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Session 3aED, Education in Acoustics: Student posters, May 25, 2016, 8:00 AM - 10:00 AM.

Vibration experiments using a clamped circular elastic plate with edible granular material loading.

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Abstract:

An apparatus called the soil-plate-oscillator (SPO), designed to study flexural vibration of a soil loaded plate, consists of a thin circular elastic (acrylic) plate (8 inch diam, 1/8 inch thick) clamped below a thick-wall cylindrical aluminum tube supporting a vertical soil (or sand) column or other granular material. A small accelerometer attached to a 1 cm diam rare earth magnet (which is fastened to the center of the plate from below) is used to detect the plate vibration response. The plate is driven from below by an AC coil (located coaxially below the plate and securely fastened) using an amplified swept sinusoidal current. The charge amplified accelerometer signal is measured vs. frequency by a spectrum analyzer. With interest in studying light density granular media (with various grain sizes) experiments were performed with uncooked brown rice, quick oats, un-popped popcorn kernels pretzel gold fish crackers and pretzel nuggets. The resonant frequency reaches a minimum and then increases with increased granular medium loading due to the material's flexural stiffness which overcomes the mass loading effects. Results (normalized to the unloaded frequency and clamped plate mass) are compared with dry sifted masonry sand. A theoretical model is used to help describe the effects.

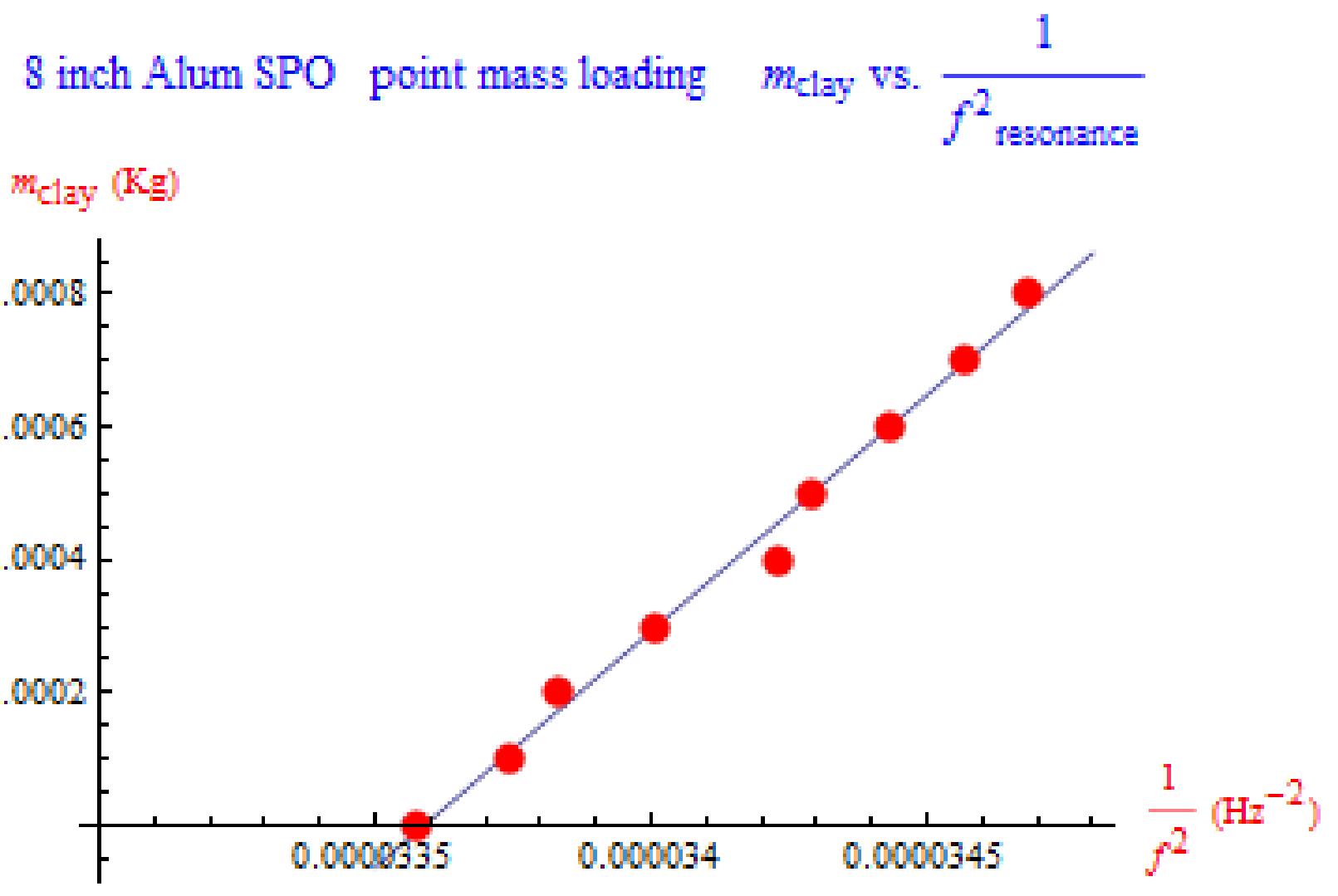

Fig 7. The unloaded SPO resonant frequency is recorded along with data for incremental 0.1 gram clay mass loading at the center of the plate. Here $M_{p\ eff}$ + $M_{accel\&mag}$ + M_{clay}= $K/(2\pi)^2$ predicts a spring constant K = 28090 N/m and $M_{p\ eff}$ = 16.2 grams. Since the clamped plate mass is M_p = 108 grams, $M_{p\ eff} / M_p = 0.15$. Snowden (JASA) predicts $M_{p\ eff} / M_p = 7/54 = 0.13$ for a point driven thin circular elastic clamped plate.

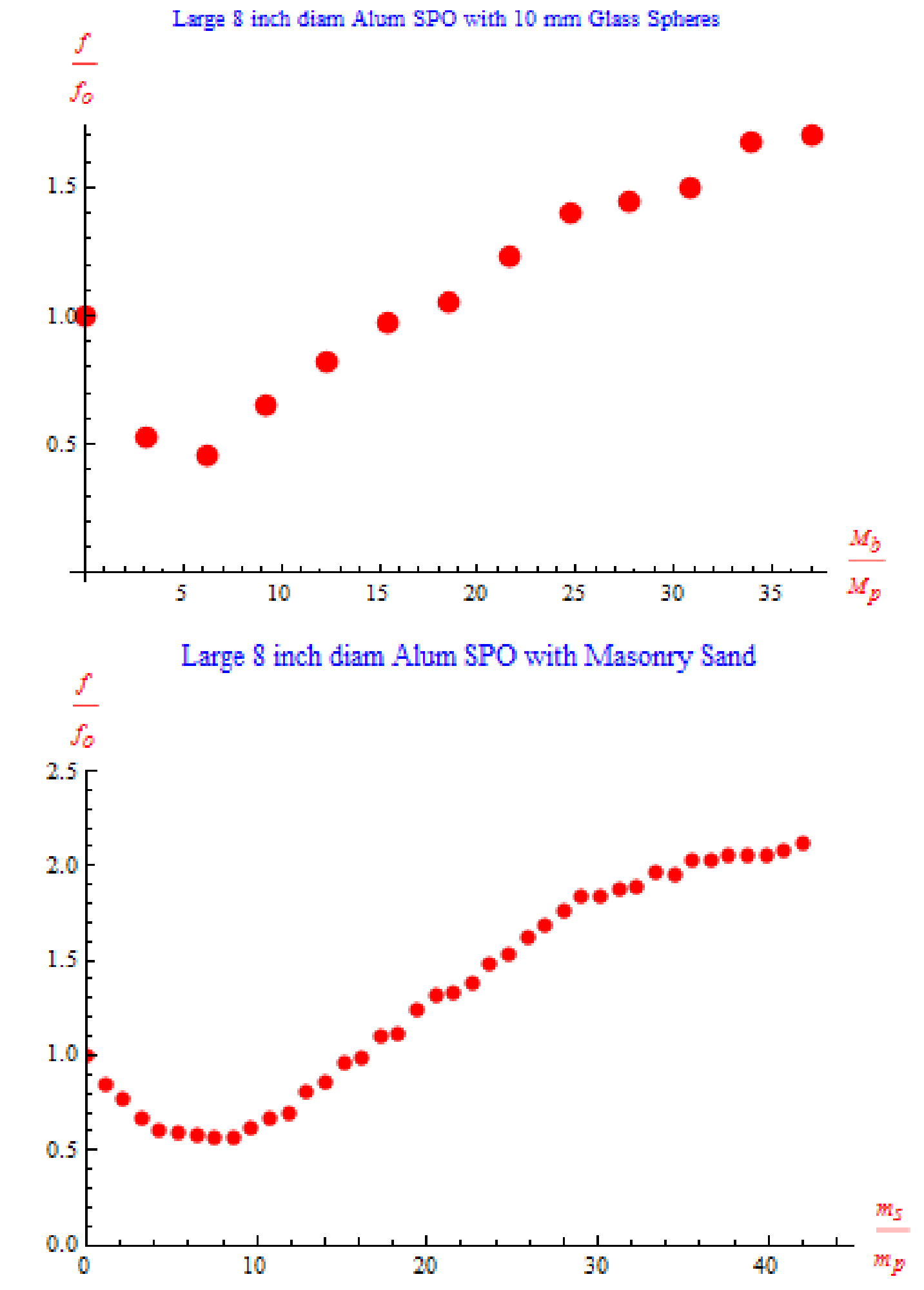

Fig 8 . Comparing resonant frequency vs. mass loading in an 8 inch diam SPO with (A) 10 mm glass spheres, (B) sifted masonry sand

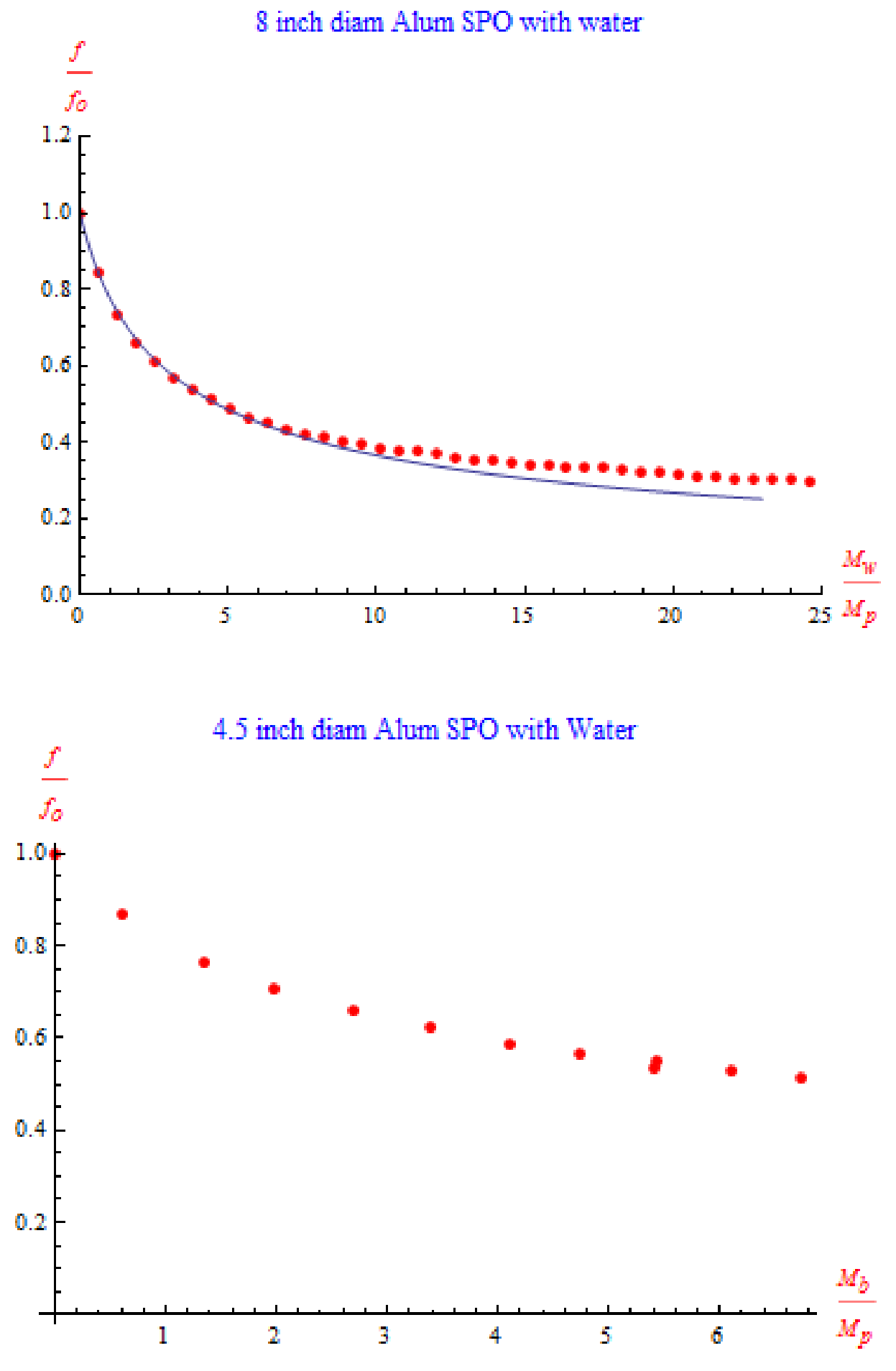

Fig 9 . Comparing the resonant frequency vs. water mass loading effects in an 8 inch diam and a 4.5 inch diam SPO

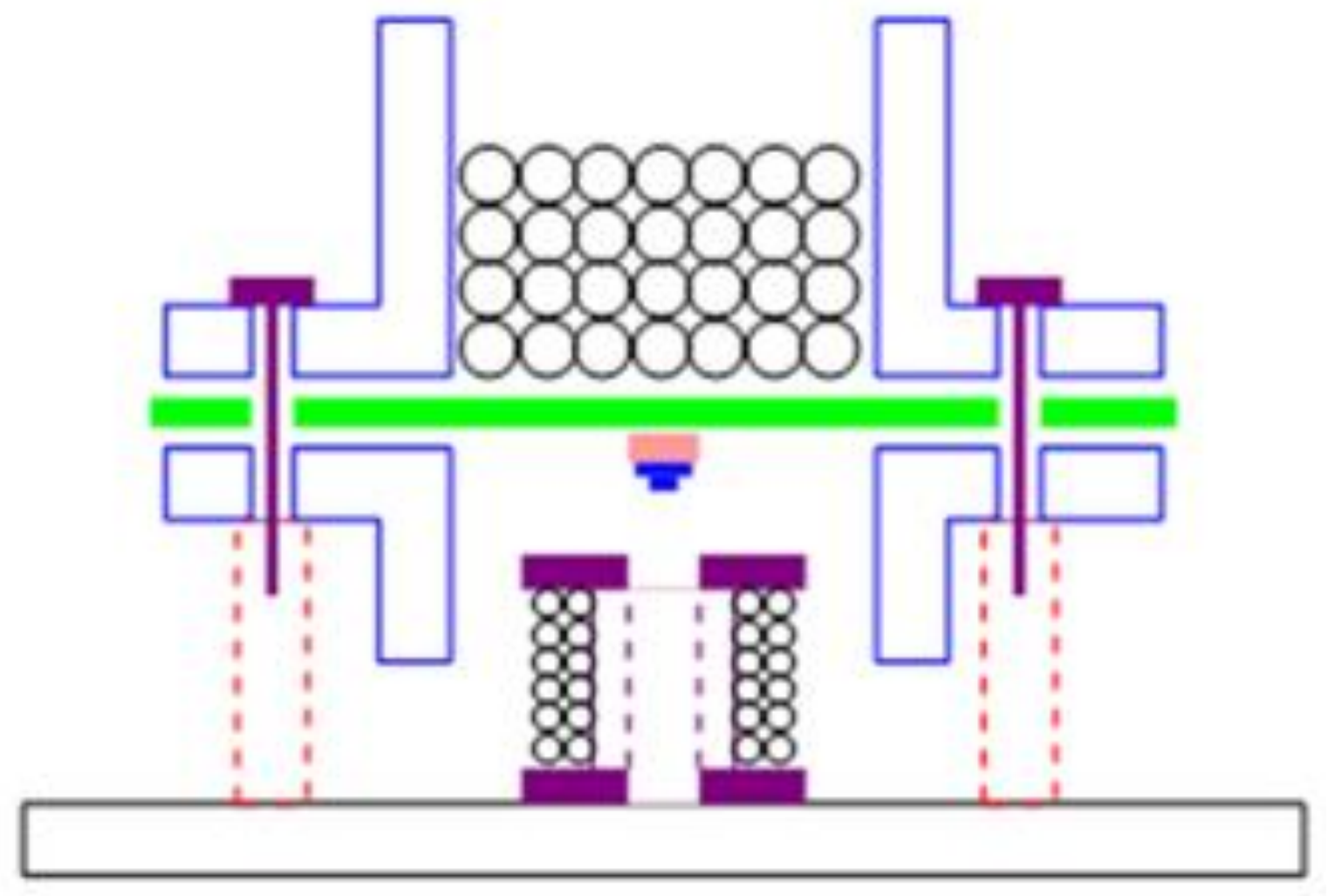

Fig 10. The Soil Plate Oscillator (Figure by Emily Santos) shows a cross-section of the two 4.5 inch diam PVC mating flanges, the 1/8 inch thick acrylic plate (green), the AC coil and the rare earth magnet and accelerometer attached to the underside. (Drawing not to scale.)

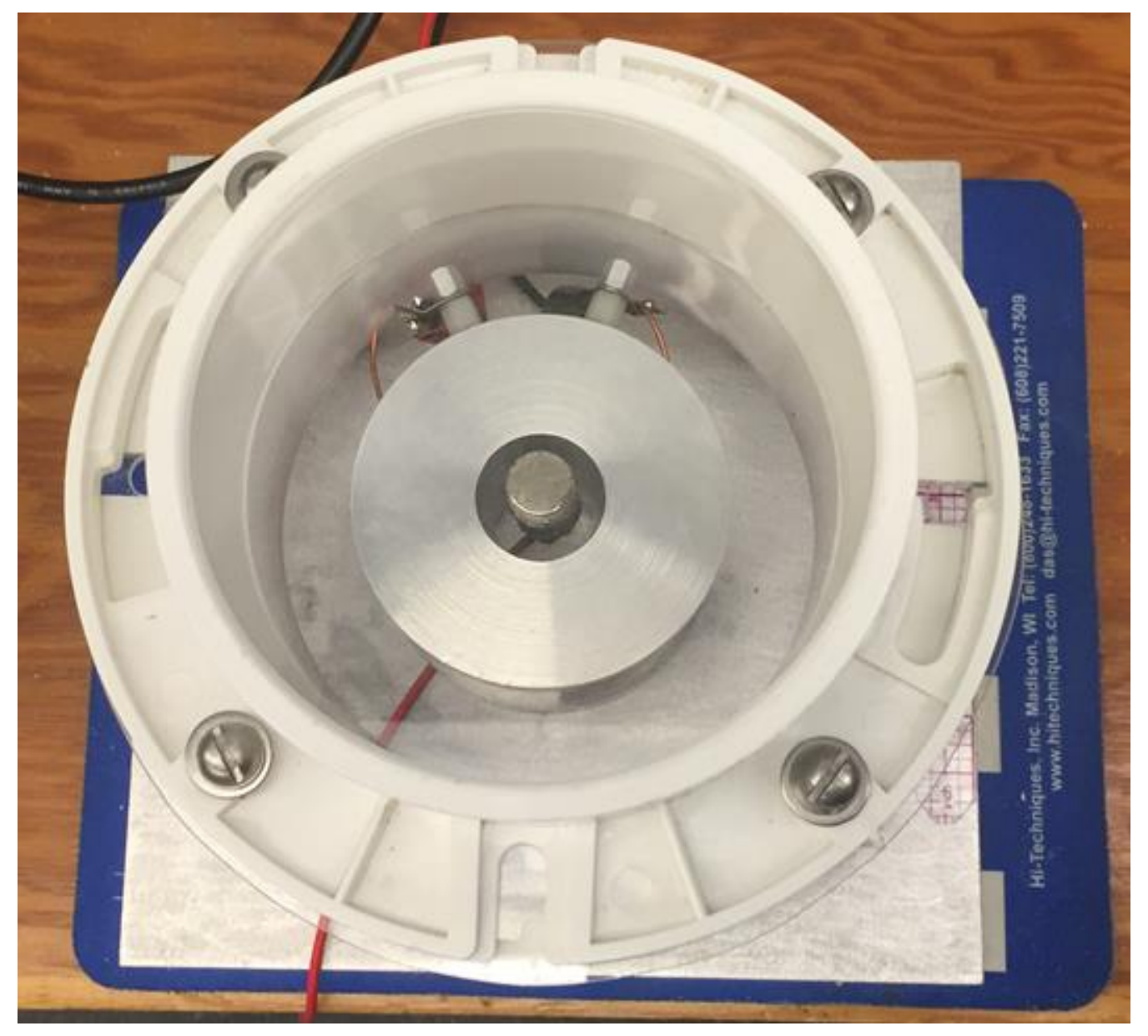

Fig.1. Soil Plate Oscillator (4.5 inch diam PVC flanges with 1/8 inch thick clamped acrylic plate). Underside: rare earth magnet with accelerometer and AC coil driven by an amplified (10 W audio amplifier) swept sine.

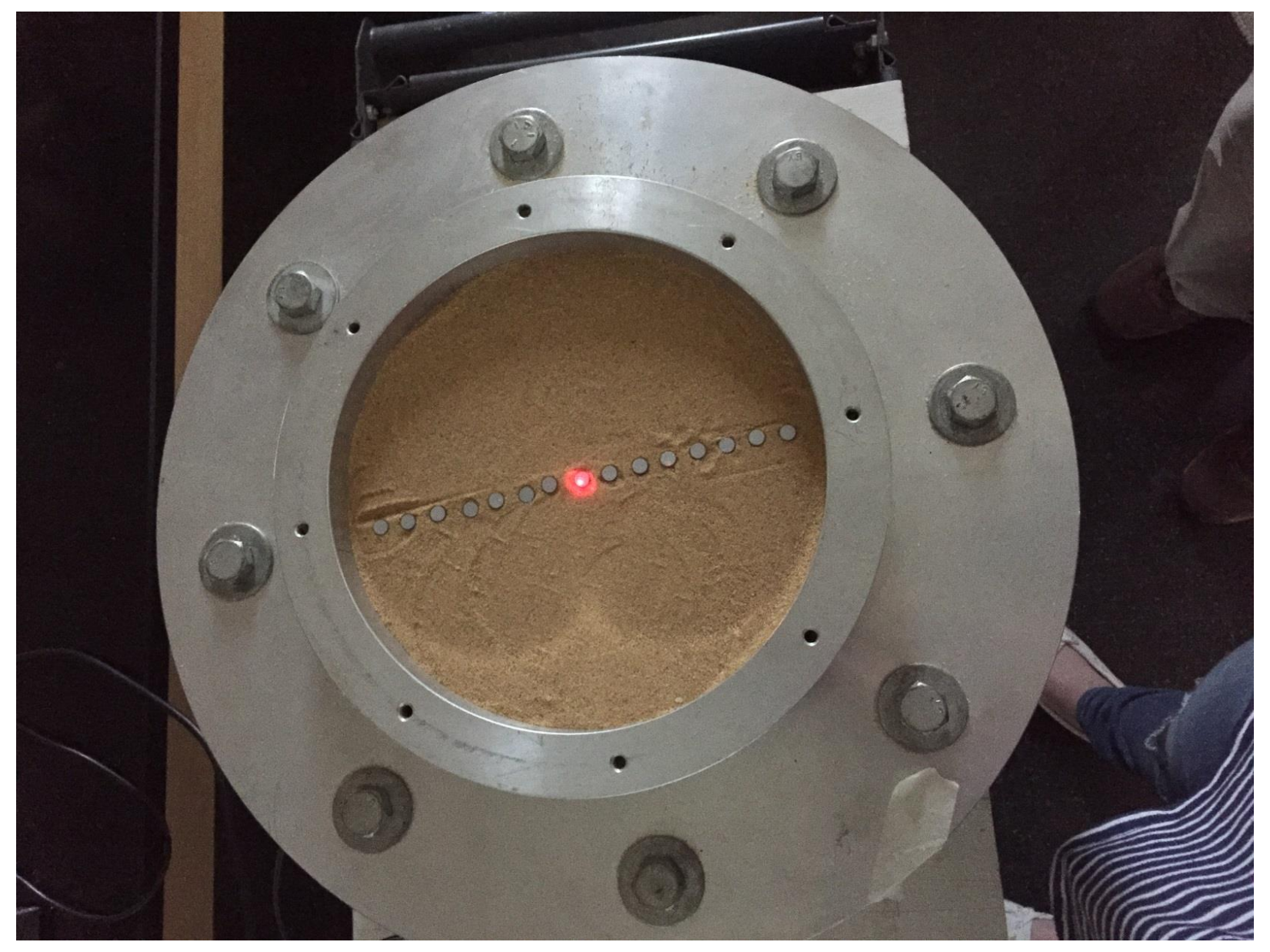

Fig. 2. Soil Plate Oscillator (8.0 inch diam Alum flanges with 1/8 inch thick clamped acrylic plate). Underside: rare earth magnet with accelerometer and AC coil driven by an amplified (10 W audio amplifier) swept sine.

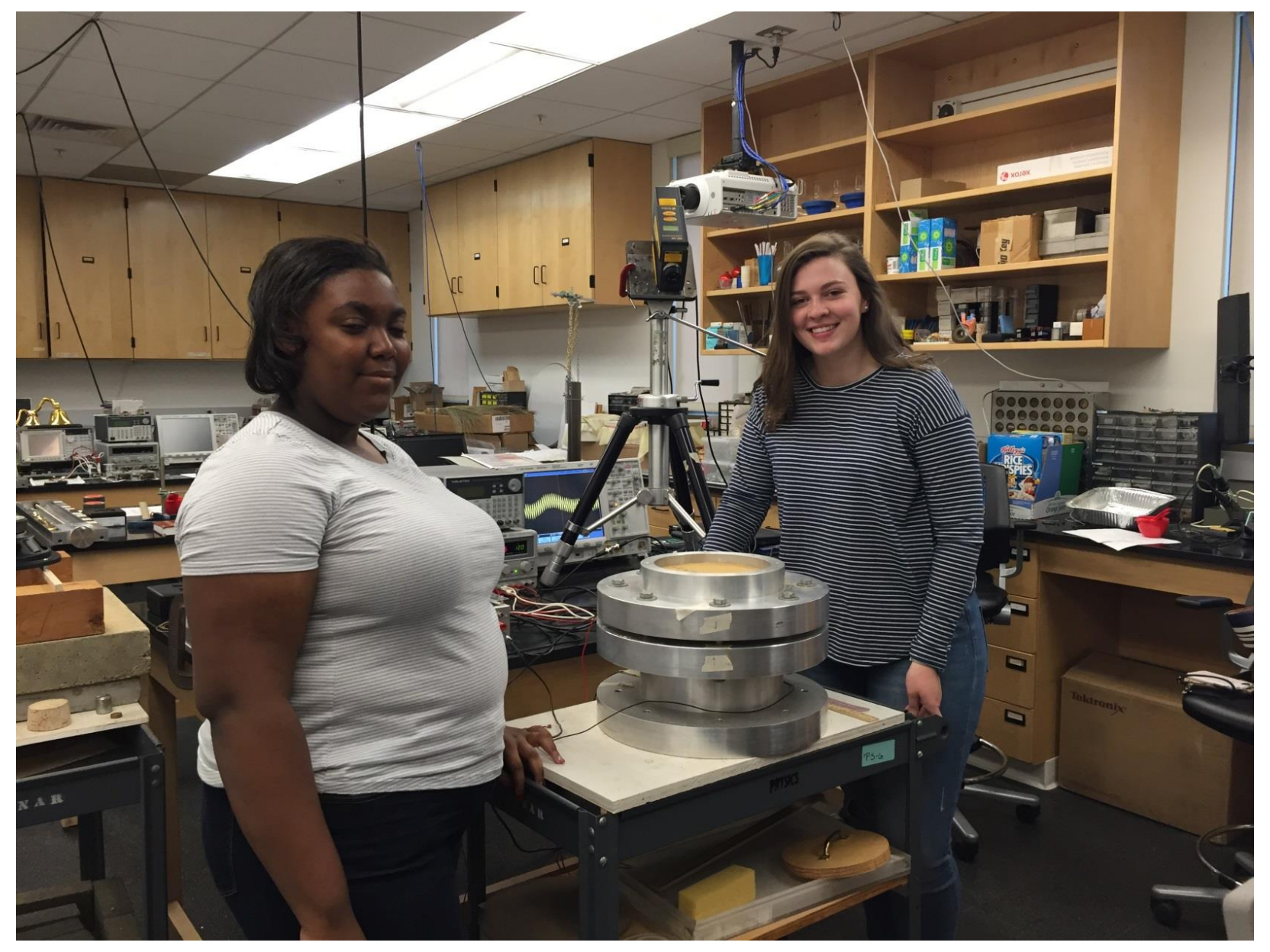

Fig. 3. Ebonie Smith and Blair Lewis measuring the soil surface particle velocity on the surface of the SPO filled with dry sifted masonry sand. A Polytec 100 laser Doppler vibrometer is used to measure the particle velocity vs. swept tone from 50 Hz to 450 Hz.

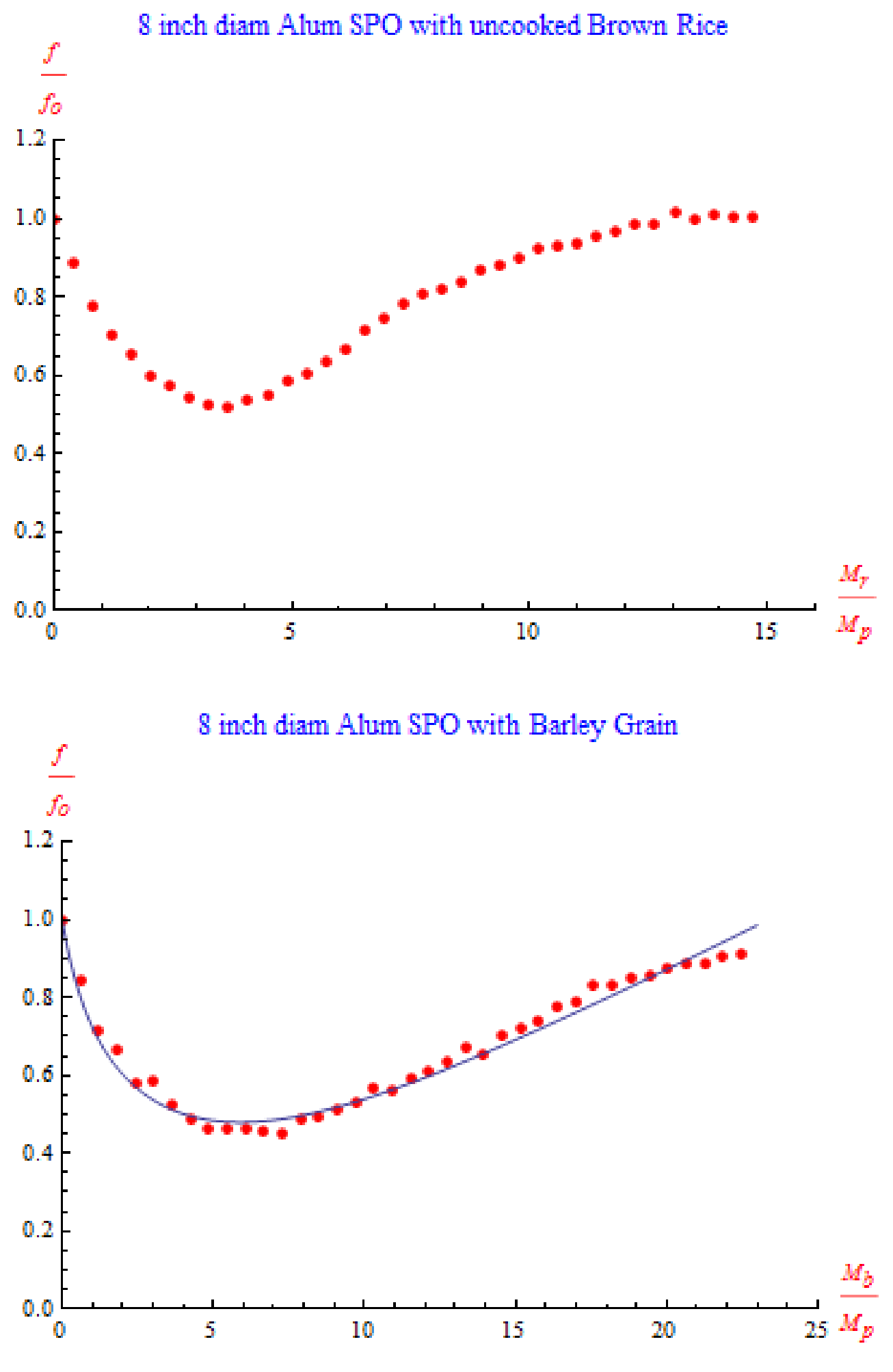

Fig 11 . Comparing the resonant frequency vs. mass loading in an 8 inch diam SPO using (above) uncooked brown rice and (below) barley. The mass is normalized to the clamped plate mass Mp = 107.5 grams.

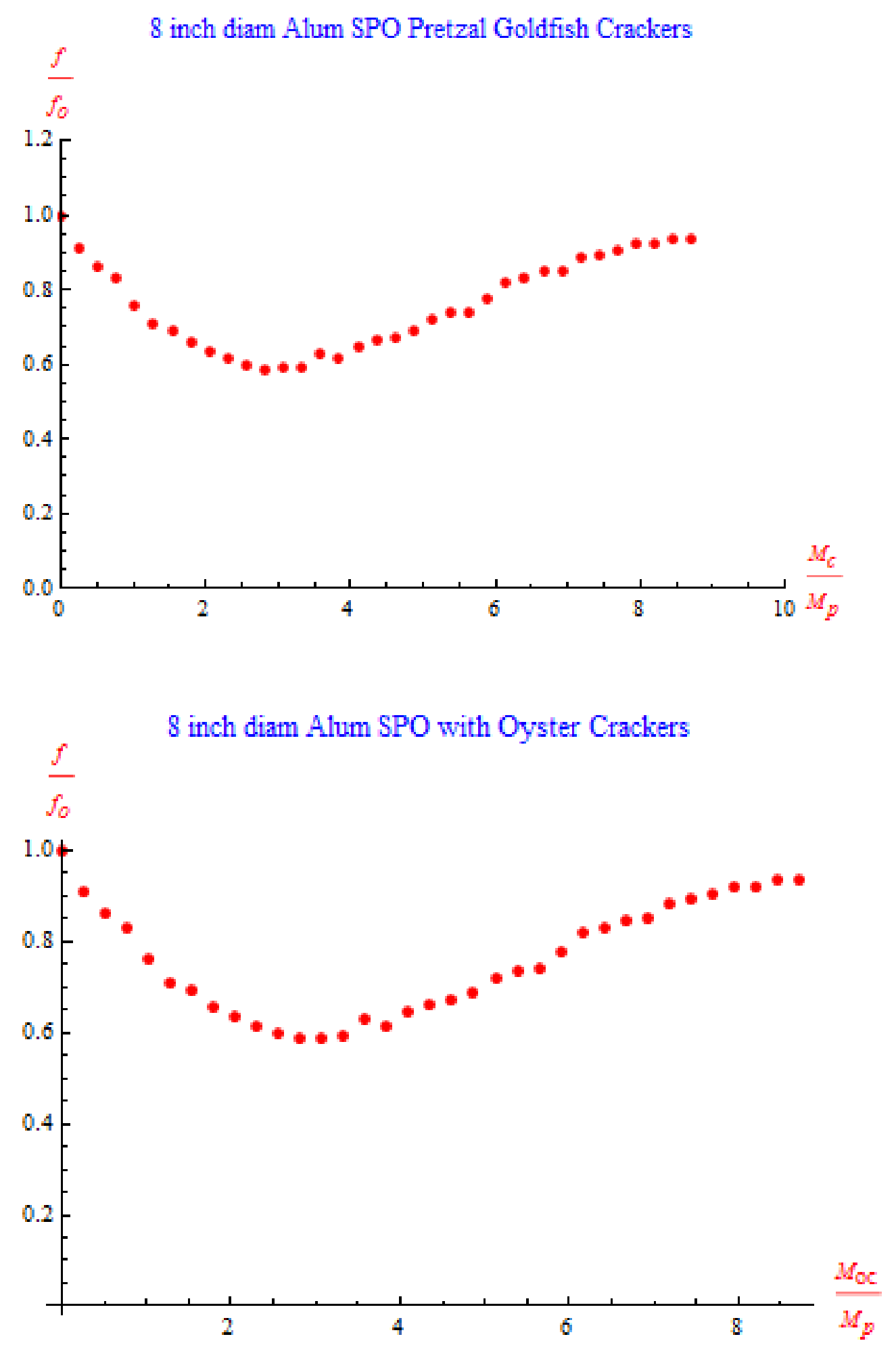

Fig 12. Comparing the resonant frequency vs. mass loading in an 8 inch diam SPO using (above) pretzal goldfish crackers and (below) oyster crackers. The mass is normalized to the clamped plate mass Mp = 107.5 grams

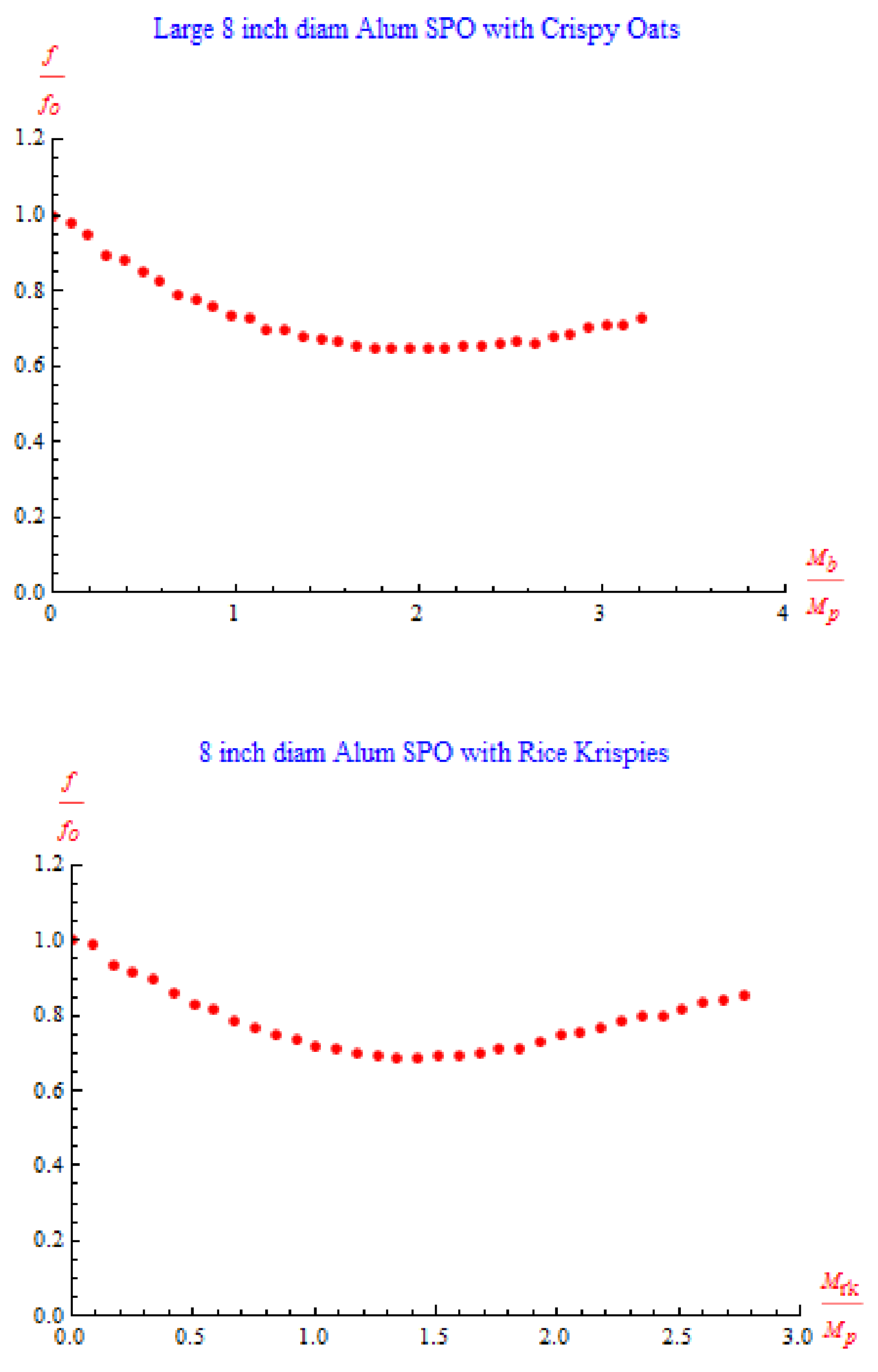

Fig 13. Comparing the resonant frequency vs. mass loading in an 8 inch diam SPO using (above) Crispy Oats ™ cereal and (below) Rice Krispies ™. The mass is normalized to the clamped plate mass Mp = 107.5 grams

In the case for fluid loading, $M_f = M_w * B$, (M_w = water mass) , M_p is the clamped plate mass 107.7 g , the "lumped - element" fluid-plate-oscillator resonant frequency model is

$$f = (1/2\pi)\{K_p/[(7/54)M_p + B * M_w]\}^{1/2} = f_p\{1/[1 + B * M_w/(7M_p/54)]\}^{1/2}$$

where f_p is the resonant frequency of the unloaded clamped plate (typically ~ 190 Hz) for the 8 inch diam SPO. In Fig. 9 the curve fit was found to be $0.65 = B/(7/54)$ or $B \sim 5.0$.

In the case of granular mass loading the effective stiffness of the granular plate overcomes the mass loading. Then one eventually measures an increase in frequency vs. the mass of the granular loading.

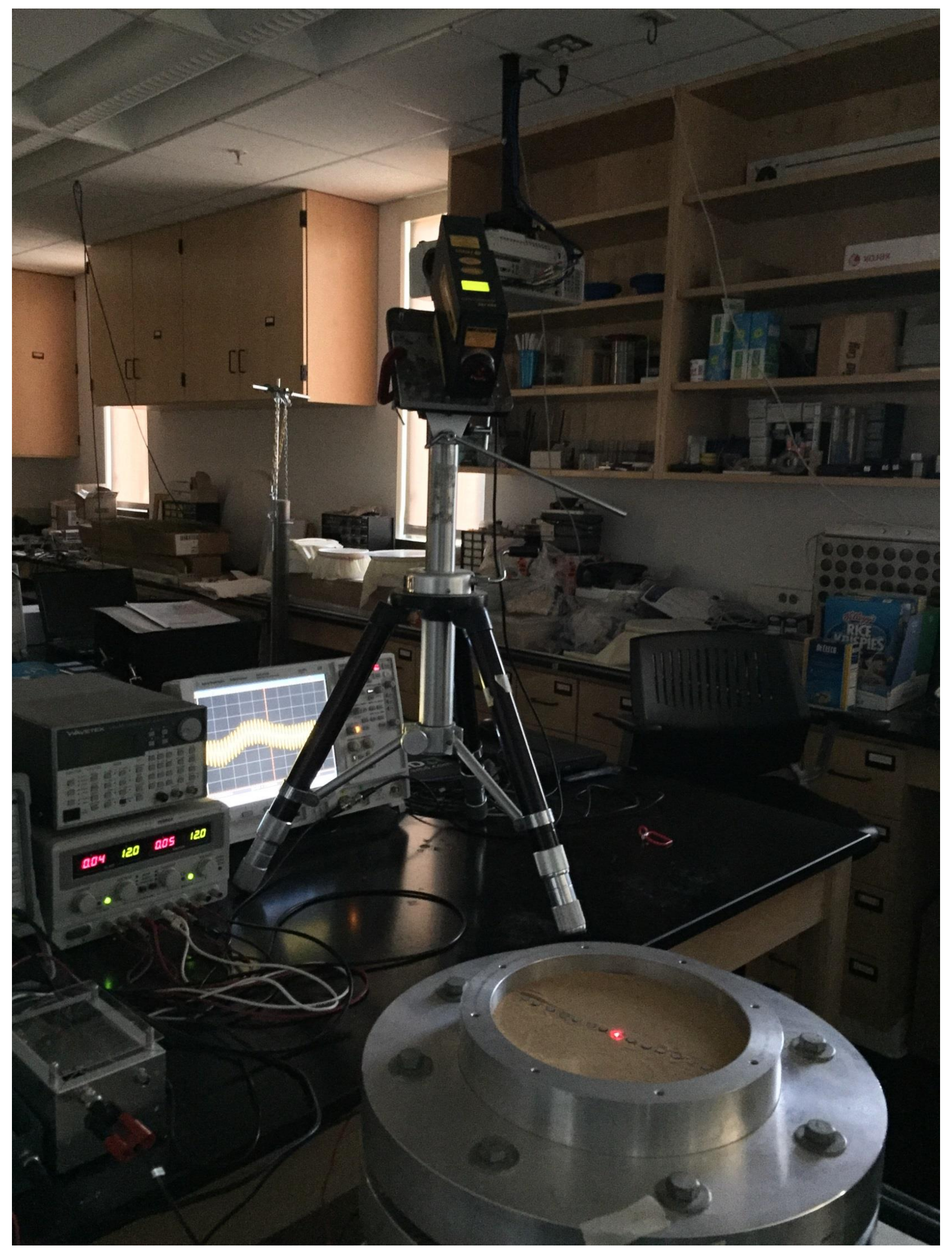

Fig. 4. The laser Doppler vibrometer measures the soil surface vibration while an accelerometer measures the driving acceleration on the underside of the plate.

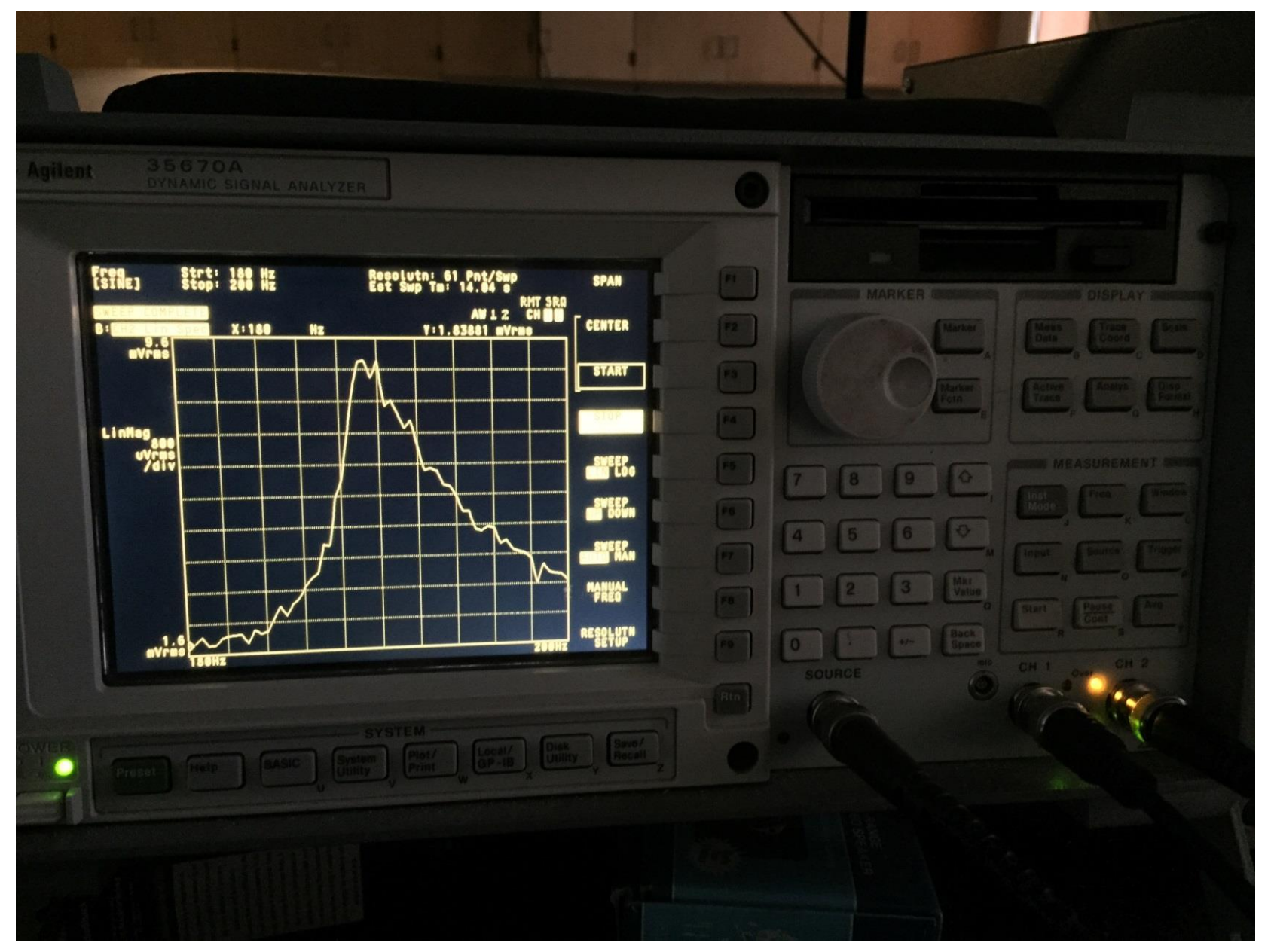

Fig. 5. The laser Doppler vibrometer swept sine response (Fig. 4) from 100 Hz to 500 Hz is measured using an Agilent 35670A dynamic signal analyzer.

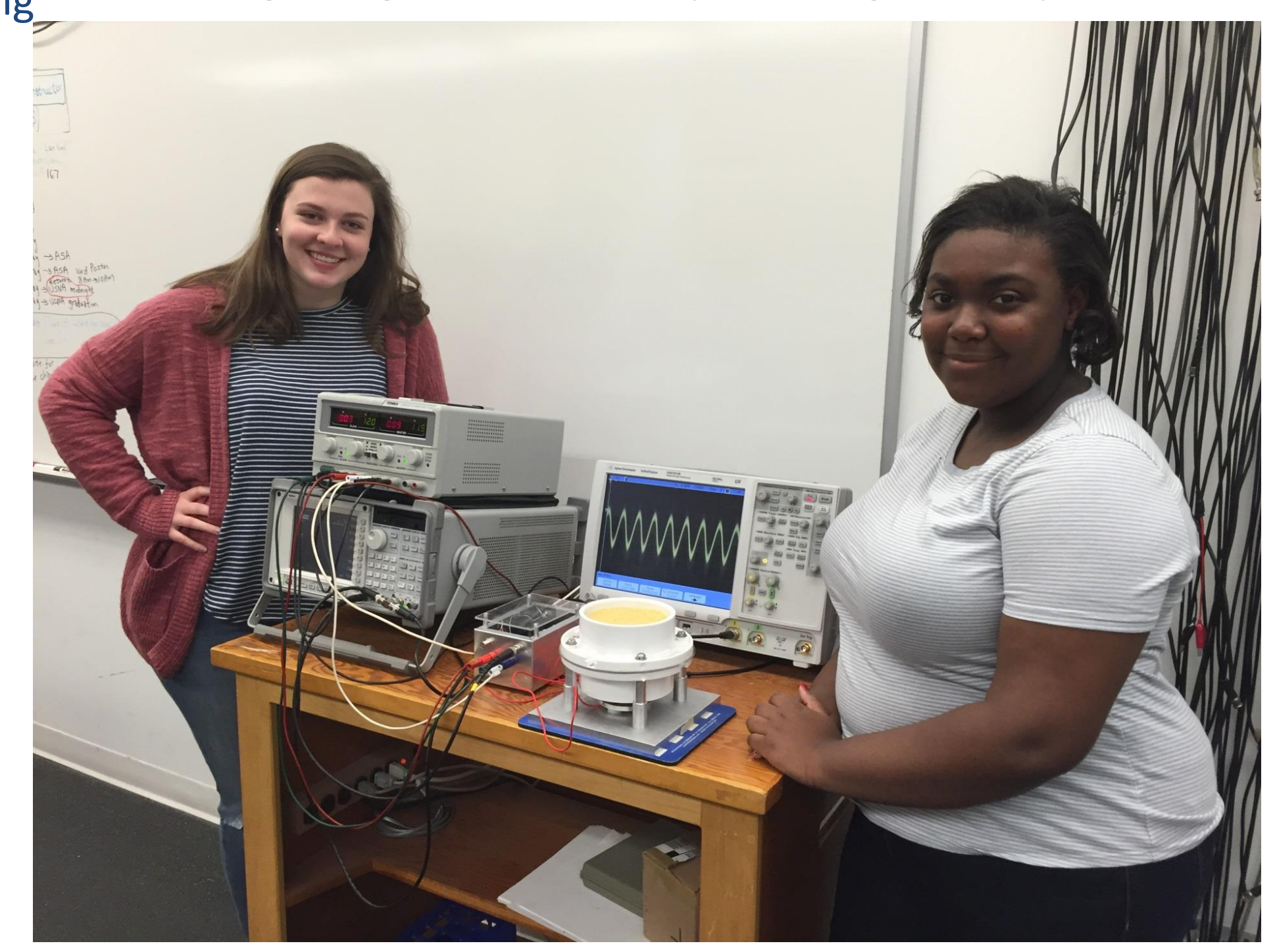

Fig. 6. SPO (4.5 inch diam) with swept spectrum analyzer, driving the audio amplifier which drives the AC coil. The accelerometer, located on the plate underside measures the resonant vibration tuning curve response.