Halbach 2.0 – Creating homogenous fields with finite size magnets

Ingo Rehberg[1] and Peter Blümler[2]

1) Experimental Physics, University of Bayreuth, 95440 Bayreuth, Germany
2) Institute of Physics, University of Mainz, 55128 Mainz, Germany

Homogenous magnetic fields can be created by suitable arrangements of permanent magnets, with Halbach rings being a well-established approach [1,2]. These rings are most effective when composed of very long (theoretically infinite) magnetic rods, modeled as line dipoles.

However, the classical Halbach concept is inherently limited when dealing with finite-sized permanent magnets. To overcome this, three-dimensional configurations of such magnets have been explored. In [3], optimal designs for both single and stacked rings of point dipoles are presented, achieving superior field strength and homogeneity compared to the original Halbach design and previous numerical approximations [4].

The key innovation is the so-called *focused configuration*, achieved by tilting the dipoles out of the plane of the ring. This design enables highly homogeneous fields that are shifted out of the magnet plane—an essential feature for single-sided magnetic resonance applications [5].

Furthermore, rotating these tilted rings relative to one another further enhances field homogeneity, albeit at the expense of a uniform field direction. However, such configurations remain suitable for NMR, as the field vector rotates only within the transverse plane of the rings, while the axial direction remains stable and can be used for rf excitation.

The theoretical predictions are validated through experimental realizations of various magnet arrangements using cuboid magnets (see Fig. 1).

The results demonstrate that these novel configurations effectively overcome the limitations of finite-sized magnets in Halbach arrays, providing enhanced field strength and homogeneity. This makes them particularly well-suited for applications in mobile magnetic resonance.

All configurations can be explored, analyzed, and exported for 3D printing via a dedicated Python GUI [6].

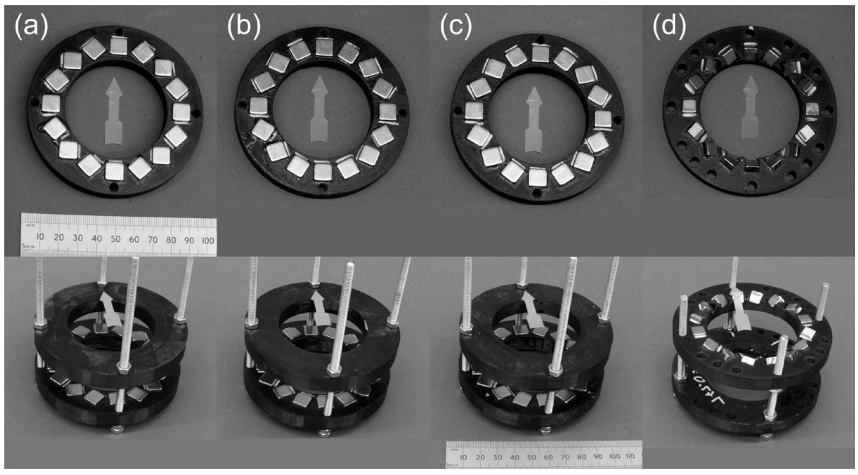

Fig. 1: Top row single rings, bottom row stacked version. (a) classical Halbach, (b) according to [4], (c,d) focused configuration (c) with focal length, f=0 , and (d) f = -0.576.

References:

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