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Symmetry breaking in a four-bar multipole trap

Octupole and other multipole ion traps are widely used as precision devices for ion transport and localization. In particular, octupole ion guides have found application in particle accelerators, the Orbitrap mass analyzer, and other complex setups. The multipole field is formed in a standard fashion as in a quadrupole Paul trap design, but with additional electrodes. In both quadrupole traps and multipole traps, voltages are applied with different phases on neighboring electrodes: 0 and π, respectively [1]. It should be noted that this scheme is a universal one, and the description of the electrostatic field in the trap in terms of harmonic polynomials applies in all of its manifestations [2, 3]. At the same time, the electrostatic field depends on many factors, for example, the electrode geometry [4, 5], the modulation of the radio-frequency voltage applied to the electrodes [6], and the spatial positions of the electrodes [7, 8]. Even a small change, to the in-phase voltage, for example, can lead to significant deformation of the effective potential from a quadratic form. In this case, we still retain the condition of a sign-alternating voltage, so that the equations of motion will satisfy Earnshaw's theorem, but the stability of localization is no longer obvious, and additional research on this topic is required.
In our work, we show that a real in-phase trap creates a quasi-octupole effective potential with symmetry breaking. The existence of three stability points is confirmed. We design and construct a prototype of the proposed trap, and experimental results obtained on localization confirm our theoretical results. The obtained result can be useful in the high-precision measurements both mass-spectrometry and other applications.

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