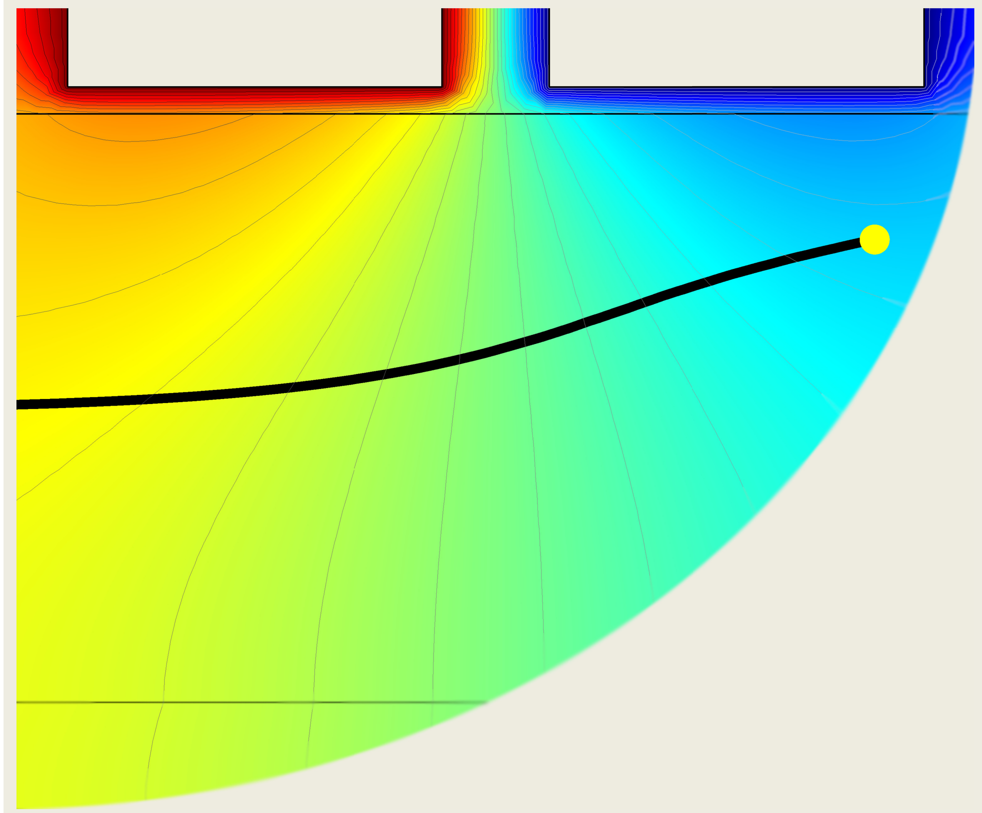

Frequency-Controlled Manipulation of Particles in a Liquid Column Based on AC Dielectrophoresis

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Abstract

In this paper, the topic of frequency-controlled manipulation of sinking particles in a stationary liquid column based on AC dielectrophoresis is studied in depth. For this purpose, the fundamentals of dielectrophoresis are presented at the beginning, in particular taking into account the radius-dependent electrical conductivity of dielectric particles. Subsequently, the modeling of the stationary liquid column is discussed in detail. The simulation results illustrate the vertical separation due to gravity and show the transient frequency- and amplitude-controlled horizontal deflection of the particles as a function of size. Thus, a flexible method for dielectric particle manipulation according to their size was verified by simulations.

Dielectrophoresis

Dielectrophoretic force:

$$F_{DEP} = 2\,\pi \cdot r^3 \cdot \epsilon_0 \cdot \epsilon_m \cdot \Re\{K(\omega)\} \cdot \nabla |E_{rms}|^2$$

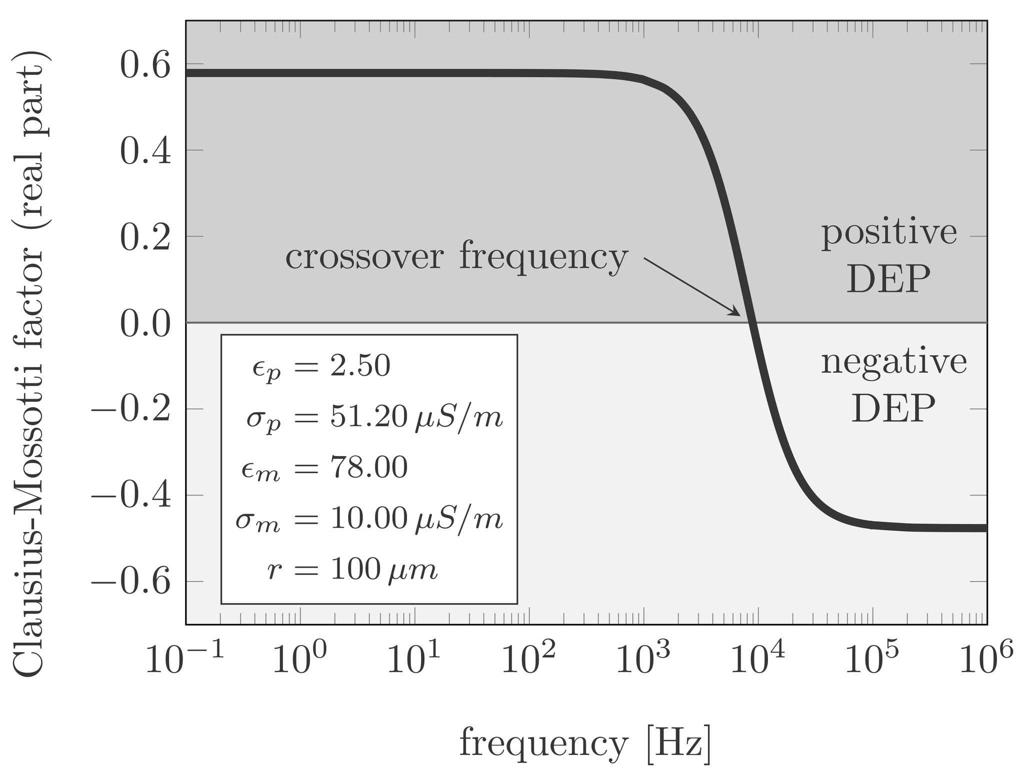
Clausius-Mossotti factor (real part):

$$\Re\{K(\omega)\} = \frac{\omega^2 \cdot \epsilon_0^2 \cdot (\epsilon_p - \epsilon_m) \cdot (\epsilon_p + 2\epsilon_m) + (\sigma_p - \sigma_m) \cdot (\sigma_p + 2\sigma_m)}{\omega^2 \cdot \epsilon_0^2 \cdot (\epsilon_p + 2\epsilon_m)^2 + (\sigma_p + 2\sigma_m)^2}$$

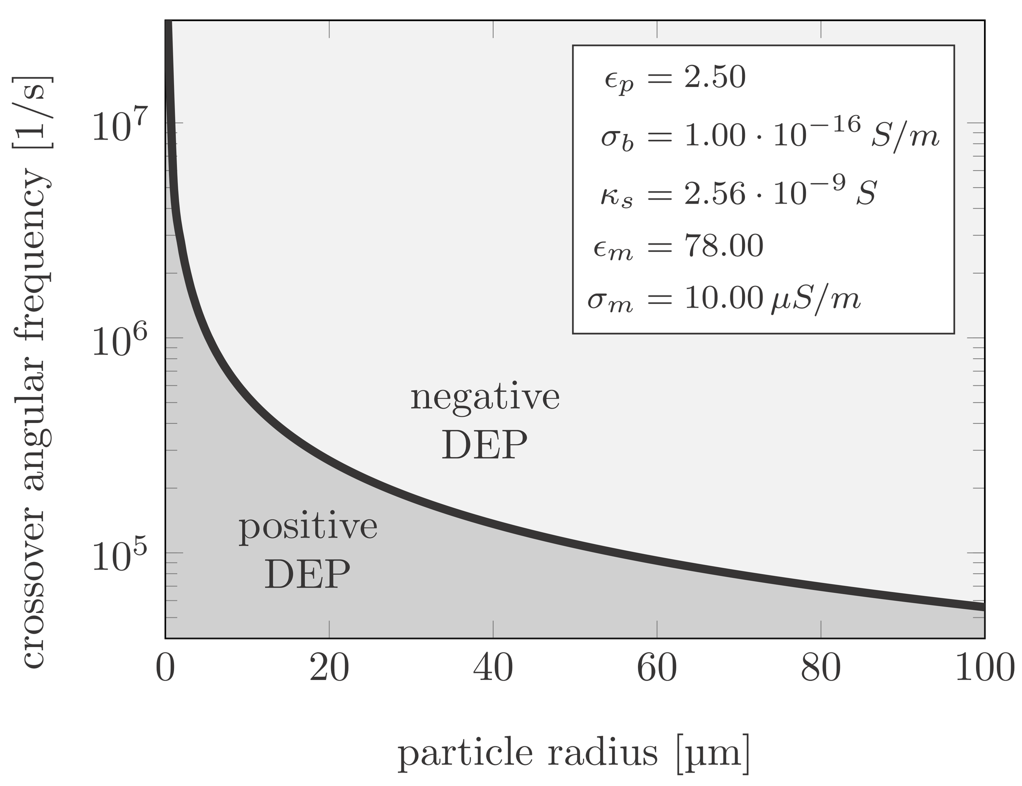
Crossover angular frequency:

$$\omega_C = \sqrt{\frac{(\sigma_p - \sigma_m) \cdot (\sigma_p + 2\,\sigma_m)}{\epsilon_0^2 \cdot (\epsilon_p - \epsilon_m) \cdot (\epsilon_p + 2\,\epsilon_m)}}$$

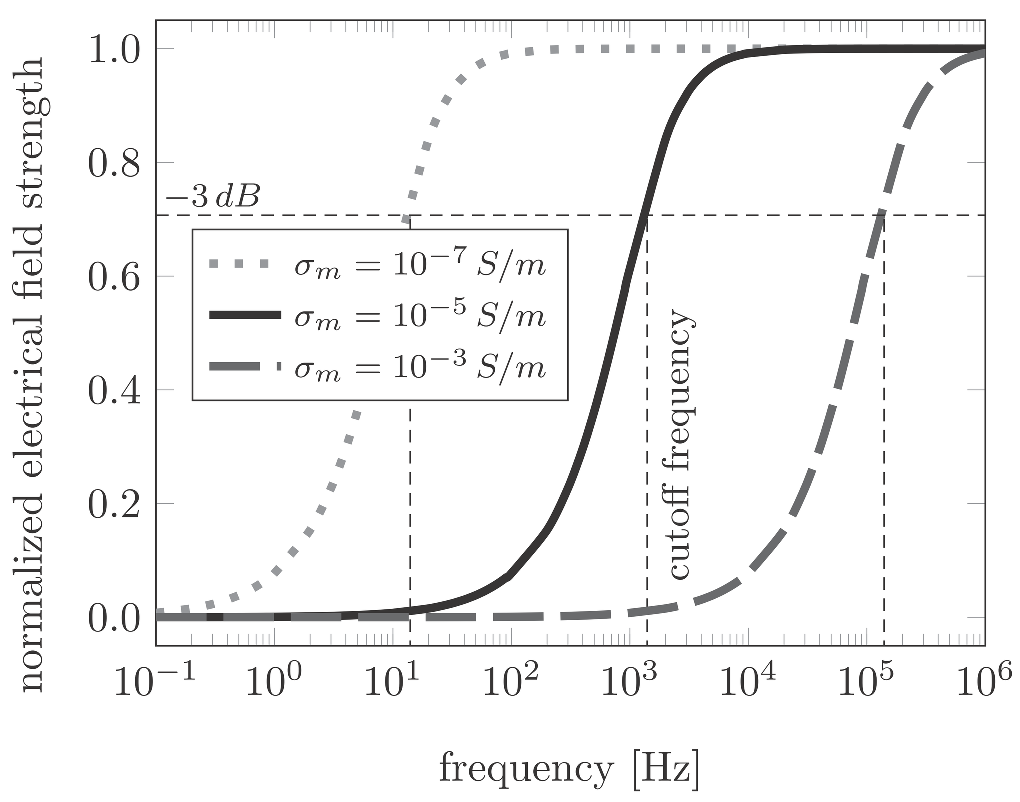
Frequency-dependent real part of the Clausius-Mossotti factor illustrating the shift from positive to negative DEP:



Radius-dependent crossover angular frequency:

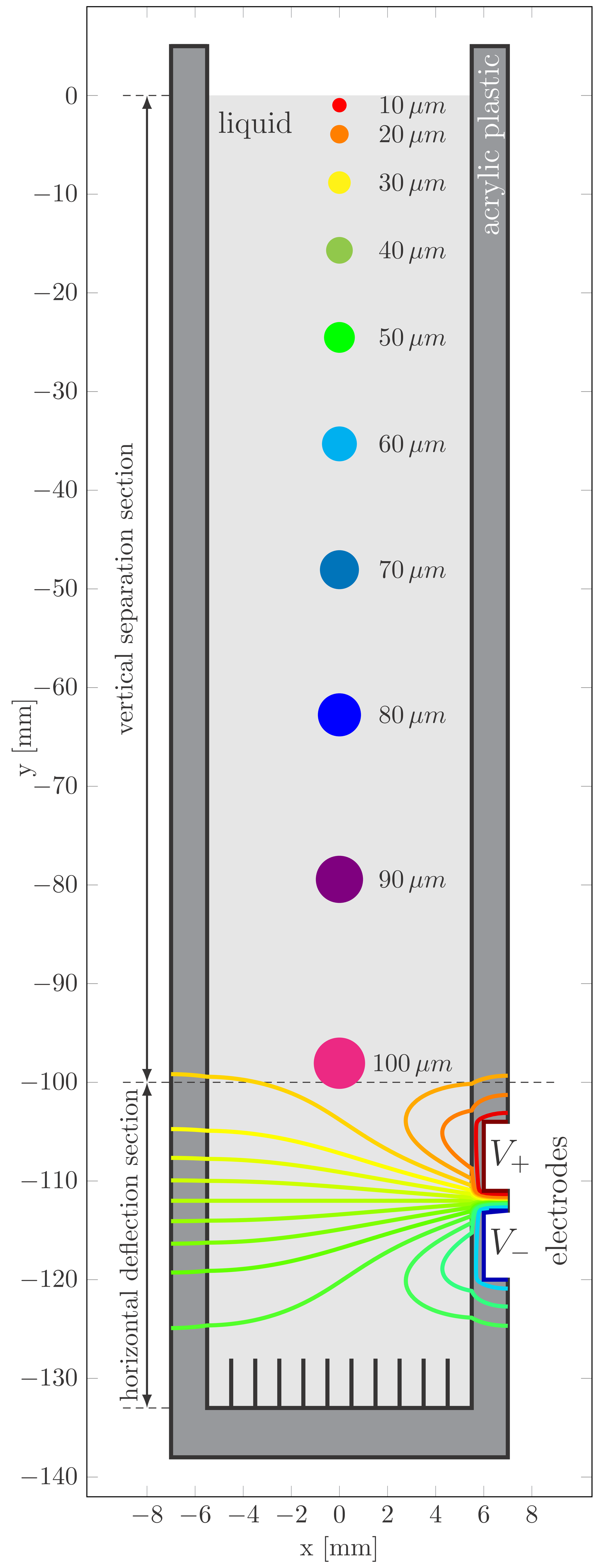


Frequency-dependent electrical field strength within liquid phase for different electrical conductivities:



Stationary Liquid Column

Stationary liquid column with radius-dependent vertically separated particles during a sink time of $t = 90s$:



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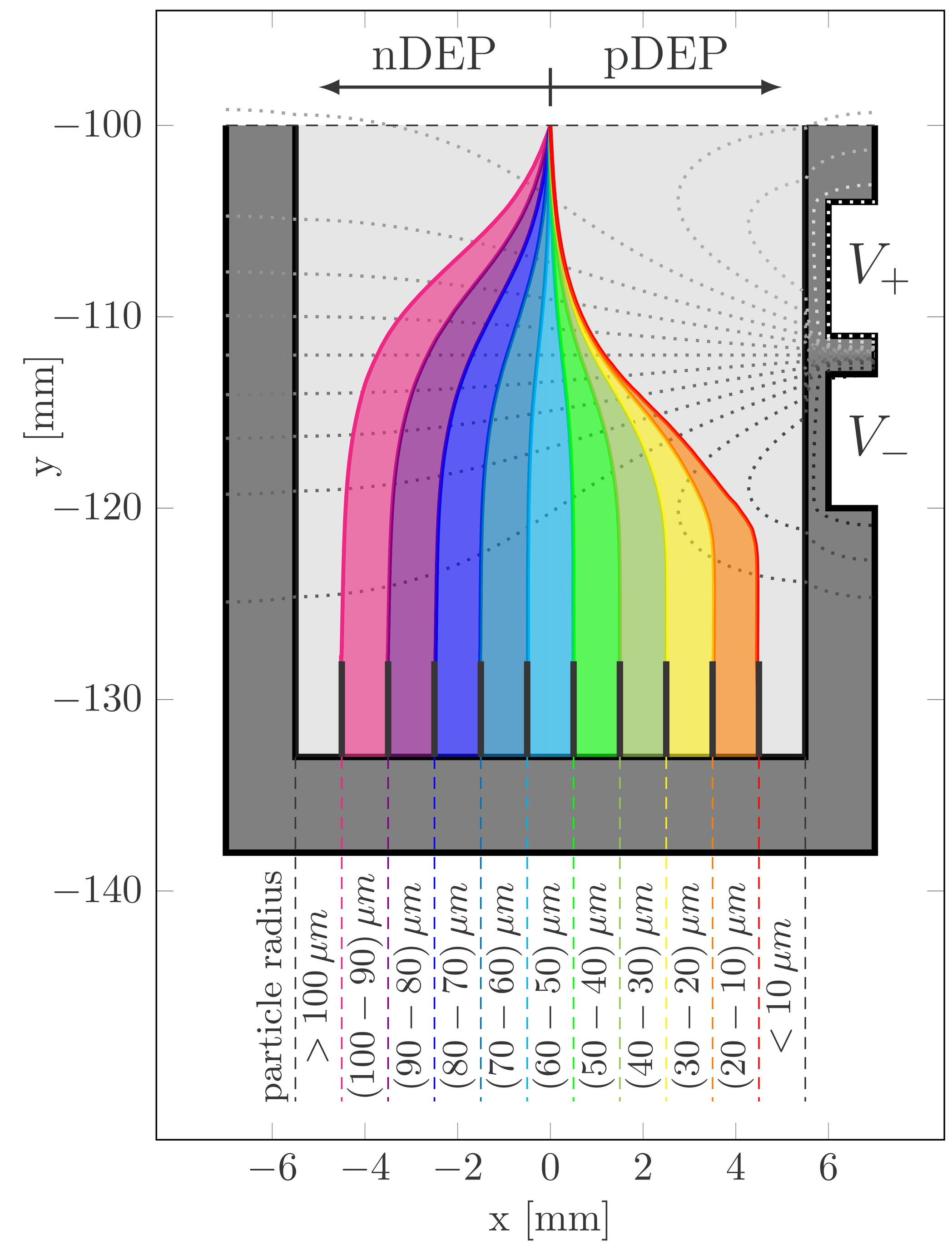
Horizontal Deflection

Horizontal deflection section of stationary liquid column showing radius-dependent deflection corridors of particles:

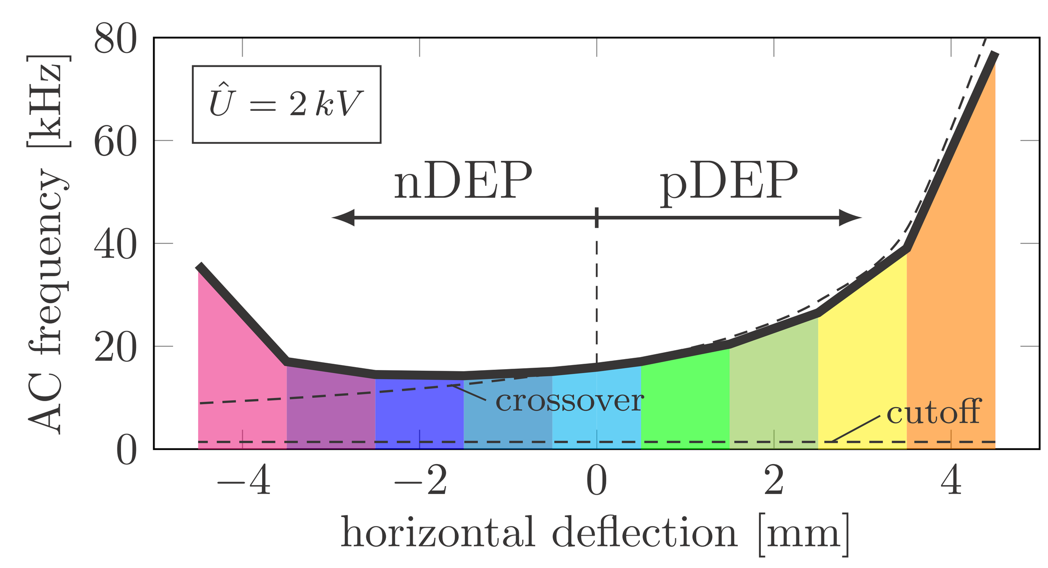


AC Control Signal

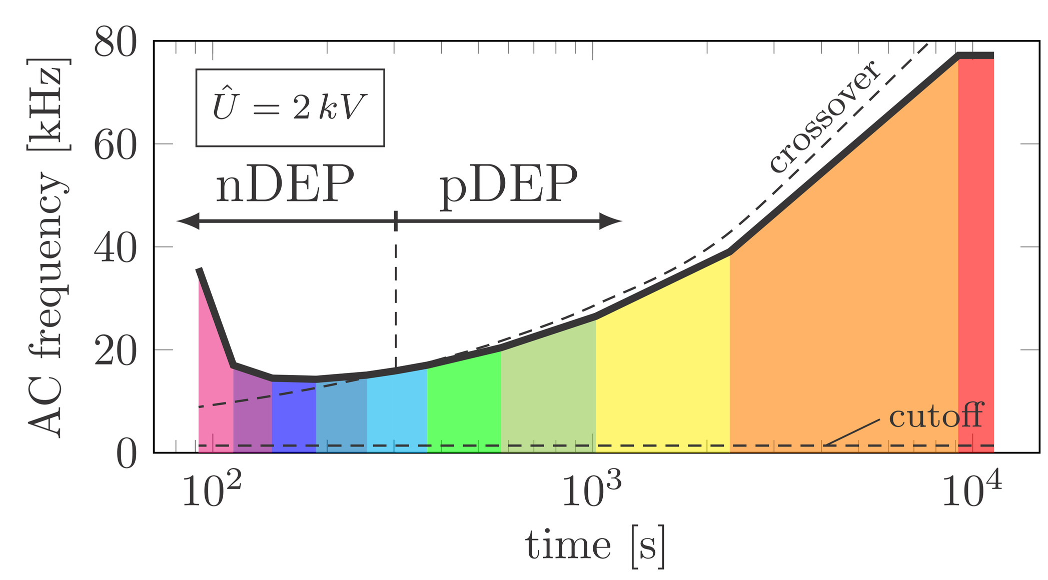
A precise horizontal deflection of the particles requires a time-varying frequency-controlled AC signal:

$$U_{AC}(t) = \hat{U} \cdot \sin(2\,\pi \cdot f(t) \cdot t)$$

Frequency-controlled horizontal deflection:



Time-varying AC frequency:



Alternatively, both the amplitude and the frequency of the AC signal can also be varied in time in combination.

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