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FORCE-FIELD TAILORING: FIRST-PRINCIPLES DERIVATION OF WALL FORMATION PHYSICS

Abstract

Long-term human habitation in space requires the ability to use extraterrestrial materials to build massive radiation-shielded artificial-gravity stations. The technology of Tailored Force Fields promises to enable formation of desired shapes from multidisperse construction material in microgravity. Briefly, this technology is based on the flight test result that solid particles placed in a resonant field in microgravity, drift to predictable nodal surfaces of the resonator, and form continuous walls there.

At IAF 2005, the status of development of TFF was summarized in the context of a mission plan to build a 5-module, 1-G radiation-shielded station. The status of validation of a unified theoretical description of the central phenomenon was also delineated.

This paper builds on the previous work, and discusses two aspects. First, a summary of discussion of various architecture options and routes towards an eventual space construction capability. Secondly, the detailed validation process of the theory. The first aspect pushes the technology development and mission planning to more realistic levels, examining various options to reduce program risk and cost while opening different applications. This uses modern system engineering techniques to compare different paths and determine optimal solutions.

At issue is the hypothesis that dielectric solid blocks can be formed into walls of desired shape using the forces developed in an electromagnetic resonator in vacuum, operating in the long-wave radio spectrum. The goal of present efforts is to develop a simulation based on first-principles physics, showing that particles starting at random locations in such a resonator will indeed drift and form walls at the predicted locations, analogous to what is observed in acoustic resonators in microgravity flight tests.

Results: As discussed previously, the equations describing electromagnetic and acoustic radiation force fields in resonators, are analogous. The analogy has been used to predict the force on an isolated sphere of millimeter dimensions in a microwave field, and shown to match the measured forces in a JPL experiment. The issue then shifts to whether multiple particles in proximity will indeed form walls, and what governs this wall formation. Recent experiments using acoustic resonators in 1-G have systematically studied the forces between two suspended particles, which a theoretical formulation using dipole fields has succeeded in modeling the attraction between particles. At this writing, the experimental results on multi-particle forces, and the theoretical formulation using diploes, are showing parallel results. A FEMLAB simulation is being used to generate the electromagnetic field solution in the presence of walls and particles. In the full paper, we expect to have brought these three paths together in a simulation program, and show

the results on how walls form in electromagnetic fields. The role of higher harmonics in establishing stable and unstable wall locations is also studied.

The capability being developed, will open the way to study the effects of dielectric properties and frequencies on the wall formation.

Conclusions: Particles in resonators experience primary radiation forces that drive them towards the stable locations. The formation of walls at these locations is determined by interparticle forces. These forces can be modeled using dipole representations. It is seen that certain orientations cause attractive forces, and these orientations correspond to the desired wall shape. Higher harmonics which are present to some small extent in practical resonators, render certain symmetric surfaces unstable, thus enabling wall formation at the more interesting surface shapes.

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