Induced charge coupling frequency of axial motion of two electrons trapped separately in 2-D planar Penning traps

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Synopsis We present a theoretical framework for evaluating the interaction frequency of two charged particles confined in 2 D planar Penning traps. The interaction frequency is evaluated in terms of the capacitance of the planar traps along with the wire connecting the two traps.

We aim to present the theoretical framework for evaluation of the interaction frequency of two electrons trapped in two separate planar Penning traps. The model we have used for evaluation of the frequency was first introduced in [1]. In our model depicted in Fig(1) we consider two 2-D planar Penning traps connected by a wire which may be dissipative or non-dissipative in nature.

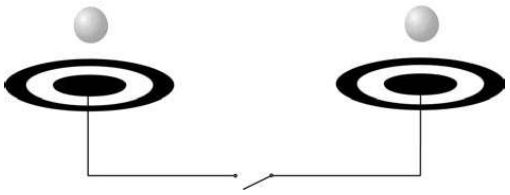

Figure 1. Schematic showing inductive coupling of two electrons

Each trap consists of 4 concentric electrodes, with 3 gaps, where the trap geometry considered is from a recent work [3]. The two traps are assumed to be completely symmetric. The interaction frequency of the two electrons is the rate at which the two electrons exchange their motional energy, similar to two coupled harmonic oscillators. The expression for the frequency is given as:

$$\omega_{int} = \frac{q^2C^2}{8\pi^2\epsilon_o^2R^4m\omega_z}\cdot\frac{1}{2C+C_w}\left(1-\frac{z_o}{\sqrt{R^2+z_o^2}}\right)^2$$

where

q = Charge on electrons
C = Capacitance of the central electrode of the trap
R = Radius of central electrode of the trap
m = Mass of electron
ω_z = Oscillation frequency of the electron
C_w = Capacitance of the connecting wire
z_o = Equilibrium position of the electron above the central electrode.

The capacitance for the planar Penning trap is evaluated using simulations done in COMSOL software and is found for the configuration with R $\approx$ 0.5mm, to be equal to 0.24 pF. We have also evaluated the capacitance of the trap corresponding to the geometry provided in [3], thecapacitance for this geometry comes out to be $\approx$ 2.73 fF. Here is the table giving the approximate interaction frequencies corresponding to these cases, when the capacitance of the wire is assumed to be negligible:

Table 1. Interaction frequency for various values of electron oscillation frequencies

Radius of central electrode R	Electron oscillation frequency ω_z	Interaction frequency ω_{int}
0.5mm	100MHz	32KHz
10μm	4GHz	5.05MHz

References

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