EECE 5698 Fall 2025
Lab 4: Laser Injection Against MEMS Microphones

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Submission Deadline: Nov 17, 2025 by 11:45 AM.
Submit your report as a group on Canvas.

Equipment

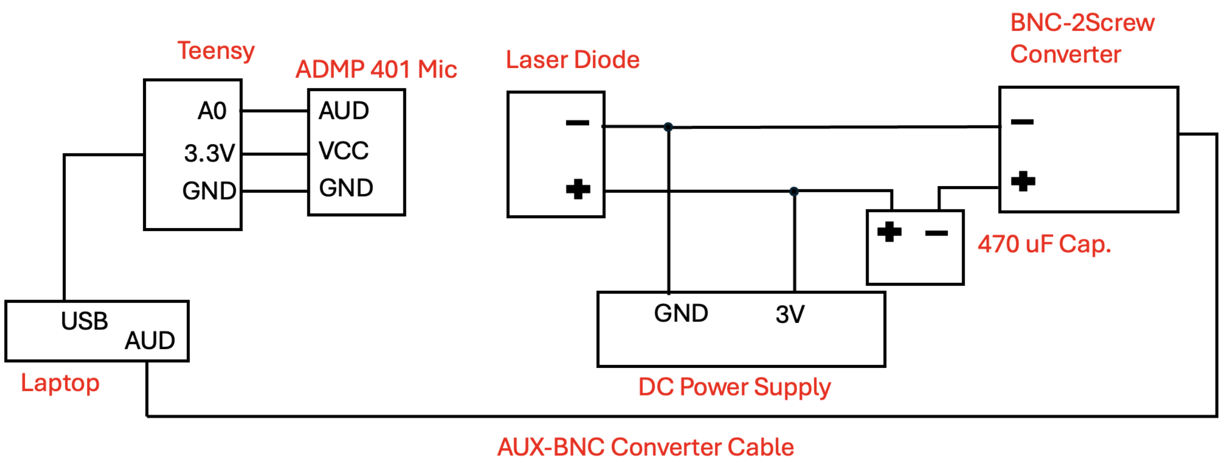


Fig. 0. Connection Diagram

- A laser pointer. The laser pointer will be driven by a 3V DC biasing voltage and the AC audio output from the laptop (#1 in Fig. 1). The outer casing of the laser pointer serves as the positive terminal, while the internal spring is the negative terminal.
- Teensy 4.0 (#2 in Fig. 1, which is a portable scope you can use with your laptop)
- AUX-BNC converter cable (#3 in Fig. 1, which routes audio signals from your laptop to the function generator's EXT modulation input)
- BNC-2Screw converter cable (#6 in Fig. 1)
- ADMP401 MEMS Microphone (#4 in Fig. 1)
- A 470 uF capacitor that safely couples the laptop audio output with the laser diode input and the DC supply (#5 in Fig. 1). The side of the casing with a gray vertical stripe indicates the negative lead (-).
- Your laptop (Use largest audio output volume), DC power supply

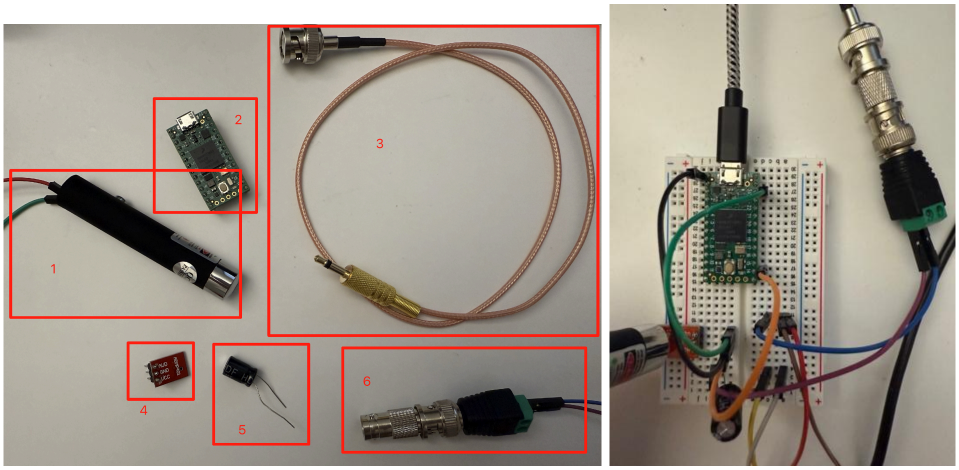


Fig. 1. Main Components

Notes

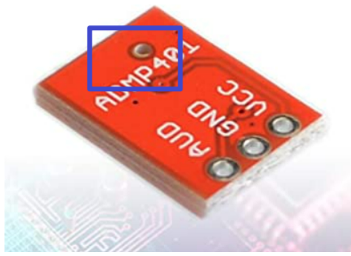
- Be sure not to point the laser pointer at your own eyes or anyone else's eyes and always wear protective goggles when injecting the laser!!!
- Use a 50k Hz sample rate for all the audio files saved in this lab.
- Most operations in this lab04 will be very similar to lab03 except that the signal injection device is changed from speakers emitting ultrasounds to lasers.
- Please be as quiet as you can since your voice might affect your neighbor's microphone signals.

Part 1: Laser Injection

Lab04 investigates another threat against microphones: laser injections. You will see that microphones can not only hear acoustic signals but also optical signals. Combining this observation with what you learned in lab02 about the conversion between different forms of energy, you should realize that signal injection attack is essentially a type of energy transformation between different modilaties of physical signals. The security research problem here is to find out which devices/materials are sensitive to which kinds of physical signals. Specifically, lab04 studies MEMS microphones sensitivity to varying optical power.

Problem 1. Frequency Response Characterization

Finish the setup and connections as shown in Fig. 0. Make sure your laptop's audio port and the laser diode are connected so that your laptop audio output can drive the laser diode. Note that you need to have the laser directly shooting at the microphone breakout board's mic port, which is a small opening on the back of the board. You can try adjusting the laser angle to see if you can get stronger injections.



Let's first examine the frequency response of your laser injection. For your laser injection signal, please use the [tone generation website]() to output a **5 kHz** signal with uniformly maximum amplitude throughout the entire process, and set your laptop audio volume to the maximum (100%). Meanwhile, use your Teensy board to run [Arduino]() and [Python scripts]() similar to Lab 03 in order to display the microphone outputs at a **50 kHz** sampling rate. When you point the laser pointer at the small hole of the microphone we mentioned earlier, you will obtain results similar to Fig. 3, where you can clearly observe an injection signal around 5 kHz. In addition, please ignore the noise in the 10–11 kHz range, which may be caused by environmental noise as well as internal noise from the ADC.

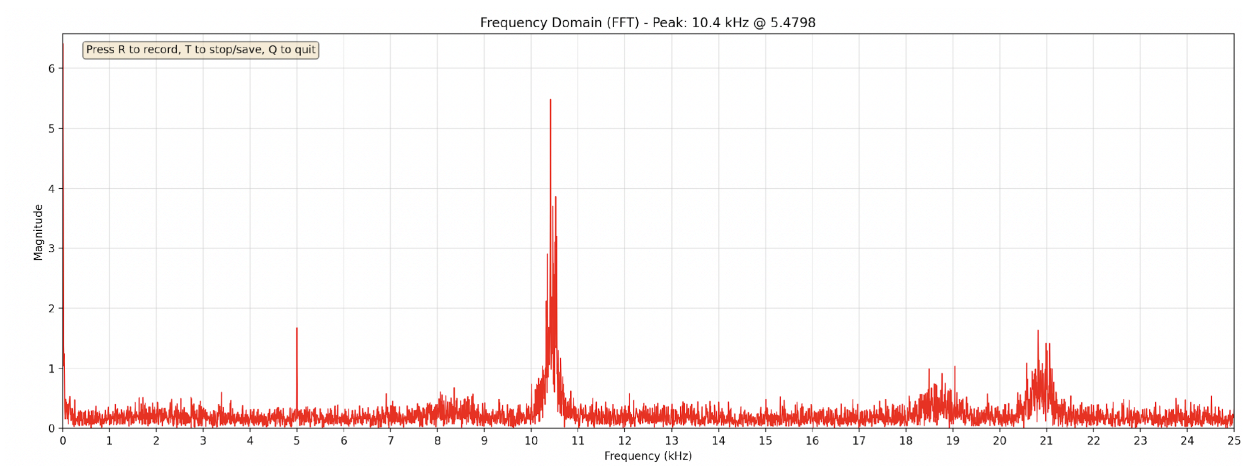


Fig. 3. Frequency response of laser injection

Question 1:

- Submit a figure replicate Fig. 3. Your FFT plots should have a frequency range of 0-25k Hz.

Problem 2. Speech Modulation

Same as lab03, let's now try injecting speech signals. Use the same injection [speech file]() that contains 20 words: "This course will teach students advanced methods to model, measure, and protect the security of embedded systems and so on."

Use your Teensy board to run Arduino and Python scripts to collect the microphone data. When you press “R” in the python plot, you can begin to record the audio, and then you can press “T” to pause and save audio.

Fig. 4 shows the mic signal I got, both time and frequency domain. Please make sure to set your computer volume to maximum and move your ear reasonably close to the laptop speaker to listen to this audio, because although the injection was successful, the sound is relatively weak due to the low laser intensity. You can try this speech-to-text tool to see whether your injected audio can be successfully transcribed.

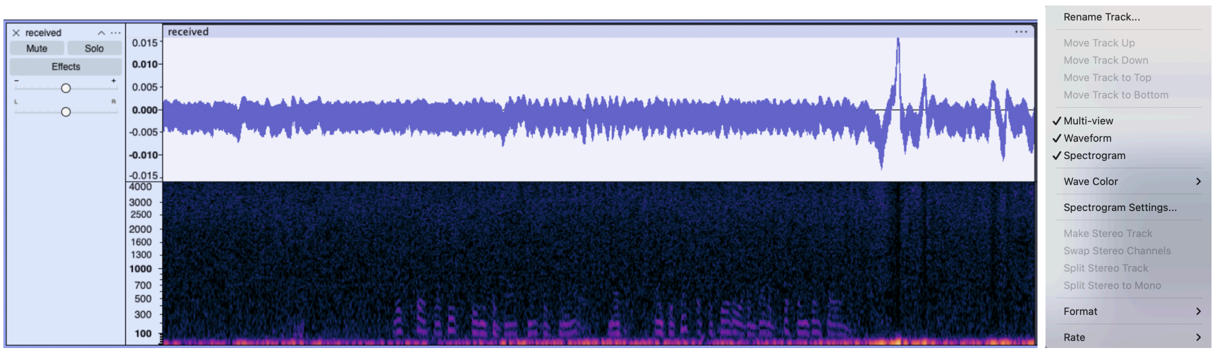


Fig. 4. The laser signals interpreted by the microphone

Question 2:

- Upload your wav file to google cloud and share a link to it so we can hear it. Make sure you grant viewer permission to all people with this link or all NEU accounts. You will lose points if we cannot access your wav file with our NEU account.
- Submit a figure of your own injection signals that replicates Fig. 4. Put the track to “Multi-view” in audacity to show the time and frequency domains simultaneously. Adjust the Y-axis range of the time domain waveform to clearly show the variations in signal amplitude. Show a frequency range of 0-4k Hz for your spectrogram.
- Upload your audio to the speech-to-text engine and get a transcript. How many did words out of the 20 words did it transcript correctly?

Part 2: Attack Smartphones & Defense Exploration

Problem 1. Attack Your Own Smartphone

Now let’s try this attack on the microphone of your own smartphone. Simply repeat the process in part 1 but this time use your own smartphones to record instead of the ADMP401 microphone. You need to aim the laser precisely at your smartphone microphone ports which are usually at the bottom of the phone. The injection effect also varies across different phone models, so if you conduct experiments on your phone’s microphone and find that the injection is unsuccessful, it is also reasonable.

Question 3:

- Upload the audio file recorded by your smartphone to google cloud regardless of whether the injection is successful or not and share a link to it so we can hear it. Make sure you grant viewer permission to all people with this link or all NEU accounts. You will lose points if we cannot access your wav file with our NEU account. Also, tell us if you think the audio quality is better or worse than the one you got in Question 2 with ADMP401.
- Submit a figure of your recorded signals that replicates Fig. 4. Put the track to “Multi-view” in audacity to show the time and frequency domains simultaneously. Adjust the Y-axis range of the time domain waveform to clearly show the variations in signal amplitude if possible. Show a frequency range of 0-4k Hz for your spectrogram.
- Upload your audio to the speech-to-text engine and get a transcript. How many did words out of the 20 words did it transcript correctly this time?

If you get relatively clear speech signals, you can then try injecting your own voice or speech contents to activate the voice assistants on your phone such as Siri. You can either record your own voice as and replay with your laptop or generate speech with this online text-to-speech engine.