Universidad Autónoma
del Estado de Morelos

Facultad
de Ciencias

Surface Structure Formation and Rotational Motion in the Mercury Beating Heart System

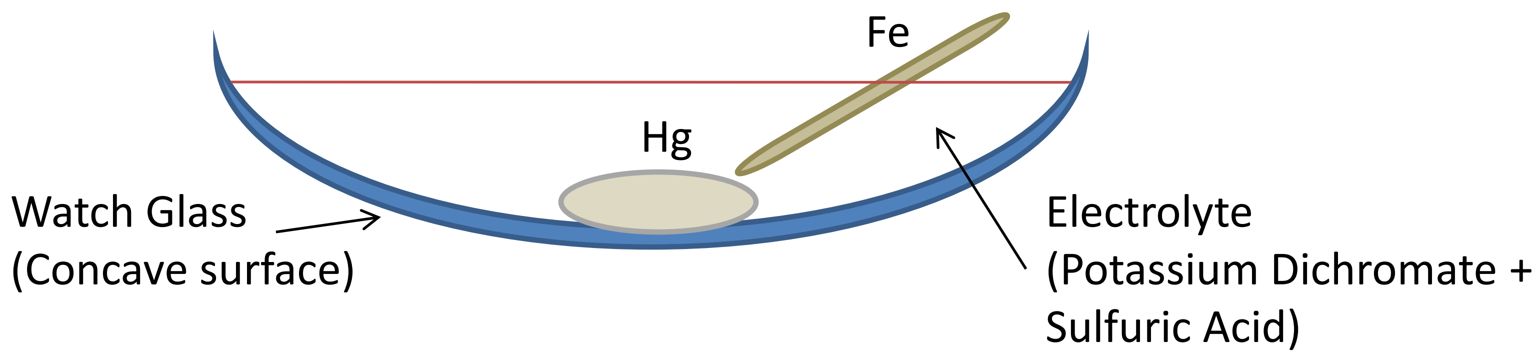
Hands-on School on Nonlinear Dynamics
Institute for Plasma Research

Feb. 16-22, 2015

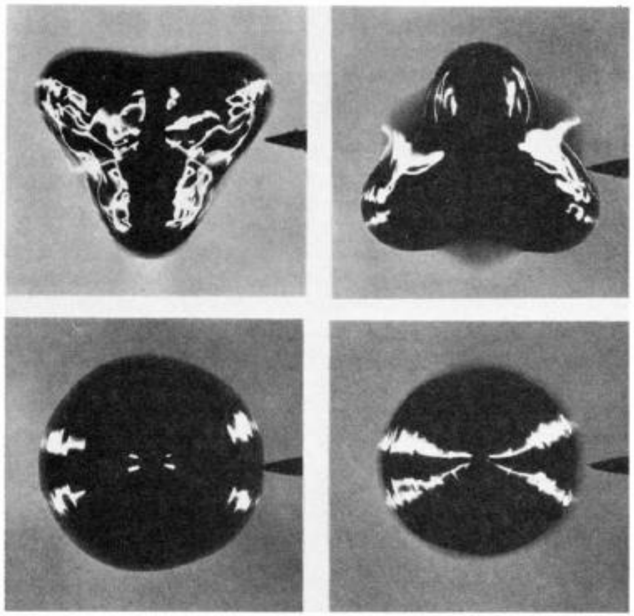
OUTLINE

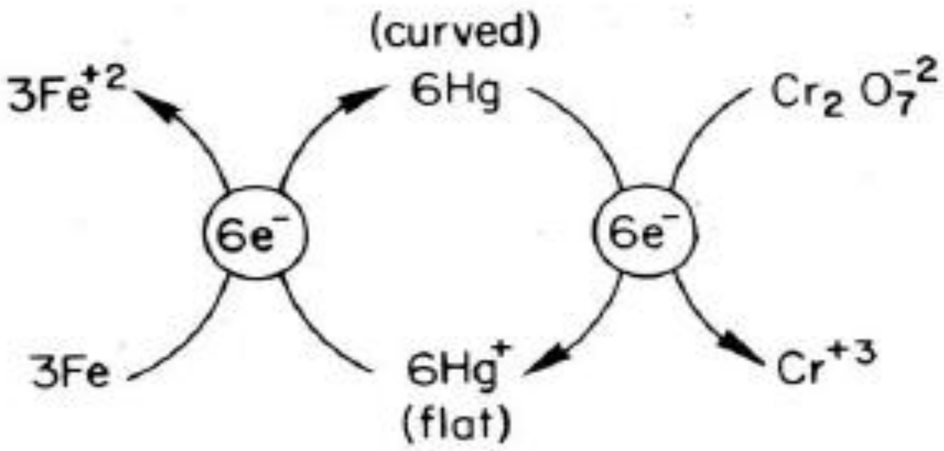
- THE CLASSIC MERCURY BEATING HEARTH (MBH)
- POTENTIAL – DEPENDENT TOPOLOGICAL MODES
- SHAPE AND SURFACE STRUCTURE FORMATION
- ROTATIONAL MOTION
- CONCLUSIONS

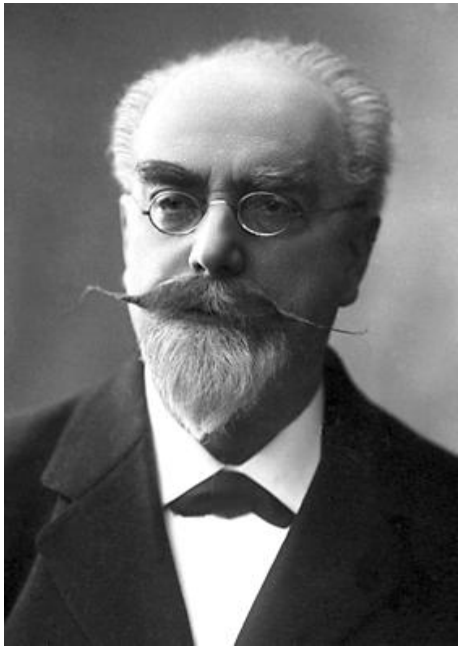
STANDARD MERCURY BEATING HEART OSCILLATOR



STANDARD MERCURY BEATING HEART OSCILLATOR



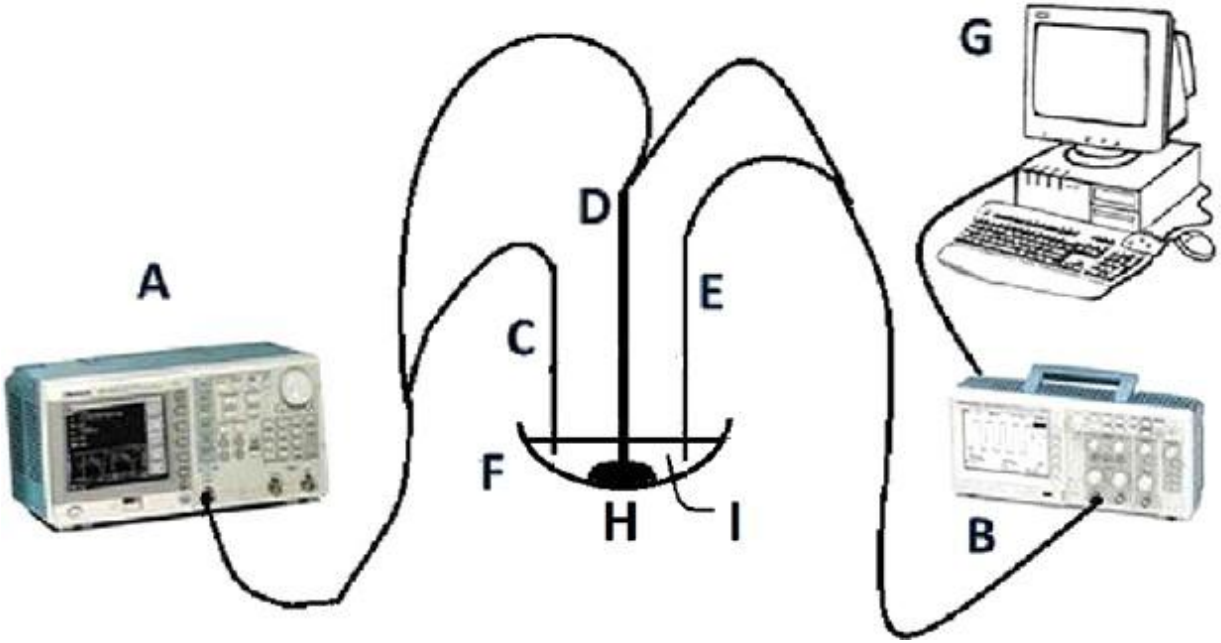




This chemo-mechanical oscillator was reported first by G. Lippmann in 1873.

Lippmann, G. The Relation Between Capillary and Electrical Phenomena. G. Ann. Phys. 1873, 149, 546–561.

POTENTIAL –DEPENDENT TOPOLOGICAL MODES IN THE MERCURY BEATING HEART SYSTEM



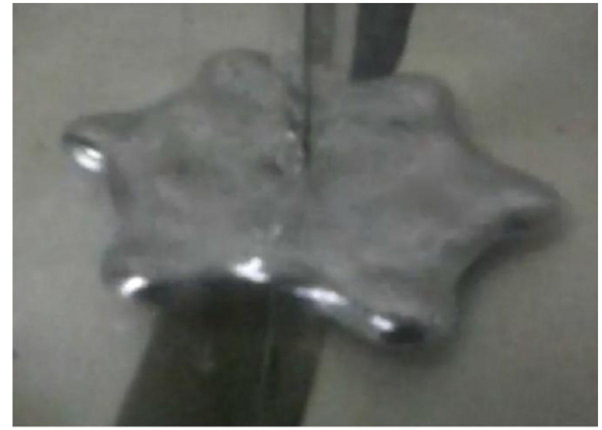
A. Square Pulse Generator.
B. Oscilloscope.
C. Iron Electrode.
D. Platinum Electrode
E. Reference Electrode.
F. Watch Glass.
G. Acquisition System.
H. Mercury Drop.
I. Acidic Solution (Sulfuric Acid).

*D.K. Verma, A. Q. Contractor, P. Parmananda, J. Phys. Chem. A **117**, 267−274 (2013).*

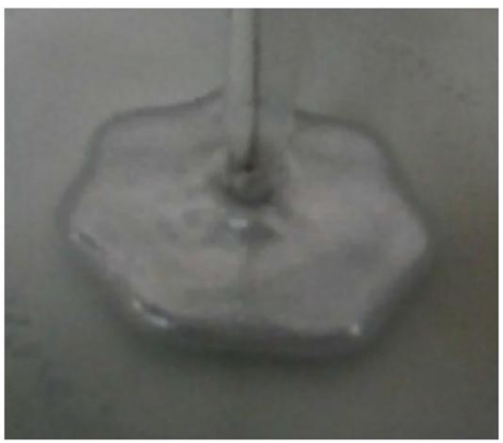
POTENTIAL –DEPENDENT TOPOLOGICAL MODES IN THE MERCURY BEATING HEART SYSTEM

Ellipse (3.0-3.7 Hz)

Triangle (3.8-4.5 Hz)



6 pointed star (7.5-8.6 Hz)



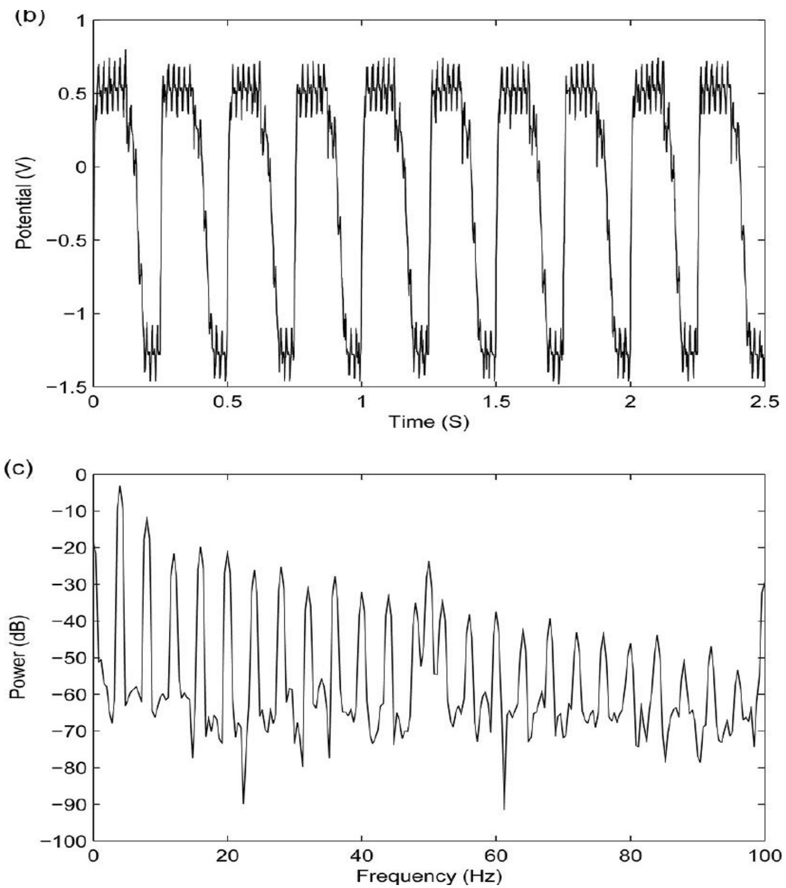
7 pointed star (9.4-10.1 Hz)

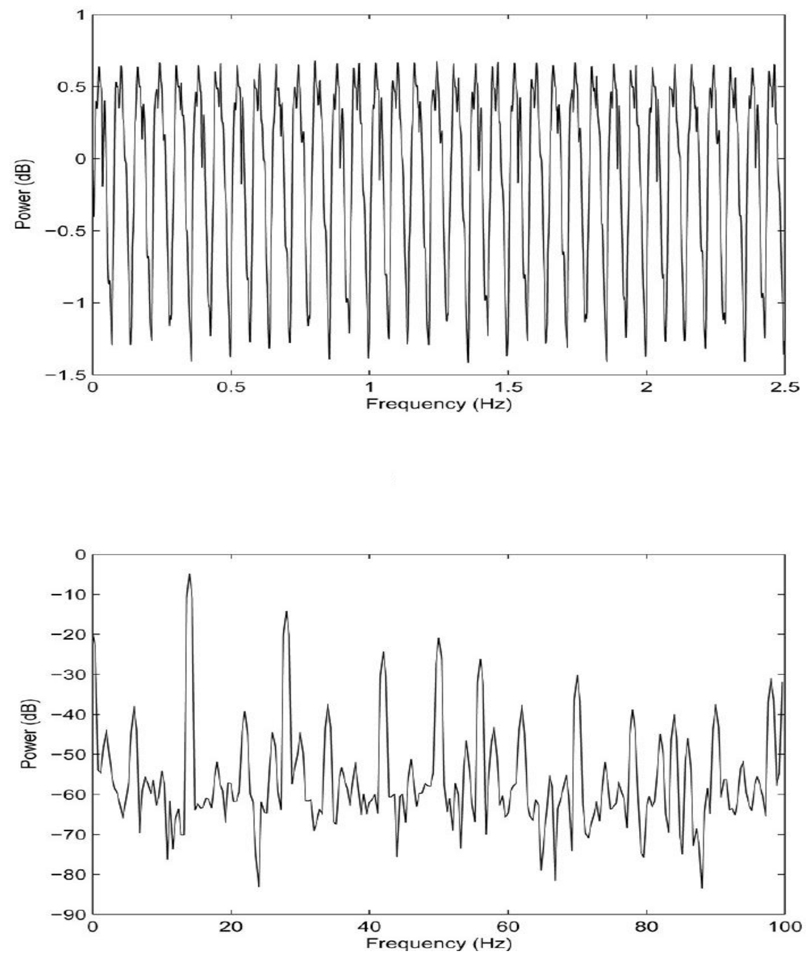
8 pointed star (10.2-11 Hz)

9 pointed star (13.1-13.4 Hz)

D.K. Verma, A. Q. Contractor, P. Parmananda, J. Phys. Chem. A ***117****, 267–274 (2013).*

POTENTIAL –DEPENDENT TOPOLOGICAL MODES IN THE MERCURY BEATING HEART SYSTEM





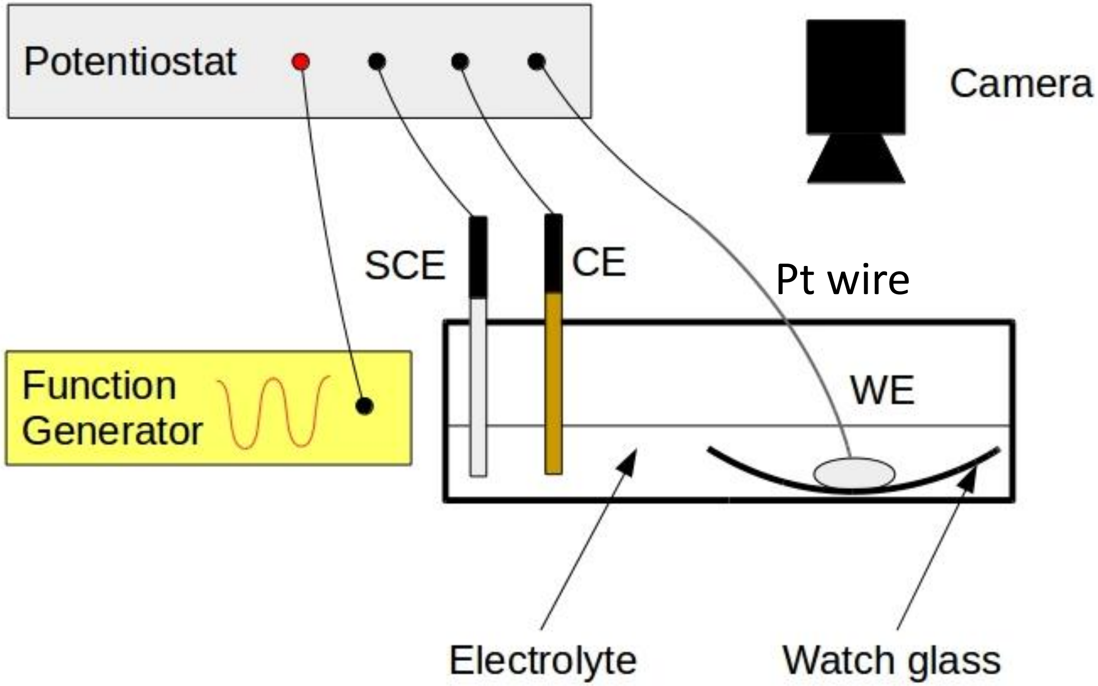
Triangular (4.3 Hz)

10 pointed star (14 Hz)

D.K. Verma, A. Q. Contractor, P. Parmananda, J. Phys. Chem. A ***117****, 267−274 (2013).*

SHAPE AND SURFACE STRUCTURE FORMATION IN THE MERCURY BEATING HEART SYSTEM

MODIFIED EXPERIMENTAL SETUP



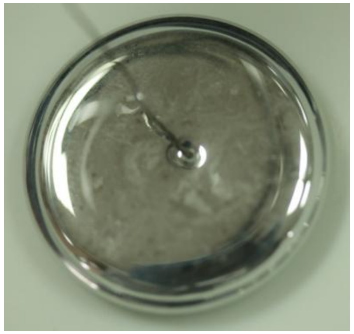
$$V(t) = V_o + A\sin(2\pi f t)$$

Potentiostat

Function Generator

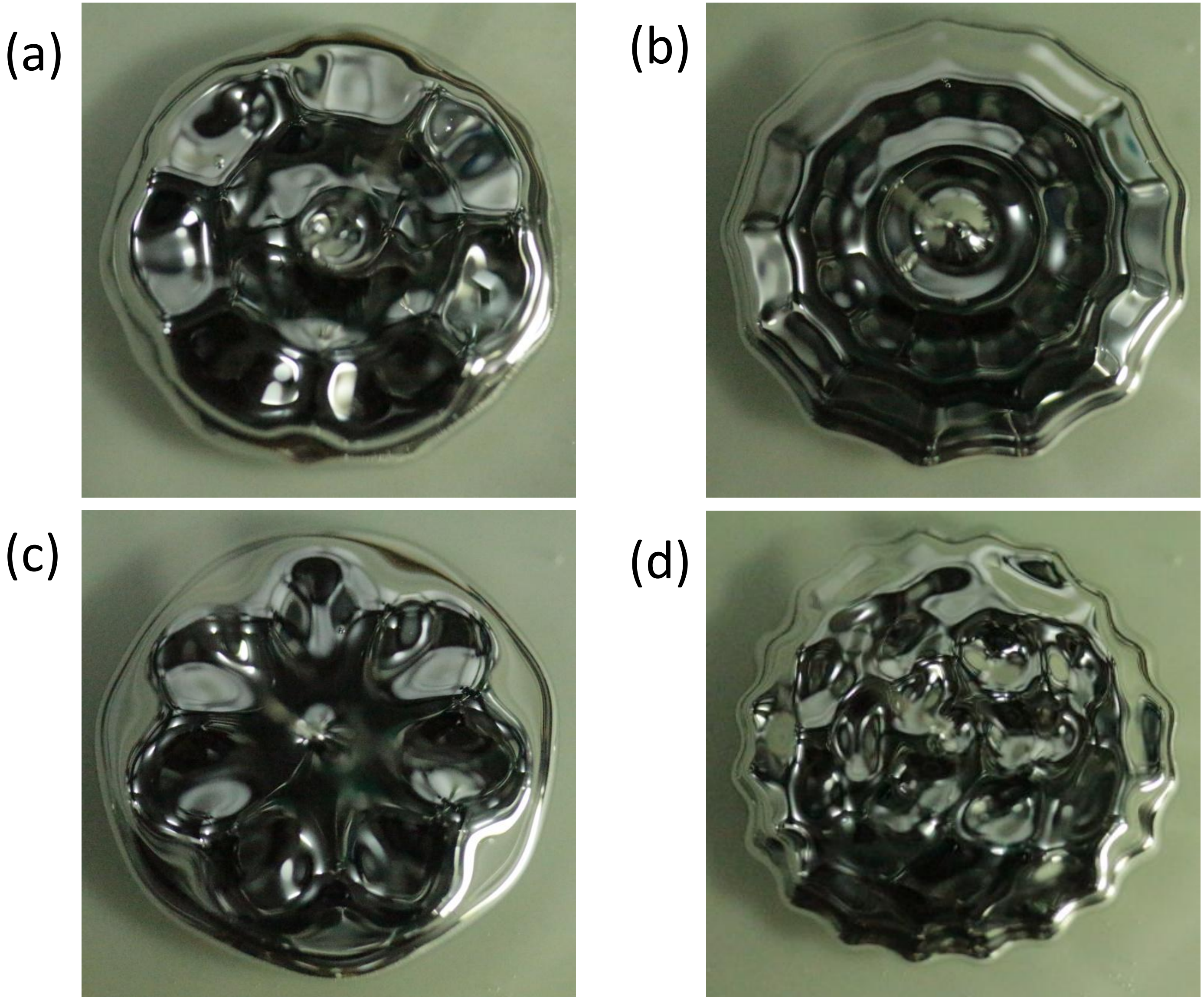
Anode: Mercury drop (23 g)
Cathode: Copper rod (6 mm)
Reference Electrode: SCE (V .vs. SCE)

Electrolyte: 1 M H_2SO_4



$$V(t) = V_o = 0\ V$$

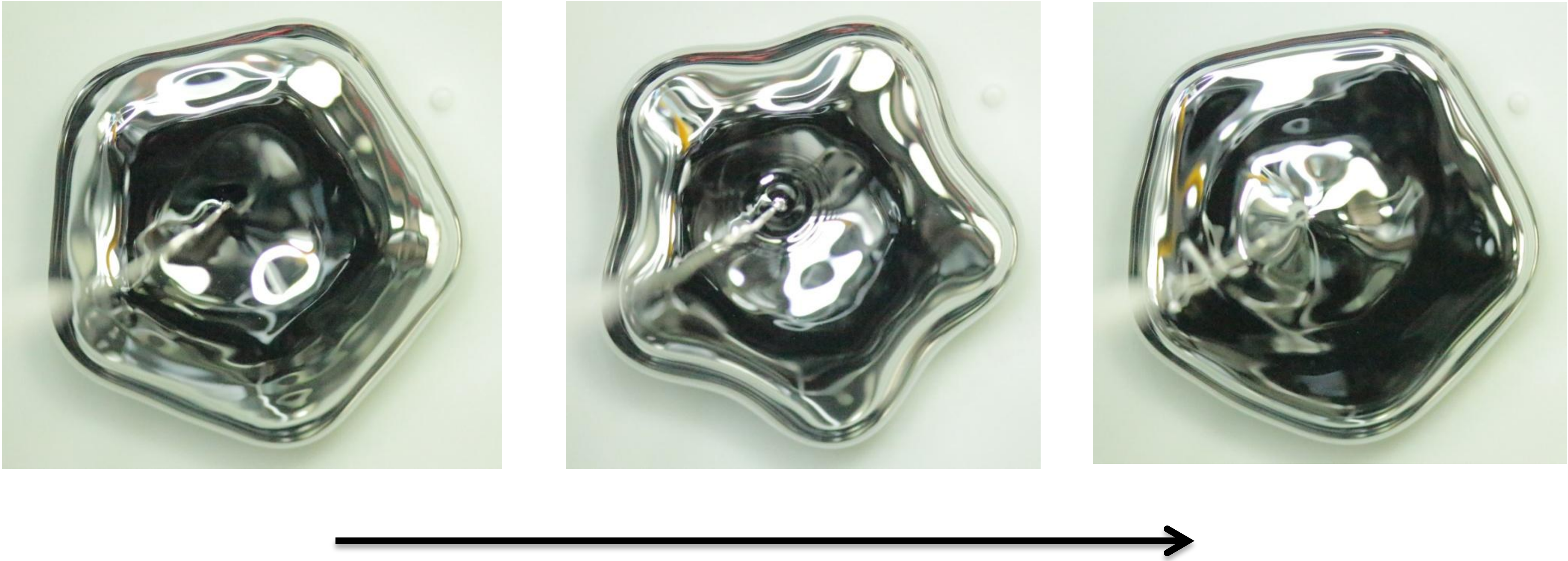
SHAPE AND SURFACE STRUCTURE FORMATION



Patterns obtained using a harmonic perturbation signal and a set point of V_o = 0 V:
(a) f = 48Hz, A = 2V; (b) f = 53Hz, A = 1V; (c) f = 70 Hz, A= 1V and (d) f = 100Hz, A = 1V.

SHAPE AND SURFACE STRUCTURE FORMATION

EVOLUTION OF THE PERIODIC SYSTEM

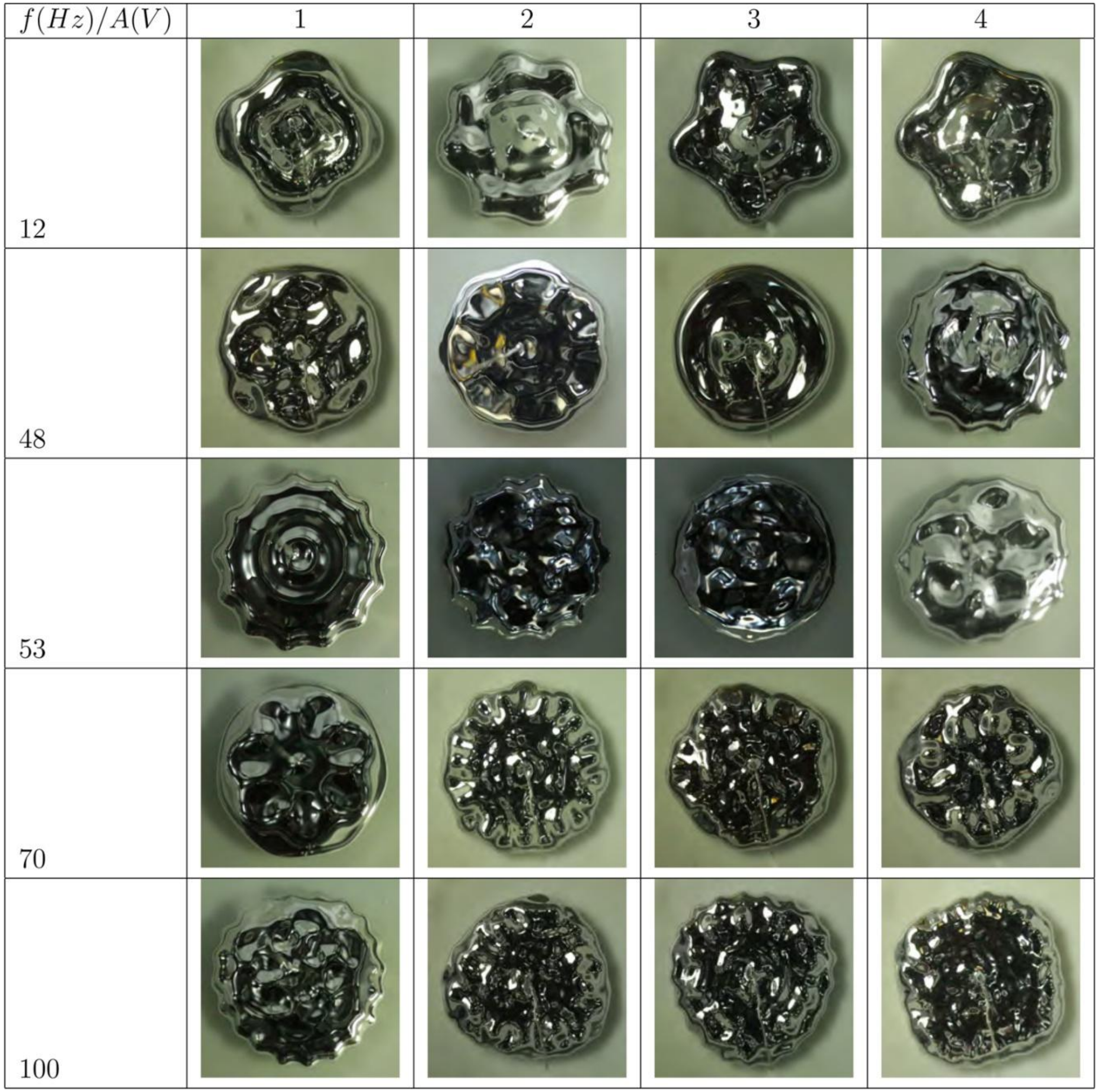


TIME

Structures sequence for a harmonic perturbation signal with frequency of 14Hz and amplitude of 2V , showing a 5 peaks star and the transitory pentagons. $V_o = 0.0$ V

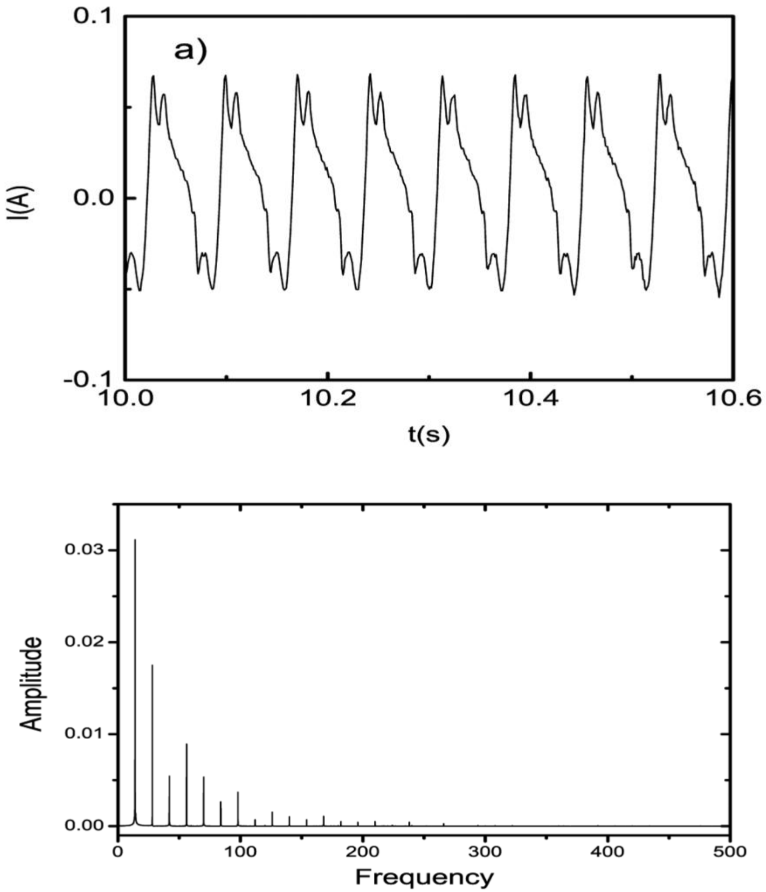
E. Ramírez-Álvarez, J. L. Ocampo-Espindola, Fernando Montoya, F. Yousif, F. Vázquez, and M. Rivera, Journal of Physical Chemistry A Vol. ***118****, 10673-10678 (2014).*

SHAPE AND SURFACE STRUCTURE FORMATION

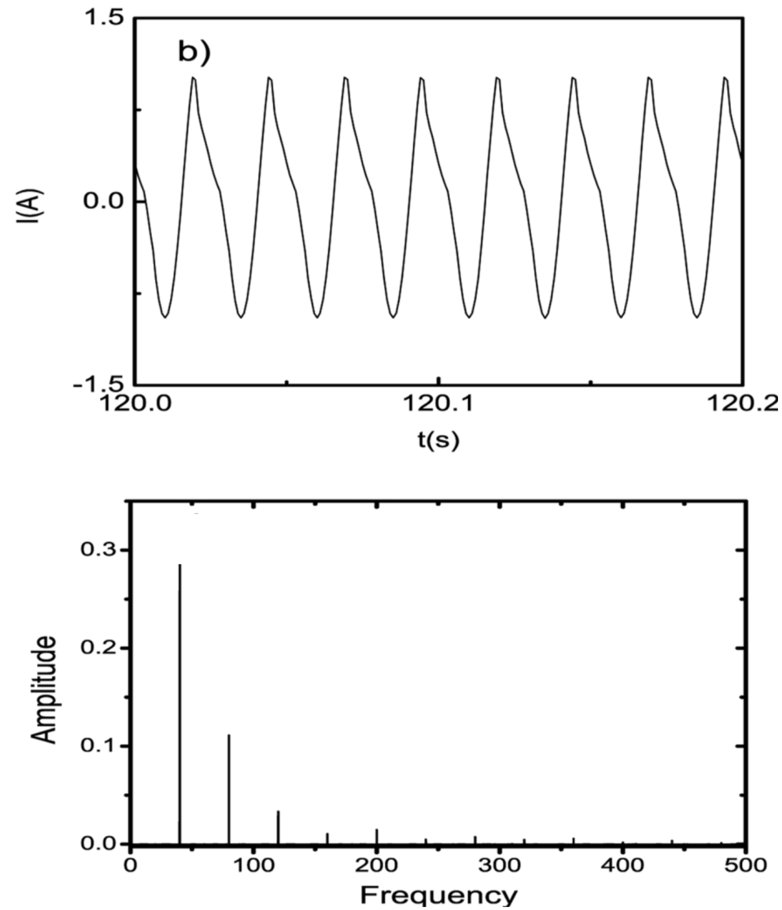


E. Ramírez-Álvarez, J. L. Ocampo-Espindola, Fernando Montoya, F. Yousif, F. Vázquez, and M. Rivera, Journal of Physical Chemistry A Vol. ***118****, 10673-10678 (2014).*

TIMESERIES FOR THE ANODIC CURRENT



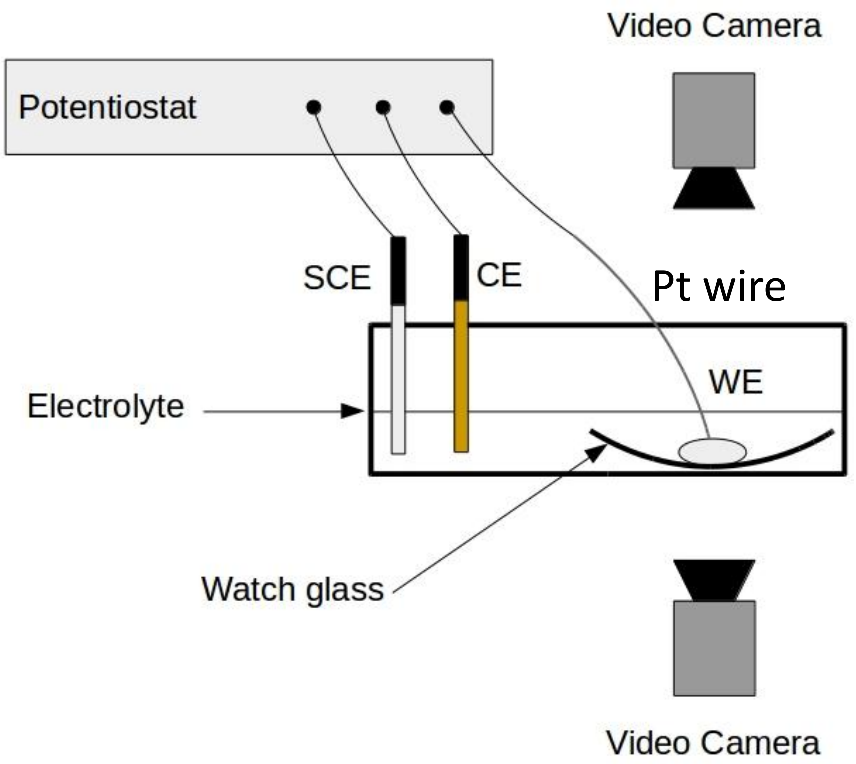
A = 1 V_{pp}, f = 14 Hz.



A = 4 V_{pp}, f = 40 Hz.

*E. Ramírez-Álvarez, J. L. Ocampo-Espindola, Fernando Montoya, F. Yousif, F. Vázquez, and M. Rivera, Journal of Physical Chemistry A Vol. **118**, 10673-10678 (2014).*

EXPERIMENTAL SETUP (VARYING NOW THE POTENTIAL V_o)



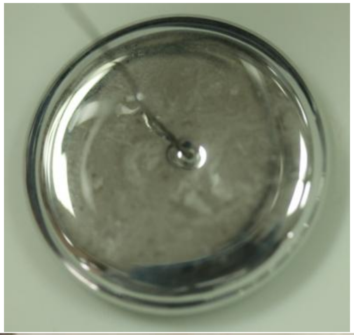
Anode: Mercury drop (23 g)
Cathode: Copper rod (6 mm)
Reference Electrode: SCE

Electrolyte: 1 M H_2SO_4

$$V(t) = V_o + A\sin(2\pi f t)$$

Rotational Motion in the Mercury Beating Heart System

TESTING DIFFERENT ANODIC POTENTIALS (V_O)



$V_o > 0$ *mV .vs. SCE*

Formation of Hg_2SO_4 Film

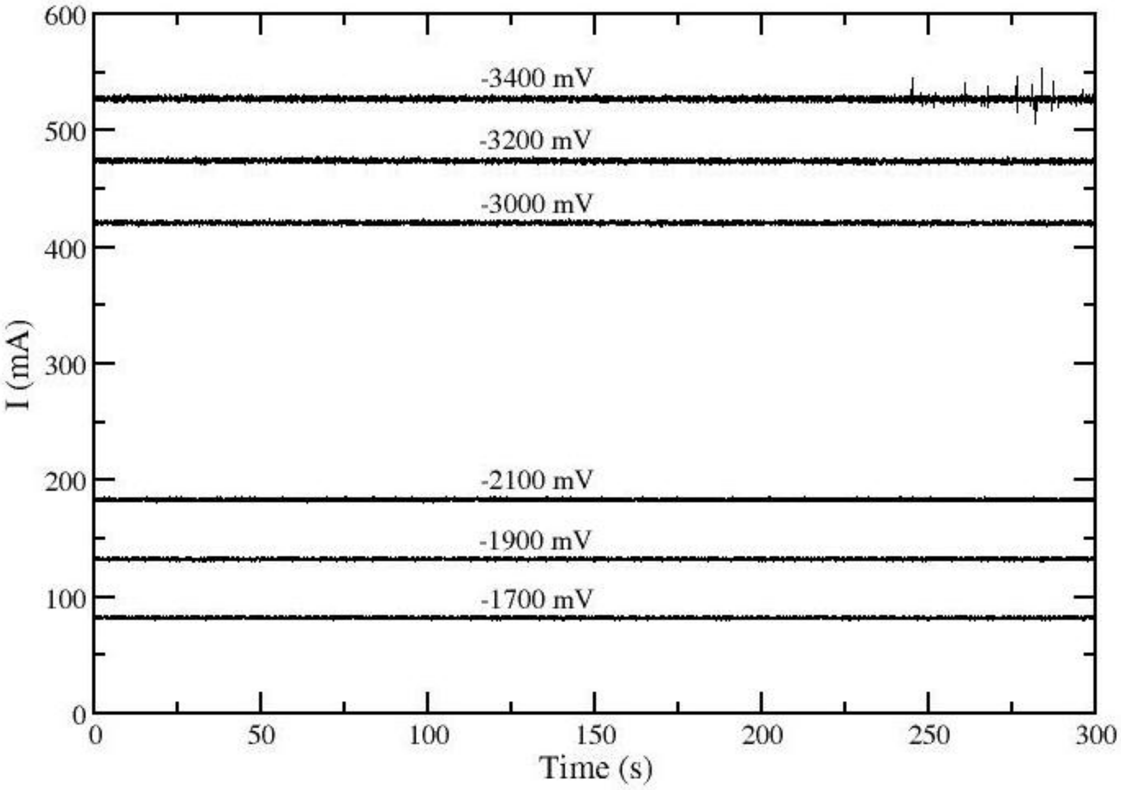
$-1600 < V_o < 0$ *mV .vs. SCE*

No significant motion detected.

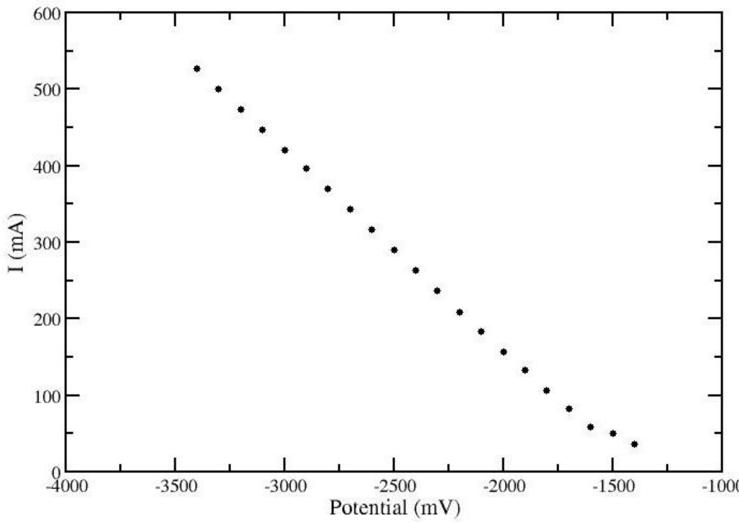
$-3400 < V_o < -1600$ *mV .vs. SCE*

Rotational Motion

BEHAVIOR OF THE ANODIC CURRENT AT DIFFERENT POTENTIALS

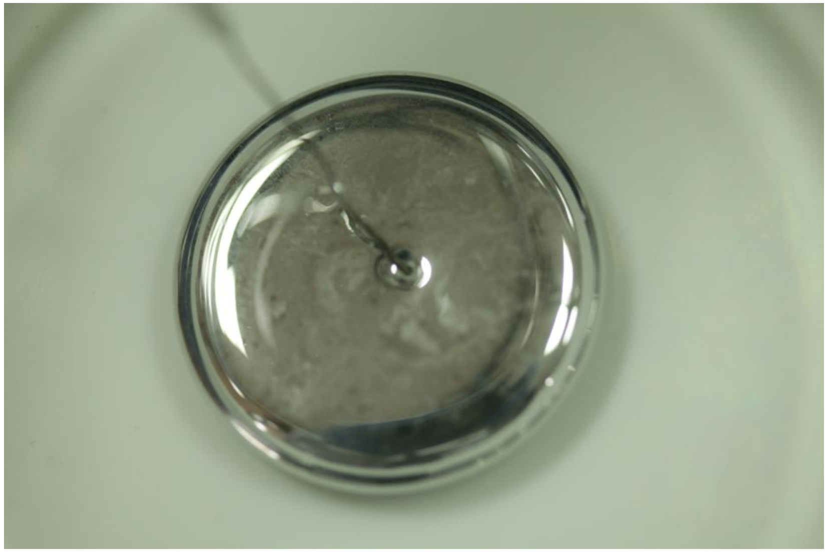


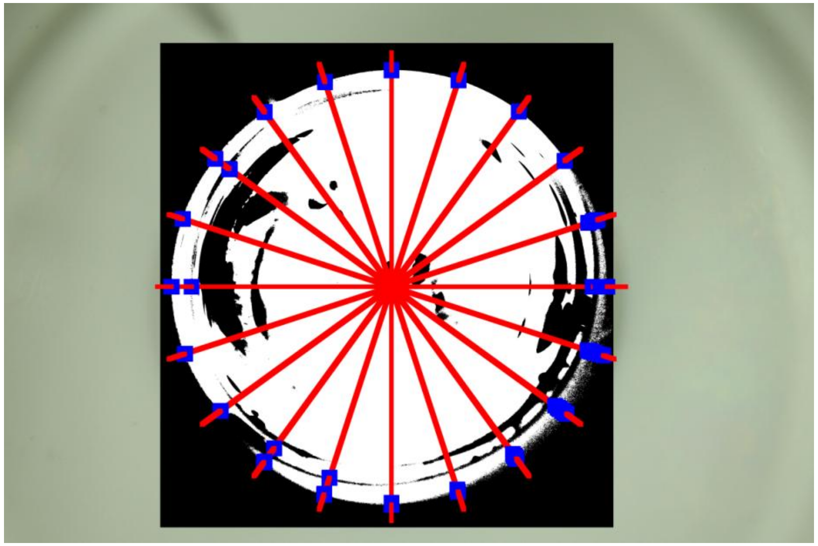
TIMESERIES FOR THE ANODIC CURRENT



ANODIC CURRENT .vs. POTENTIAL

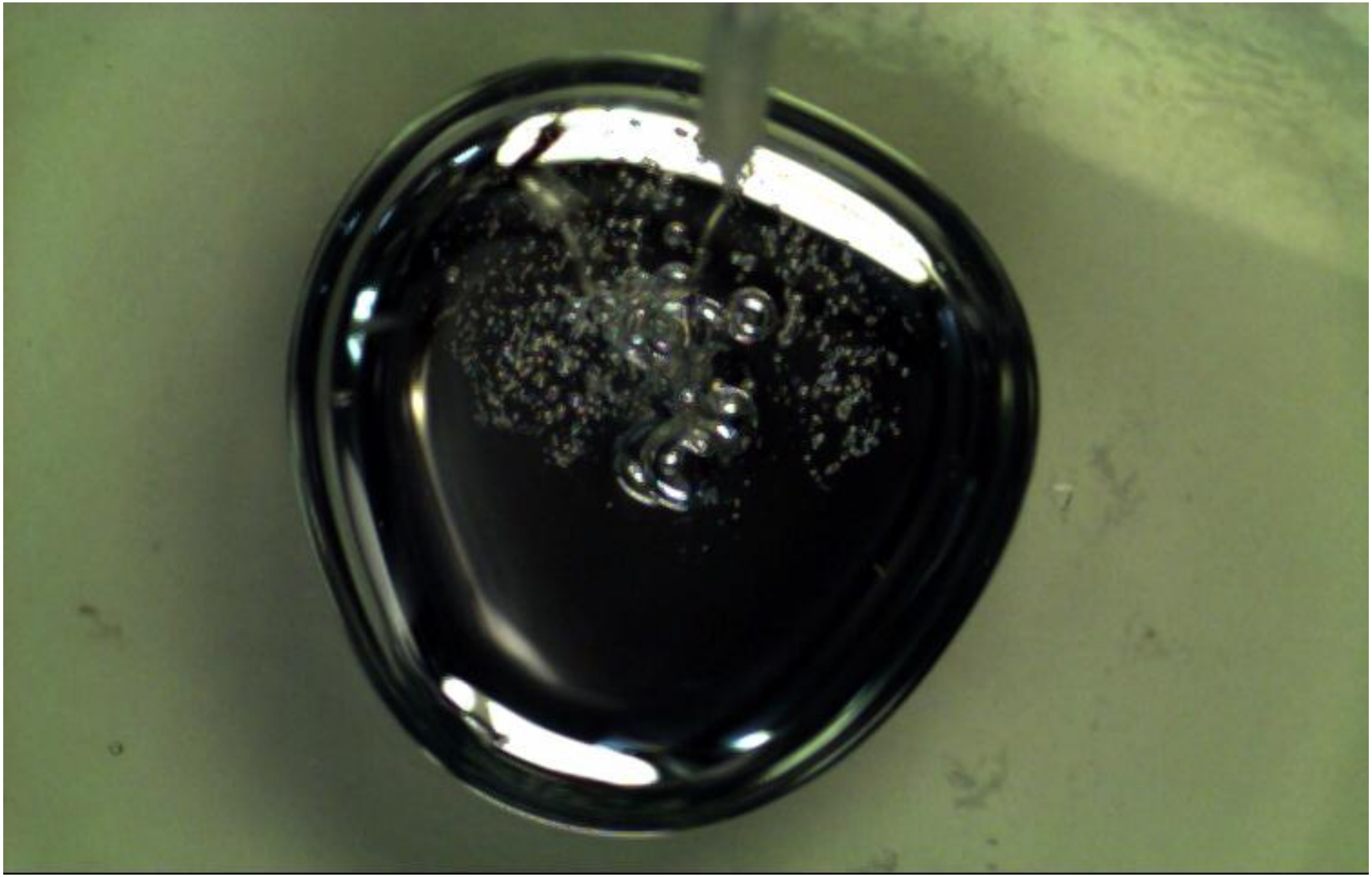
STUDYING THE ROTATIONAL MOTION USING IMAGE ANALYSIS



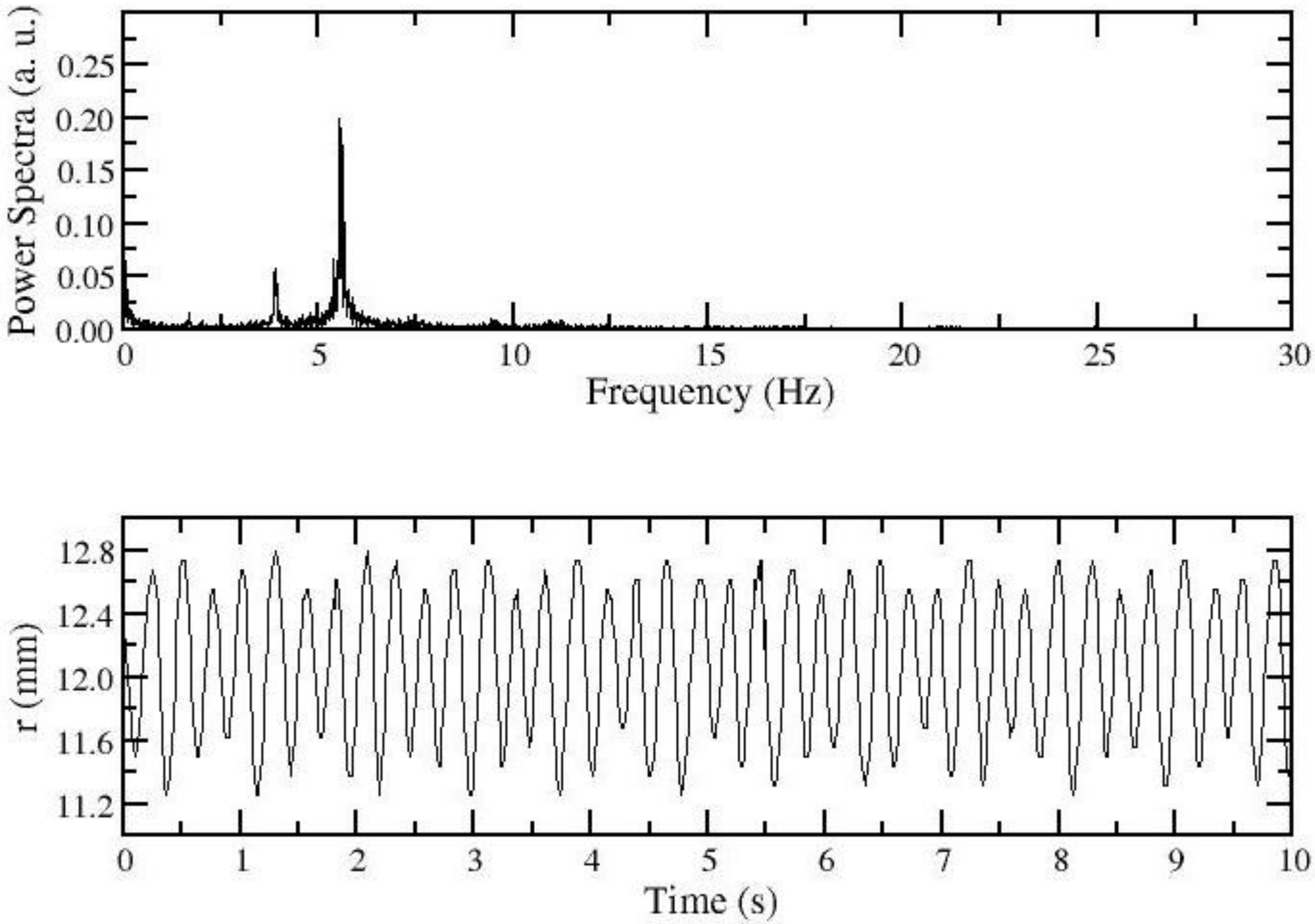


r(t): Distance (mm) from the perimeter to the center of the drop for **ϴ** = 0°

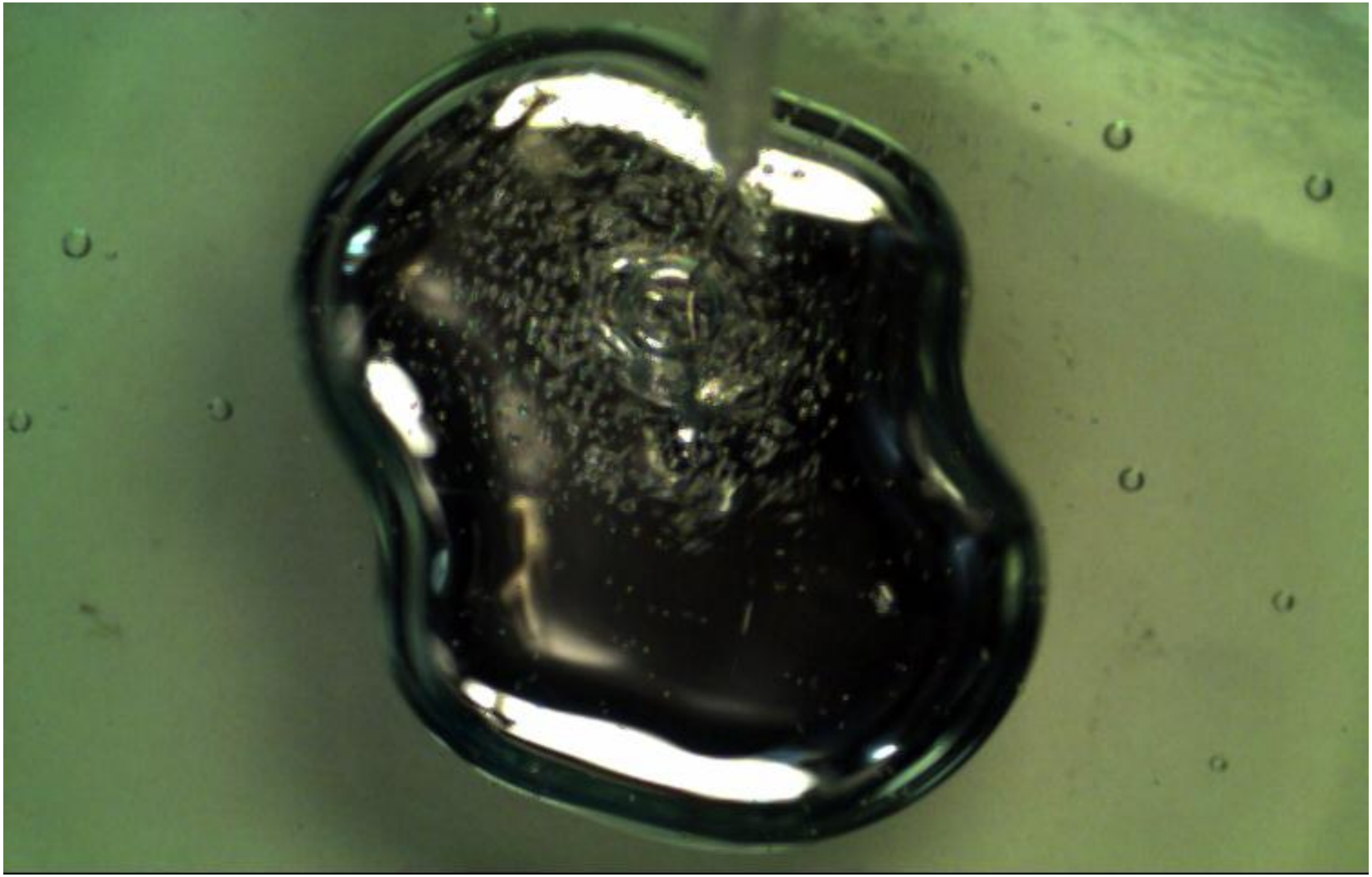
BEHAVIOR OF THE MERCURY DROP AT V_O = -1600 mV



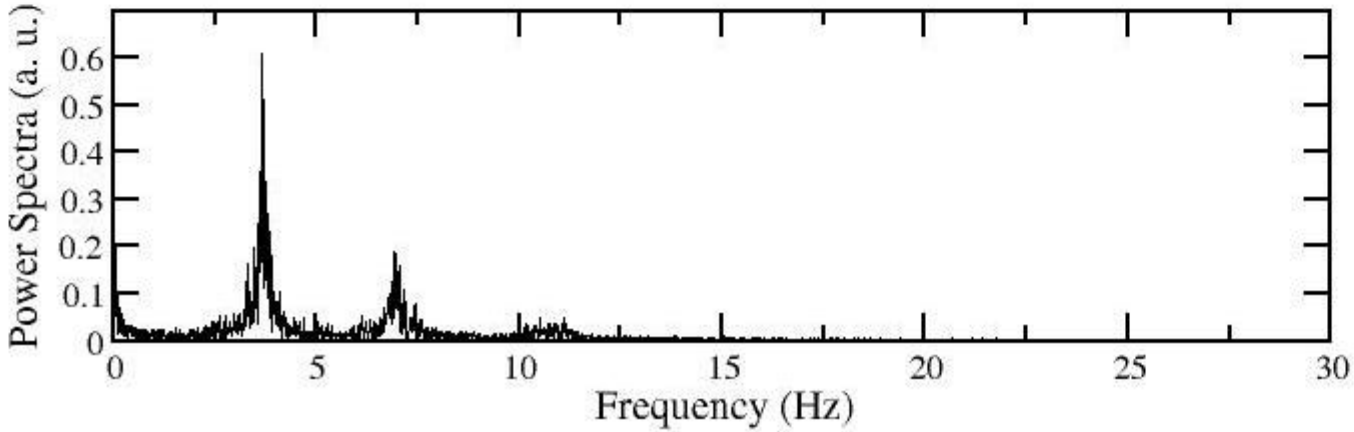
TIMESERIES AND POWER SPECTRA (-1600 mV)

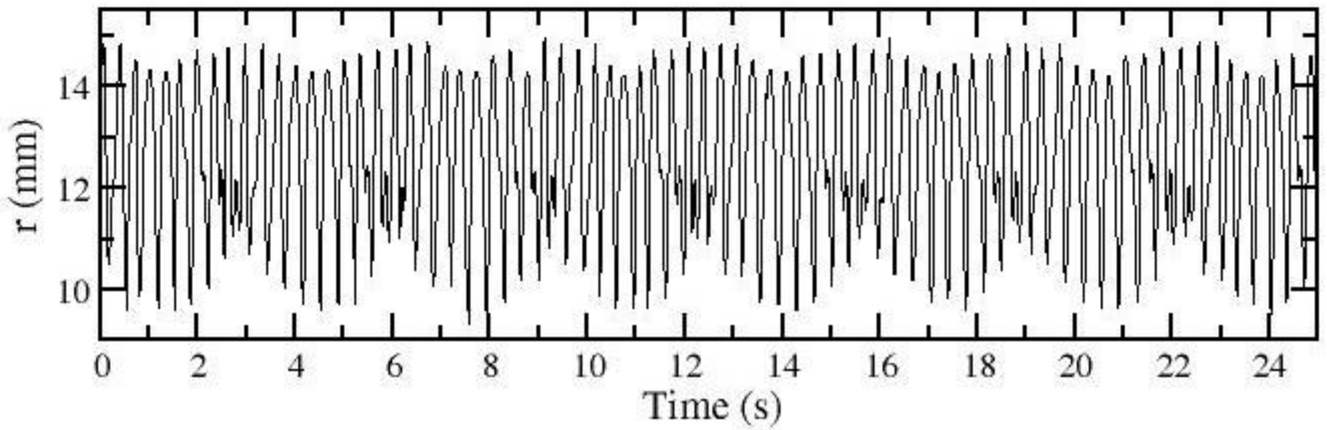


BEHAVIOR OF THE MERCURY DROP AT V_O = -2800 mV

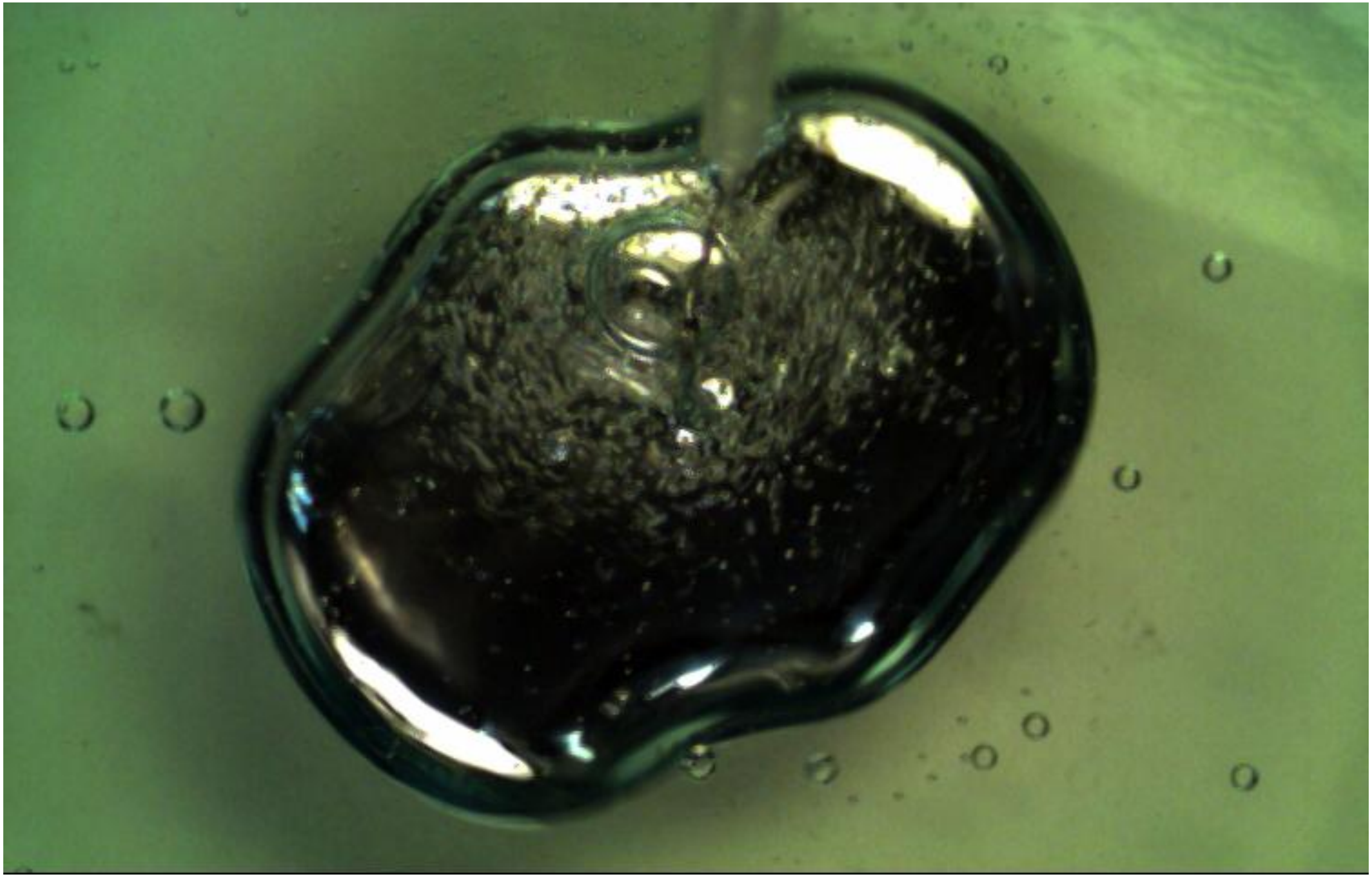


TIMESERIES AND POWER SPECTRA (-2800 mV)

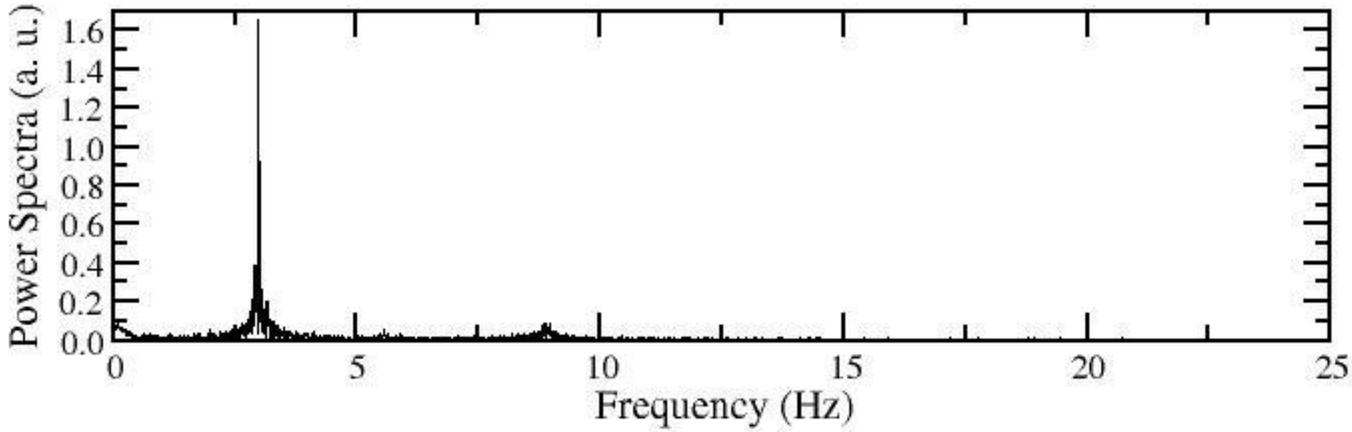


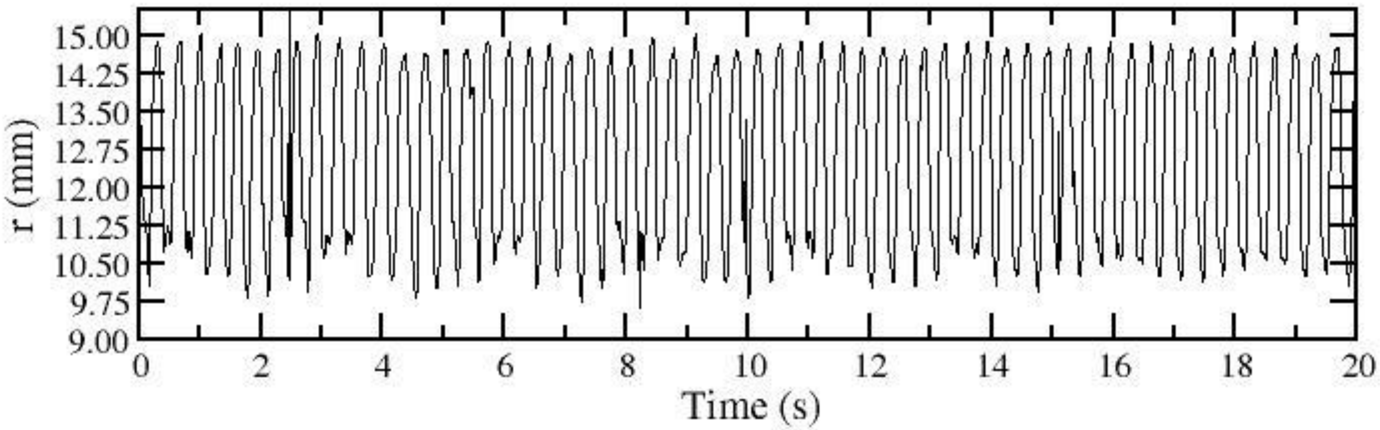


BEHAVIOR OF THE MERCURY DROP AT V_O = -3200 mV

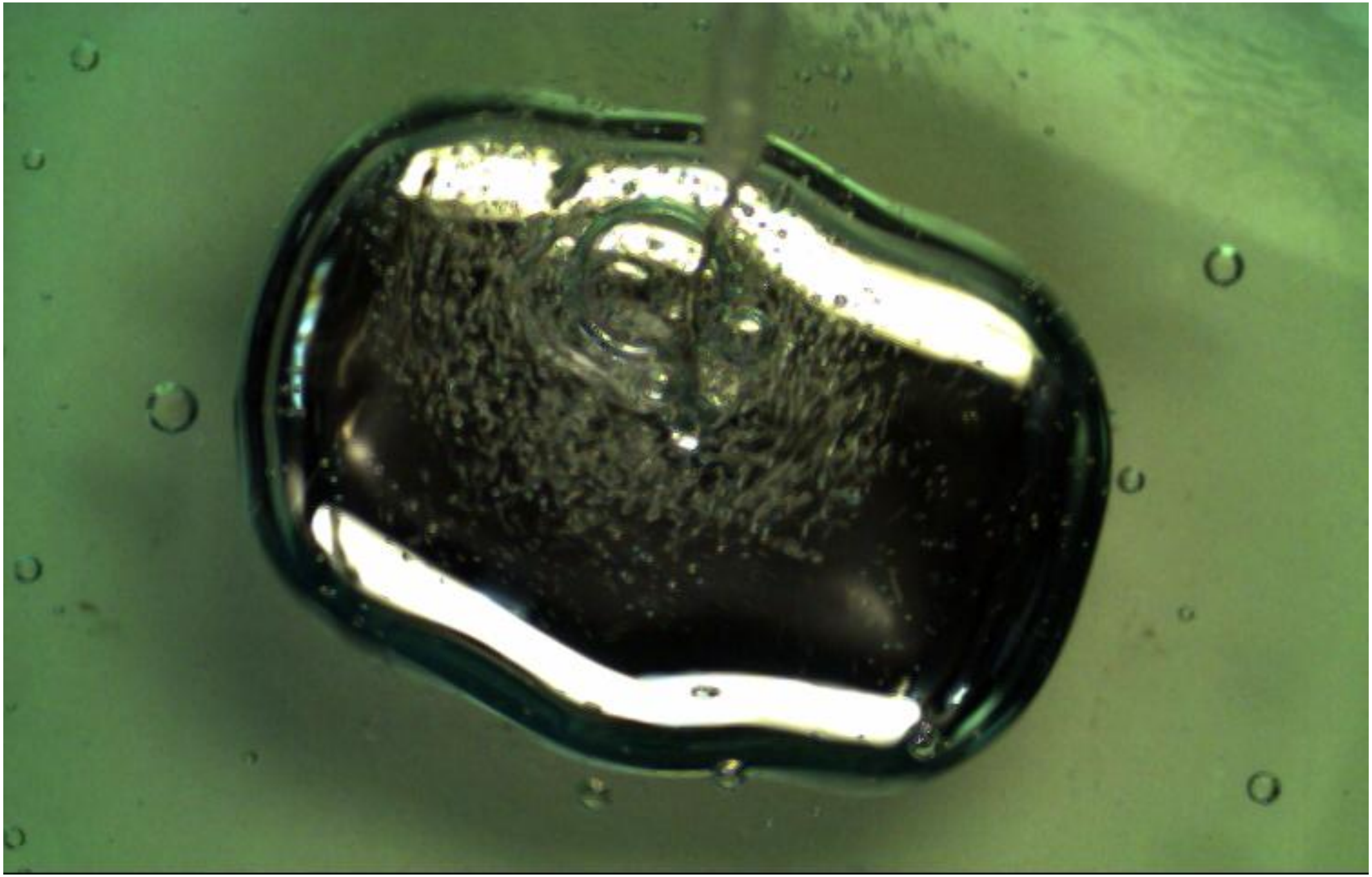


TIMESERIES AND POWER SPECTRA (-3200 mV)

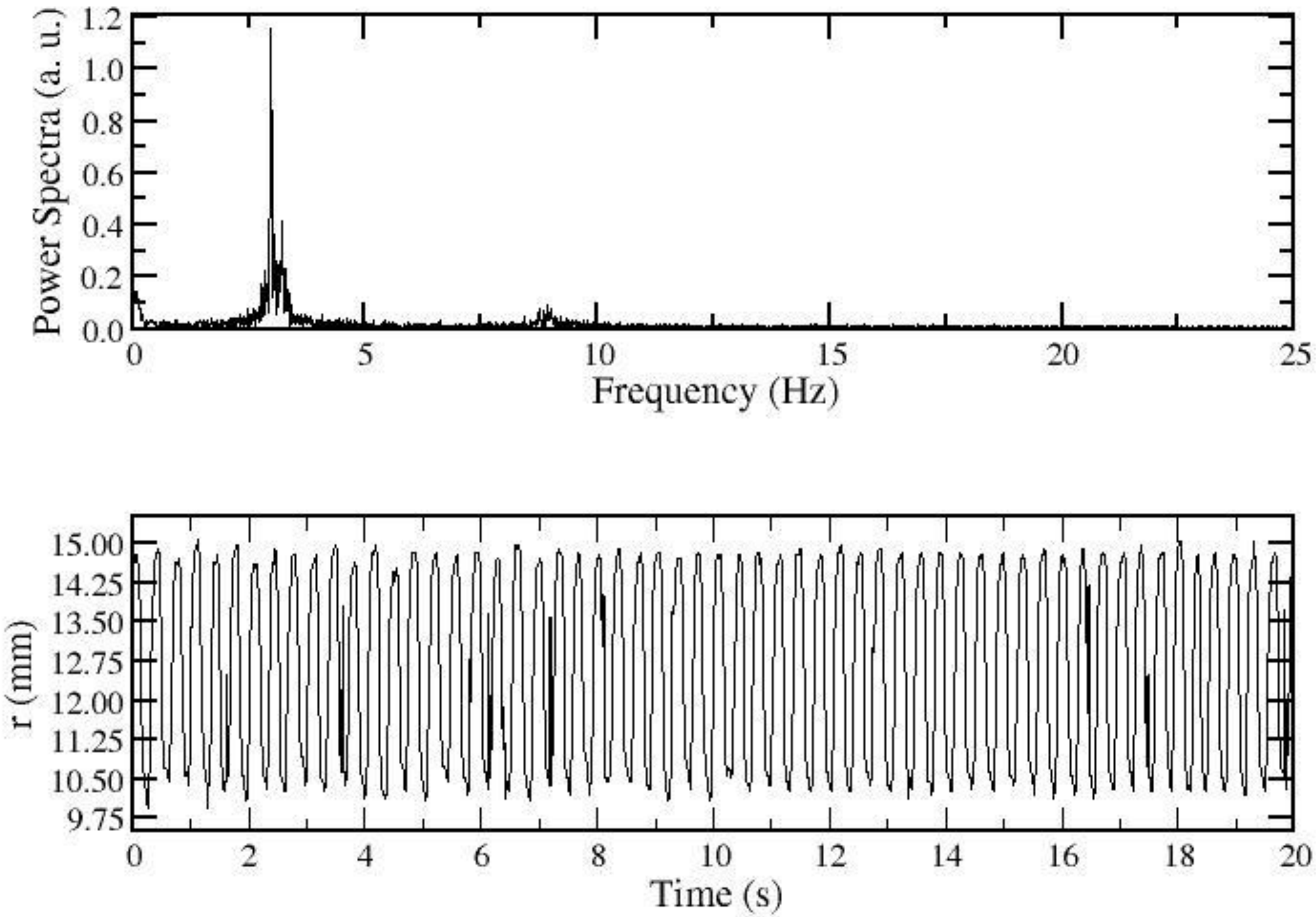




BEHAVIOR OF THE MERCURY DROP AT V_O = -3400 mV



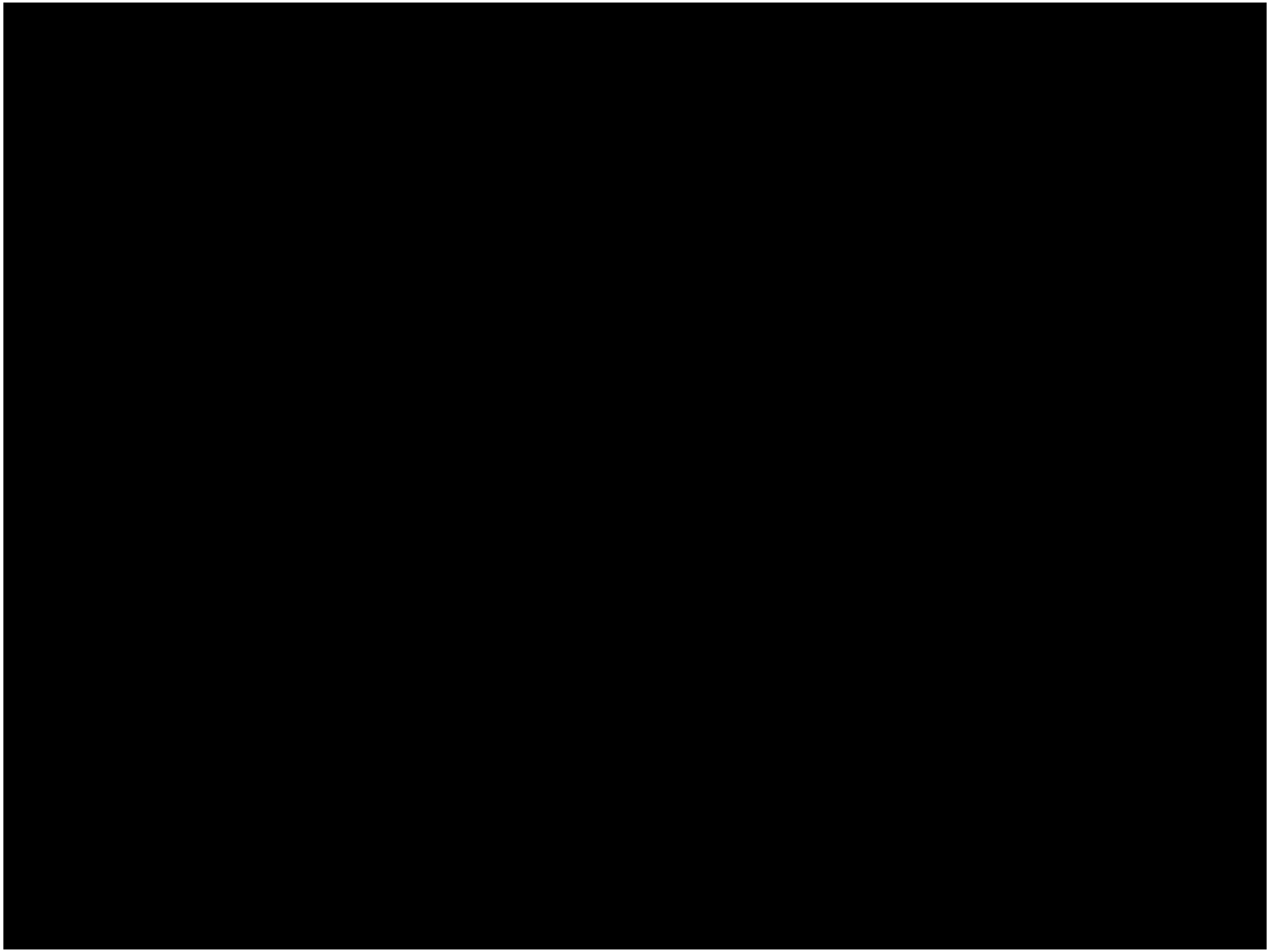
TIMESERIES AND POWER SPECTRA (-3400 mV)



BEHAVIOR OF THE MERCURY DROP (BOTTOM VIEW)

Potential (mV)	State of Motion/Shape
[0, -1500]	~Static/Circular
(-1500, -1600]	Rotating /~Triangle
(-1600 , -3200]	Rotating/Irregular (P)
(-3200, -3400]	Rotating/~Rectangle

TESTING DIFFERENT ANODIC POTENTIALS (V_O) AND HARMONIC FORCING PERTURBATION



CONCLUSIONS

•This new experimental setup for the MBH system offers a variety of interesting phenomena: Pattern Formation, Rotational Motion and combined effects.

•In all these cases, the local variations on the surface tension of the mercury drop play a crucial role.

•The physical mechanism responsible for this phenomena is still unknown.

COLLABORATORS

Marco Rivera (FC-UAEM, México)
Elizeth Ramírez-Álvarez (TU-München, Germany)
Jorge Ocampo-Espíndola* (M. Sc., México)
Fernando Montoya* (IBT UNAM, México)

Professor Punit Parmananda (IIT Bombay, India)

THANK YOU!