ABSTRACT
The applications of dusty plasma research are far-reaching, from understanding astrophysical systems to studying plasma-wall interactions in magnetically-confined plasma experiments. Consequently, dusty plasma environments can be difficult to control and replicate in laboratory settings. This paper details the construction, vacuum operation, and initial results of a multifaceted dust dropper, which is being implemented in the Princeton Plasma Physics Laboratory Dusty Plasma Experiment (DPX). The cylindrical polyelectrolyte (POM) shaker comprises four pairs of electromagnets and neodymium magnets, with eight stabilizing springs. The amplitude and frequency of a damped current determine the dust dispersal rate, while a biased metallic mesh regulates the area of dispersion and size, charge, and velocity of dropped particles. Dispersal rates from 100 to 10,000 particles/s are observed, and reproducibility of dust cloud formation is achieved.

INTRODUCTION
Normal plasma = Electrons + Ions + Neutral atoms
Dusty plasma = Normal plasma + Granular particulates (nm-µm)
Dusty plasma research is relevant to many areas of science:
• Astrophysics – Interstellar media [1]
• Technological processing – Computer chips and thin films [1]
• Magnetically-confined plasma experiments – Fusion research [2]

MOTION OF THE SHAKER
A function generator supplies voltage pulses of duty cycle 5% to the dust dropper via an amplifier (Fig. 1). The driving force, \( F(t) \), of the shaker can be written as a Fourier expansion of these periodic pulses of amplitude \( F_0 \), duty cycle \( D \), and frequency \( f \):

\[
F(t) = F_0 + \sum \frac{2m+1}{2} \sin(2\pi f(2m+1) + (1 - \cos(2\pi D) + \sin(2\pi f(m+1)))
\]

The driving force of the shaker is a linearly increasing function of time:

\[
F(t) = F_0 + \frac{1}{2} \sum \frac{2m+1}{2} \sin(2\pi f(2m+1) + (1 - \cos(2\pi D) + \sin(2\pi f(m+1)))
\]

The instantaneous power delivered to the system is the product of the force and velocity (as determined from the solution of the equation of motion). The time-averaged power delivered to the dropper is

\[
P(t) = \frac{1}{T} \int_0^T F(t) \text{d}t = \frac{1}{2} \sum \frac{2m+1}{2} \sin(2\pi f(2m+1) + (1 - \cos(2\pi D) + \sin(2\pi f(m+1)))
\]

The power absorbed by the shaker for several damping coefficients.

RESULTS
RESONANT FREQUENCY
The resonant frequency of the dust dropper ranges from 7 to 10 Hz. The motion of the dropper is most consistent with that of a driven underdamped oscillator with damping coefficient of approximately 0.5% (Fig. 4).

DUST DISPERSAL RATE
At resonance, dust dispersal rates tend to:
• Increase as the applied voltage increases (Fig. 5).
• Exhibits strong sensitivity to the conditions of a dust sample (Fig. 6).

RESULTS (CONTINUED)
DUST CLOUD FORMATION
Dust clouds form in dusty plasmas when the electrostatic force on the charged dust particles balances the force of gravity (Fig. 7).

CONCLUSION
Although dust dispersal rates are still somewhat unpredictable, this dust dropper can:
• Regulate the size of particles and area of dispersion
• Support a wide range of dispersal rates
• Create reproducible dusty plasma environments (clouds) from only dropped dust

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