Supplementary data

Magnetic force-based multiplexed immunoassay using superparamagnetic nanoparticles in microfluidic channel

Kyu Sung Kim and Je-Kyun Park*

Department of BioSystems, Korea Advanced Institute of Science and Technology (KAIST),
373-1 Guseong-dong, Yuseong-gu, Daejeon 305-701, Korea

E-mail address: jekyun@kaist.ac.kr

The magnetic fields outside a rectangular magnet were determined by following eqs\(^1\):

\[
\mathbf{B}_x(x, y, z) = \frac{\mu_0 M_s}{4\pi} \sum_{k=1}^{2} \sum_{m=1}^{2} (-1)^{k+m} \ln \left[ \frac{(y - y_1) + [(x - x_m)^2 + (y - y_m)^2 + (z - z_k)^2]^{1/2}}{(y - y_2) + [(x - x_m)^2 + (y - y_2)^2 + (z - z_k)^2]^{1/2}} \right]
\]

\[
\mathbf{B}_y(x, y, z) = \frac{\mu_0 M_s}{4\pi} \sum_{k=1}^{2} \sum_{m=1}^{2} (-1)^{k+m} \ln \left[ \frac{(x - x_1) + [(x - x_1)^2 + (y - y_m)^2 + (z - z_k)^2]^{1/2}}{(x - x_2) + [(x - x_2)^2 + (y - y_m)^2 + (z - z_k)^2]^{1/2}} \right]
\]

where \(\mathbf{B}_x\) and \(\mathbf{B}_y\) is magnetic field in the direction of \(x\)-axis and \(y\)-axis, respectively, \(\mu_0\) is the vacuum permeability, \(M_s\) is a magnetization of the magnet and \((x_1, x_2), (y_1, y_2)\) and \((z_1, z_2)\) denote the positions of the edges of the magnet with respect to the \(x\)-, \(y\)-, \(z\)-axes. The magnet is magnetization along \(z\)-axis. The magnetic fields and magnetic field gradients were evaluated using above eq 1 and eq 2 using MATLAB (The MathWorks, MA). We set \(x_1 = -50\), \(x_2 = 0\), \(y_1 = 0\), \(y_2 = 25\), \(z_1 = 0\), \(z_2 = 10\) mm and \(M_s = 9.0 \times 10^6\) A m\(^{-1}\) (Fig. 1a). As shown in Fig. 1b and 1c, we evaluate \(\mathbf{B}_x\) and \(\mathbf{B}_y\) across a surface from \((1, 0)\) to \((7, 25)\) at \(z = 1\) mm. The
magnetic fields were over 0.2 T. These values were enough to saturate magnetization of iron oxide magnetic nanoparticles.\textsuperscript{2-4} Therefore, the velocities of microbeads conjugated with magnetic nanoparticles are proportional to the magnetic field gradient, $\nabla \mathbf{B}$. The magnetic field gradients, $dB_x/dx$ at $y = 10$ mm and $dB_y/dy$ at $x = 2$ mm, were calculated. As shown in Fig. 1d and 1e, the magnetic field gradient along y-axis, $dB_y/dy$, is much less than the magnetic field gradient along x-axis, $dB_x/dx$. Therefore, the effect of the magnetic field gradient along y-axis, $dB_y/dy$, could be nearly ignored.

References


Fig. 1 (a) Scheme of a NdFe35 permanent magnet and the location of a microfluidic device from the permanent magnet. (b) The evaluated magnetic field along x-axis by NdFe35 permanent magnet across a surface from (1, 0) to (7, 25) at z = 1 mm. The channel of microfluidic device was aligned from y = 7.5 mm to y = 12.5 mm at x = 1, 2, 3, 4, 5, 6, 7 mm and z = 1 mm. (c) The evaluated magnetic field along y-axis by NdFe35 permanent magnet across a surface from (1, 0) to (7, 25) at z = 1 mm. The channel of microfluidic device was aligned from y = 7.5 mm to y = 12.5 mm at x = 1, 2, 3, 4, 5, 6, 7 mm and z = 1 mm. (d) Calculated values of the magnetic field gradient in the x-direction, dB_x/dx, at y = 10 mm and z = 1 mm. (e) Calculated values of the magnetic field gradient in the y-direction, dB_y/dy, at x = 2 mm and z = 1 mm.