Optical Tweezer Simulation
Overview

- This work simulates the optical trapping force on a spherical particle in a focused laser beam produced by a high numerical aperture (NA) lens using EM Explorer.

- The following simulation parameters are based on the work of Rohrbach and Stelzer [1]

  - **High-NA Lens:** $\text{NA} = 1.2$
  - **Medium:** $n = 1.33$
  - **Spherical particle:** $d = 200\text{nm}$, $n = 1.57$
  - **Focused Laser Beam**
  - **Input Paraxial Gaussian Beam:**
    - Wavelength = 1064nm
    - Fill ratio to lens aperture = 55%
  - **FDTD Simulation Domain**
Focused Laser Beam Field

- The focused electromagnetic (EM) field produced by the high-NA lens is simulated internally using the focusing lens simulation engine of EM Explorer (version 4.6).
  - The calculated field is used as the incident field to excite the FDTD simulation domain via the “focused_beam” command (version 4.6).
  - The FDTD simulation domain encloses the particle of interest.

- The focusing lens simulation engine can also be used as a standalone module in EM Explorer Pro (via “focusing_lens” command, version 4.6)
  - Independent of the FDTD simulation engine
  - Used in conjunction with other simulation engines in EM Explorer Pro (e.g., near-field to far-field simulation engine, film stack simulation engine, etc…) to propagate and transform the field.
Focused Field Amplitude in Free space

Input beam polarization = X

800nm upstream focal plane

800nm downstream focal plane

Focal plane
Particle Trapping Force

• The trapping force on a particle in a focused field can be calculated as follows [1-3].

\[ \vec{F} = \kappa \int_{V} \nabla |\vec{E}|^2 \, dv = \kappa \int_{S} |\vec{E}|^2 \, d\vec{s} \]

where the integration is over the particle volume or surface. \( \vec{E} \) is the total electric field with the presence of the particle, calculated by the FDTD simulation engine of EM Explorer. \( \kappa \) is a constant.

• A simple numerical implementation of the above trapping force calculation is written as a user-defined function in TCL scripting language. It is called by the main EM Explorer script to calculate the trapping force after the FDTD simulation is done.
Calculated trapping force as a function of particle axial position relative to focal point
References

