator magnets to industrial sensor applications. Often, the magnitude of the field at a specific distance from an arbitrarily shaped magnet of variable strength is a necessary parameter for designing end-use systems. Several online magnetic field calculators exist, but are limited in the geometry and parameters the user can control. We used the “Magnetic Field, No Currents” mode of the AC/DC module of Comsol Multiphysics to simulate field strength of permanent magnets for aiding application optimization. Questions we answered were:

- Does cube/disc magnet shape affect B-field?
- How does B-field scale with magnet aspect ratio along different axes?
- How does B-field scale with magnet volume?
- How does direction of polarization affect B-field strength along different axes?
- What is the alignment tolerance along different axes?

Computational Methods:

We executed various simulations to establish optimal magnet and detector arrangement for maximal/minimal field strength and alignment tolerance. Magnet geometry, remnant flux density, and surrounding material parameters were varied. Size of solution sphere was modulated based on input magnet geometry.

Results:

Variation of B-field with aspect ratio and polarization

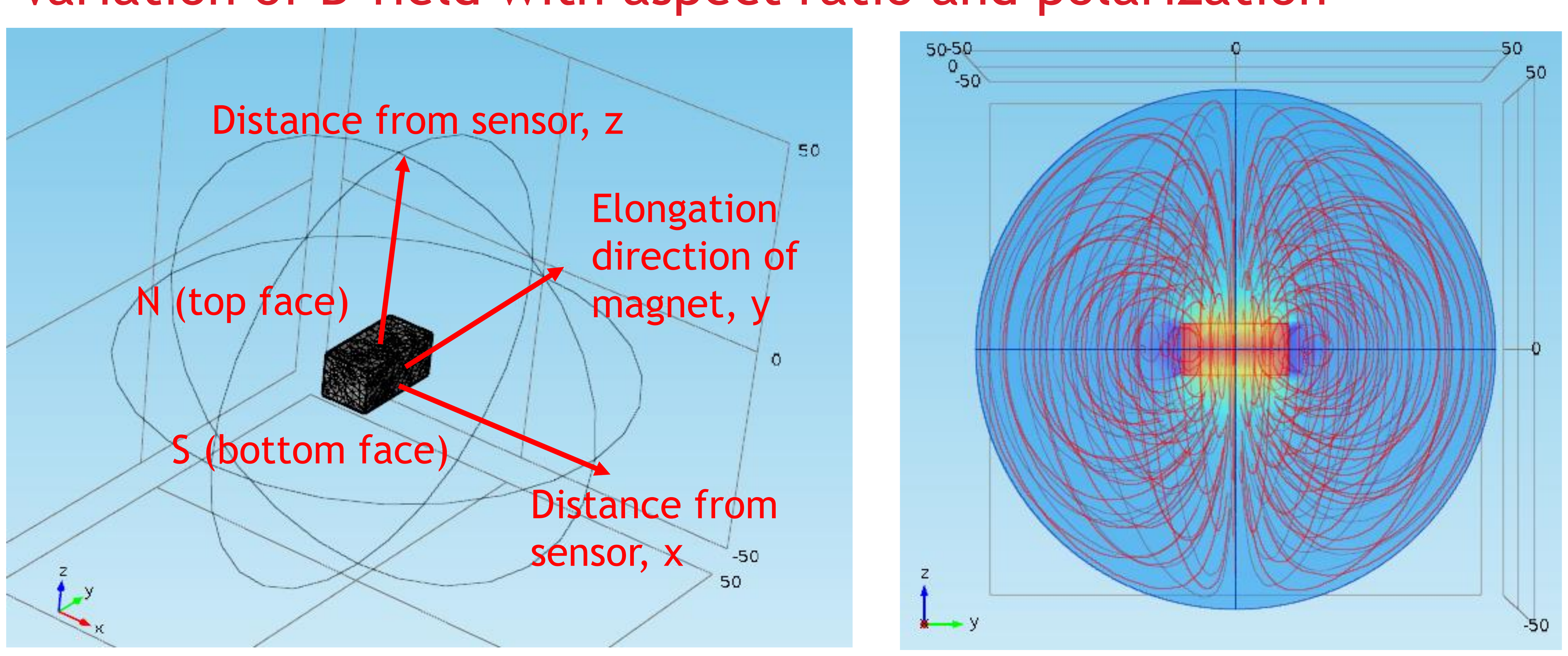


Figure 1. Geometry (left) and magnetic field line distribution (right) of bar magnet.

- Magnet volume dictates maximum B-field strength
- Fixing magnet volume and varying aspect ratio minimally affects B-field
- Polarization direction impacts field strength from magnet edge

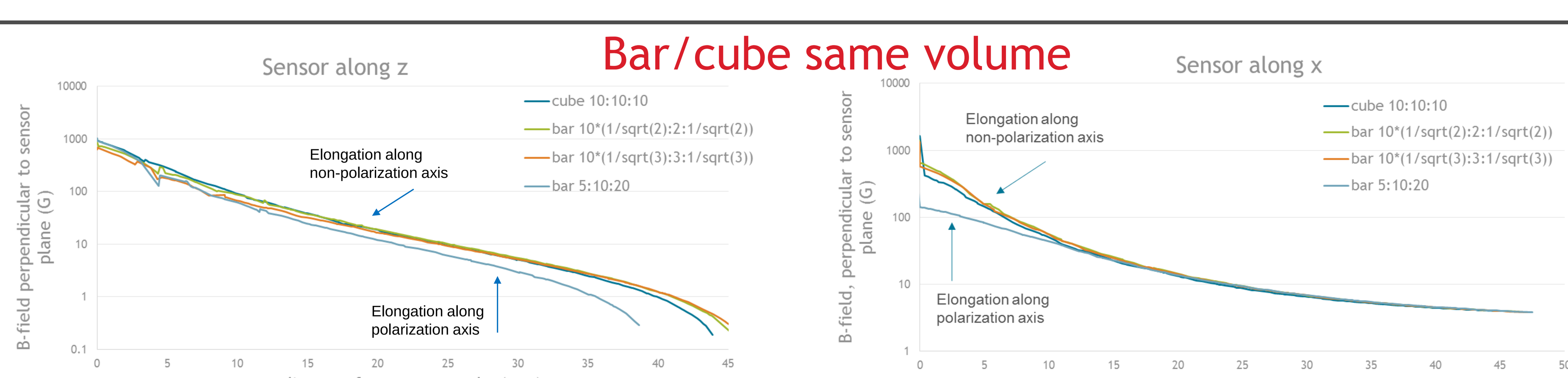
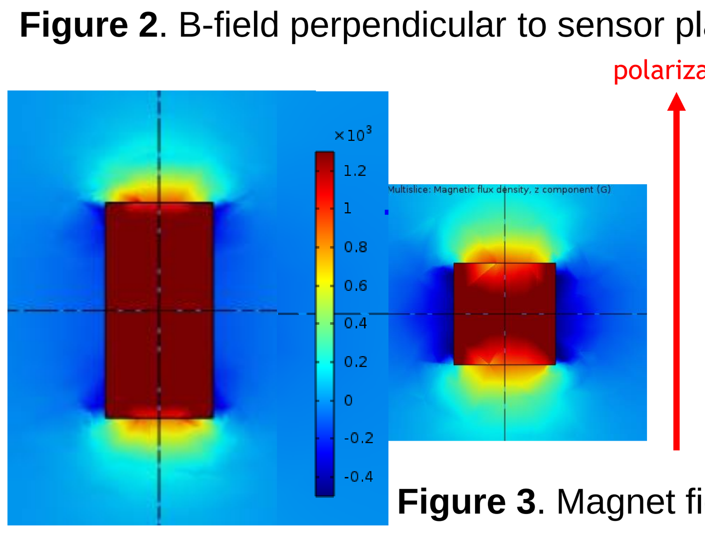


Figure 2. B-field perpendicular to sensor plane for sensor along x (left) and z(right) axis of magnet.



- Polarization in short direction → higher B-field closer to magnet edge.

Figure 3. Magnet field strength for magnet polarized along long (left) and short (right) axis.

- Negligible dependence of B-field on cube or cylinder geometry

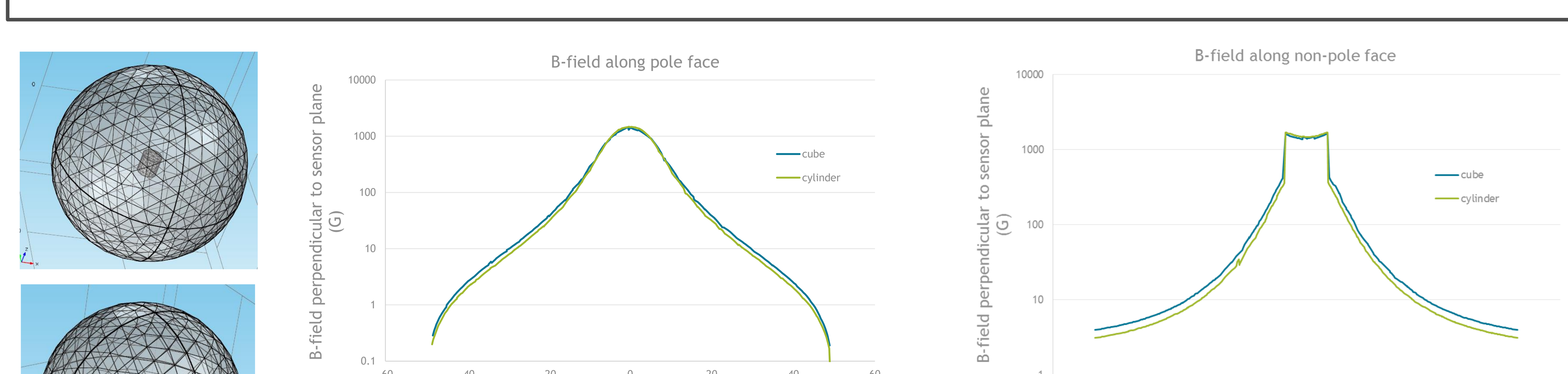


Figure 4. Magnet field strength for cube vs. cylindrical magnet geometry.

Two magnets embedded in steel disc

- Goal: to determine size and arrangement that ensure resolvable magnetic peaks
- Possible application: rotational mechanism that senses position by magnetic field.

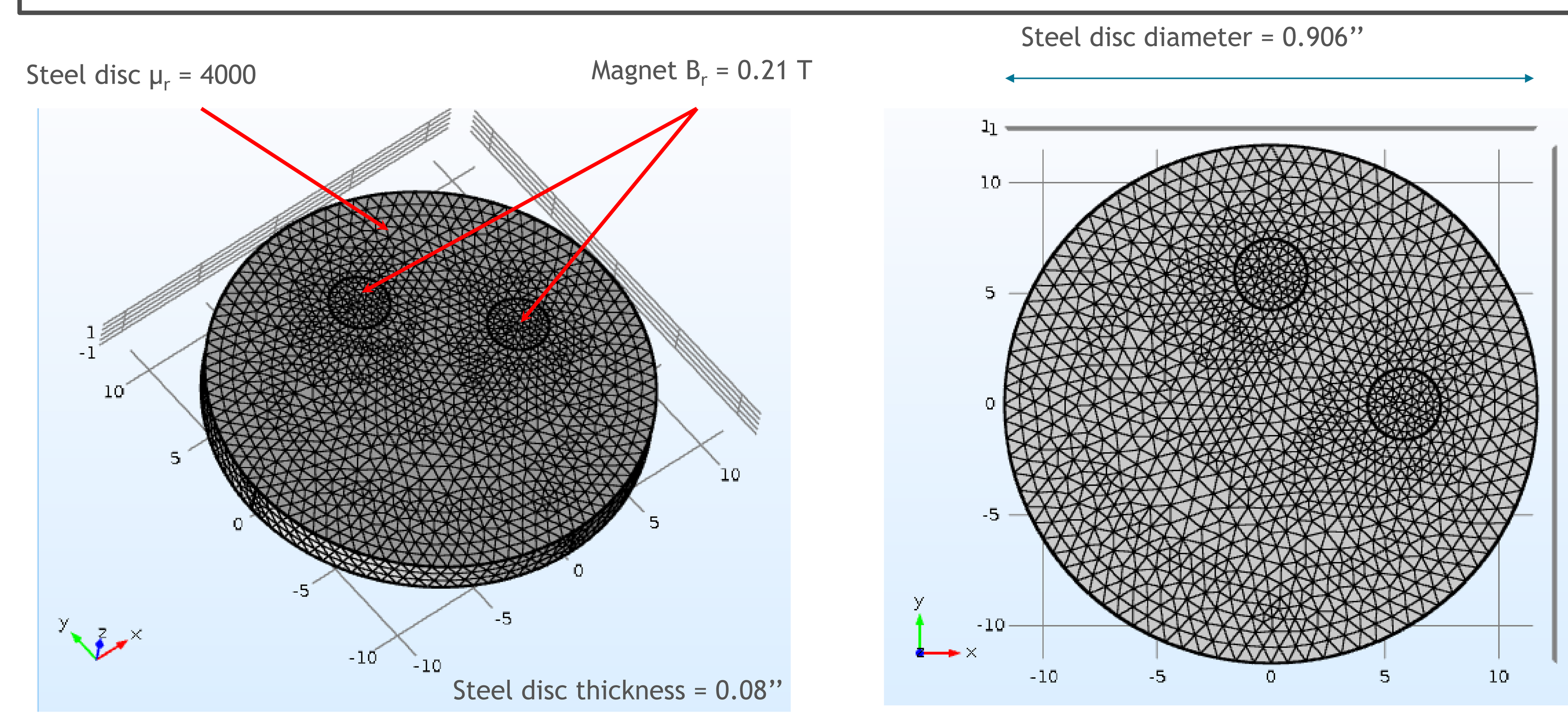


Figure 5. Geometry and material parameters of two magnets embedded in steel disc.

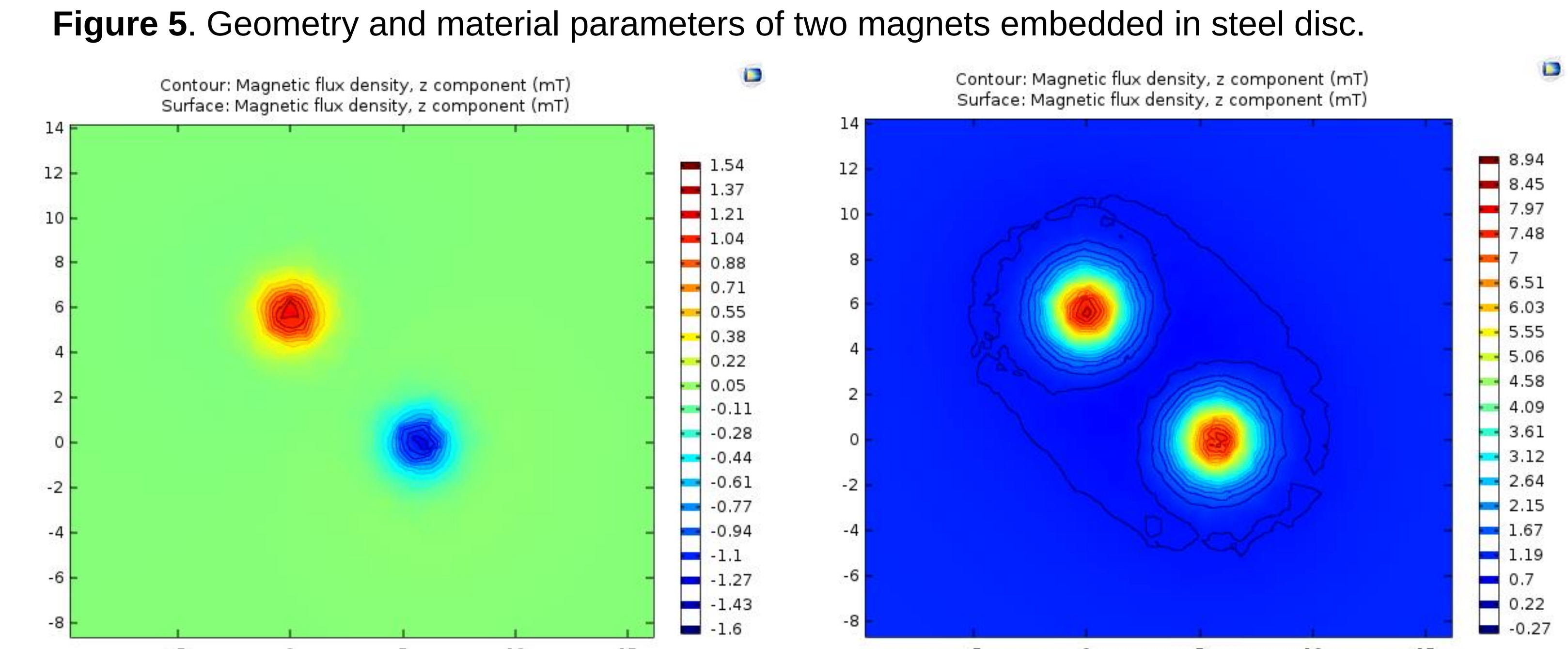
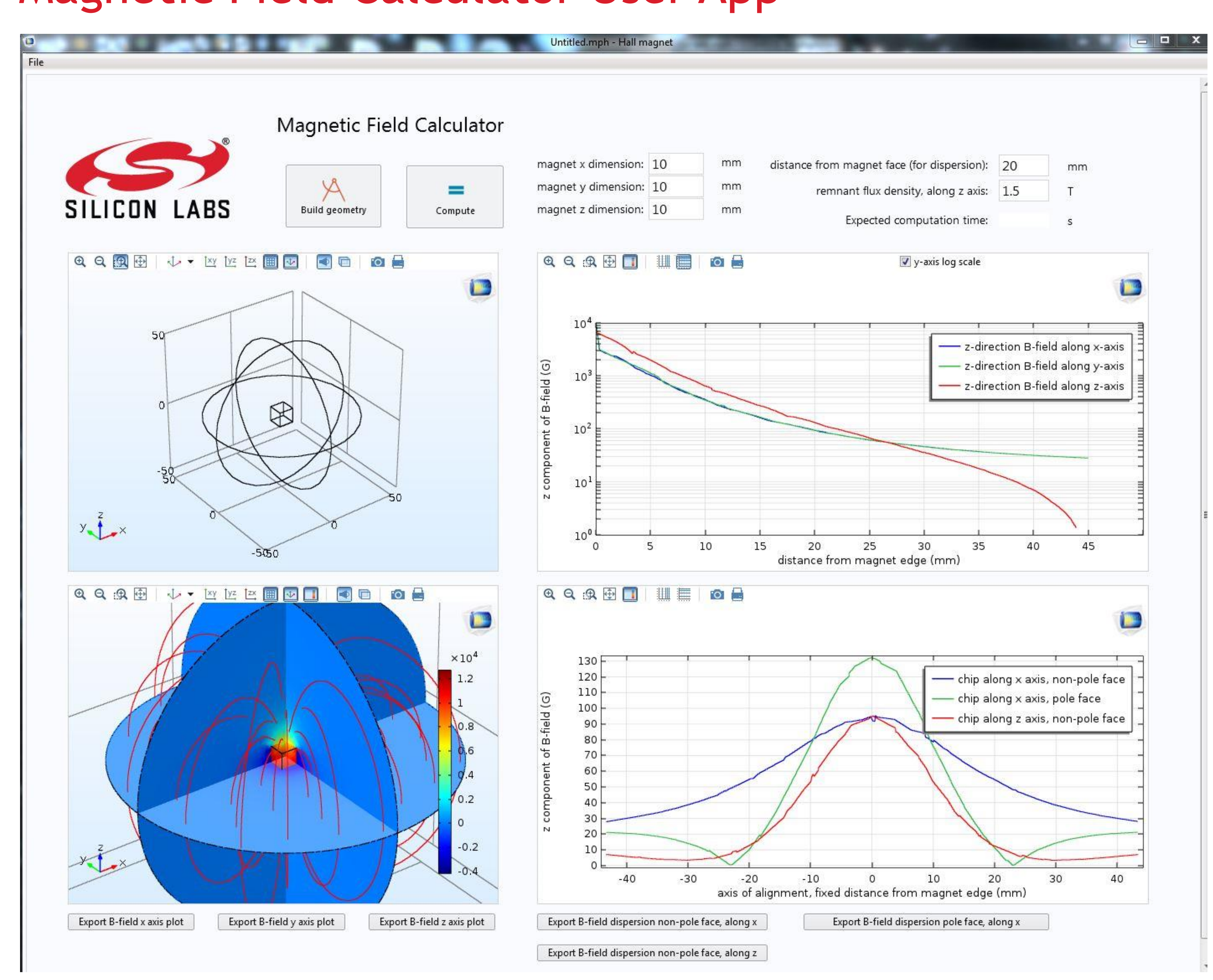


Figure 6. Contour plots show resolvable magnetic field peaks a fixed distance above the steel disc for magnets with poles oriented anti-parallel (left) and parallel (right).

Magnetic Field Calculator User App



- Comsol Application Builder used to design a comprehensive GUI for users to input material, distance, and geometrical parameters to simulate B-field and dispersion along different axes.
- In process of employing COMSOL Server™ as a tool for evaluating rectangular magnets with Hall Effect magnetic field sensors.

Conclusions:

- Various simulations yielded useful rules-of-thumb for optimal magnet/sensor set-ups for end-use customer applications, results verified with experimental magnet/sensor measurements
- A user app using Comsol Application Builder enables customers to input magnet material and geometry parameters and view field strength and sensor alignment tolerance along different axes

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