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ELECTROSTATIC LEVITATION AND TRANSPORT OF LASER FUSION TARGETS

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ELECTROSTATIC LEVITATION AND TRANSPORT OF LASER FUSION TARGETS*

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ABSTRACT

Several levitation concepts have been evaluated resulting in the electrostatic quadrupole being chosen as the most universal. A levitator has been constructed to handle laser fusion targets during and between the processing steps. The levitator is based on a quadrupole rail which is segmented to provide electrically controlled transport and confinement along the rail. This device has demonstrated transport both vertical and horizontal of targets with appropriate mass to size ratios and exhibits remarkably stable confinement at atmospheric pressure.

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Projected laser fusion targets for power reactors will require surface finishes on the order of 100 to 1000 Å and targets must be delivered with reliabilities approaching 100% at rates of 1 to 10 per second. One concept to provide these targets is to sequentially lead a single target through several well characterized processes.[1] Non-contact support, manipulation, and transport of these targets ease contamination problems and should improve the controllability of any process. Several levitation schemes seem capable of this task but with reservations specific to the material of the target, process and technique of levitation. Of these schemes the electrodynamic levitator appears the most versatile.

The electrodynamic levitator applies a centering force on the target through the charge on the shell precisely the way a quadrupole mass spectrometer centers ions along its axis.[2] As shown in Figure 1 four electrodes are given a combination of a.c. and d.c. fields to provide stable levitation for particles of a particular charge-to-mass ratio. In the quadrupole mass spectrometer, the fields are tuned to give maximum resolution while in the case of a levitator, the fields are tuned to stably levitate the maximum range of charge-to-mass ratios. With particles of low charge-to-mass ratio further stability is gained by aligning two of the electrodes with gravity and applying a counteracting field.

Figure 2 shows the electrode geometry employed to suspend and transport targets. The normal quadrupole electrodes are segmented and the transport fields are applied to all four adjacent segments in addition to the levitation fields. Every third electrode segment is tied together and is driven with one phase of a three phase supply to provide the transport fields. This arrangement allows the direction of target travel to be unique.

Figure 3 shows the simple circuit required to levitate and transport the shells. Typical levitation voltages are 2000 volts at 60 Hz A.C. and a 300 volts D.C. gravity counter potential. This circuit uses conventional power transformers and can drive transport systems up to 100 meters long. The transport fields are supplied through programmable power supplied to provide a frequency, i.e. transport velocity variability. In its eventual usage these fields could also be 60 Hz with adjustment of the electrode length to speed or slow the particle. This system would then use conventional and very inexpensive circuitry.

The system transports targets at velocities of from .01 to 10 cm/sec in air. The lower velocity is limited by the circuitry and the upper velocity is determined by the equating of the air drag with the maximum transport fields the circuitry can provide. The system levitates shells reliably for several days. When fully loaded, shells are spaced every third segment and travel in unison with only slight coupling of motion between adjacent particles.

Operating, horizontally or vertically, the direction of the targets transport is changed by reversing the phases of the transport fields. In vertical operation, the maximum transport field is used to assure stability as the transport forces imposed at the target only marginally exceed the force of gravity. In horizontal operation, the D.C. gravity bucking fields allow remarkably smooth and stable operation under all conditions.

The targets are commercially available Ni shells with diameters up to 800 μm. These shells are injected and charged by an axially mounted injector. This injector consists of two plates separated by 1 cm across which ∿ 10 Kv is impressed. The shells oscillate randomly between the plates, charge exchanging at each plate. A small hole in one plate allows an occasional charged shell to be propelled down the axis of the levitator electrodes. Typical charge-to-mass ratios of 10^{-4} C/Kg are measured and agree well with 4×10^{-4} C/Kg calculated by Cho[3] for a shell on a plate in a field.

$$q = 1.65 \cdot 4\pi \varepsilon_0 R_S^2 E$$

The main disadvantage to electrodynamic levitation for processing is that charge must be maintained on the shell during the process. Some of our current processes, especially plasma coating processes, would not be directly extendable to electrodynmic levitation. Other processes such as DT fill, sorting, and neutral beam coating are directly extendable.

In the future, we must develop simple controlling circuitry to reliably transport shells. The levitator must be mated to each process and then the transition between the different process environments must be developed. Electrodynamic levitation is pursued as the first choice for non-contact manipulation and support of processes needing reliable, precise control of three dimensional high expense objects.

References

1) C. D. Hendricks and W. L. Johnson, "Power Plant Production of Inertial Confinement Fusion Targets," Lawrence Livermore Laboratory Report, UCRL-52539, February 15, 1979.

2) R. E. Wuerker, H. Shelton and R. V. Langmuir, J. Appl. Phys. 30, 342 (1959).

3) A. Y. H. Cho, "Contact Charging of Micron-sized Particles in Intense Electric Fields," J. Appl. Phys. (USA), Vol. 35, No. 9, 2561-4 (Sept. 1964).

Figure Captions

Fig. 1 The standard quadrupole rail is used to discriminate between different charge-to-mass ratio as operated in a quadrupole mass spectrometer. The same configuration can also be tuned to levitate a wide range charge-to-mass ratio particles as operated in the transport levitator.

Fig. 2 In the transport levitator the rails are segmented and a three phase transport field is applied between the segments. Particles occupy a slot at every third segment in a fully loaded transport system.

Fig. 3 The voltage supplies for this system are simple 60 cycle power transformers combined with DC supplies.

Q-pole rail

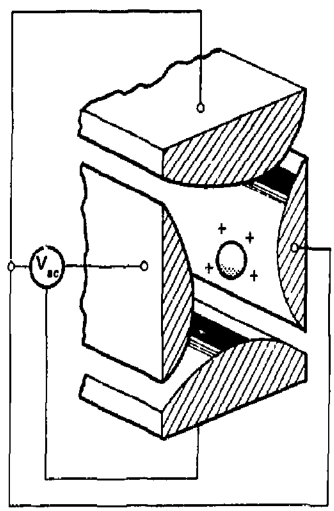
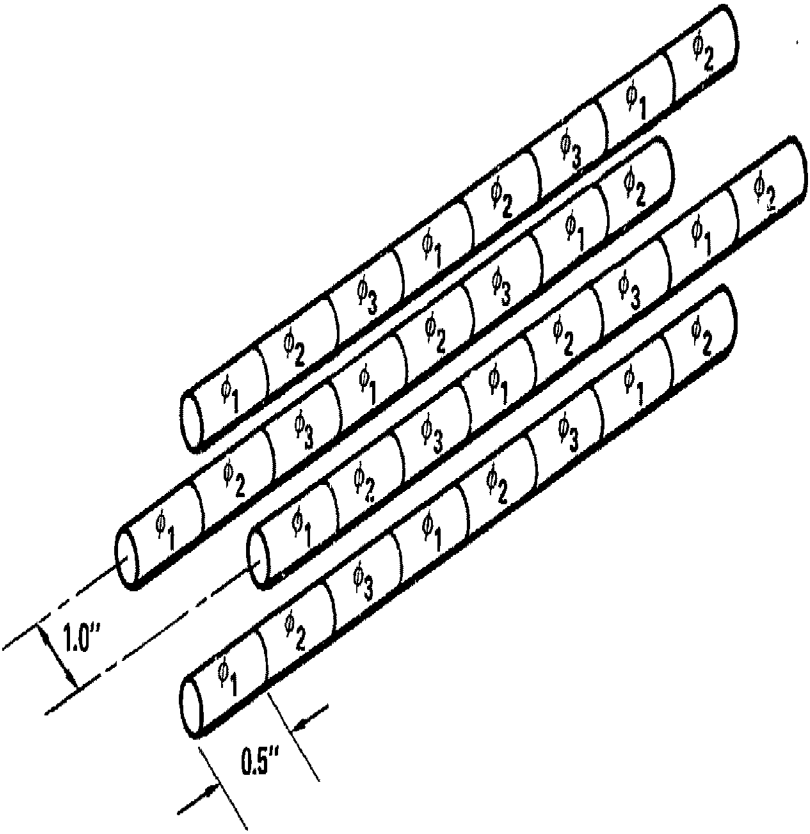


FIGURE 1


ϕ_1 ϕ_2 ϕ_3 ϕ_1 ϕ_2 ϕ_3 ϕ_1 ϕ_2
ϕ_1 ϕ_2 ϕ_3 ϕ_1 ϕ_2 ϕ_3 ϕ_1 ϕ_2
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ϕ_1 ϕ_2 ϕ_3 ϕ_1 ϕ_2 ϕ_3 ϕ_1 ϕ_2
1.0"
0.5"

FIGURE 2

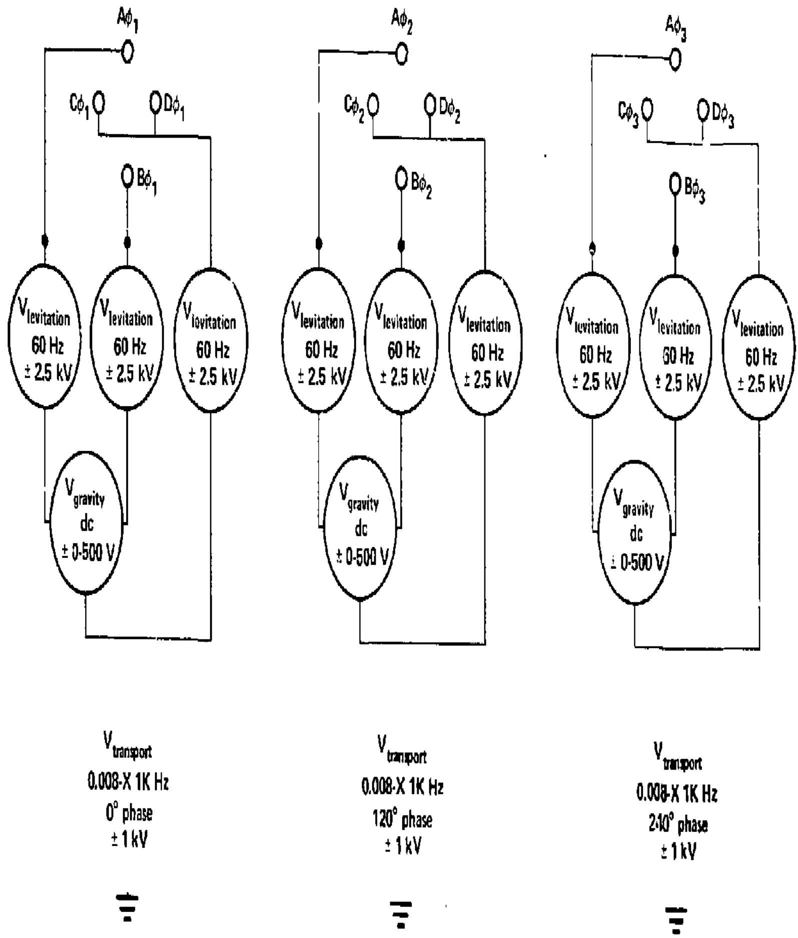
Aφ1
Cφ1
Dφ1
Bφ1
V levitation 60 Hz ± 2.5 kV
V levitation 60 Hz ± 2.5 kV
V levitation 60 Hz ± 2.5 kV
V gravity dc ± 0-500 V
Aφ2
Cφ2
Dφ2
Bφ2
V levitation 60 Hz ± 2.5 kV
V levitation 60 Hz ± 2.5 kV
V levitation 60 Hz ± 2.5 kV
V gravity dc ± 0-500 V
Aφ3
Cφ3
Dφ3
Bφ3
V levitation 60 Hz ± 2.5 kV
V levitation 60 Hz ± 2.5 kV
V levitation 60 Hz ± 2.5 kV
V gravity dc ± 0-500 V
V transport 0.008-X 1K Hz 0° phase ± 1 kV
V transport 0.008-X 1K Hz 120° phase ± 1 kV
V transport 0.008-X 1K Hz 240° phase ± 1 kV

FIGURE 3