Atom trapping simulation

January 25, 2017

Theoretical

Calculation of field intensity was done following Kimble A state-insensitive, compensated nanofiber trap, where they got the following equations for the field of a fiber with radius a.

$$E_x\left(r,\phi,z,t\right)=A_{lin}\frac{\beta_{11}J_1\left(h_{11}a\right)}{2q_{11}K_1\left(q_{11}a\right)}\left[\left(1-s_{11}\right)K_0\left(q_{11}r\right)\cos\left(\phi_0\right)+\left(1+s_{11}\right)K_2\left(q_{11}r\right)\cos\left(2\phi-\phi_0\right)\right]e^{i\left(\omega t-\beta_{11}z\right)} \quad (1)$$

$$E_y\left(r,\phi,z,t\right)=A_{lin}\frac{\beta_{11}J_1\left(h_{11}a\right)}{2q_{11}K_1\left(q_{11}a\right)}\left[\left(1-s_{11}\right)K_0\left(q_{11}r\right)\sin\left(\phi_0\right)+\left(1+s_{11}\right)K_2\left(q_{11}r\right)\sin\left(2\phi-\phi_0\right)\right]e^{i\left(\omega t-\beta_{11}z\right)} \quad (2)$$

$$E_z\left(r,\phi,z,t\right)=iA_{lin}\frac{J_1\left(h_{11}a\right)}{K_1\left(q_{11}a\right)}K_1\left(q_{11}r\right)\cos\left(\phi-\phi_0\right)e^{i\left(\omega t-\beta_{11}z\right)} \quad (3)$$

$$s_{11}=\left[\frac{1}{\left(h_{11}a\right)^2}+\frac{1}{\left(q_{11}a\right)^2}\right]\left[\frac{J_1^{'}\left(h_{11}a\right)}{h_{11}aJ_1\left(h_{11}a\right)}+\frac{K_1^{'}\left(q_{11}a\right)}{q_{11}aK_1\left(q_{11}a\right)}\right] \quad (4)$$

$$h_{11}=\sqrt{k_0^2n_1^2-\beta_{11}^2} \quad (5)$$

$$q_{11}=\sqrt{\beta_{11}^2-k_0^2n_2^2} \quad (6)$$

$$I\left(r;\phi=0,z=0,t=0\right)\equiv I\left(r\right)=\sqrt{\left|E_x\right|^2+\left|E_y\right|^2+\left|E_z\right|^2} \quad (7)$$

Here, ϕ denotes the azimuthal position in the transverse plane, ϕ_0 indicates the polarization axis for the input polarization relative to the x axis, n_1 and n_2 are the indices of refraction inside and outside the waveguide, β_{11} is the mode propagation constant, $1/h_{11}$ is the characteristic decay length for the guided mode inside the fiber, $1/q_{11}$

is the characteristic decay length for the guided mode outside the fiber, A_{lin} is the real-valued amplitude for the linearly polarized input, J_l is the lth Bessel function of the first kind and K_l is the lth modified Bessel function of the second kind.

After calculating the field intensity, we want to get the trap potential the ^{87}Rb atoms see. For this we look at a resonance frequencies of the atom and compute the dipole potential a field with certain intensity will cause (Following Optical dipole traps for neutral atoms)

$$U_{dipole}\left(r\right) = \frac{\pi c^2 \Gamma}{2\omega_0^3}\left(\frac{2+\mathcal{P}g_F m_F}{\Delta_{2,F}} + \frac{1-\mathcal{P}g_F m_F}{\Delta_{1,F}}\right) I\left(r\right) \tag{8}$$

Here g_F is the well-known Landé factor and $\mathcal{P}$ characterizes the laser polarization ($\mathcal{P} = 0, \pm 1$ for linearly and circularly $\sigma^{\pm}$ polarized light). The detunings $\Delta_{2,F}$ and $\Delta_{1,F}$ refer to the energy splitting between the particular ground state $^2S_{1/2}$, F and the center of the hyperfinesplit $^2P_{3/2}$ and $^2P_{1/2}$ excited states, respectively. The two terms in brackets represent the contributions of the $D2$ and the $D1$ line to the total dipole potential. ω_0 is the optical transition frequency of the $D1$ line, and Γ is the natural line width of this line.

Results

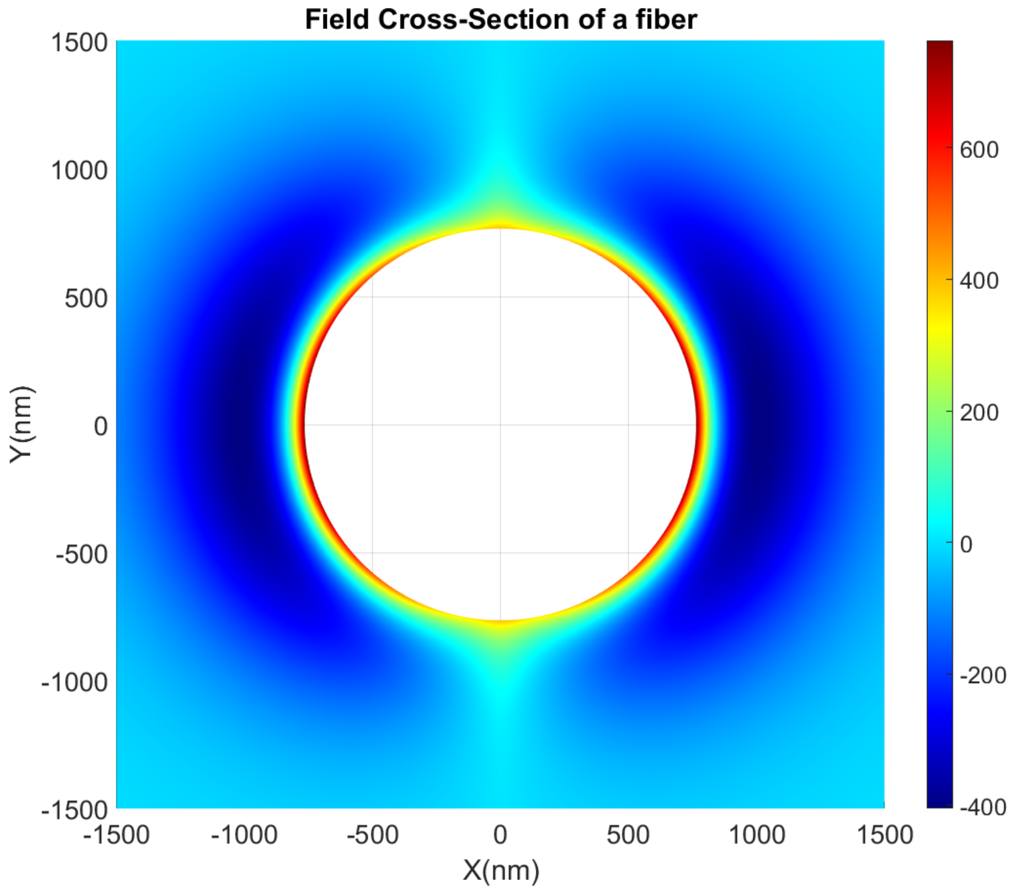

Figure 1: Fiber Red + Blue Field Cross-Section

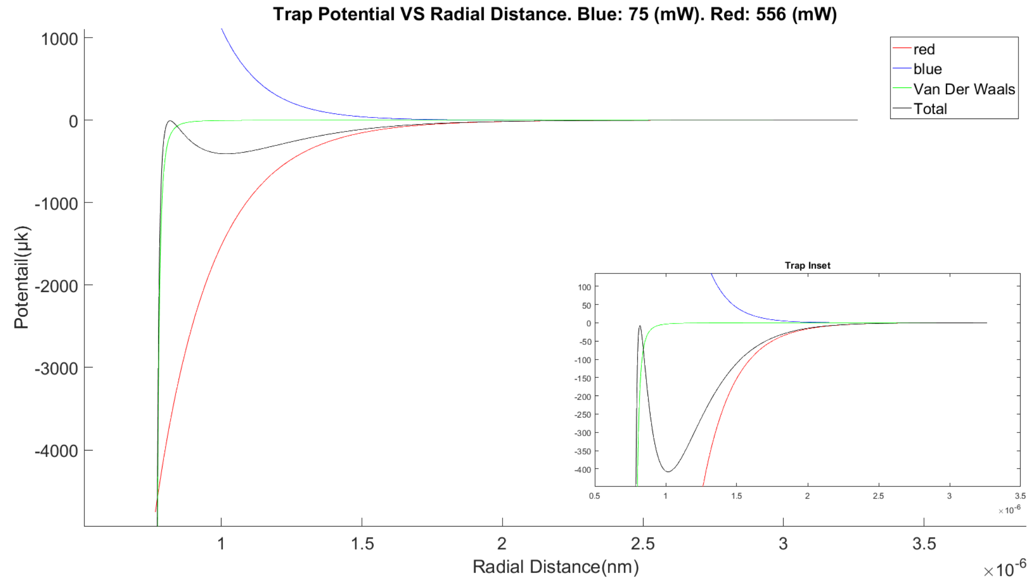

Figure 2: A slice of the total potential

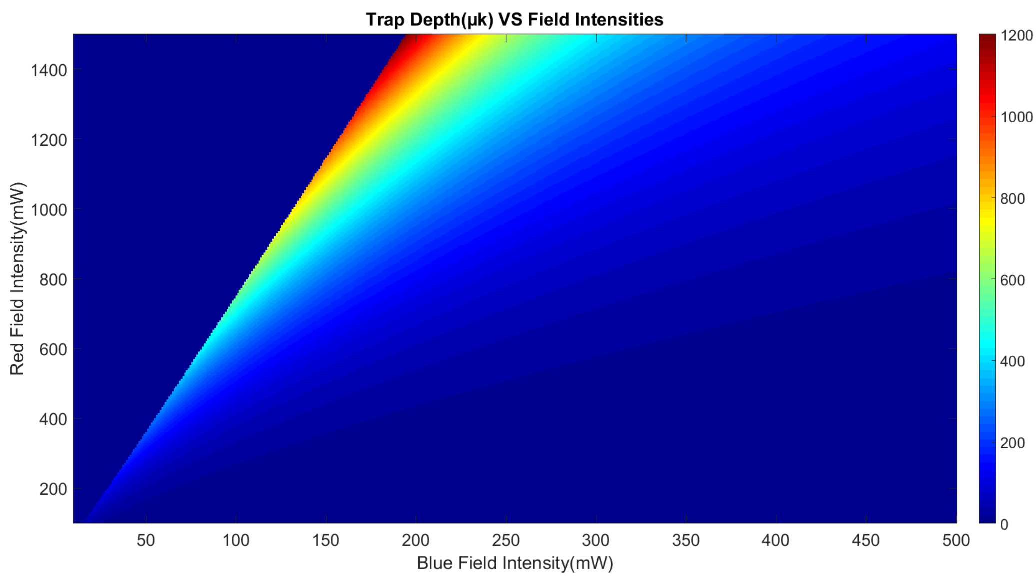

Figure 3: Trap depth for various field intensities

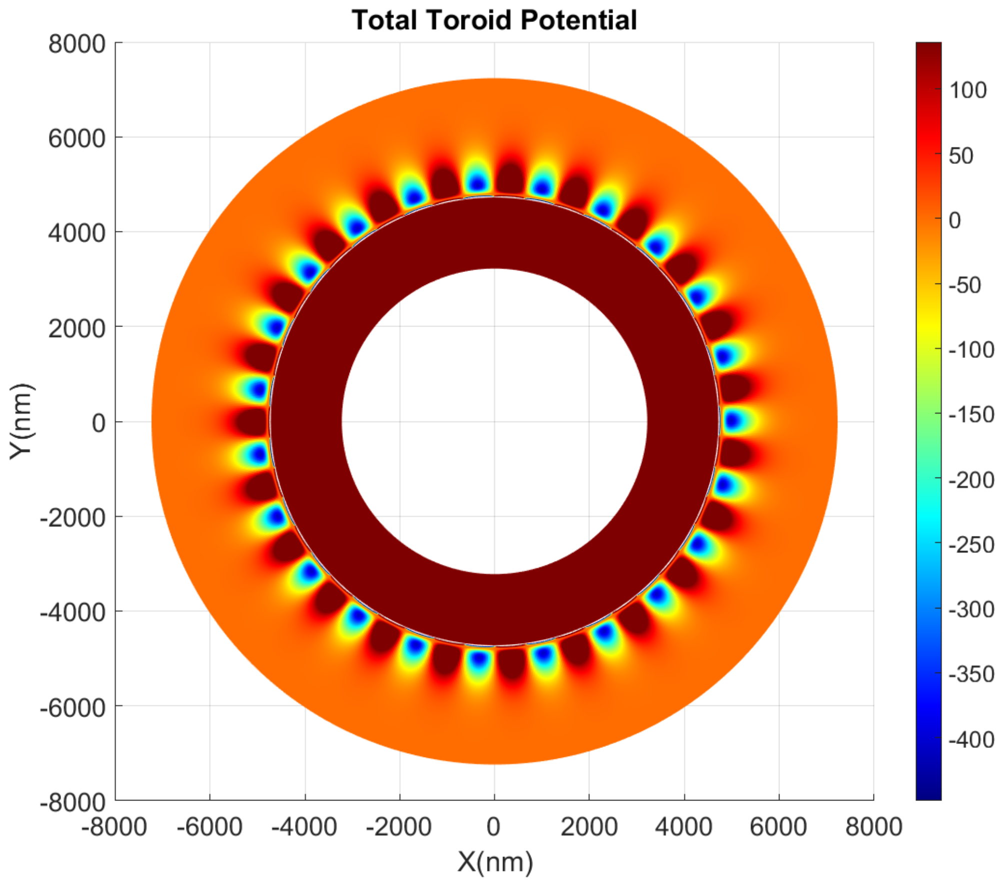

Figure 4: Top view of trap potential

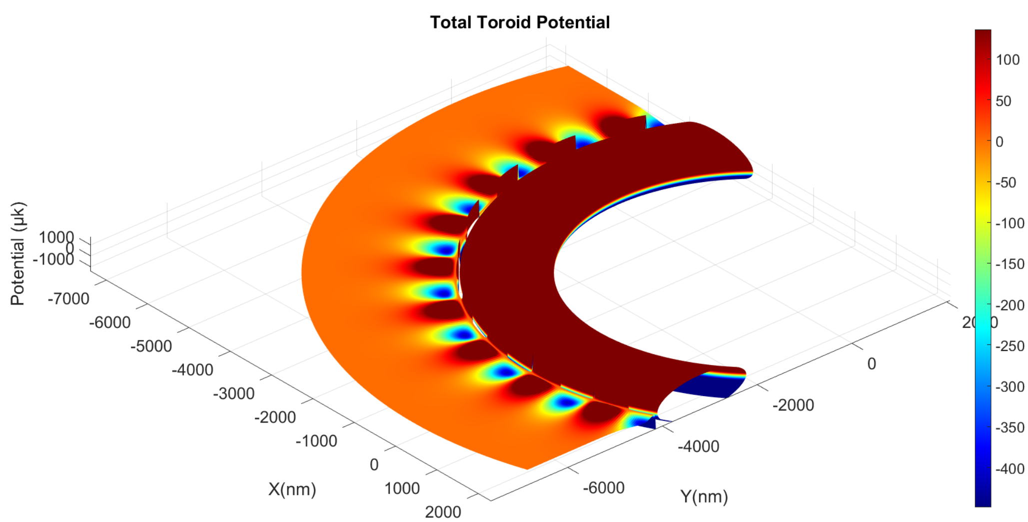

Figure 5: Perspective view of trap potential