4 - 25 Simulations of Guiding of Highly Charged Ions: A Test Calculation for a Perfectly Insulating Nanocapillary

Liu Shidong, Zhao Yongtao, Wang Yuyu, Zhou Xianming, Cheng Rui and Lei Yu

Ion guiding through insulating capillaries has been discovered more than one decade[1]. The experiments and theoretical simulations reveal that the self-organized charge-up plays a dominant role in low-energy ion transmission[1−3]. Although a lot of achievements are obtained in experiments and simulations, yet many details of guiding mechanisms are not fully understood. To further understand the guiding mechanism, we perform a simulation program based on the idea proposed in Ref. [3] and some results are reported.

3 keV Ne^{7+} ions with the current density of 100 pA/mm^2 are injected into a single nanocapillary with a diameter of 100 nm and a length of 10 μm. In this case, the number of ions inserted into the capillary per second is ~1. The divergence of the ion beam is about 0.3°, which is measured experimentally.

First, we assume that the capillary materials are perfect insulators, which means that the charges deposited on the capillary wall are fixed and would be NOT dissipate. The codes for simulations are written by means of MATLAB Language. Fig. 1 shows the ion trajectories (red lines) within the nanocapillary and the distributions of deposited charges (blue dots) for tilt angle of 3°. It can be seen that the ion transmission if fully blocked in this extreme condition.

Next, we consider the the dissipation of the deposited charges on the capillary wall. The results is presented in Fig. 2 for various numbers of inserted ions (150, 500, 1 950, 3 950, and 5 950 from top to bottom). From Fig. 2, one can readily see that before the guided equilibrium is established, ions follow oscillatory trajectories towards the capillary exit. With enough inserted ions, the ions are transmitted along the capillary axis. This shows that the migration of the charges caused by the conductivities of the capillary materials is of great importance in the establishment of equilibrium among the charging, discharging of the deposited charges and the incident current. More detailed study is in progress.

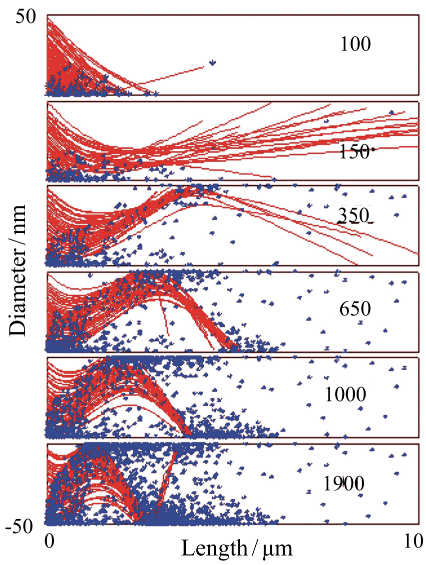

Fig. 1 (color online) The ion trajectories for 3 keV Ne^{7+} ions in the single nanocapillary and the distributions of deposited charges on the capillary inner wall. The tilt angle is 3°. The ratio of the capillary length to its diameter is not scaled for graphical reason.

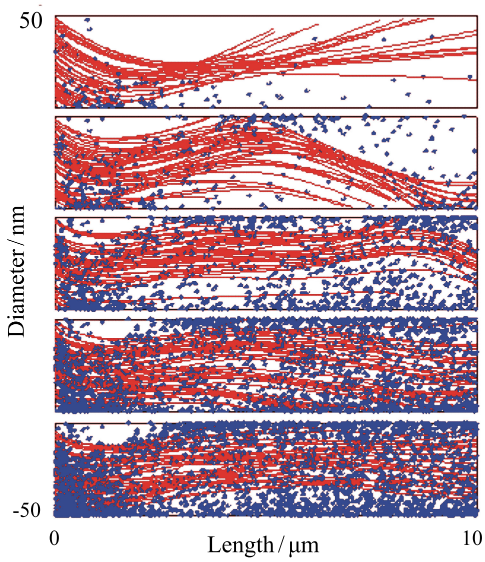

Fig. 2 (color online) Trajectories of 3 keV Ne^{7+} ions in the single nanocapillary and distributions of deposited charges on the capillary inner wall. The tilt angle is 2°. The ratio of the capillary length to its diameter is not scaled for graphical reason.

References

[1] N. Stolterfoht, D. Schneider, K.G. Harrison, et al., Phys. Rev. Lett, 88(2002)133201.

[2] K. Schiessl, W. Palfinger, et al., Phys. Rev. A, 72(2005)062902.

[3] N. Stolterfoht. Phys. Rev. A, 87(2013)012902.