Soundiation: User Manual

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Version 1.0

➢ GUI start

- *Soundiation* runs on Microsoft Windows with MATLAB 2010a or above versions installed.

- *Soundiation* supports parallel computation:
  - Parallel computation greatly reduces computational time, depended on the cores number of computer.
  - To enable parallel computation, we need to activate MATLAB parallel pool by simply typing

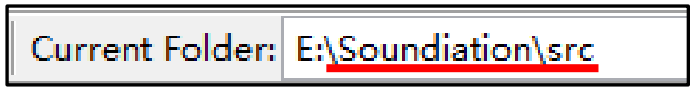
```
>> matlabpool;          % for MATLAB 2010a
```

  or

```
>> parpool;
```

  on Command Window before running the GUI.

- Start *Soundiation* in MATLAB:
  - Set the Current Folder direction to ".\Soundiation\src":



  or type

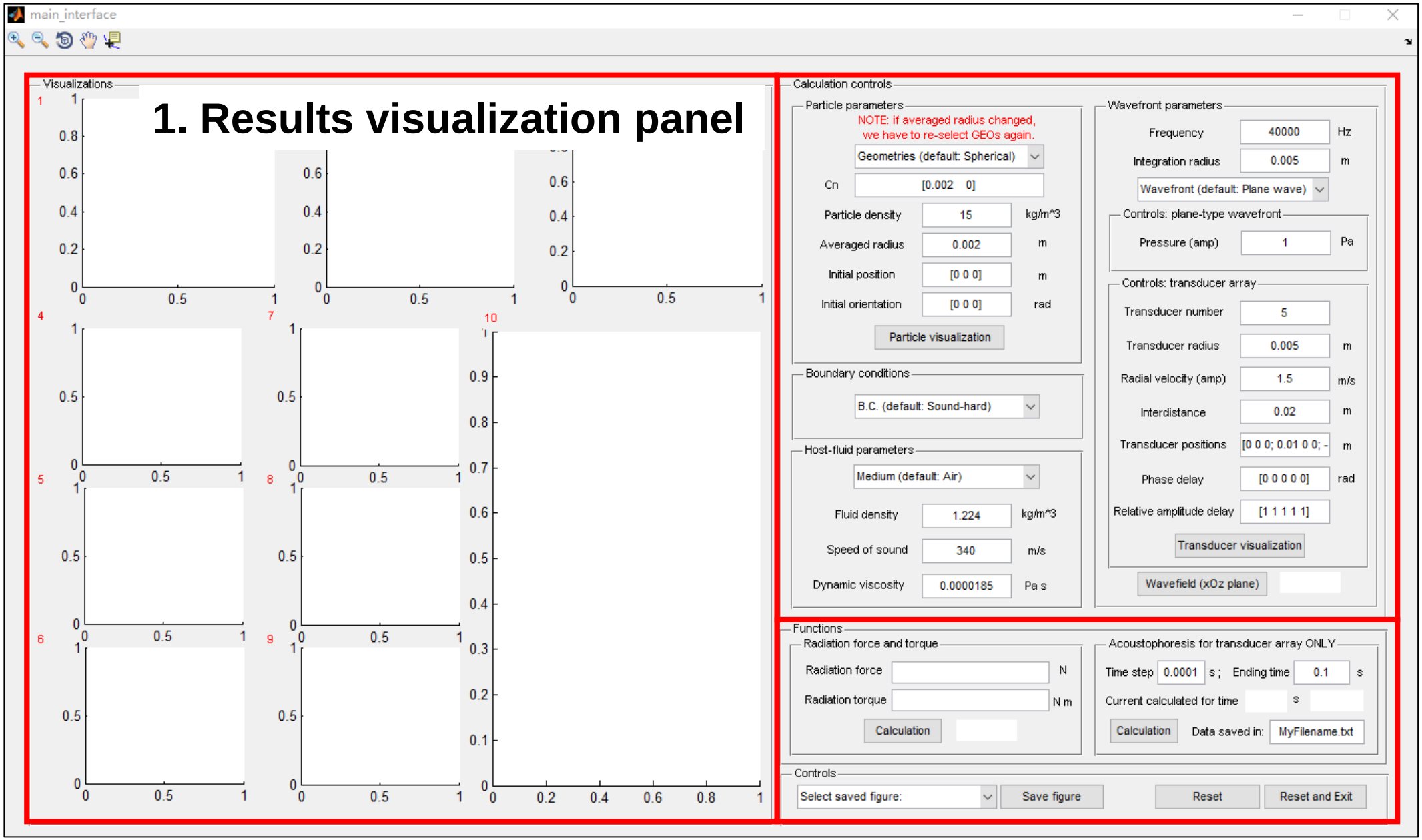
```
>> addpath('<folderpath>\Soundiation\src');
```

  on Command Window to open the interface.
  - Type

```
>> main_interface;
```

  on Command Window to open the interface.

➢ Main interface



2. Parametric control panel

3. Functional panel and Control panel

➢ Result visualization panel

Figure 1:
Visualize the levitated particle.

Figure 2:
Visualize the position relationship between transducer array and the levitated particle.
(If Transducer array (circular oscillator) feature is selected)

Figure 4 to Figure 9:
Visualize the time-variation position and orientation.
(If Transducer array (circular oscillator) feature is selected)

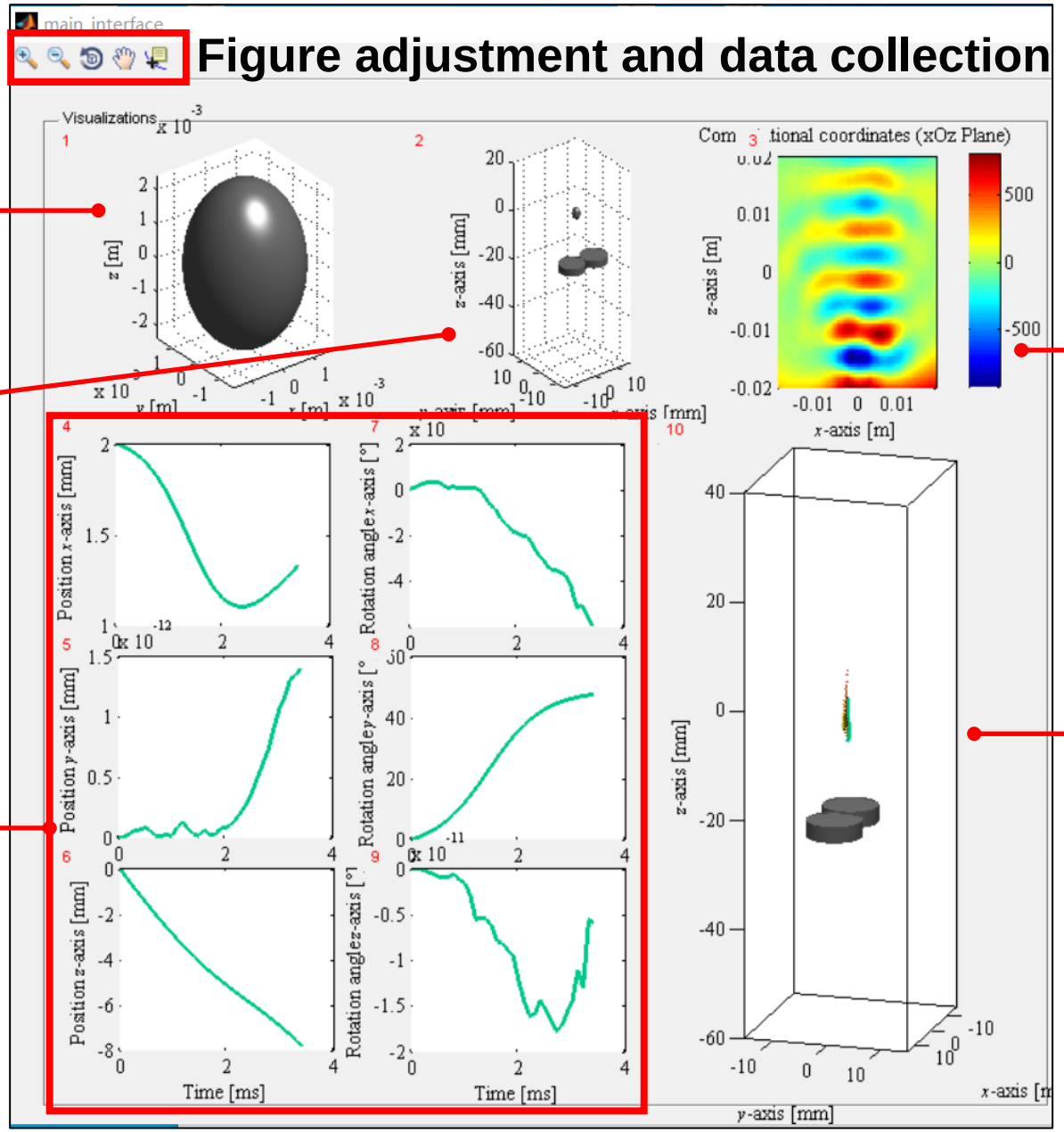


Figure 3:
Visualize incident pressure wavefield.

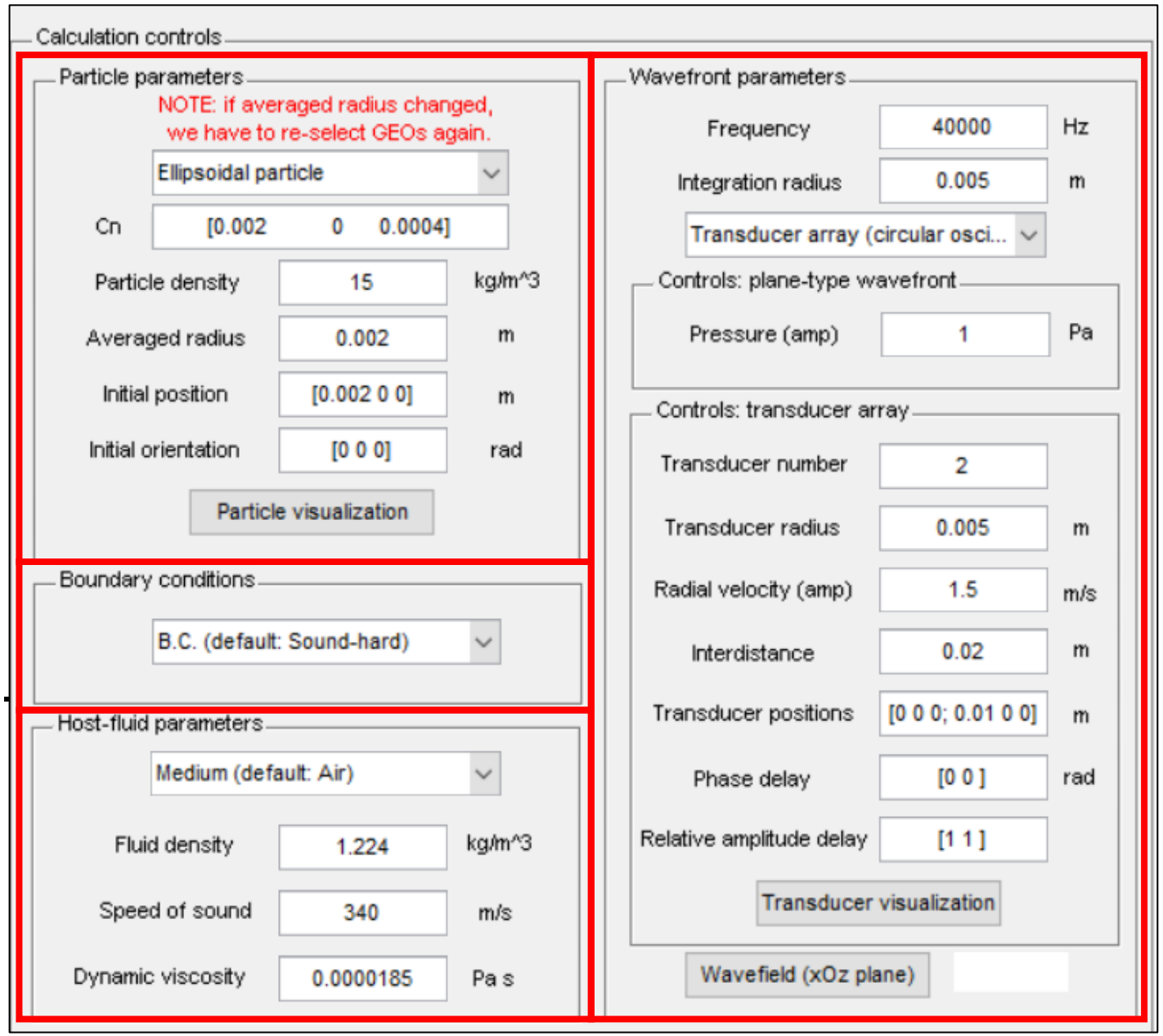
Figure 10:
Visualize the time-variation trajectory. The solid line and the arrows indicate the translational and rotational motions, respectively.
(If Transducer array (circular oscillator) feature is selected)

➢ Parametric control panel (Overall)

Particle parameters:
Define the particle physical properties.

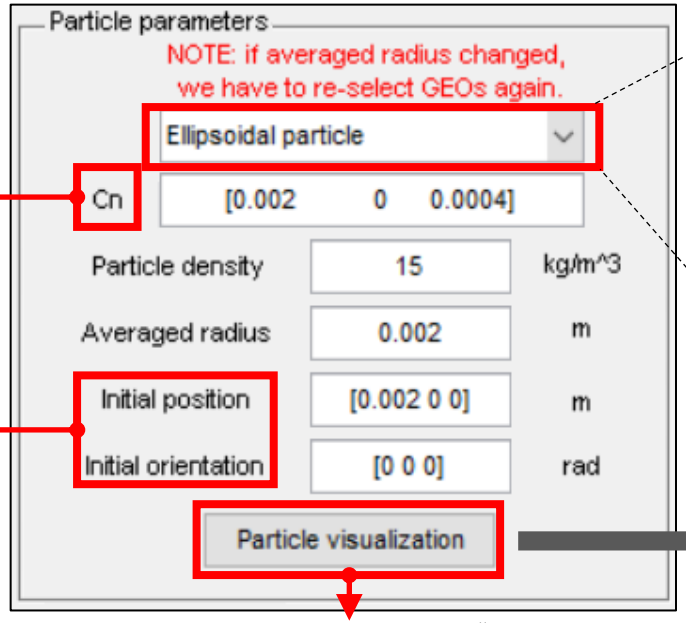
Boundary conditions:
Define the boundary condition of the particle.

Medium parameters:
Define the medium physical properties.

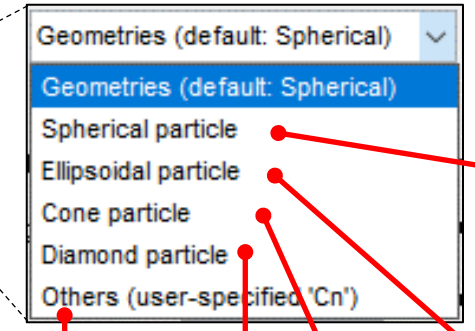


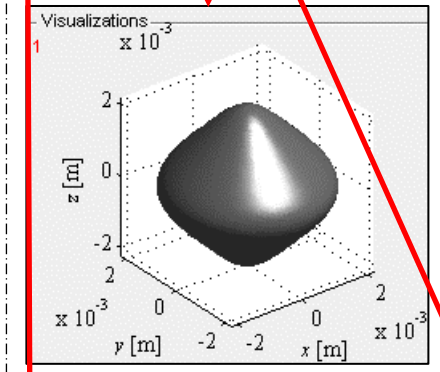
Wavefront parameters:
Define the incident wavefield.

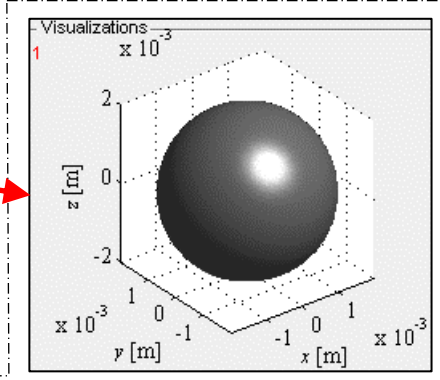
➢ Parametric control panel (Particle & Medium parameters, and B.C.)

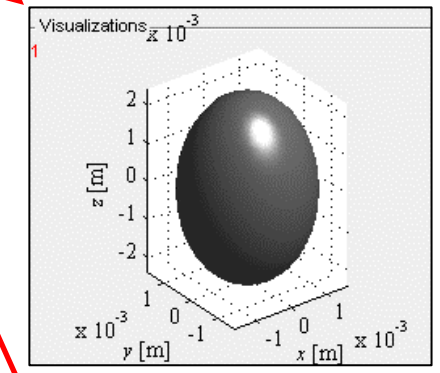


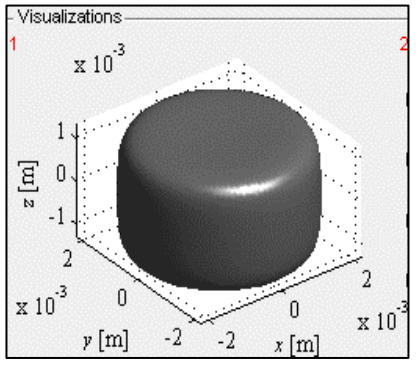
Visualize the geometry based on "Particle parameters" in **Figure 1** of "Result visualization panel"; at the same time, the particle geometric data is created and saved in "*particle_data.stl*", which can be directly imported to **COMSOL** for further numerical calculations.

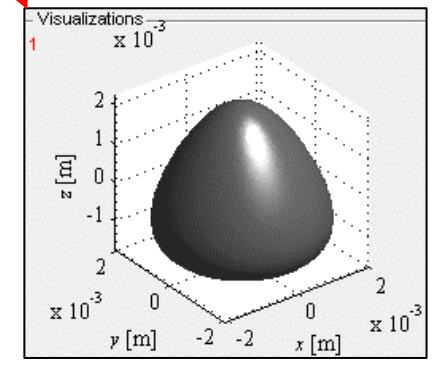






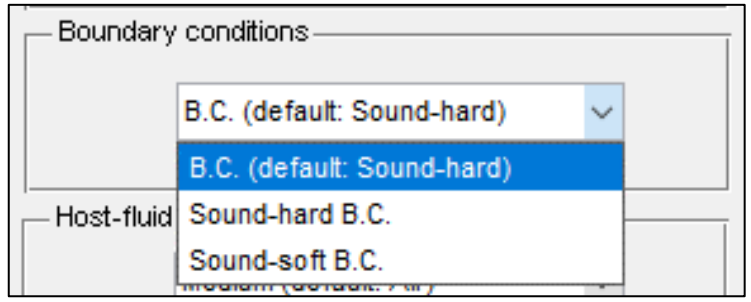




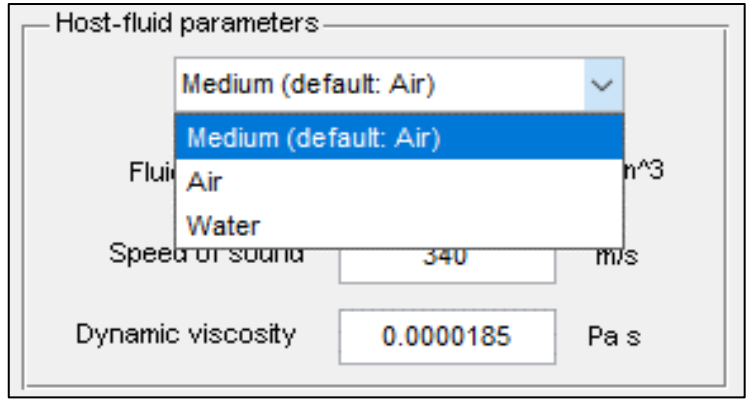


User-specified mapping coefficient:
Cn = [0.002 0 -0.0005 0 -0.00025]

Cn: geometric mapping coefficients;
(The 'Cn' of four typical geometries of *spherical, ellipsoidal, cone,* and *diamond* particles are provided. User can also *self-specify* the 'Cn' for more complex geometries)
Initial position&orientation: define the initial position of mass center of particle deviated from origin of Cartesian coordinates;
the initial angle between symmetric axis of particle and x-, y-, and z-axes.

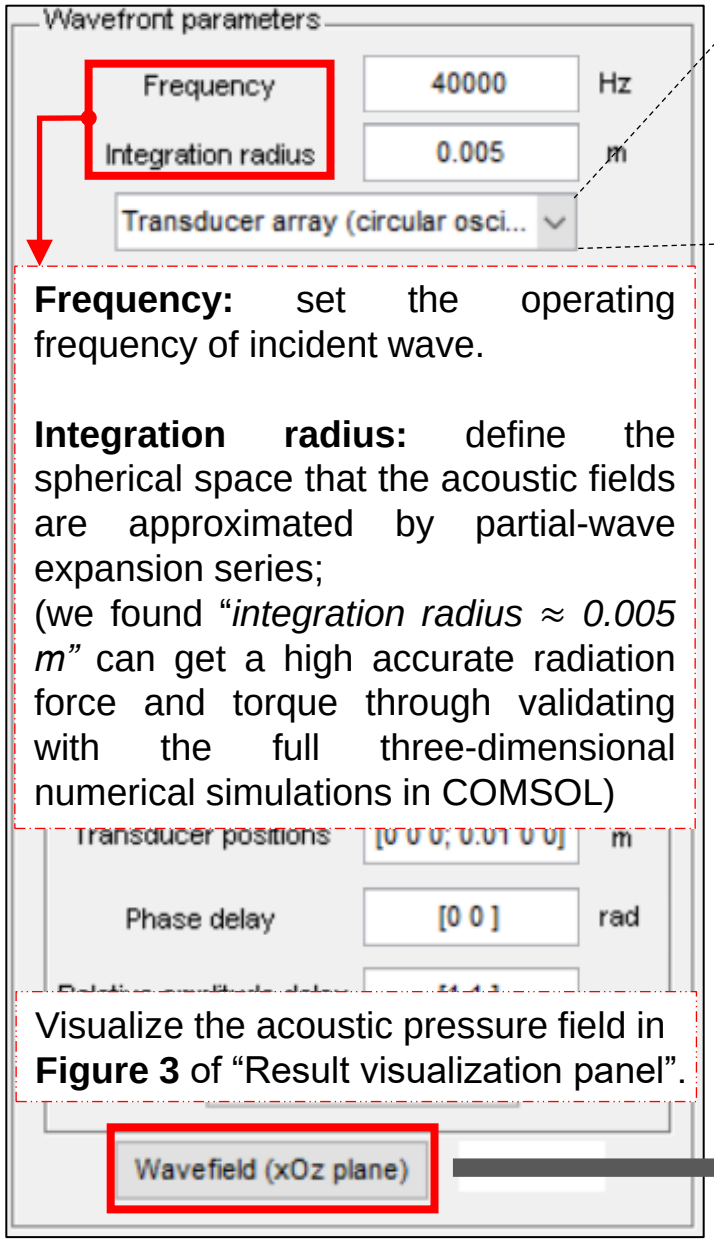


Boundary conditions:
there are two common options, *sound-hard (Neumann)* and *sound-soft (Dirichlet)* conditions.



Medium:
there are two common options, *air* and *water* medium.
The medium properties are automatically implanted once the "Medium popup menu" is selected.

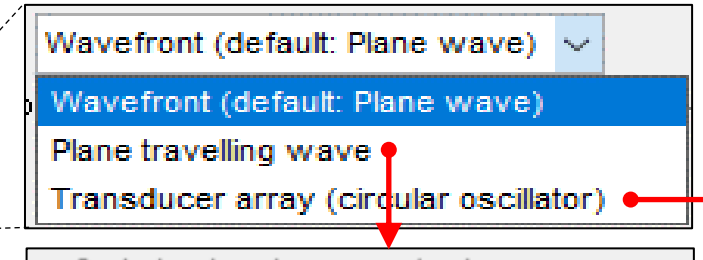
➢ Parametric control panel (Wavefront parameters)

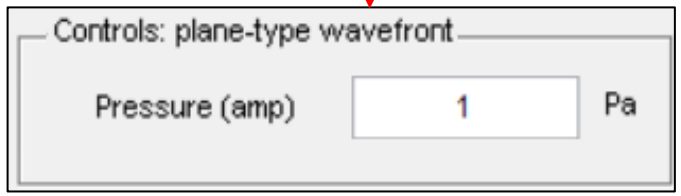


Frequency: set the operating frequency of incident wave.

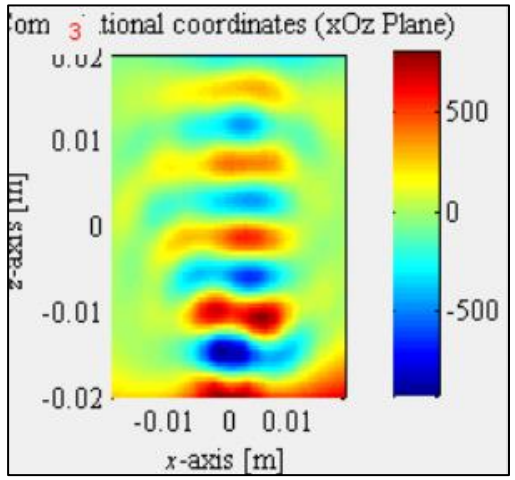
Integration radius: define the spherical space that the acoustic fields are approximated by partial-wave expansion series;
(we found "*integration radius ≈ 0.005 m*" can get a high accurate radiation force and torque through validating with the full three-dimensional numerical simulations in COMSOL)

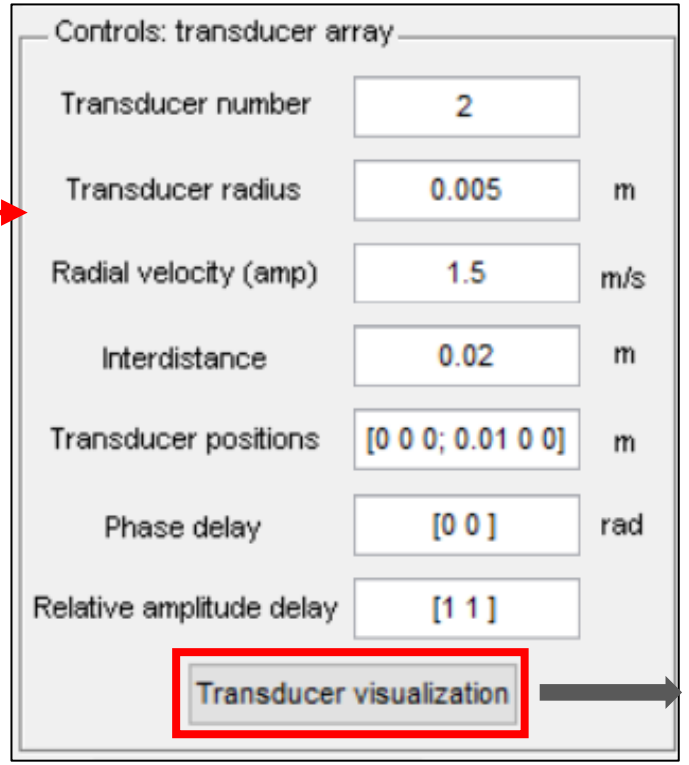
Visualize the acoustic pressure field in **Figure 3** of "Result visualization panel".



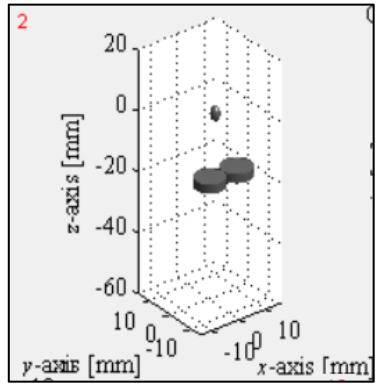


Pressure (amp): set the pressure amplitude of the incident plane wave.
(**ONLY** activated when the "Wavefront popup menu" selects Plane travelling wave feature)





Visualize the particle-transducer system based on "Particle parameters" and "Controls: Transducer array" parameters in **Figure 2** of "Result visualization panel".

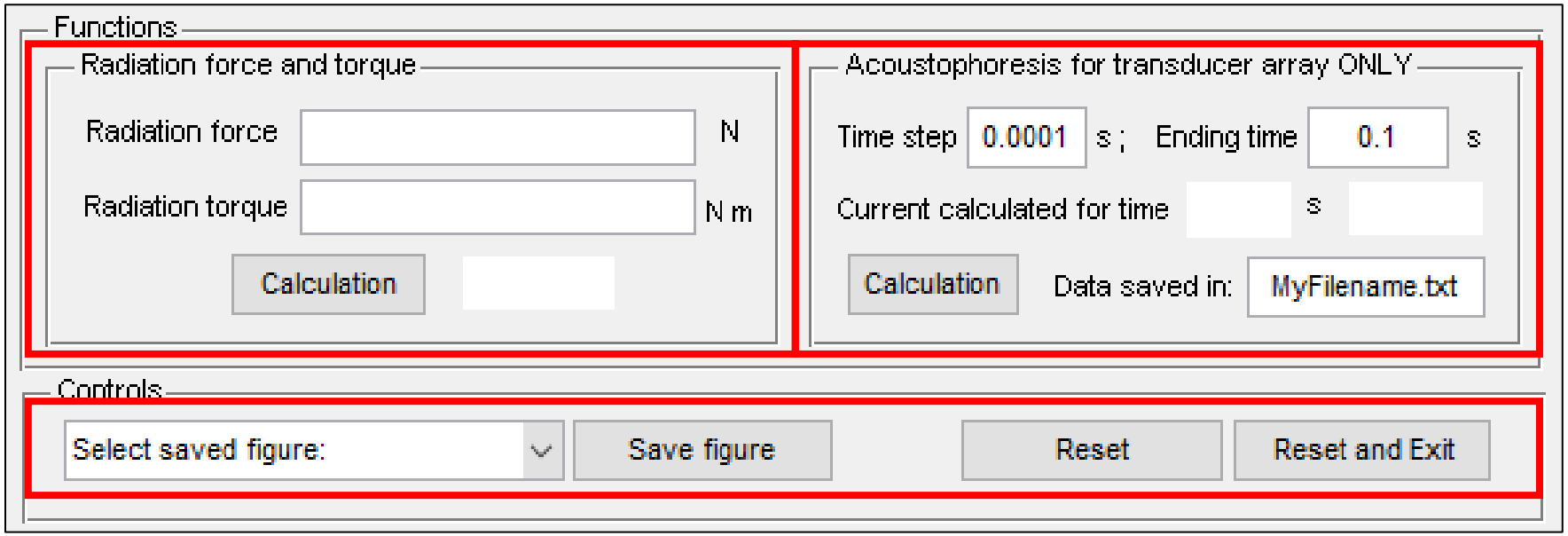


Radial velocity (amp): set the radial vibration amplitude of the circular oscillator of the transducers.
Interdistance: set the initial vertical distance between the coordinate origin and transducer array.
Transducer positions: set the initial positions of transducer. Each row gives the x-, y-, and z-positions of a transducer.
Phase&Relative amplitude delay: set the phase and amplitude parameters of the transducer array.
(The above parameters **ONLY** activated when the "Wavefront popup menu" selects Transducer array (circular oscillator) feature)

➢ Functional panel and Control panel

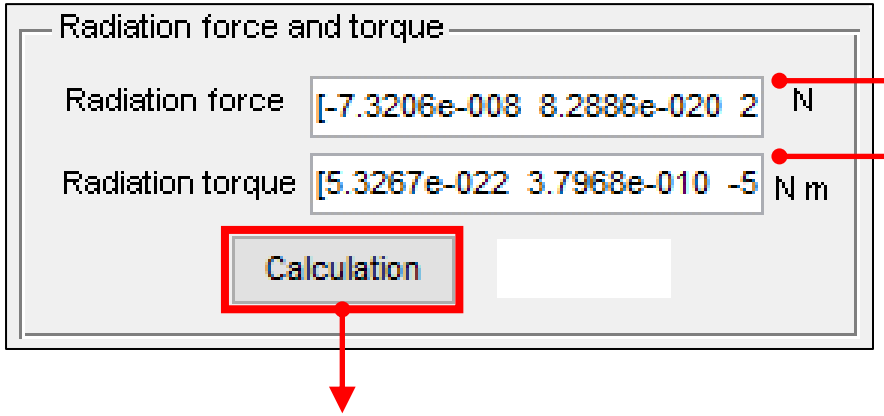
Prediction of the radiation force and torque

Calculation the acoustophoretic process of the particle



Save figures and Reset parameters to default values

➢ Functional panel



Click on the "Calculation" button to predict the radiation force and torque.

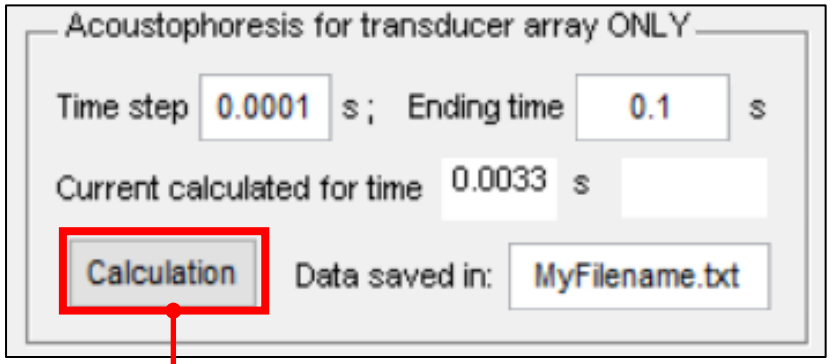
Present the predicted radiation force and torque:

Radiation force = [-7.3206e-008 8.2886e-020 2.6585e-006] N,

Radiation torque = [5.3267e-022 3.7968e-010 -5.9868e-023] $\mathrm{N}\cdot\mathrm{m}$;

i.e.,

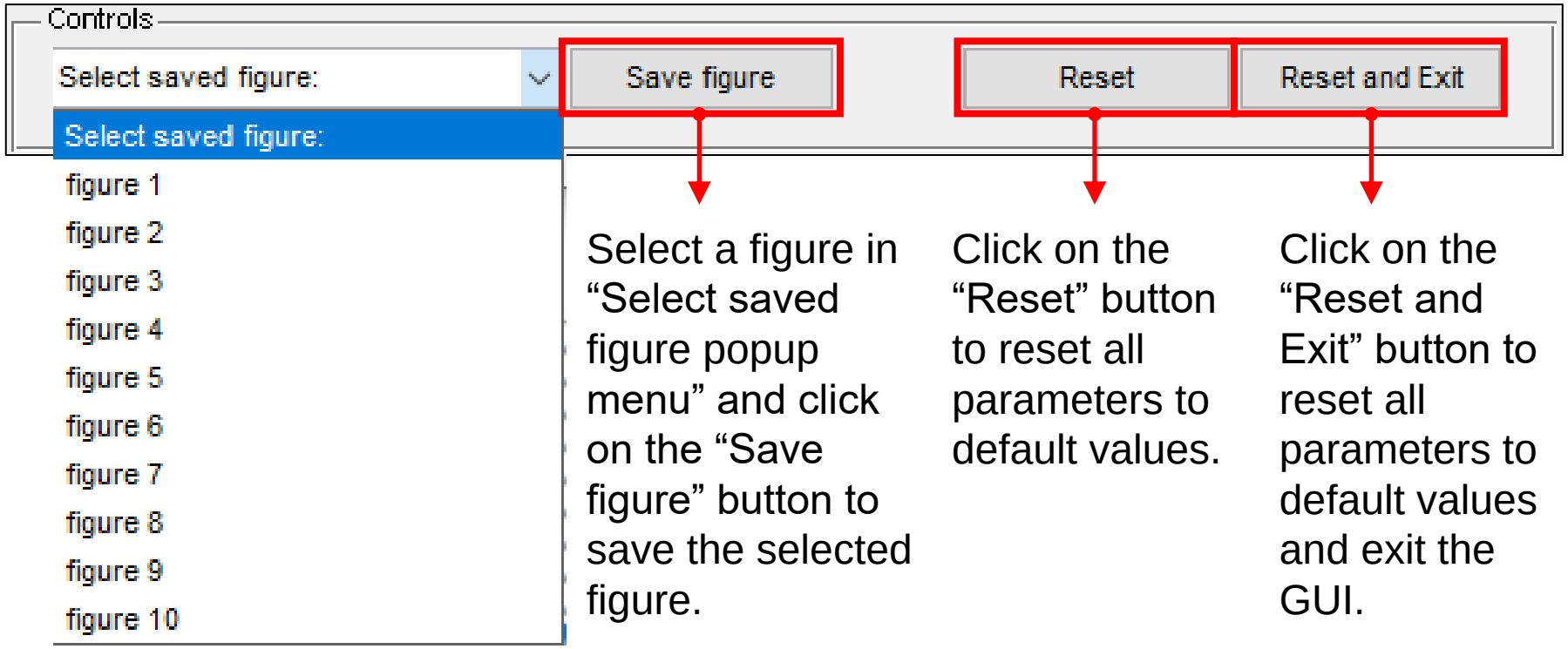
$$\begin{cases} F_{\mathrm{rad},x} = -7.3206\times10^{-8}\ \mathrm{N} \\ F_{\mathrm{rad},y} = +8.2886\times10^{-20}\ \mathrm{N}, \text{ and} \\ F_{\mathrm{rad},z} = +2.6585\times10^{-8}\ \mathrm{N} \end{cases} \quad \begin{cases} T_{\mathrm{rad},x} = +5.3267\times10^{-22}\ \mathrm{N}\cdot\mathrm{m} \\ T_{\mathrm{rad},y} = +3.7968\times10^{-10}\ \mathrm{N}\cdot\mathrm{m}. \\ T_{\mathrm{rad},z} = -5.9868\times10^{-23}\ \mathrm{N}\cdot\mathrm{m} \end{cases}$$



Click on the "Calculation" button to start the acoustophoretic prediction.

Time step: set the time step for iterative calculation of the particle dynamics.
Ending time: set the ending moment.
Current calculated for time: indicate the progress of the calculation.
Data saved in: specify the fold direction to save the data of the particle position and orientation at different moments in file "MyFilename.txt".
Note: when the vertical distance between the mass center of particle and transducer array (i.e., the interdistance) small than *0.01 mm, we stop the dynamic calculation and regard the particle cannot be trapped.*
(The above parameters **ONLY** activated when the "Wavefront popup menu" selects Transducer array (circular oscillator) feature)

➢ Control panel (Save figures, Reset and Exit)

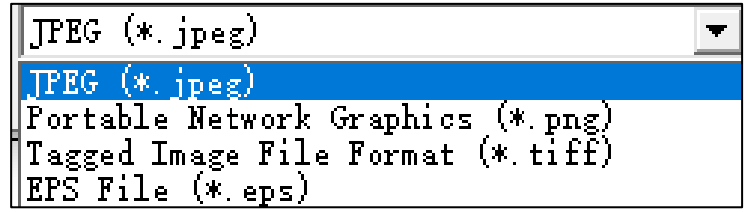


Select a figure in "Select saved figure popup menu" and click on the "Save figure" button to save the selected figure.

Click on the "Reset" button to reset all parameters to default values.

Click on the "Reset and Exit" button to reset all parameters to default values and exit the GUI.

After clicking on the "Save figure" button, a new window will present. The user need to specify a filename and format to save the selected figure. The software supports '*.jpeg', '*.png', '*.tiff', and '*.eps' formats.



➢ Template: saved data of particle acoustophoresis (MyFilename.txt)

```
%Computational parameters

Geometry = Ellipsoidal particle;
    Cn = [0.002            0      0.0004];
    Particle density = 15 [kg/m^3];
    Particle radius = 0.002 [m];
    Initial position = [0.002 0 0] [m];
    Initial orientation = [0 0 0] [rad];

Boundary condition = B.C. (default: Sound-hard);

Medium = Medium (default: Air);
    Fluid density = 1.224 [kg/m^3];
    Fluid sound speed = 340 [m/s];
    Fluid dynamic viscosity = 0.0000185 [Pa s];

Wave type = Transducer array (circular oscillator);
    Frequency = 40000 [Hz];
    Integration radius = 0.005 [m];
    Transducer number = 2;
    Transducer radius = 0.005 [m];
    Transducer vibration radial velocity = 1.5 [m/s];
    Interdistance between the particle and the array = 0.02 [m];
    Transducer position matrix = [0 0 0; 0.01 0 0] [m];
    Transducer phase delay = [0 0 ] [rad];
    Transducer relative amplitude delay = [1 1 ];
```

Parameters saved in "MyFilename.txt": the saved computational parameters, including the particle parameters, the boundary condition, the medium parameters, and the wavefront parameters.

➢ Template: saved data of particle acoustophoresis (MyFilename.txt)

```
%Dynamic data:

Time [ms]     X_position [m]     Y_position [m]     Z_position [m]     X_angle [rad]     Y_angle [rad]     Z_angle [rad]
0.000000  0.002000  0.000000  0.000000  0.000000  0.000000  0.000000
0.100000  0.001990  0.000000  -0.000325  0.000000  0.010207  -0.000000
0.200000  0.001976  0.000000  -0.000642  0.000000  0.022184  -0.000000
0.300000  0.001959  0.000000  -0.000952  0.000000  0.036192  -0.000000
0.400000  0.001938  0.000000  -0.001255  0.000000  0.052507  -0.000000
0.500000  0.001913  0.000000  -0.001550  0.000000  0.071411  -0.000000
0.600000  0.001883  0.000000  -0.001840  0.000000  0.093175  -0.000000
0.700000  0.001847  0.000000  -0.002123  0.000000  0.118038  -0.000000
0.800000  0.001806  0.000000  -0.002401  0.000000  0.146180  -0.000000
0.900000  0.001759  0.000000  -0.002672  0.000000  0.177683  -0.000000
1.000000  0.001707  0.000000  -0.002938  0.000000  0.212502  -0.000000
1.100000  0.001649  0.000000  -0.003198  0.000000  0.250422  -0.000000
1.200000  0.001586  0.000000  -0.003451  0.000000  0.291036  -0.000000
1.300000  0.001521  0.000000  -0.003696  -0.000000  0.333745  -0.000000
1.400000  0.001455  0.000000  -0.003932  -0.000000  0.377769  -0.000000
1.500000  0.001389  0.000000  -0.004158  -0.000000  0.422205  -0.000000
1.600000  0.001328  0.000000  -0.004375  -0.000000  0.466098  -0.000000
1.700000  0.001272  0.000000  -0.004582  -0.000000  0.508538  -0.000000
1.800000  0.001223  0.000000  -0.004780  -0.000000  0.548753  -0.000000
1.900000  0.001182  0.000000  -0.004971  -0.000000  0.586172  -0.000000
2.000000  0.001150  0.000000  -0.005155  -0.000000  0.620451  -0.000000
2.100000  0.001127  0.000000  -0.005336  -0.000000  0.651449  -0.000000
2.200000  0.001112  0.000000  -0.005513  -0.000000  0.679183  -0.000000
2.300000  0.001105  0.000000  -0.005689  -0.000000  0.703768  -0.000000
2.400000  0.001106  0.000000  -0.005863  -0.000000  0.725379  -0.000000
2.500000  0.001112  0.000000  -0.006038  -0.000000  0.744217  -0.000000
2.600000  0.001124  0.000000  -0.006214  -0.000000  0.760493  -0.000000
2.700000  0.001141  0.000000  -0.006392  -0.000000  0.774424  -0.000000
2.800000  0.001162  0.000000  -0.006574  -0.000000  0.786230  -0.000000
2.900000  0.001186  0.000000  -0.006760  -0.000000  0.796141  -0.000000
3.000000  0.001213  0.000000  -0.006954  -0.000000  0.804413  -0.000000
3.100000  0.001241  0.000000  -0.007156  -0.000000  0.811333  -0.000000
3.200000  0.001270  0.000000  -0.007368  -0.000000  0.817254  -0.000000
3.300000  0.001301  0.000000  -0.007594  -0.000000  0.822613  -0.000000
3.400000  0.001331  0.000000  -0.007833  -0.000000  0.827991  -0.000000
```

Time-variant data saved in “MyFilename.txt”:
the saved position and orientation data of the particle in different moments.