Laser Microphone Surveillance

Sergey D. Koloydenko
Department of Computer Systems and Technologies
National Research Nuclear University MEPhI (Moscow Engineering Physics Institute)
Moscow, Russian Federation
sergey.koloydenko@mail.ru

Ksenia V. Tcyguleva
Department of Computer Systems and Technologies
National Research Nuclear University MEPhI (Moscow Engineering Physics Institute)
Moscow, Russian Federation
ksesha1234567@gmail.com

***Abstract*—This article describes the creation of an electronic device based on catching a laser beam, which can be used to eavesdrop from a safe distance. Photosensitive element receives bounces of laser beam caused by micro-vibrations in response to pressure waves created by noise. Voltage changes can be withdrawn as sound after amplification. A laser beam can be directed into the room window, then it reflects off it and returns to a receiver. This allows for safe and stealthy surveillance. But still, this technology can be upgraded.**

Keywords*—*laser; surveillance; photosensitive elements; sound capturing; speech to text conversion

I. Introduction

People always wanted to possess valuable information, so espionage history goes back into several centuries. With the development of science, new technologies were discovered, and the government constantly wanted hi-tech devices in their arsenal [1]. Lasers became no exception.

Waves, produced by human voice vibrate nearby objects, making it possible for an analog electronic device to convert these vibrations into the audio signal. It can be accomplished using "laser microphone", which receives bounces of reflected a laser beam off the vibrating object. Laser deflections caused by vibrations can be transformed into audio signal, amplified, and filtered [2].

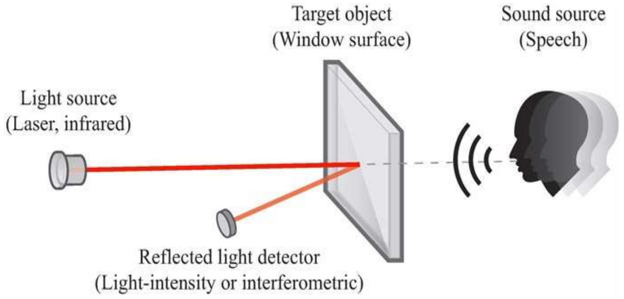

Fig. 1. Simple depiction of laser microphone's working method.

The technique of using a light beam as spying device was invented by Leon Theremin in the Soviet Union in 1947 and was used into "Buran" device, reliable on 500 m distance with post-processed signal to remove noise[3], to spy on U.S, British and French embassies in Moscow [4]. Laser microphones were popular in the 90s but fell out of favor with the rise of computer eavesdropping technologies which provided more value. But now some anti-terror unis, CIA and FBI for example [5,6], find the use of it, because of its safety and stealthiness.

With the development of technology, laser microphones were upgraded: better receivers, amplifiers and different auxiliary software were created. Overall construction became easier to use and produce not only for the government but also for private military companies. As components become cheaper and more available, even a regular person can build a spying device themselves nowadays, although it is forbidden by law [7]. The project has no intention of spying on other people and it was only used for tests on existing audio files.

Despite various advantages, technology has some drawbacks: it is difficult to set up and to configure, analyzing raw audio can be hard. But still, there is a considerable amount of improvements which can be implemented.

The main objective of the research was to build a laser microphone and make it easier to perform surveillance with it. Operating with text files is more comfortable than with raw audio, so the project was focused on converting speech into text. That required usage of computer software.

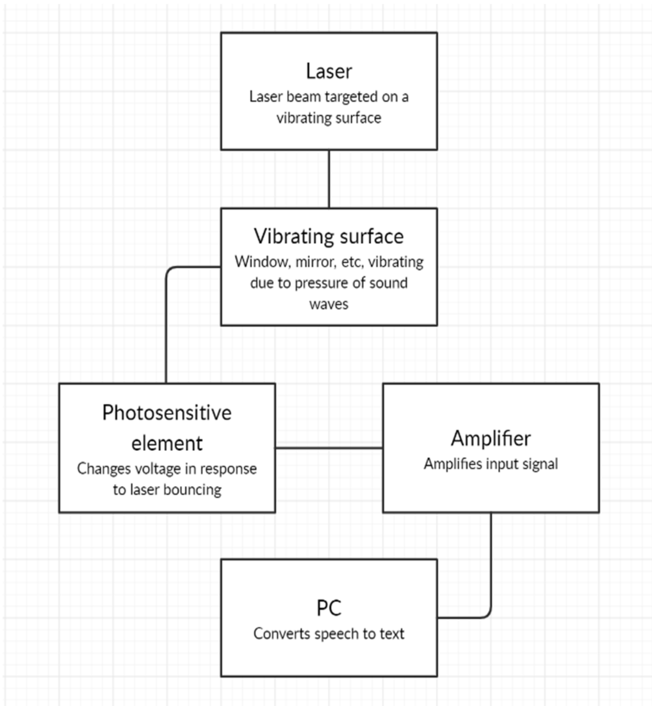

Fig. 2. Diagram for the device.

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II. Research Materials and Methods

The whole device consists of two main parts: laser beam and receiver. The idea of the project was to make a simple device from cheap parts. All the components could be easily obtained.

Laser in laser microphones is usually infrared because it is invisible to the human eye, but it is hard to aim and should be paired with red or any other color from the visible spectrum. Using only red laser in tests is a viable option because photo elements are sensitive enough for it.

On a receiving end there can be photoresistor, a simple device that changes its resistance reacting to light, or phototransistor, which has a faster response and acts as an amplifier.

After being received, the sound should be amplified before outputting because incoming vibrations are very small: even a human ear can hardly detect them.

Fig. 3. Red dot laser.

Before constructing the device, test subject was created to prove that technology works. It consisted of 5mW 5 V 650 nm red laser and receiver, based on cheap photoresistor from a night lamp, made of cadmium sulfide. It can receive wavelengths from 600 to 800 nm. NPN transistor was added to the circuit to amplify the outcoming signal. The sound was outputted on headphones, connected to the circuit. As a replacement for window glass, speakers with attached glass were used. The laser beam was aligned parallel along with receiver for best performance.

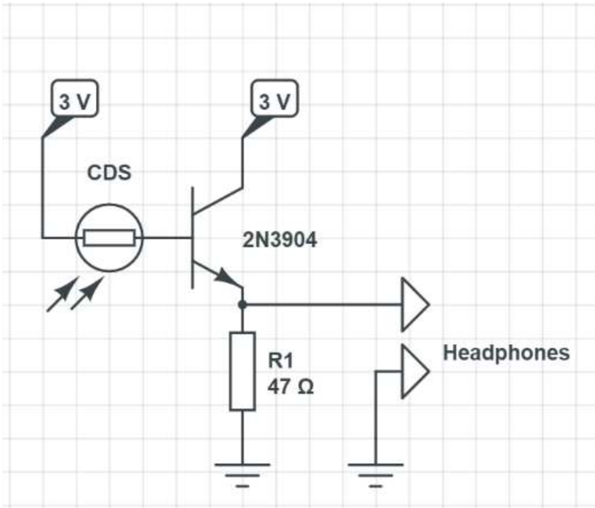

Fig. 4. Test subject receiver's circuit [8].

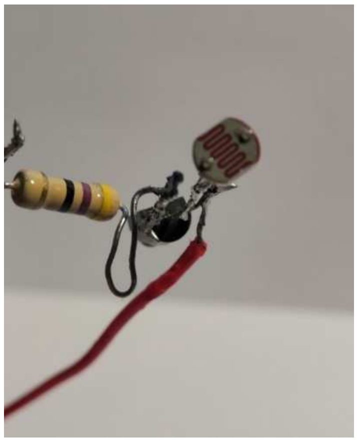

Fig. 5. Photoresistor from the night lamp and transistor.

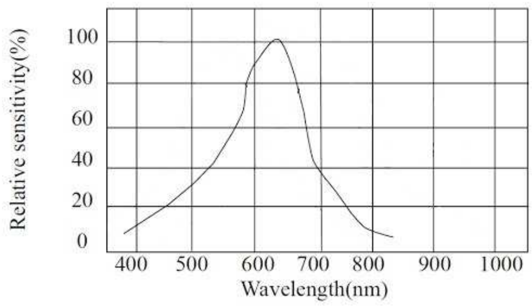

Fig. 6. Photoresistor's sensitivity to wavelength graph.

Tests were successful: technology was proved. The output sound of the test model was slightly hearable and recognizable, but not comfortable enough for practical use even after amplification, and the rate of noise was low.

The next step was creating a more sensitive device with higher amplification with output on headphones.

The device consisted of 5mW 5 V 650 nm red laser, which can be swapped to a 3mW 5 V 850 nm infrared laser for stealth action, and receiver, based on a phototransistor (BPW85C). It can receive wavelengths from 620 to 980 nm. LM386 integral amplifier was added to amplify the outcoming signal and 50 Ohm trimmer potentiometer to increase or decrease the volume of an output signal. Later AUX cable was connected to the circuit so it could be plugged into PC. The audio was output on headphones connected to the PC.

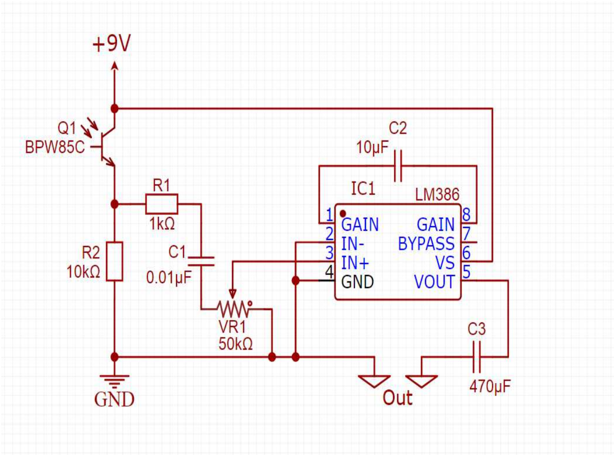

Fig. 7. Device receiver's circuit [8].

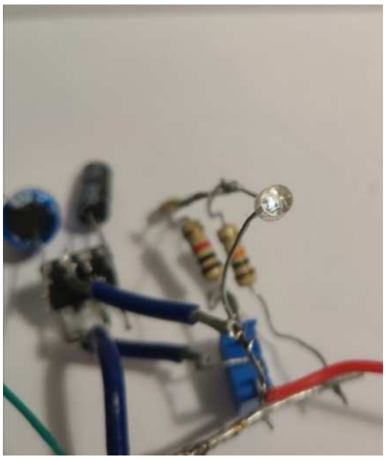

Fig. 8. Phototransistor, LM386 amplifier connected to resistors and condensers.

This phototransistor reaches its peak of sensitivity during the usage of an infrared laser. Using a red laser is still a viable option. The laser must be slightly offset from the center of the phototransistor or photoresistor so when it moves across the surfaces, there is a corresponding change in voltage. The whole device is very sensitive to ambient light so it should be operated in darkness [9].

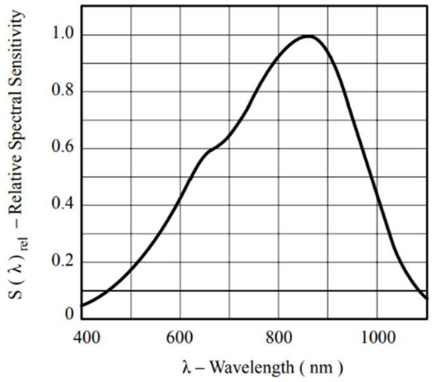

Fig. 9. Phototransistor's sensitivity to wavelength graph.

The sound was comfortably heard and recognized but the noise was also loud. Overall, the performance of this device was better than the test one and it was ready for the next step.

Although this device has many advantages: it is stealthy, it is hard to track the position of an operator, it has a decent range of work. But there are disadvantages as well: it takes a lot of time and patience to properly set up and to configure the device. With that overall usage becomes not so easy. However, some changes can be implemented to make it more comfortable for an operator. For example, analyzing and finding keywords in text is easier than in raw audio.

Conversion of speech to text assumed usage of neural networks, so Python programming language was chosen for the project. Python Kaldi library was the best option because it provided an offline tool for speech recognition. Also, PyAudio library was used to record audio and work with it. Before starting the transformation, some changes can be applied to the audio track. After amplification, some noises caused by other vibrations became louder, so there was a common option to remove them – using fast Fourier transform. In Python, FFT can be performed with Numpy library. It relates a signal sampled in time to the same signal sampled in frequency.

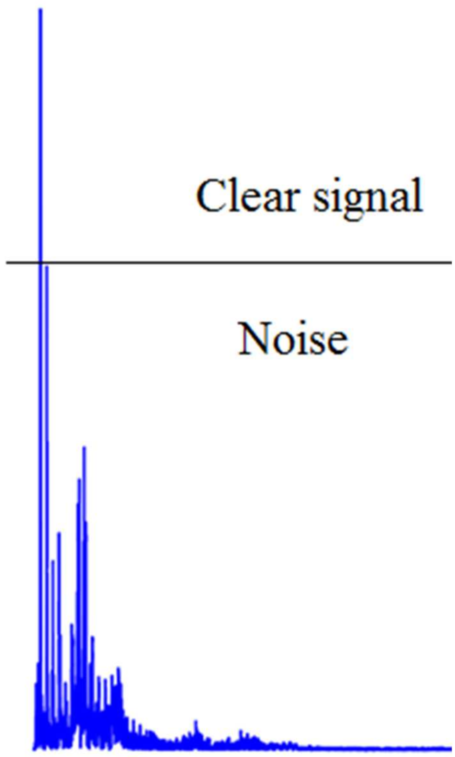

Fig. 10. Power spectrum of frequencies.

This allows us to track spikes of most powerful frequencies which usually refer to clean signal and remove other frequencies that are below some point [10].

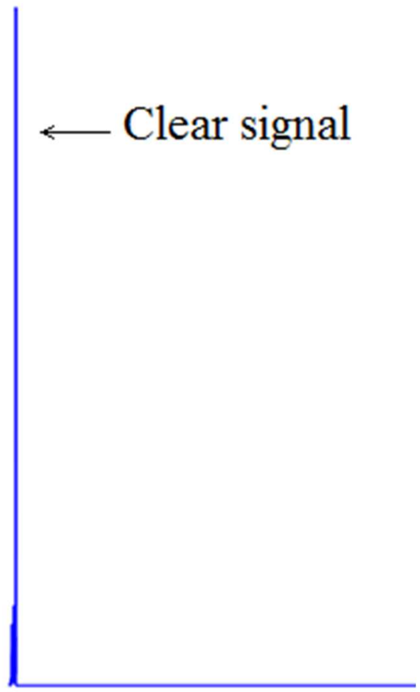

Fig. 11. Power spectrum of frequencies after removing noise.

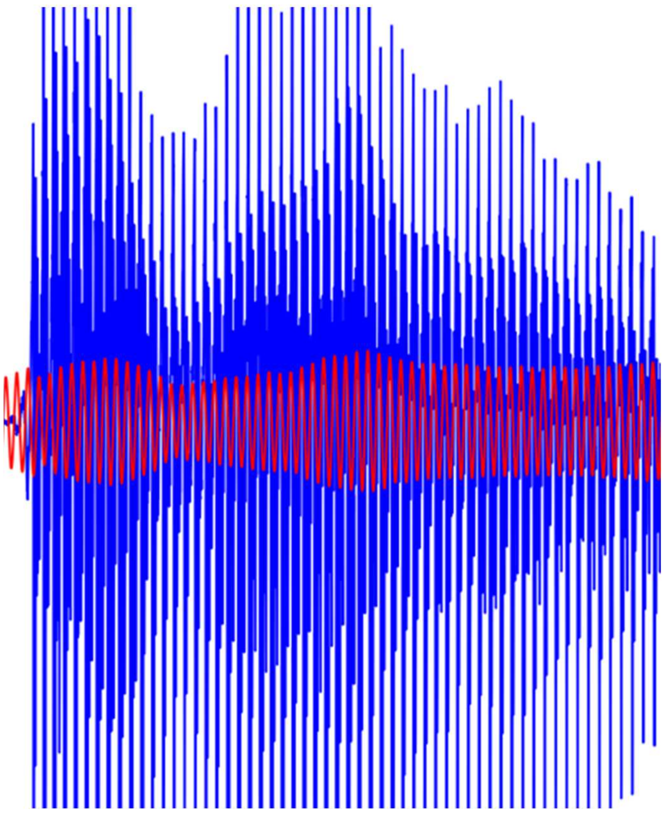

Fig. 12. Removal of noisy frequencies after fast Fourier transform (blue – signal before FFT, red – after).

After completing fast Fourier transform, parts of noise were diminished or removed, as shown in (fig. 12), but one other problem appeared, that did not allow to use this method.

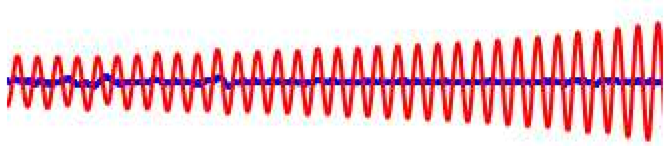

Fig. 13. Appearance of additional noise after fast Fourier transform (blue - signal before FFT, red – after).

The appearance of other noises led to a worse perception of audio by a human ear and Kaldi recognizer, so overall using fast Fourier transform was useless. Both codes with FFT and without it could be found on GitHub [11].

The conversion was completed alongside with recording of incoming audio. Kaldi did not always recognize words properly and sometimes did not recognize them at all, but the overall text is understandable: around 60-70% of words are recognized correctly. It is possible to run the program several times to form better results.

III. RESULTS

As a result, a simple laser microphone was built. Output audio was comfortably heard, however there were some noises. Before converting speech to the text there was an option to remove excess noise using fast Fourier transform, but it the end it only made it worse. Still, speech could be converted to text.

Although speech recognition may not be the best, still some keywords could be highlighted, so overall analysis of incoming information will be easier.

IV. DISCUSSION AND CONCLUSIONS

The project showed that simple and cheap, but quite effective surveillance device can be built at home, and with software some additional utilities can be added. With better components laser microphone becomes much more powerful, but this requires special equipment.

As it is very easy to create a surveillance device for a regular person, the question of security becomes important. Even though rain, fog and light can counter laser microphone it is still a solid device which is hard to track. Guaranteeing safety is very important nowadays because of the enormous amounts of information people produce and work with. For example, using devices, which produce acoustic noise, or darkened windows.

Even though the performance of speech recognition is good it still can be upgraded, for example, working with dictionaries. Trying to remove noise some other way is also an option. Still, it is possible to make some other additions to the device.

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