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Noncontact Acoustic Forces for Surface Decontamination

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Introduction

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- The performance of space bound hardware can be improved by minimizing contamination
- Hardware responsible persons and Contamination Control Engineers (CCEs) have various means to clean and maintain cleanliness of contamination sensitive surfaces
  - Managing contamination starts early in the build of hardware
  - As hardware manufacturing and assembly progresses, cleaning methods that are utilized vary depending on cost and schedule risks
- With these in mind, the following effort potentially provides an additional means in a CCEs playbook to manage particulate contamination

Particulate Removal

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- Particulate contamination removal mostly rely on exerting enough force to overcome the adhesion forces
  - Adhesion forces include van der Waals, electrostatic, gravitational, capillary, chemical, etc.
- Removal methods range from hydrodynamic (rinse, CO2 jet, etc.), ultrasonic (solvent tanks), mechanical (brush, drag wipe, etc.), and others
  - The effectiveness of these methods continue to be the subject of studies with associated advantages and disadvantages for each
- We are introducing a method that potentially provides significant advantages to many of the limitations in historically utilized particulate removal methods

Acoustic Field Induced Forces (FIF)

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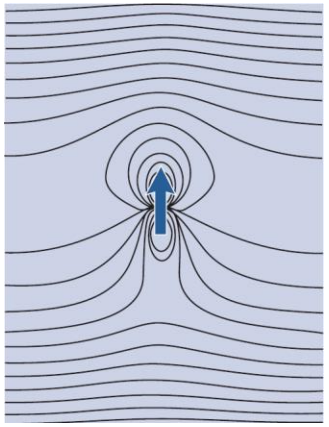
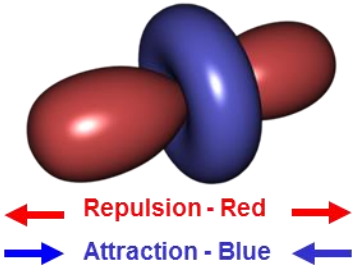
- Acoustic FIF can remove particles from a surface through non-contact means
  - Acoustic wave motion is used to induce forces onto particles with a difference acoustic impedance from its host medium (by altering the energy density distribution)
  - This is based on a fundamental physical property of waves and their interaction with matter (waves carry energy and momentum with no net mass flow)
- Additionally, particles can be trapped, translated, and isolated away from clean surfaces

A plane wave incident upon a rigid particle





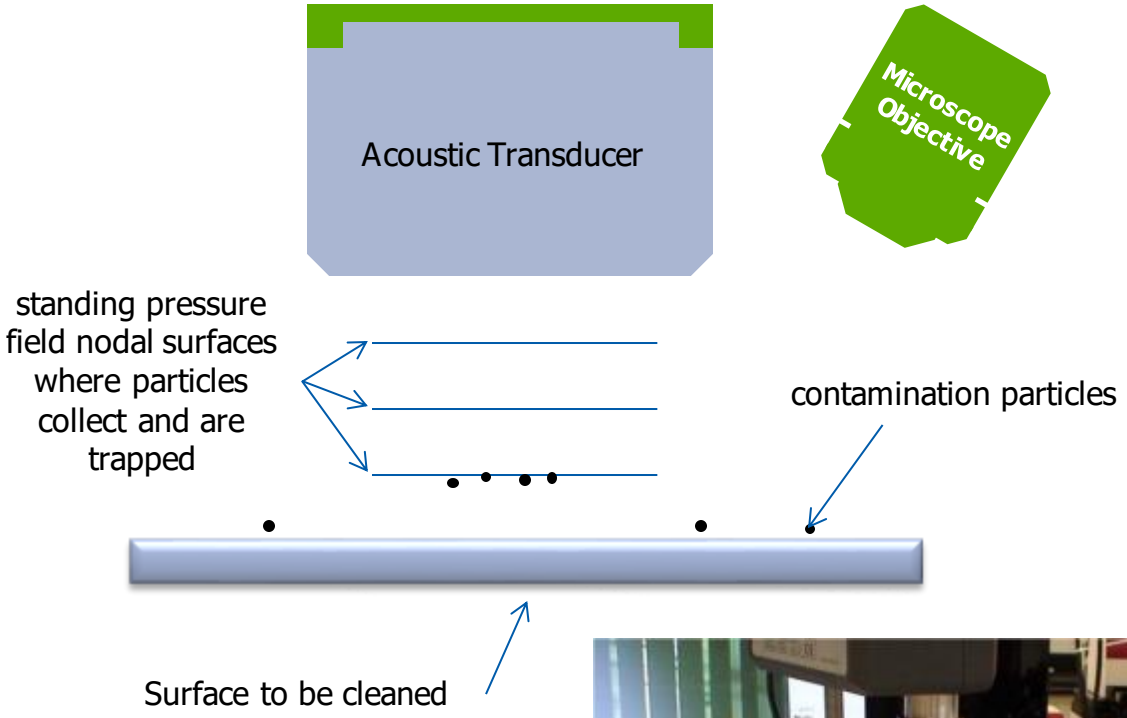
Primary force

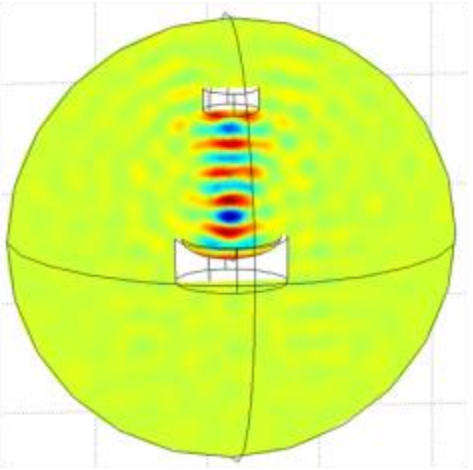
Secondary force

k wavenumber
a particle radius

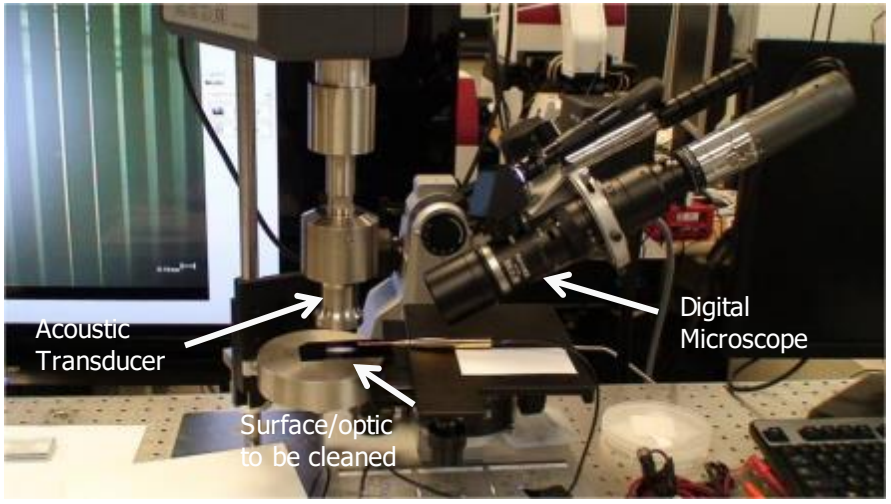
Field-induced forces onto a small (ka<<1) particle

Experimental Setup



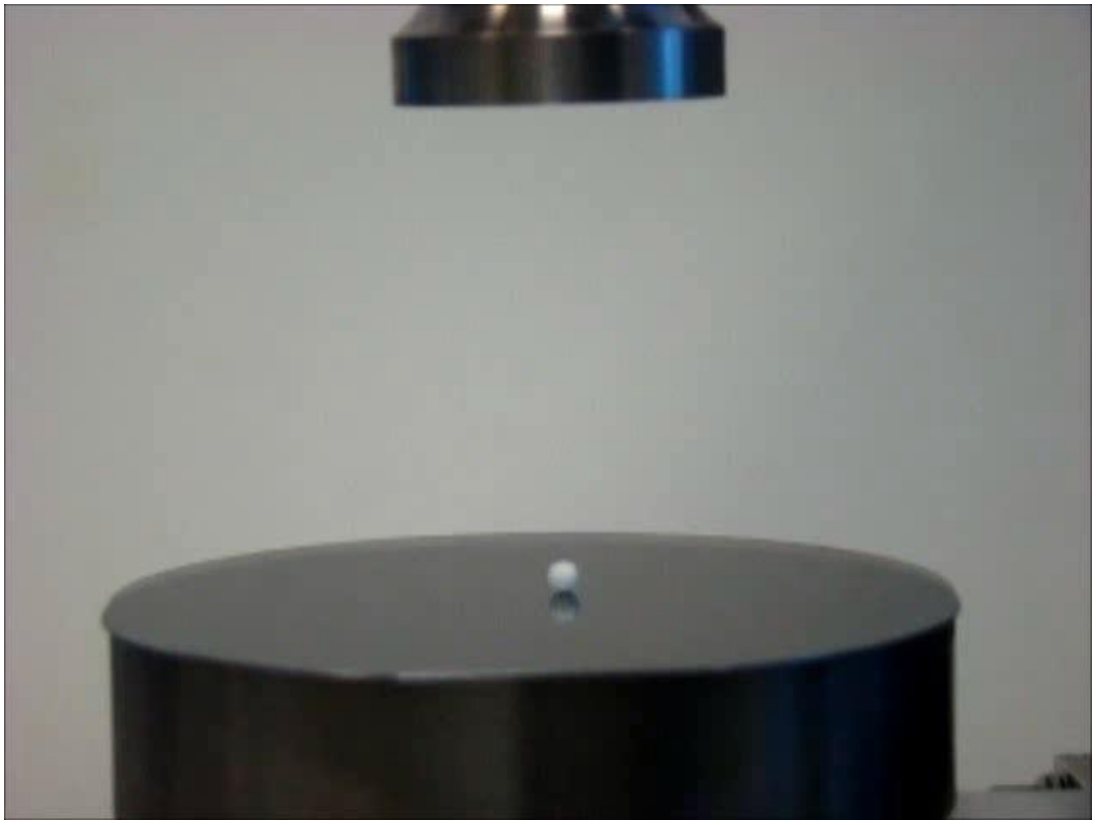


Pressure field between transducer and surface modeled in COMSOL



Large Scale Particle Proof of Concept

System Robustness



Small Scale Particle Proof of Concept

Stable trapping of corn starch particulates (~10um) at high frequency

Acoustic Phased Array

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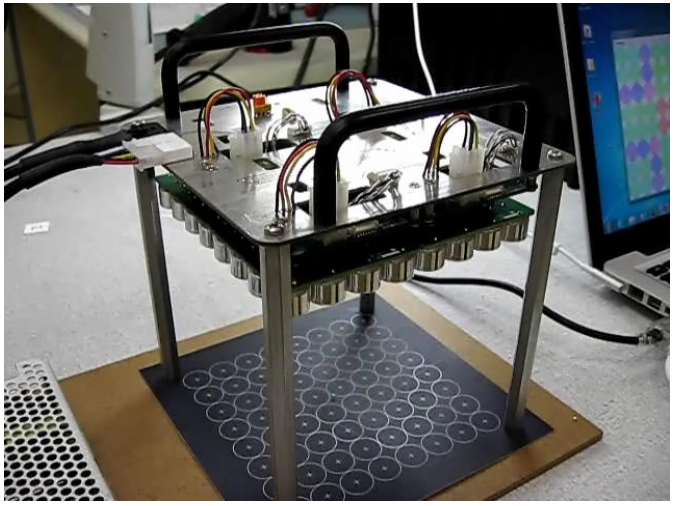
No moving parts



Results Before and After FIF Application

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20μm glass beads on glass slide

before

after

Si Wafer Sample Cleaning - before

Si Wafer Sample Cleaning – first scan

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Si Wafer Sample Cleaning – second scan

Si Wafer Sample Cleaning – third scan

Summary/Conclusions

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New method for achieving contamination control over large surfaces with the following features

- Noncontact – less possible damage to surface or cross contamination
- No moving parts – less chance of impact / particle generation
- Trapped contamination allows for surety for location of particles after liftoff
- Ability to characterize contamination

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Backup

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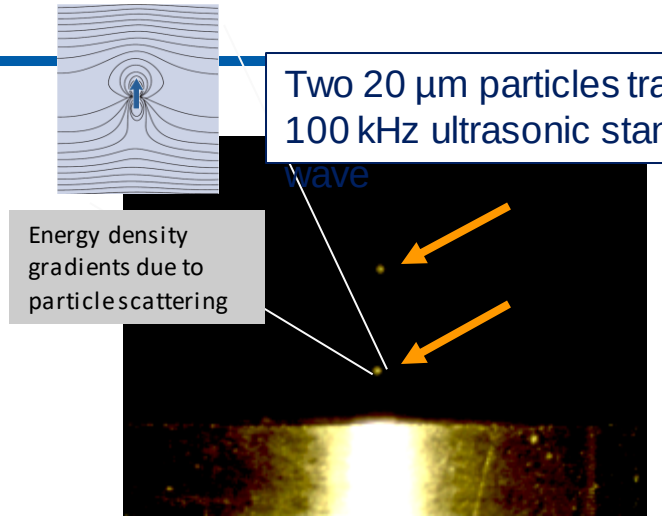
Objective: A non-contact method for removing particulates from optical surfaces in-situ.

Description: Field-induced forces (FIF), created by standing waves, are proposed as a non-contact tool to: *detach, trap, translate, and isolate* of particulates adhered to an optical surface.

Current TRL 4 for acoustic FIF,
2 for EM/optic FIF



Impact: Enabler for cleaning and decontamination of optical surfaces on the ground and in space. Enables devices to operate at their intended performance immediately.

Innovativeness: The use of field forces to induce non-contact forces to detach, trap, translate, and isolate particulates adhered to an optical surface is new

Likelihood of rapid transition: High probability of insertion resulting from successful component and basic system experiments in the lab

Most significant risk to success: At certain particle sizes and smaller, FIF may not be able to detach these particles against their surface adhesion forces and thus at such scales would only be used in trapping, translation, and isolation.

Feature	Benefit
Non-contact	Avoids contact with highly sensitive coatings on optical surfaces
Scalable	Field wavelength tuned for a address a variety of particle sizes
Flexible	System can be tailored to various geometry surfaces
Adaptable	Utilizes more than one field type to accommodate different conditions (e.g. air and vacuum)

Acoustic FIF can be applied to surfaces in an air environment, EM/optic FIF can be applied to surfaces in vacuum

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