

### **Spatiotemporal dispersion analysis and theoretical model fitting of self-excited dust acoustic waves in cryogenic water-ice plasma**

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We investigate the spatiotemporal dispersion characteristics of self-excited dust density waves propagating through dense, levitated cryogenic water-ice grain clouds (Telectrode  $\approx$  150 K, 13.56 MHz RF power at 40 W) across dynamic neutral gas pressure sweeps. Utilizing high-speed video recording at 1900 frames/s, a time-domain Hilbert transform algorithm is implemented to construct two-dimensional empirical dispersion density maps  $S(k, \omega)$  on a fixed  $4000 \times 2000$  grid matrix (Menzel et al. 2011; Tadsen et al. 2015). Wave frequencies substantially higher than those commonly reported for room-temperature dusty plasmas are observed. Empirical dispersion ridges are systematically evaluated against Thermal DAW, Linear DAW, Discrete Dust Lattice Wave (DLW), and Continuum DLW theoretical models (Rao et al. 1990; Farokhi et al. 1999). We demonstrate that incorporating a low-wavenumber confinement offset  $\omega_0$  eliminates systematic residual errors near  $k \rightarrow 0$  without requiring unphysical thermal parameter values. More significantly, evaluating the Thermal DAW and Discrete DLW descriptions against the empirical dispersion ridges shows that these two models capture the observed curvature, indicating that the dispersion relation is not strictly linear in wavenumber. Furthermore, dynamic pressure sweeps reveal a clear inverse frequency-pressure relationship ( $d\omega/dP < 0$ ), potentially driven by Epstein neutral gas friction (Flanagan & Goree 2010). The methodology and results presented establish an experimental and analytical frame-work for probing collective modes in cryogenic, non-spherical ice clouds.

### **Langmuir probe for Caltech Water-Ice Dusty Plasma Experiment**

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Langmuir probe measurements of electron temperature ( $T_e$ ) are being conducted for the Caltech Water-Ice Dusty Plasma Experiment, where ice grains are formed by injecting water vapor into a cold, capacitively coupled plasma (CCP). To better understand the impact of ice grain formation on the surrounding plasma, measurements of  $T_e$  were taken with and without the presence of ice grains. Based on preliminary results, a probe bias exceeding +20 V DC is necessary to characterize the plasma's full range of electron energies. Langmuir probes are difficult to implement in CCPs due to I-V curve smearing caused by sheath oscillations<sup>1</sup> and spurious RF pickup by probe electronics. Two methods are being used to reduce this effect. The first method aims to decrease smearing by taking measurements at a fixed phase of the RF cycle over a range of probe biases. The second method attempts to avoid RF effects via data collection in the plasma afterglow. Initial measurements using traditional techniques and the first method both show a higher  $T_e$  than expected. Both reduction methods for RF effects will be attempted, refined, and presented.

<sup>1</sup>A. Garscadden and K. G. Emeleus, Proceedings of the Physical Society 79, 535 (1962).

### **Thermal imaging with a temperature-sensitive polymer using electrical impedance tomography**

Tara T. Zhan

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Temperature mapping across large, flexible surfaces would benefit robotics and wearable sensors for healthcare, but infrared cameras cannot image curved or obstructed objects, and grids of point sensors require complex wiring that scales with area. We are developing a thermal imaging sheet that avoids both limits by pairing electrical impedance tomography with a temperature-sensitive polymer whose conductivity increases as it is heated. A thin film of the polymer is cast onto a flexible board with sixteen perimeter electrodes. Heating raises the conductivity only where the heat lands, altering how current spreads between every pair of electrodes, so an image of the interior can be

reconstructed from edge measurements. A known heat source is applied at chosen positions while impedance is recorded across all electrode pairings. Reconstructions place a single localized region of raised conductivity at the heat source, and its magnitude grows with the temperature applied, showing that the sheet recovers both where heat is applied and how intense it is. Ongoing work quantifies temperature sensitivity and spatial resolution, improves film durability, and extends testing to curved surfaces.

### **Development of a sample mount and high dynamic range power meter for ytterbium-based quantum interfaces**

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Quantum networks rely on interfaces between optical photons and matter-based qubits. Rare-earth-ion solid-state systems, particularly ytterbium in yttrium orthovanadate ( $^{171}\text{Yb}^{3+}:\text{YVO}_4$ ), offer a promising platform due to their long spin coherence lifetimes and fast microwave control. This project develops a cryogenic compatible sample mount for the  $^{171}\text{Yb}^{3+}:\text{YVO}_4$  crystal, and a cost-effective, high dynamic range laser power meter that is optimized for the zero-phonon optical transition between the  $^2F_{7/2}(0)$  ground state and the  $^2F_{5/2}(0)$  excited state of the ytterbium ion at 984.5nm. This project aims to improve the operational efficiency of the experimental setup, by improving the accessibility of the  $^{171}\text{Yb}^{3+}:\text{YVO}_4$  crystal and developing a highly compact and reproducible power meter. These developments provide a practical foundation for advancing ytterbium-based quantum network research, enabling more efficient characterization and control of the  $^{171}\text{Yb}^{3+}:\text{YVO}_4$  spin-photon interface for future quantum networking applications.

### **Theoretical optimization of pick-up coil configurations for vibrating sample magnetometry**

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Accurately measuring the magnetization of materials relies on maximizing the induced voltage in the pick-up coils of a vibrating sample magnetometer. Historically, established coil geometries have provided a baseline for these measurements, but advanced materials analysis requires greater sensitivity and lower noise. This project investigates a new, optimal pick-up coil configuration and ideal vibration direction to maximize signal detection. Using numerical methods and computational simulations, we evaluated the spatial distribution of magnetic field derivatives to dictate precise coil positioning and shape. Our analysis identified novel coil geometries that yield at least two and a half times the signal pickup of standard configurations. These specially shaped and oriented coils capture significantly more of the induced signal. Implementing this optimal configuration will enable more accurate readings of magnetic moments, substantially reducing noise and improving the precision of future magnetic measurements.

### **Engineering a cryogenic cold finger for high-frequency characterization of superconducting microwave resonators**

Ella Guo

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Quantum phenomena such as superconductivity emerge only under extreme conditions, requiring ultra-low temperatures to reach the superconducting state. In this project, superconducting microwave resonators fabricated from NbO thin films that exhibited magnetic-field-induced superconductivity are being studied beyond conventional direct-current transport measurements to investigate the origin of the superconducting state. These measurements require high-frequency characterization while the resonators are positioned at the center of a superconducting magnet and kept at a temperature near that of a dilution refrigerator, approximately 10 mK. Since the mixing chamber, the coldest stage of the dilution refrigerator, is not located at the center of the superconducting magnet, a thermal connection is needed between the mixing chamber and the resonators. A cryogenic cold finger was therefore designed and is being fabricated to provide this thermal connection while keeping the resonators positioned at the center of the magnetic field. The primary thermal link is made from high-purity silver, which is annealed to improve its thermal

conductivity. Once fabrication is complete, the performance of the cold finger will be tested to determine how effectively it keeps the resonators at ultra-low temperatures during high-frequency measurements in applied magnetic fields.