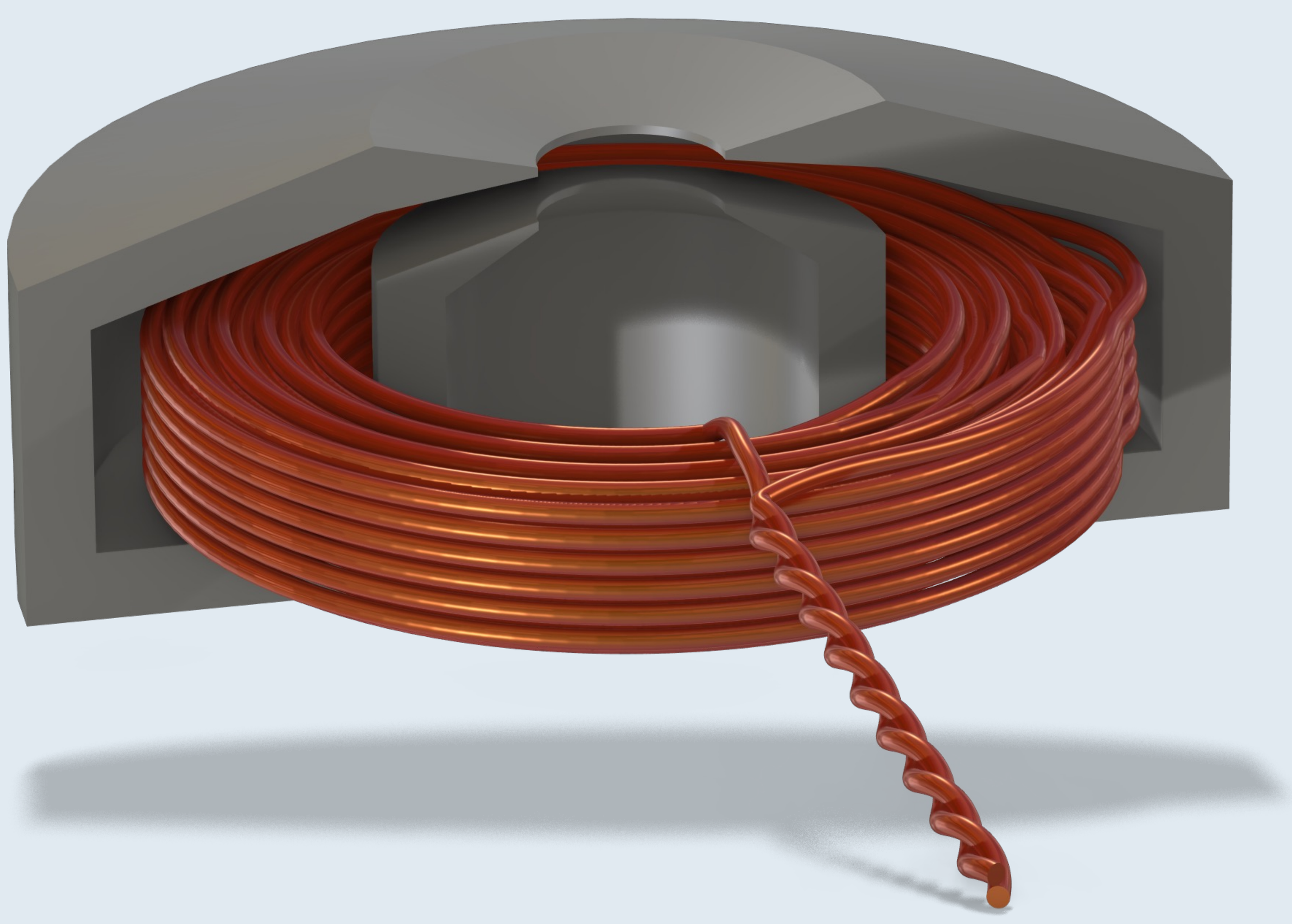

Magnetic Field Study of Circular Wire Coils with COMSOL Multiphysics®

Optimizing the magnetic field distribution generated by ideal and realistic circular wire coil configurations for electron optics applications.

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Introduction

In electron optics, precise magnetic field control is essential in semiconductor and chip production. As the industry pushes toward smaller, more complex devices, the need for advanced optics with minimal errors grows. To meet these stringent demands, continuous improvements in electron optics are vital for ensuring the quality and efficiency of future semiconductor manufacturing. The aim of this work is to minimize aberrations caused by circular wire coils of our state-of-the-art multi beam mask writer (MBMW) (Ref 1). In electron optics, the coils can be used for lensing, as well as modifying electron beam rotation. While these coils usually provide a homogeneous longitudinal magnetic field at the optical axis, the asymmetric windings of real coils can cause transversal fields that can negatively impact their performance in the optic setup. In addition, the presence of a yoke (especially its shape) highly impacts the resulting magnetic field.

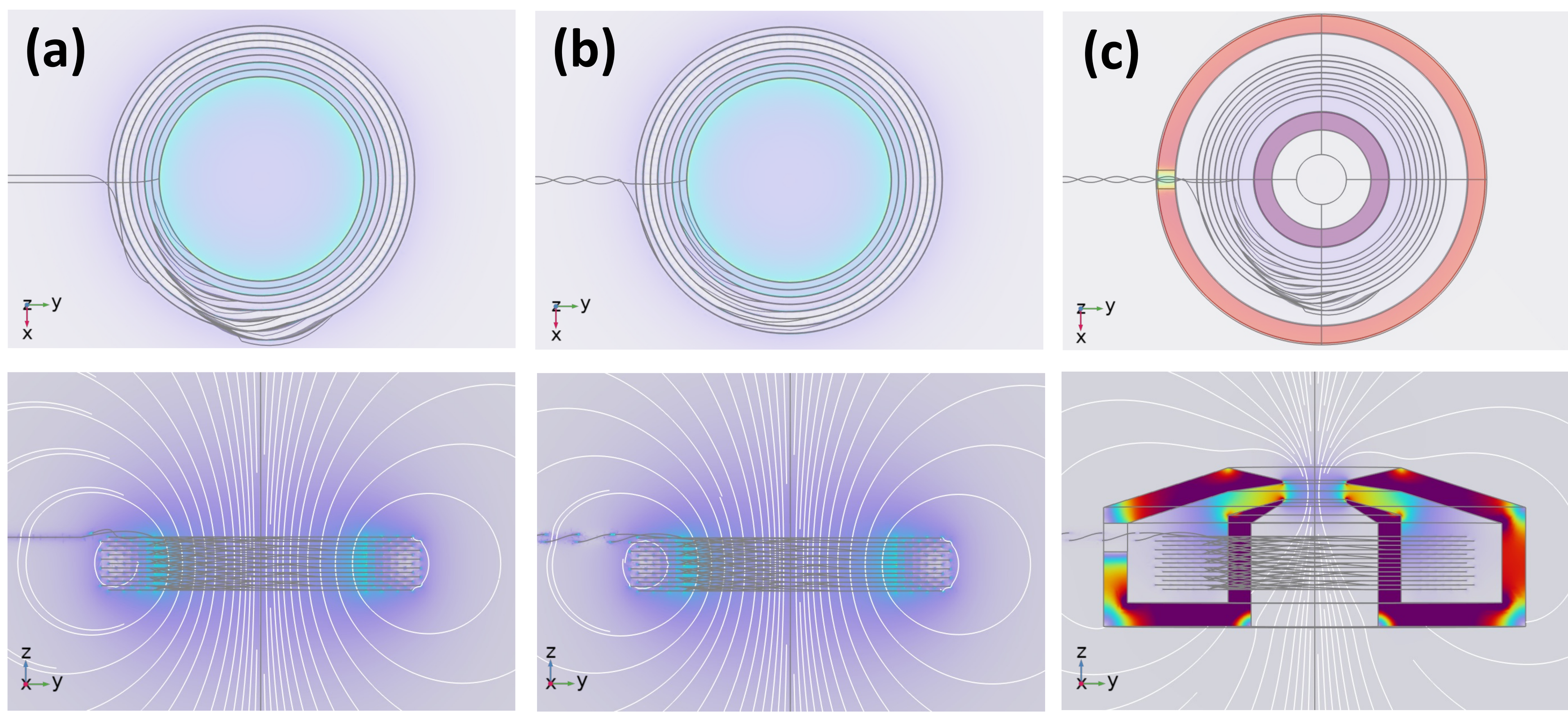

FIGURE 1. Design examples. The alternating chiralities of windings in real coils results in wire bulging (a). Note the twisted/straight (a, b) In/Out connections and iron yoke (c).

Methodology

COMSOL Multiphysics® allowed us to run detailed simulations utilizing the Magnetic Fields physics interface within the AC/DC Module. The coil was designed as a 1D curve object with a current that was applied using the Edge Current node. In some cases, a soft iron yoke was added with a custom magnetization curve, as can be seen in Figure 1(c). The magnetic field along the coil's longitudinal and transverse axis was studied, especially the impact of various configurations of In/Out connections (Figure 1 (a, b)), layer transitions between windings, coil bulging due to limited volume (Figure 1(b)), and the presence of the yoke. The primary objective was to maximize the longitudinal magnetic field component B_z while minimizing the transverse components B_x and B_y, which arise due to coil imperfections.

Results

Our results indicate that some designs approaches can significantly influence the magnetic field distribution. As can be seen in Figure 2, some coil properties, such as In/Out connection types, hardly influence the magnetic flux at the axis. Others designs types, such as the addition of wire bulging or the presence of the yoke, significantly influence the shape, magnitude, and peak positions of the magnetic flux. Yoke strongly decreases transversal fields and increases the longitudinal flux at the optical axis.

This workflow was vital for minimizing aberrations in the elements of our optical system by optimizing the wire coil and yoke geometry, as well as estimating the errors they create.

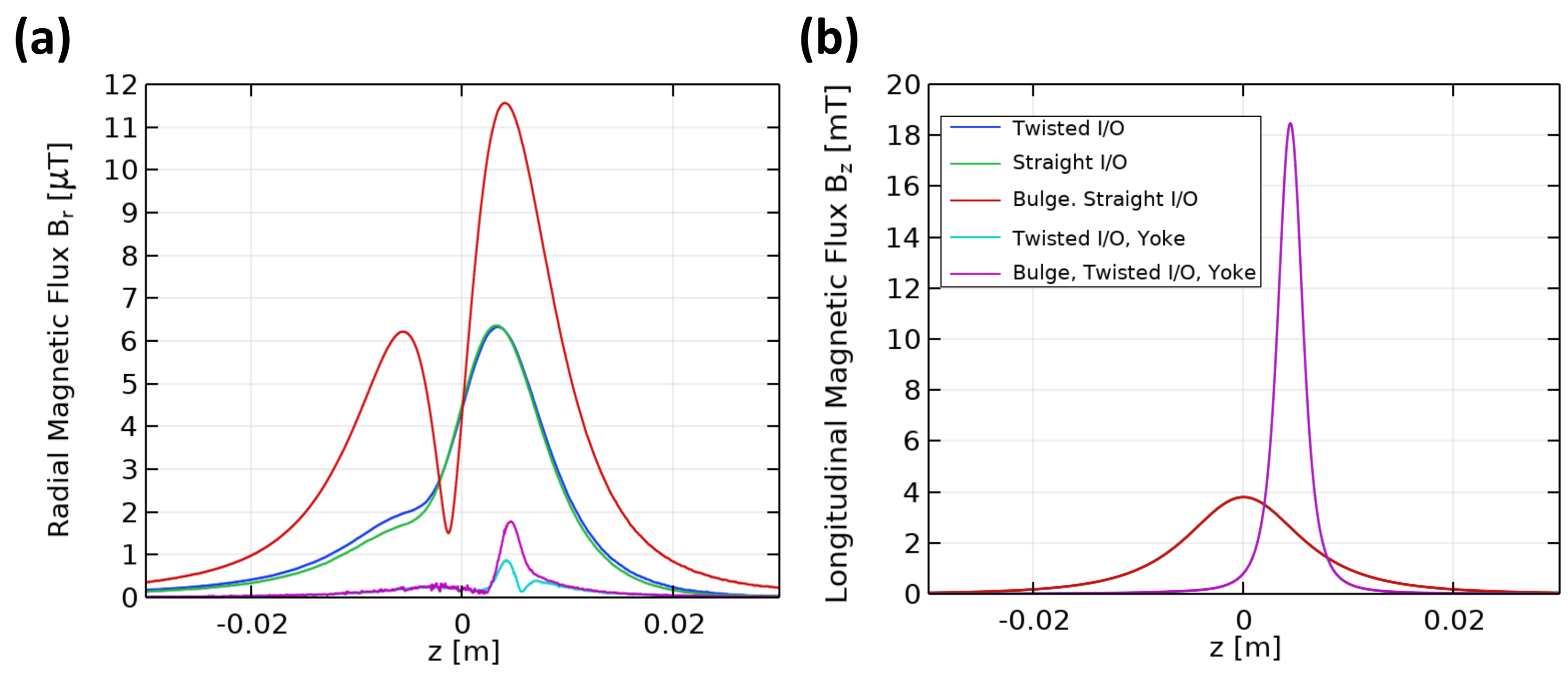

FIGURE 2. Radial (a) and longitudinal (b) components of the magnetic flux on the vertical axis for several coil designs.

REFERENCES

1. C. Klein and E. Platzgummer, "MBMW-101: World's 1st high-throughput multi-beam mask writer", Photomask Technology 2016 SPIE, vol. 9985, pp. 998505, 2016.

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