Effects of Forcing on Synchronized Rijke Tubes

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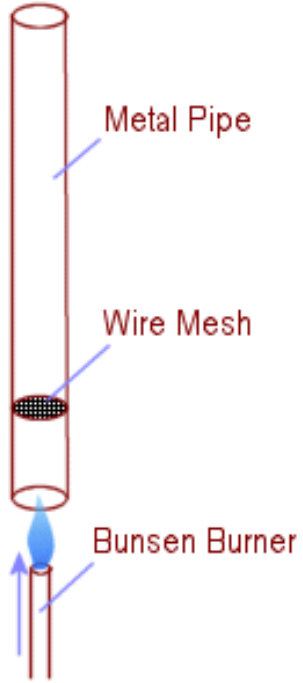
Motivation

- Relation between Rijke tube and general combustion

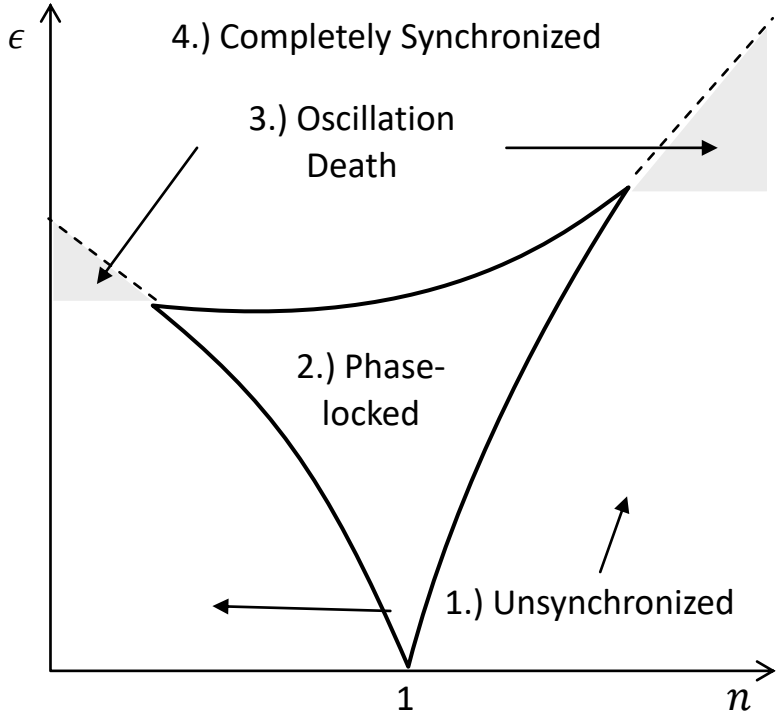


Objectives

- Examine 2 things:
  1. Examine how Rijke tubes synchronize when coupled together.
  2. Examine how forcing affects that synchronization.

Synchronization Regions

- To traverse the synchronization diagram **vertically** (i.e., reduce coupling strength), the transmission coefficient of the coupler would be reduced by packing it with sound damping material.
- To traverse the synchronization diagram **horizontally**, the ratios of the lengths of the Rijke tubes would be varied.
- For each of the four test cases, the forcing frequency and amplitude would be varied to determine the effects.



Experimental Setup Overview

- Similar to the image on the right, with a few differences:
  - Tubes made out of steel.
  - Tubes connected with small coupler pipe.

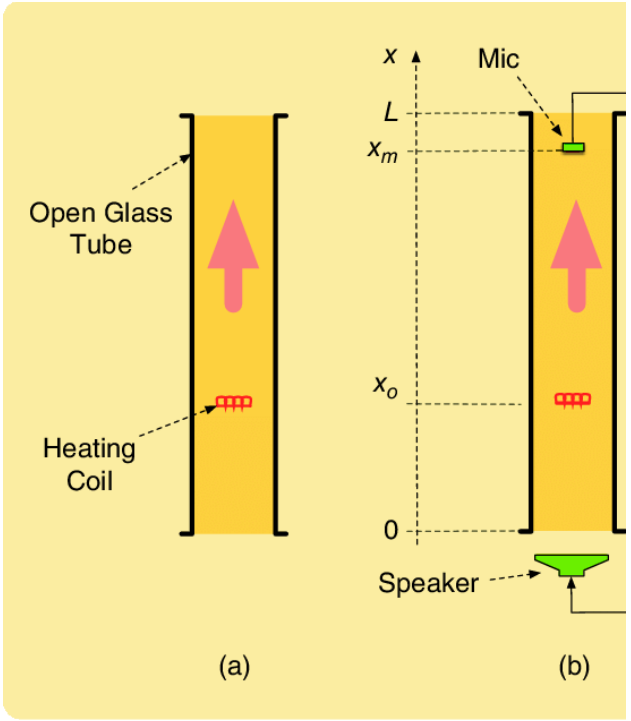
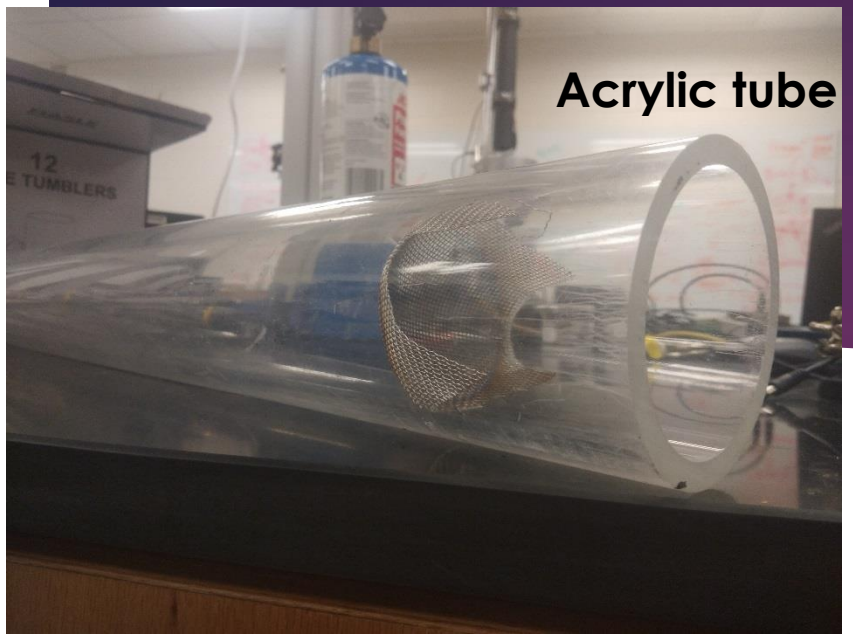
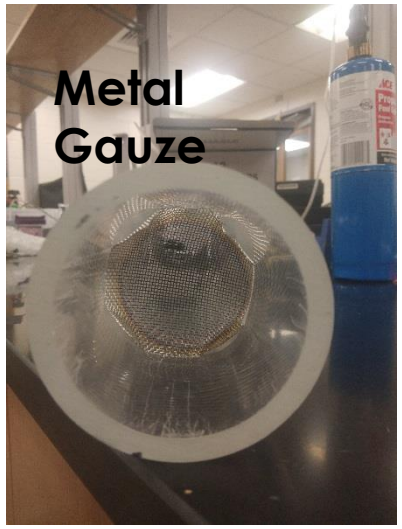
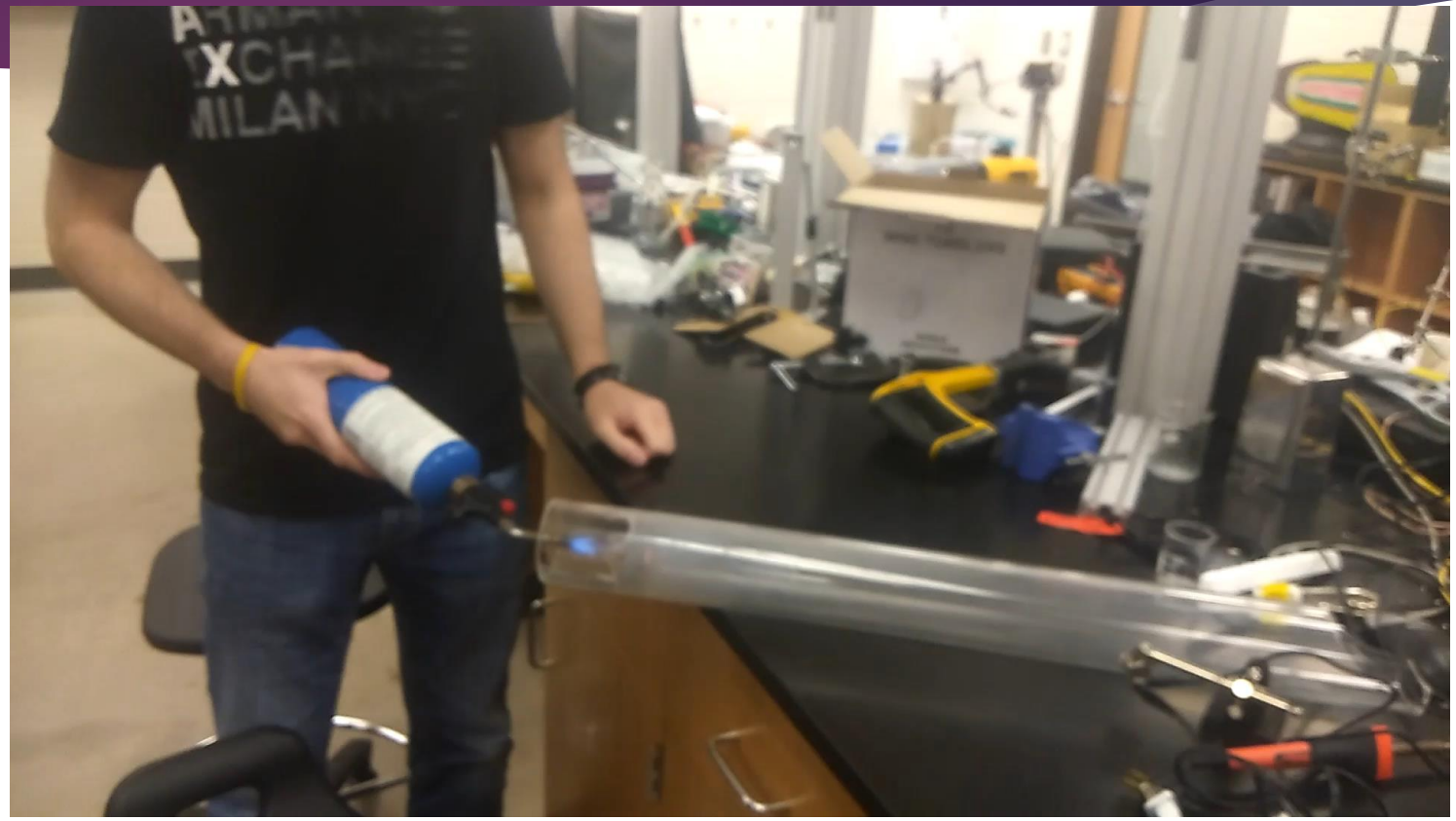


Image Source: https://www.researchgate.net/figure/a-The-Rijke-tube-shown-with-a-heating-element-placed-toward-the-bottom-suspension_fig1_273706574

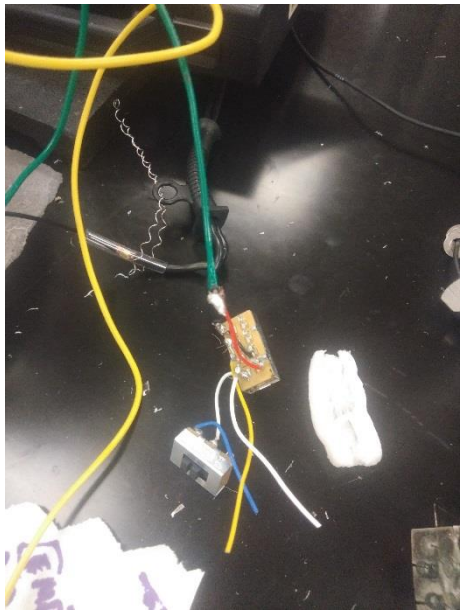
Gas Torch Tubes







Electric Heater



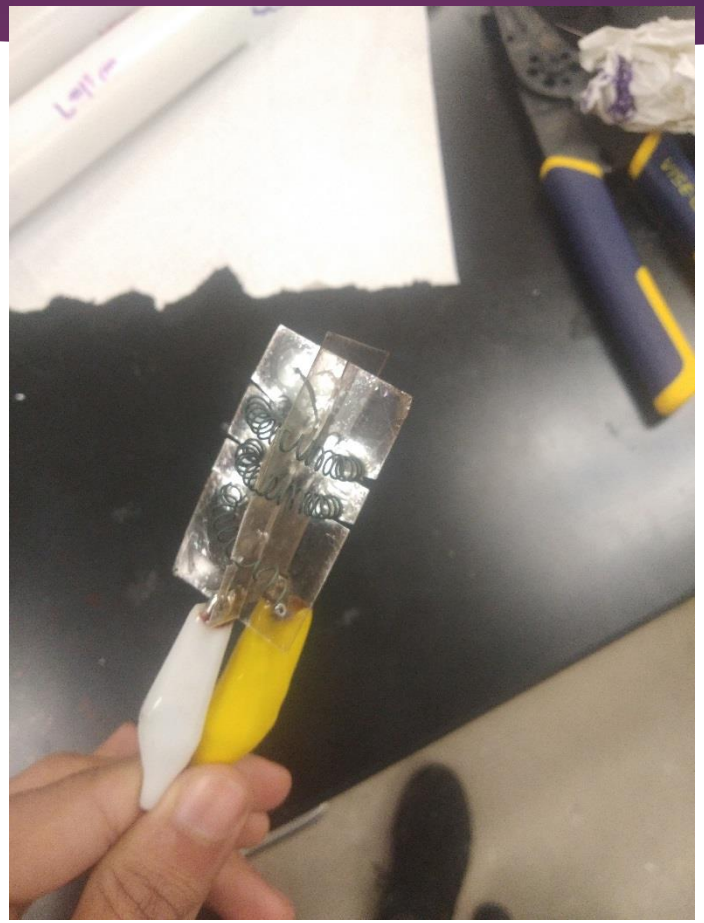
Hair-Dryer

Variac

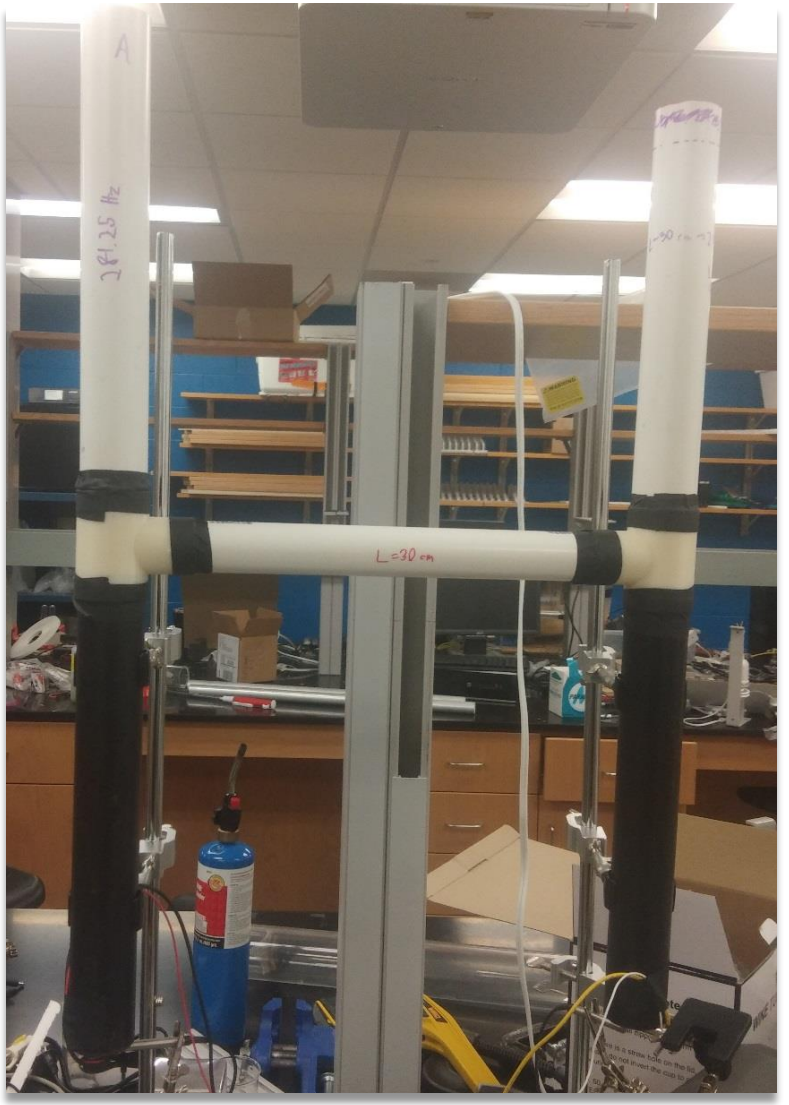
Mica Tiles

Nichrome Wire

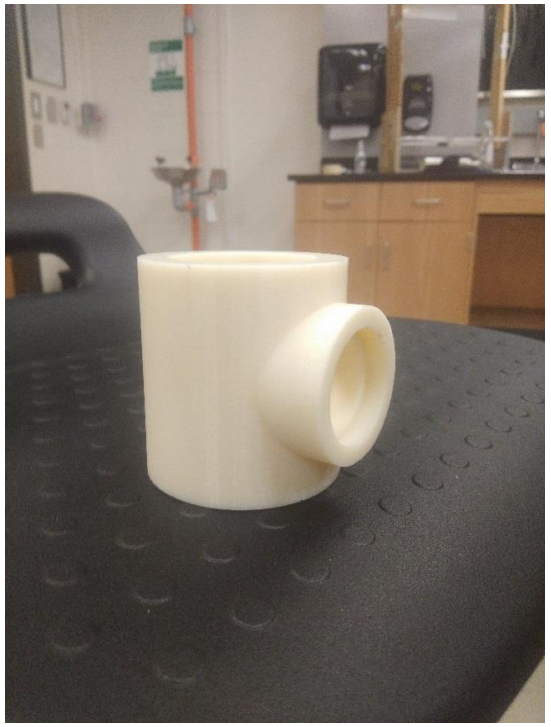
Electric Heater

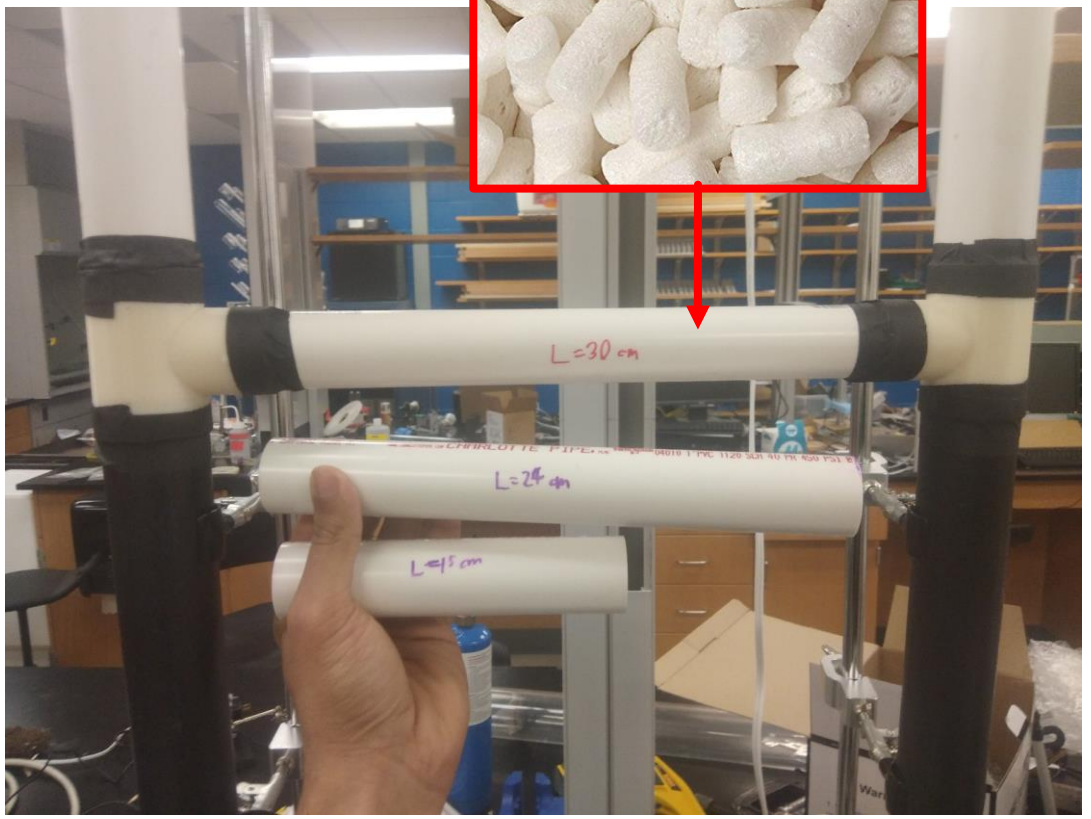


Experimental Setup

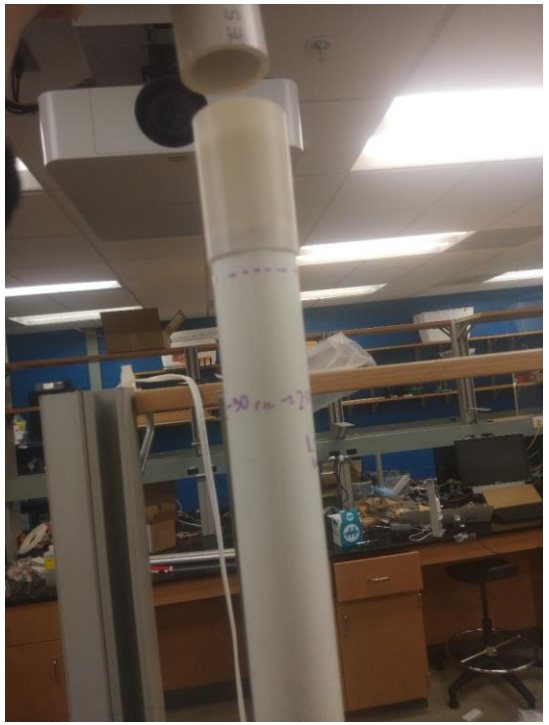


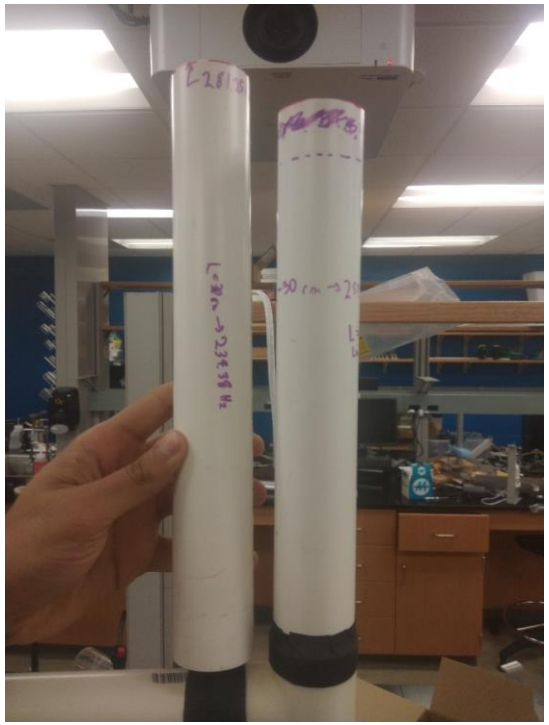
Experimental Setup
T-joints & Coupler Lengths



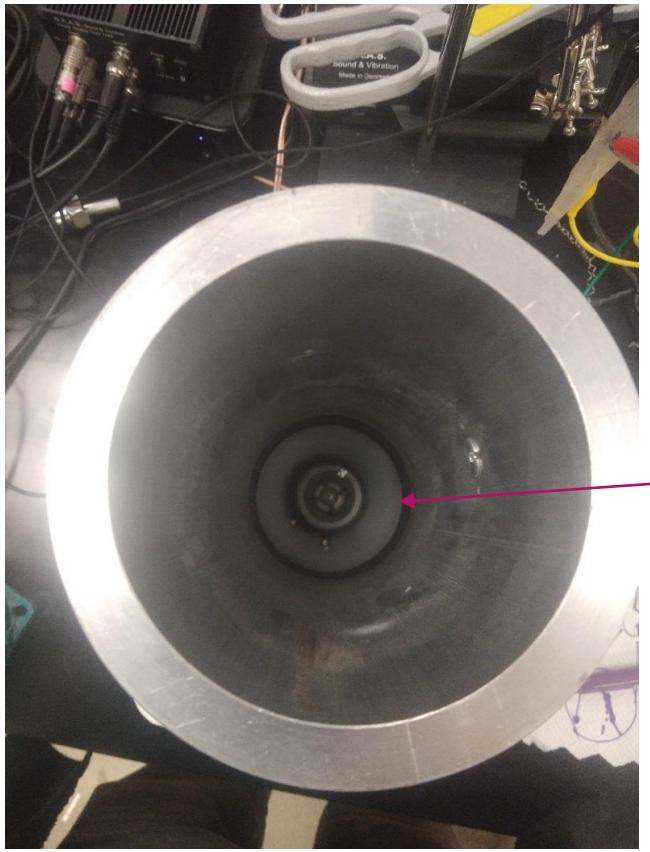


Experimental Setup
Different Tubes & Length Extenders

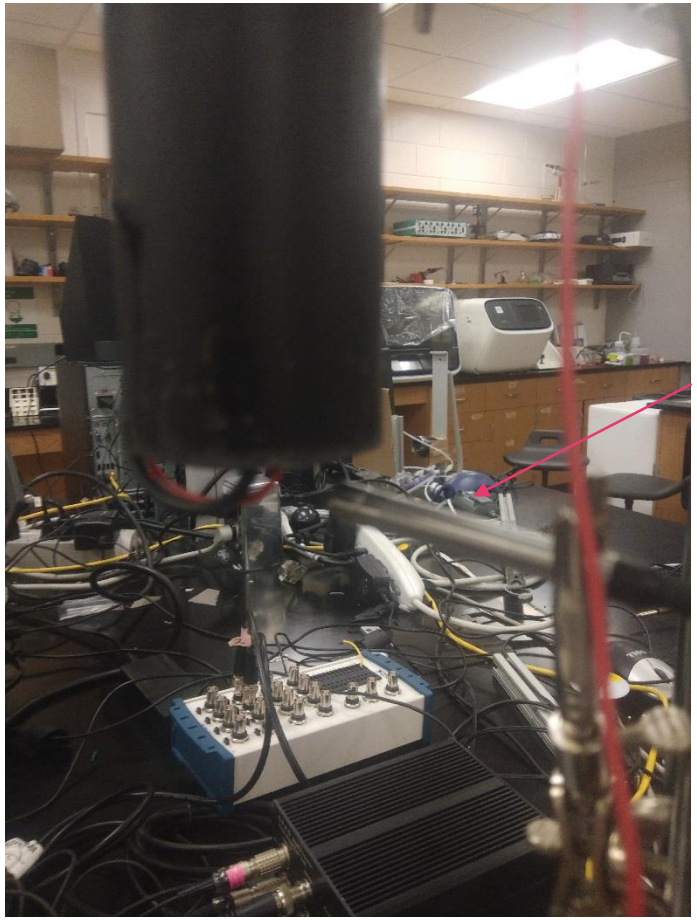


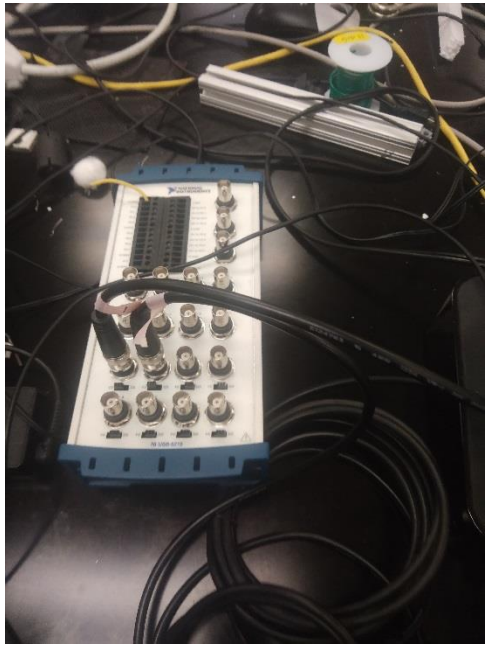


Forcing Tube (Not Used)



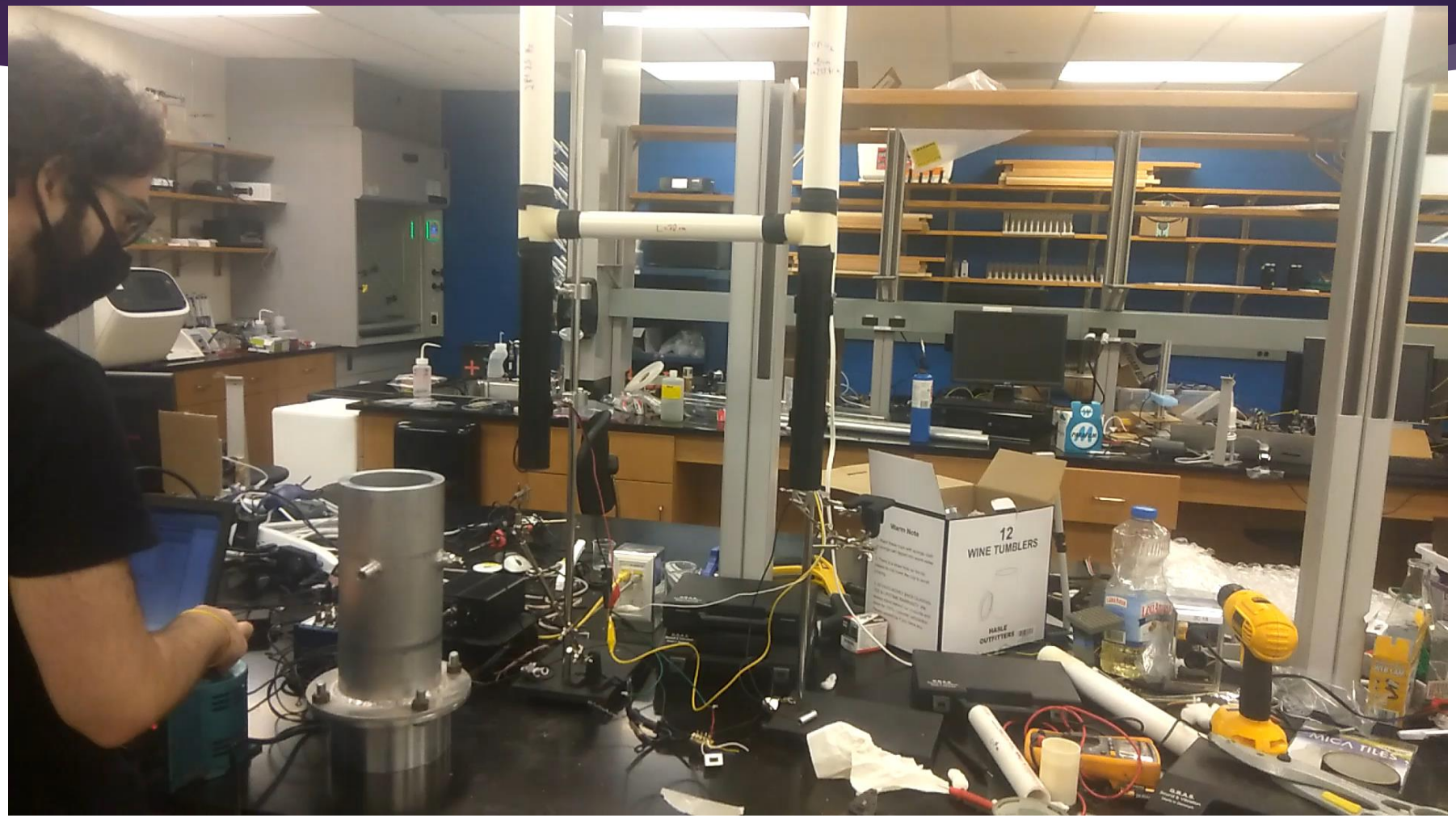
Microphones & DAQ Setup





Acquisition System

Synchronization



Results & Discussion
Relevant Theory

- Synchronization can be detected by visually inspecting the time variation of the phase difference:

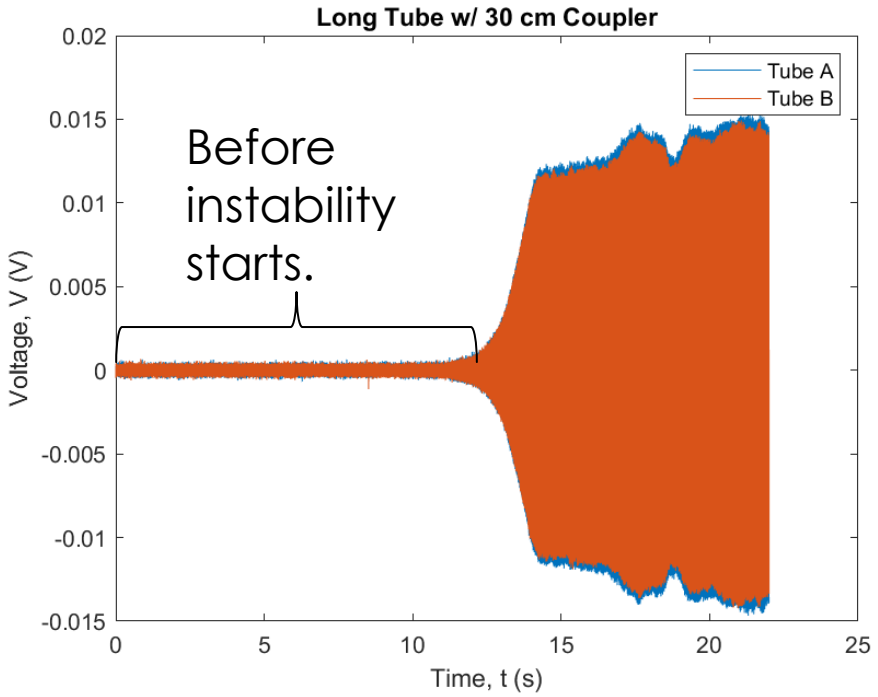
$$\Delta\phi = \phi_1 - \phi_2$$

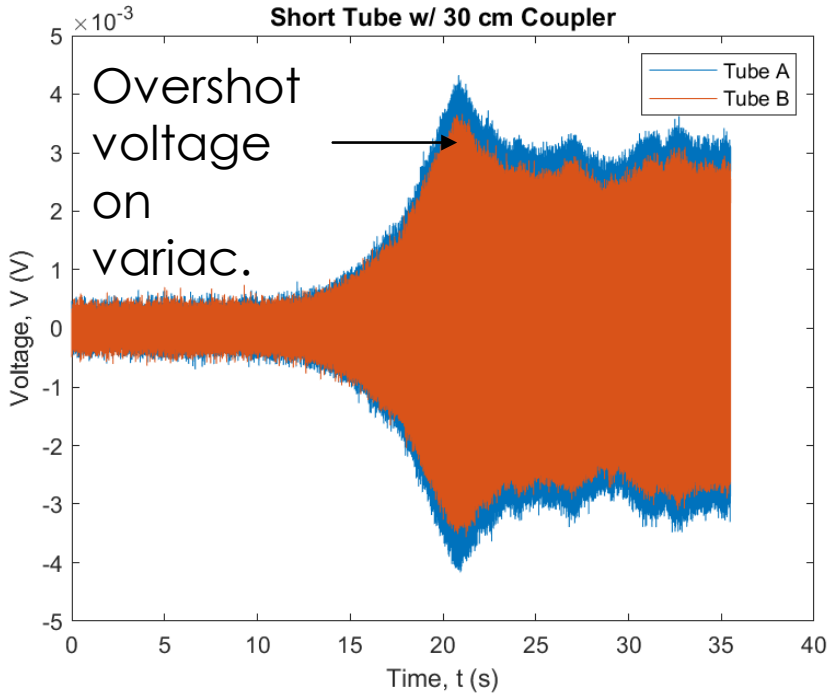
- Alternatively, one can compute the phase-locking value (PLV):

$$PLV = \frac{1}{T}\left|\sum_{t=1}^{T} e^{i\Delta\phi}\right|$$

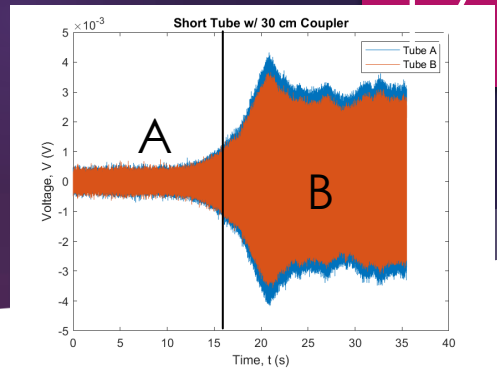
  - PLV ≈ 1 => phase-locked.
  - PLV ≈ 0 => no synchronization.

Results & Discussion
Time Series

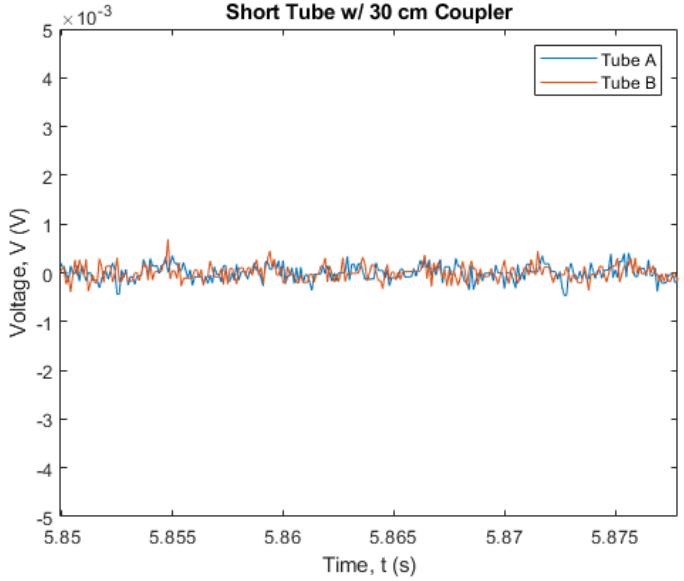




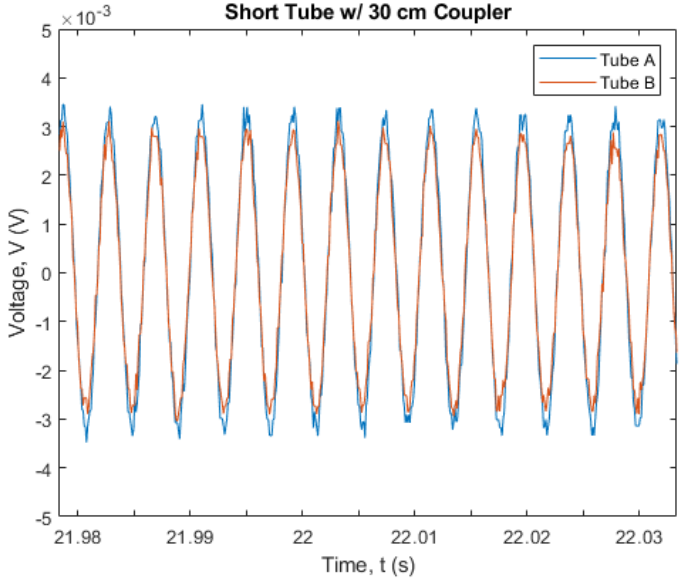
Results & Discussion
Time Series (Zoomed In)



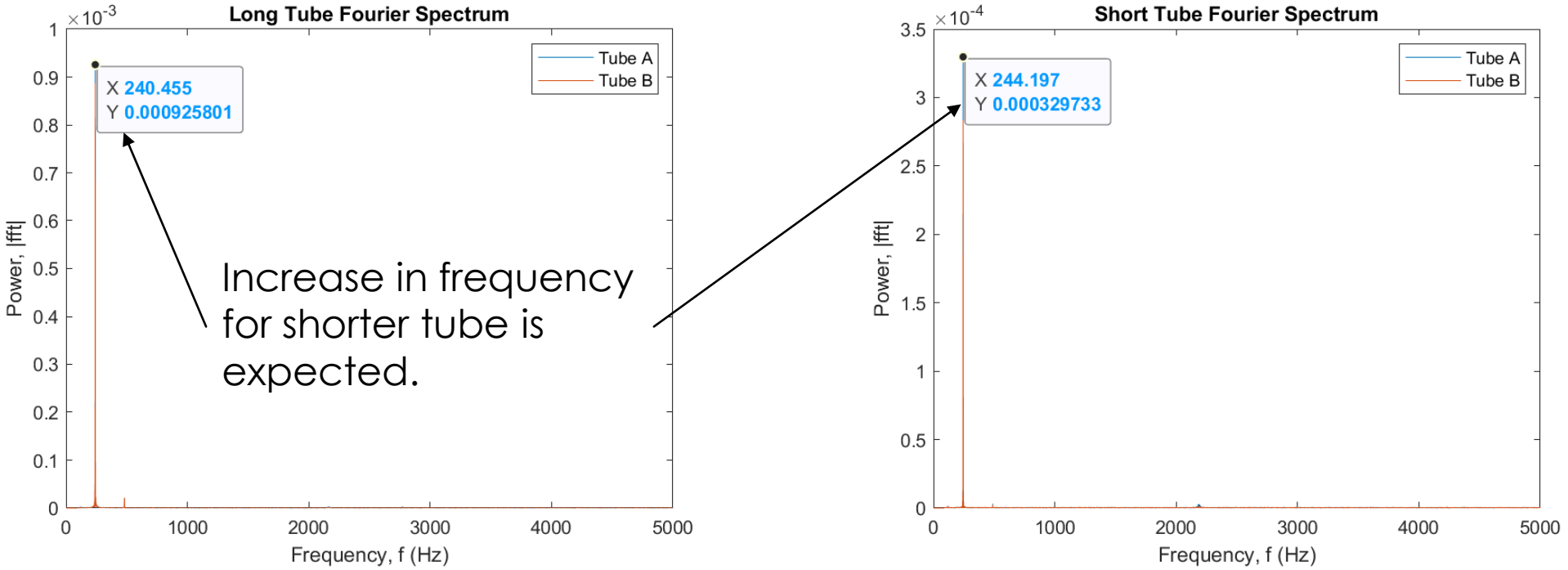
A = Noise



B = Thermoacoustic Oscillation

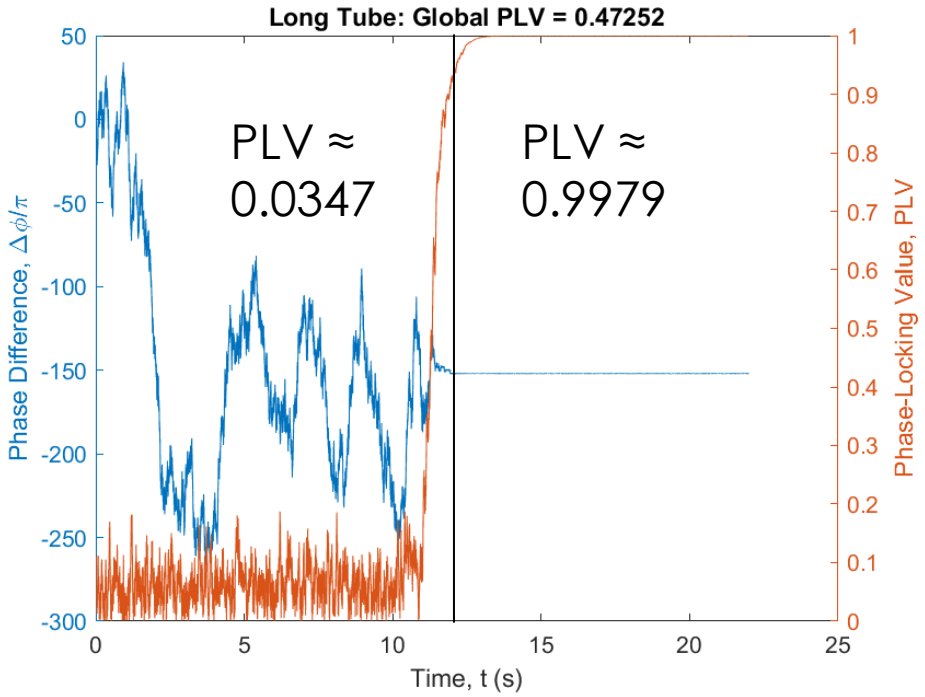


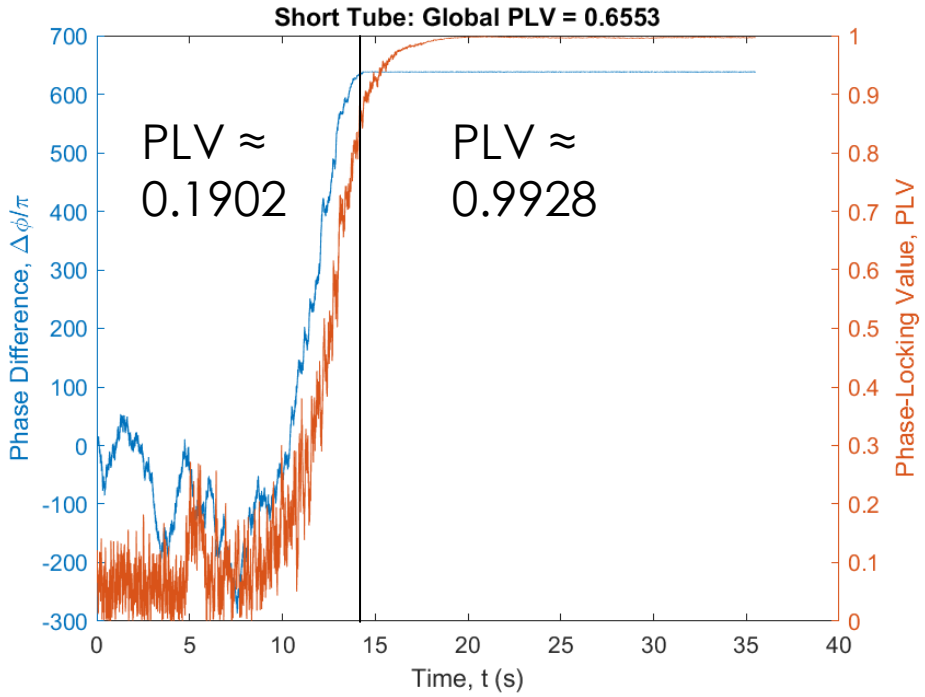
Results & Discussion
Frequency Spectra



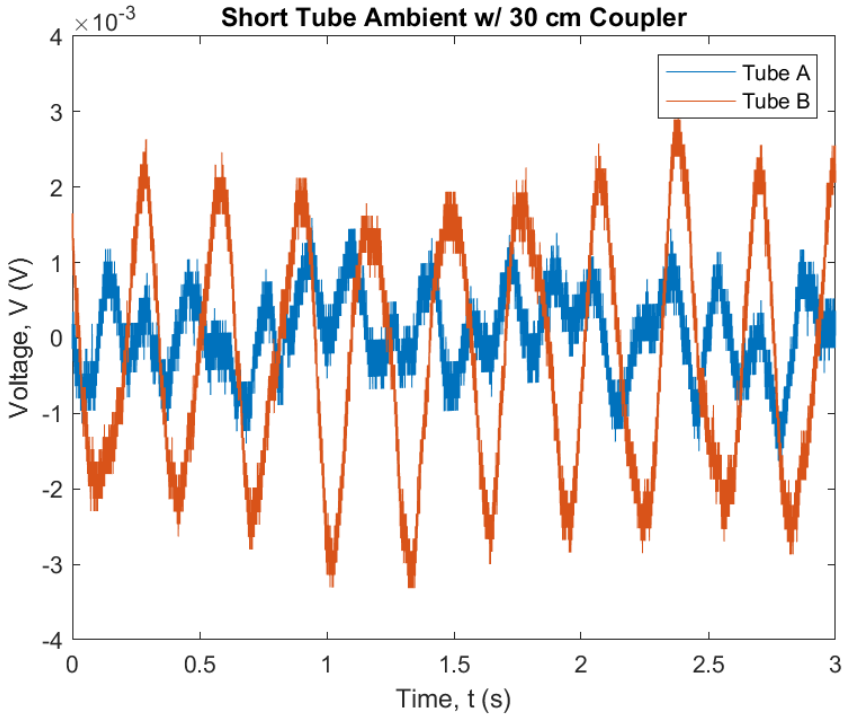
- Operating with a 15 cm long coupler produced the same frequency tones for each case.

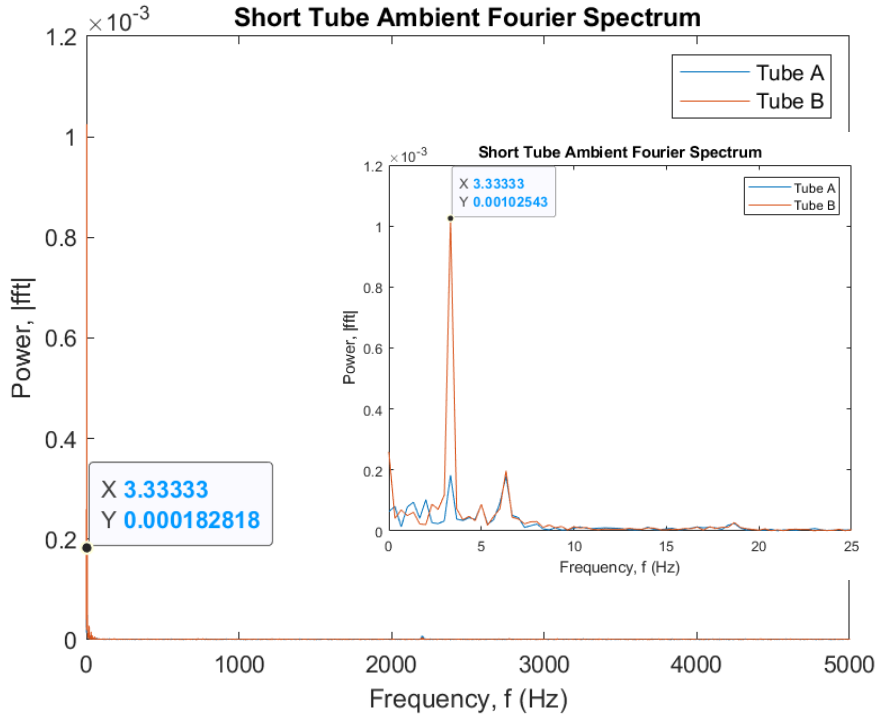
Results & Discussion
Phase Difference & Phase-Locking Value





Results & Discussion
Ambient Data





- Collected without running the Rijke tubes.
- Illustrates the presence of a low frequency ambient pressure oscillation in the room.
  - Caused by ventilation system in the room.
- This tone was removed via a high-pass filter applied to the data (cut-off = 100 Hz).

Conclusions

- What have we actually observed?
  - Normal synchronization, but seen through the lens of Rijke Tubes
  - What this means we accomplished
- What do we want to do from here?

Issues with Setup

- Steel gets really hot, so limited to 1 minute.
- Forcing tube altered the acoustics, preventing the formation of the thermoacoustic instability.
- Adding packing peanuts to the coupler stopped all oscillations from occurring.
- Leakage issues at joints.