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Role of charge patches in ion guiding through nanocapillaries in a PET polymer

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Synopsis: We studied the dynamic properties of ion guiding through nanocapillaries in insulating polyethylene terephthalate (PET). The angular distribution of the transmitted ions was measured as a function of time. The temporal evolution of the angular transmission profiles was acquired for the capillary diameters of 200 and 400 nm. The tilt angle was varied from 0° to 6.5°. The transmission profiles exhibit significant changes in position as time varies. This observation is explained by the formation of temporary charge patches produced in the interior of the capillary besides the primary charge patch created in the entrance region.

The guided transmission of highly charged ions through nanocapillaries in insulating material has received considerable attention [1]. The guiding phenomenon implies that a highly charged ion preserves its incident charge state during the transmission through the capillaries. Evidently, the ions do not suffer close collisions with the capillary wall even when they are tilted with respect to the incident beam direction.

The ion guiding is provided by the self-organizing built-up of a significant charge patch located near the entrance region. Additional weaker patches may temporarily be produced after the formation of the first patch. They change their position and strength so that dynamic properties of the ion guiding become important. Experimentally, the dynamic effects can be observed by measuring transmission profiles (i.e., the angular distributions of the emitted ions) as a function of time [1-3].

The left-hand column of Fig. 1 contain a series of transmission profiles for the capillary diameters of 200 nm. Each transmission profile is normalized to the deposited beam charge, which is a measure of time. Each profile indicates the total charge Q_d collected till the instant when the profile is measured. The transmission profiles exhibit three peak structures, whose positions appear to be rather constant. Hence we fitted the experimental data by a superposition of three Gauss functions. Except for the central peak at 5° the positions of the first and third peak were treated as adjustable parameters, as well as the all peak heights. The mean values of the emission angle are varying as shown in the right-hand column of Fig. 1. The results exhibit oscillatory displacements within a wide angular range.

We attribute the oscillatory behavior to temporary charge patches formed inside the capillaries. This conclusion is based on the finding that at the reversal points, the mean angles deviates from central angle 5° by more than the aspect angle of 1°.

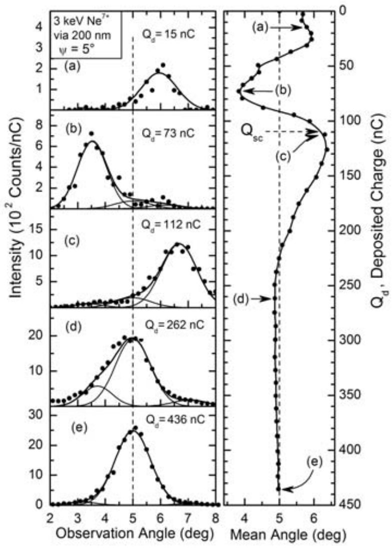

Fig. 1: Transmission profiles for 3 keV Ne^{7+} ions passed through 200 nm PET capillaries and their profile mean emission angle.

The occurrence of three peaks with rather fixed positions may be counterintuitive, since the transmission profile is continuously moving with an oscillatory behavior. However, the distinct peaks were identified in several measurements after changing the tilt angle and the capillary diameter.

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