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ON THE POSSIBILITY OF ACHIEVING A CONDENSED CRYSTALLINE
STATE IN COOLED PARTICLE BEAMS

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ABSTRACT

Calculations have shown that when a plasma of one kind of particle (one-component plasma or OCP) is below a certain temperature, it will undergo a phase transition and the particles will form a crystalline (bcc) array.¹ The relevant parameter is $\Gamma = (q^2/a)/kT$ (where a is the average spacing and T the temperature) and the transition takes place at $\Gamma = 170$. The properties of proposed storage rings for heavy ions with $q \gg e$, are such that an ordered array may actually be realized.²

We have performed molecular dynamics calculations for an idealized system in which an average (constant in time) focusing force was assumed, perpendicular to the x-axis: $F = Kr$, ($r^2 = y^2 + z^2$). The calculations were done as if in the moving frame; the particles had no velocity other than that arising from their thermal motion. No effects of the circular orbits were included. Under these circumstances, with $\Gamma = 180$, the particles form cylindrical shells around the "beam axis" as is shown in figure 1, with hexagonal two-

Figure 1:
Upper part: Projection of 2000 particles in a molecular dynamics calculation onto the plane perpendicular to the beam (x-axis) for $\Gamma = 180$.
Lower part: distribution of particles in the outer shell with the shell unfolded into a plane. All but the innermost shell show a similar pattern.

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dimensional order within the surface of each shell, except the innermost one. The pair correlation function in figure 2 is plotted against the coordination number $n(r)$: the number of neighbors up to r . The pronounced peaks contain 14 and 44 nearest neighbors, indicating approximate three-dimensional bcc order. The two-dimensional correlation function shows peaks with 6 and 12 particles that are characteristic of triangular order. All distances are in units of $\xi \equiv (q^2/K)^{1/3}$ where q is the charge and K the average focusing constant mentioned above.

When the number of particles per unit length is reduced, only what was previously the innermost shell remains, as is shown in figure 3, and when it is further reduced, to the point where the two-particle Coulomb repulsion can be overcome by the focusing force, the particles in this shell line up in a straight line along the beam (x-axis).

For higher temperatures ($\Gamma = 40$) the particles still form an outer shell, but the inner shells become blurred. Further calculations are planned to simulate somewhat more realistically the condition in a storage ring: the effective shear that is needed to represent the circular motion and the periodicity that is more likely to approximate the strong-focusing conditions that are used at most storage rings.

Figure 2:
Pair correlation functions $g(r)$ starting with particles in particular shells, plotted as a function of coordination $n(r)$ (total number of particles up to that radius). The upper curves show the three-dimensional pair correlation where the first peak has a coordination of 14 characteristic of bcc structure, except for the outer shell that clearly has no particles outside it. The lower curves are the two-dimensional pair correlation within each of the three outer shells, with the coordination of 6 for the first peak, characteristic of the triangular order in two dimensions.

Figure 5: Same as the upper part of figure 1 but with only 100 particles (above) and 50 particles (below).

REFERENCES

1. E. L. Pollock and J. P. Hansen, Phys. Rev. A8, 3110 (1973).
2. J. P. Schiffer and P. Kienle, Z. Phys. A, 321, 181 (1985);
J. P. Schiffer and O. Poulson, Europhys. Lett. 1, 55 (1986).

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