Research and Creative Experience for Undergraduates (RCEU) Program 2024

Ultrasonic Acoustic Levitation for Analysis of Evaporating Condensed Phase Fuel Droplets

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Introduction

- Acoustic levitation uses sound to suspend small objects including liquid droplets [1]
- This enables researchers to experimentally determine the properties of free-floating liquid fuel droplets

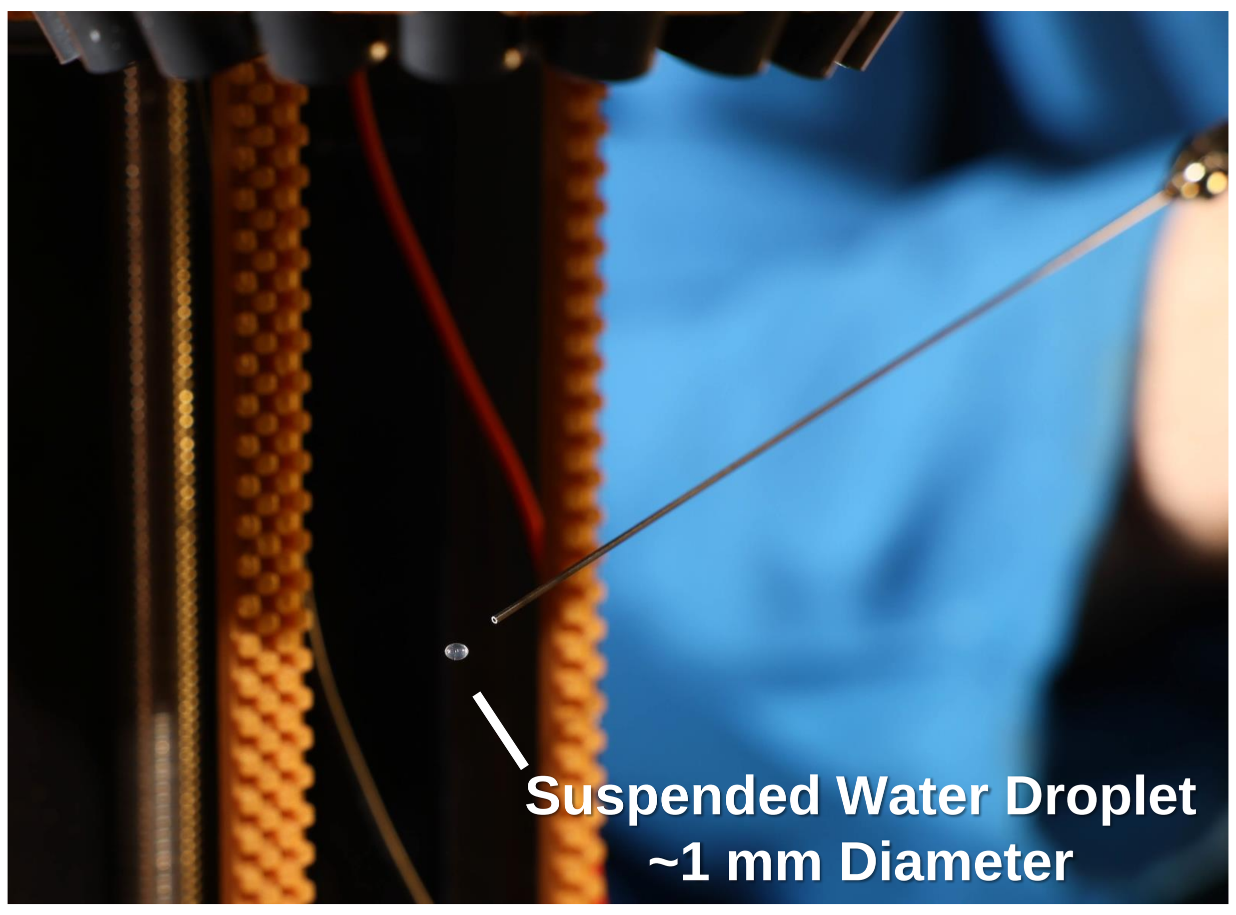

Fig. 1: Water droplet dispensed into acoustic levitator

- TinyLev [1] works by using two arrays of ultrasonic speakers positioned opposite each other, outputting $f = 40\ \mathrm{kHz}$ periodic pulses
- This creates a standing wave within the levitator, trapping small solids and liquid droplets at the pressure nodes
  - Ultrasonic levitation suspends droplets without the use of a support fiber

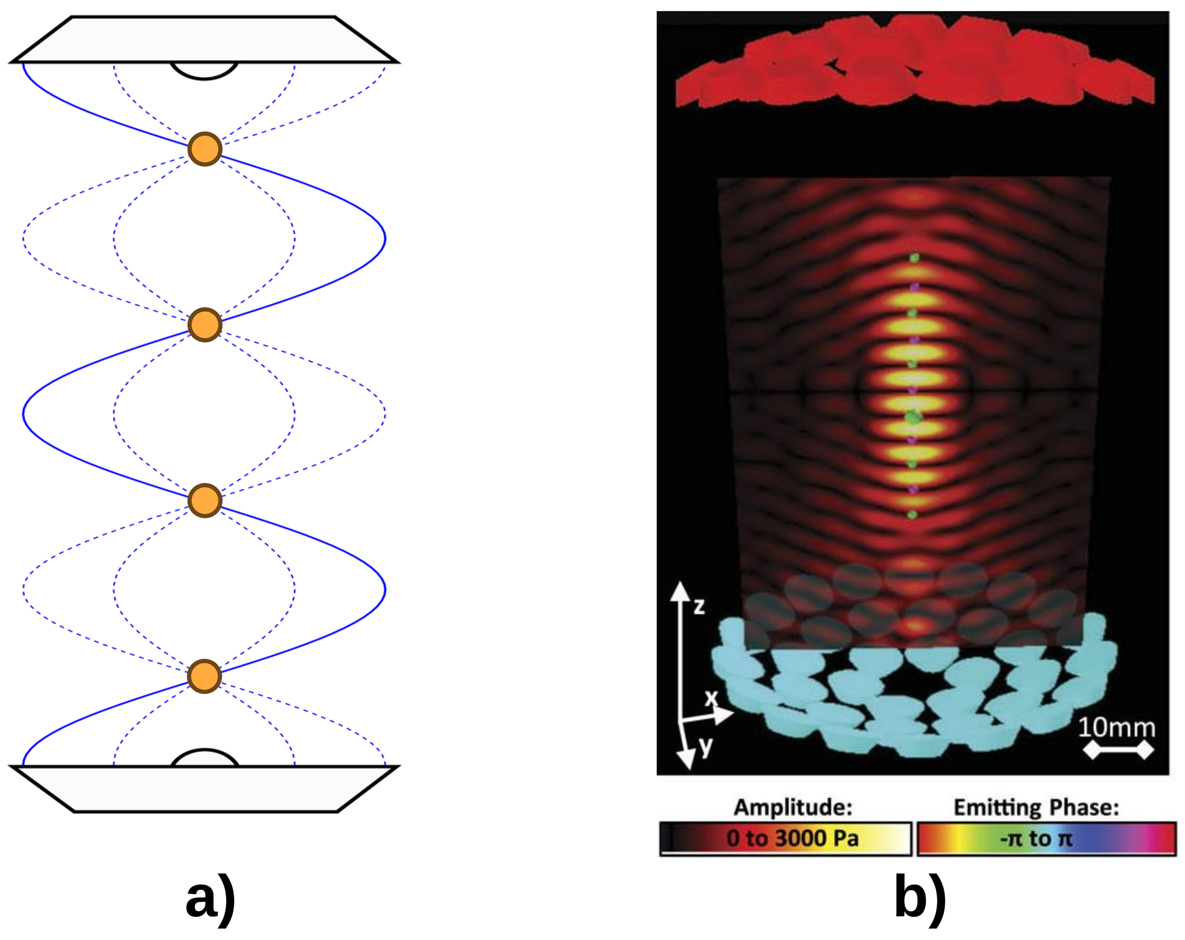

Fig. 2: Acoustic levitating standing wave a) schematic and b) pressure field simulation (taken from [1])

Impact

- Understanding how liquid fuels evaporate is a key concept that is relevant to condensed phase combustion
- By imaging a suspended fuel droplet over time, the evaporation rate of different liquid fuels can be quantified

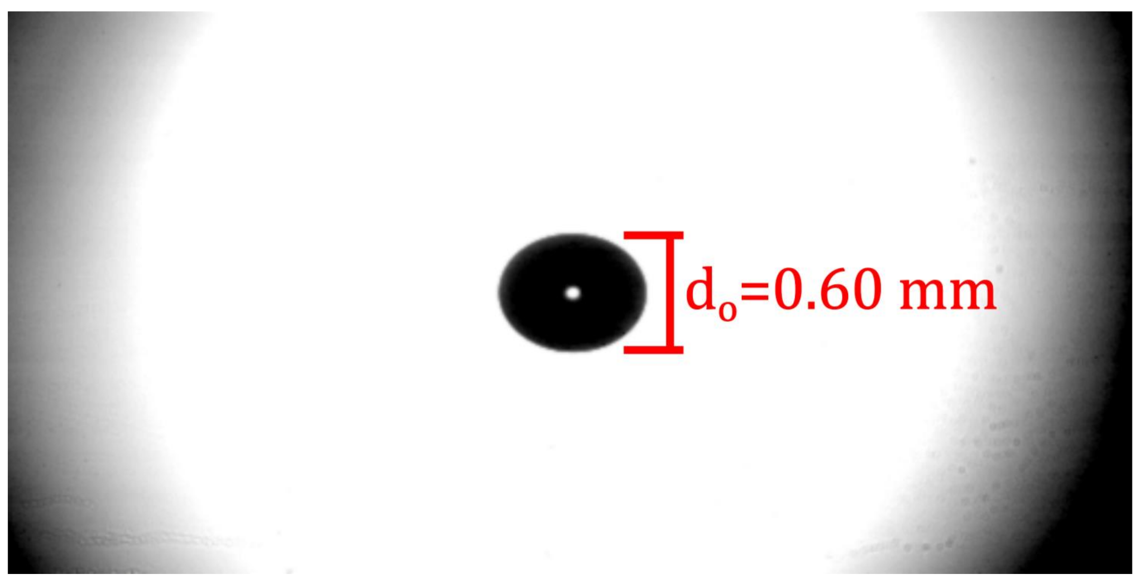

Fig. 3: Backlit image captured of levitating ethanol droplet

Key Findings

- The experiment conducted captures the evaporation rate of ethanol and isopropanol using the *d*-squared law

$$d^2 = d_0^2 - k_e t$$

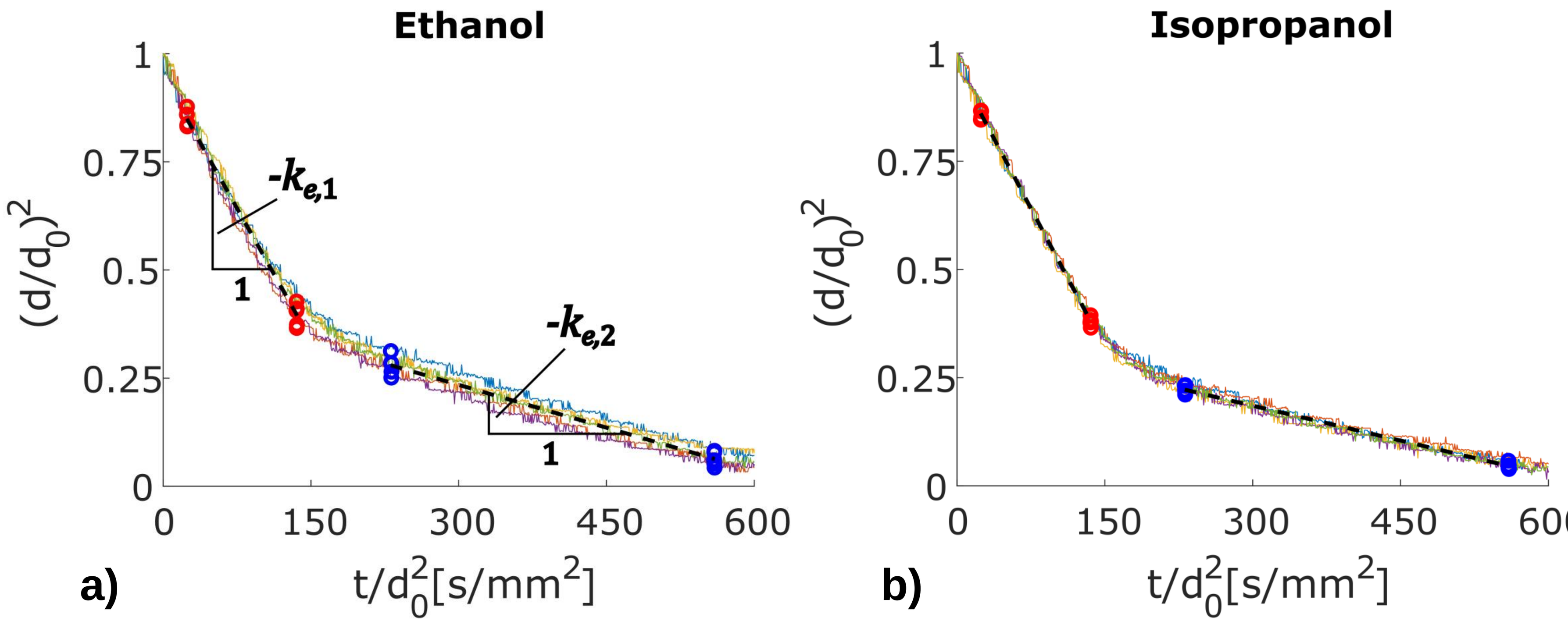

Fig. 4: Droplet evaporation lifetime for a) ethanol and b) isopropanol

Table 1: Evaporation constants for the two-stage regression for ethanol and isopropanol

Evaporation Constant	Ethanol (mm^2/s)	Isopropanol (mm^2/s)
$k_{e,1}$	0.0041	0.0043
$k_{e,2}$	6.59E-4	5.36E-4

- Both fuels experience a two-stage droplet regression
- Fuels experience a similar first-stage regression due to their similar boiling temperatures: ($T_{\text{boil,eth}} = 351.5\ \mathrm{K}, T_{\text{boil,iso}} = 355.5\mathrm{K}$) [2]

References

1. Marzo, Asier, Adrian Barnes, and Bruce W. Drinkwater. 2017. "TinyLev: A multi-emitter single-axis acoustic levitator." Review of Scientific Instruments 88 (8). https://doi.org/10.1063/1.4989995.
2. Linstorm, P. 2023. "Nist Chemistry Webbook, Nist Standard Reference Database Number 69." In , 9:1–1951. https://ci.nii.ac.jp/naid/20001287495/.

Acknowledgements

The author would like to thank Mr. Tony Hall, Dr. David Lineberry, and Matthew Maybee for their assistance throughout the project. All RCEU projects were sponsored in part by the Alabama Space Grant Consortium, the UAH Office of the President, Office of the Provost, Office of the Vice President for Research and Economic Development, the College of Science, the College of Arts, Humanities, and Social Sciences, and the College of Education.