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The use of Light Pipe as a learning tool

Voice nominal bandwidth signal transmission in baseband

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***Abstract*—Development of good understanding of the basic physics concepts occurring in optical transmission is very important for the undergraduate electrical engineering student qualification. In this report we describe a low-cost simple experimental set-up to demonstrate optical signal propagation in light pipes. It is successfully demonstrated the transmission of a voice nominal bandwidth signal in baseband. This set-up can be easily replicated in high school physics labs.**

***Keywords*—light pipe; voice baseband; optical transmission; learning tool**

I. Introduction

Optical telecommunications is the most modern solution for data transmission [1]. Therefore, is very important that undergraduate engineering students have a solid knowledge of the basic physics principles that support it, which is best learned through experimentation. Generally, undergraduate laboratory setups for optical telecommunications demonstrations are composed by a nonelectronic information source, a transducer, that converts the input to an electrical signal, which then is fed into a light-emitting device, like a LED or a LASER, whose light signal is transmitted through the transmission media. In the receiving end, light is converted back into an electrical signal which finally is transduced to some sort of information representation. Most of the time the optical signal at the receiving end is converted back in an electrical representation through some sort of photodetector. The diagram in Figure 1 represents this process.

The vast majority of experimental setups are designed to analyze telecommunications efficiency employing fiber-optics as a transmission media, including different types of multiplexation so that the student can get fairly acquainted with modern technology. These setups can be quite expensive besides, depending upon the experimental arrangement, limiting the student's capability of probing with technical parameters important for the understanding of the physical phenomena behind the experiment.

In this work, we describe a low complexity optical telecommunications setup which allows the students to grasp the basic physical/engineering concepts by moving away from the traditional laboratory setup. Building the experimental arrangement with readily available parts and modules, and transmitting a 4kHz bandwidth signal through a light pipe as a transmission media grants student's access to the essential principles of optical telecommunications.

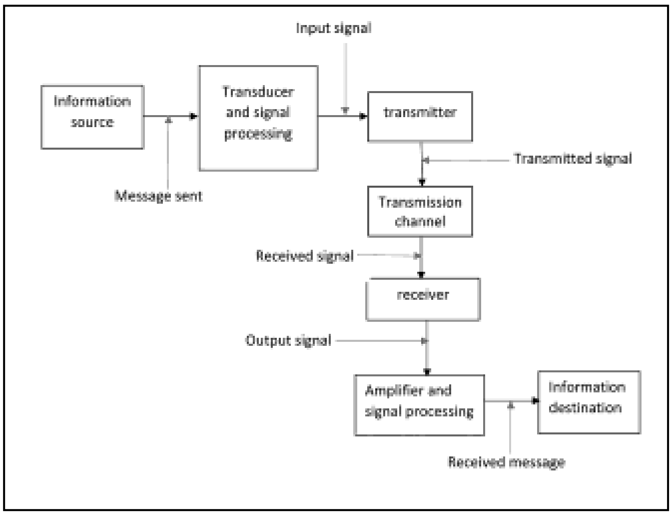

Fig. 1. Optical telecommmunications system diagram.

During the experimental setup validation, the students also characterized each component and verified the system capability to work as a telecommunications solution for short distances by comparing the results with those of an open-air transmission. Finally, the system capability was demonstrated by transmitting an audio signal through the light pipe.

II. System Description

A. System Architecture

Figure 2, bellow, shows a schematic representation of the system's architecture, comprised of a light pipe in between a transmission (TX) and a reception (RX) system.

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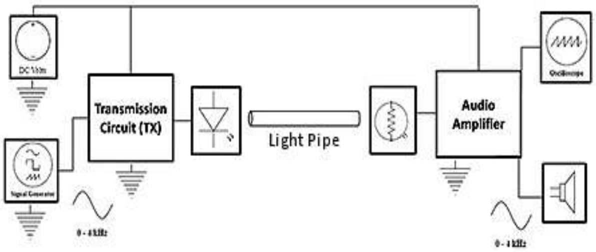


Fig. 2. Schematic architecture representation.

B. System details

The light sources used, a red LED and a multimode GaAs LASER, are off the shelve components emitting at around 630 nm. The receiver CdS Light Dependent Resistor (LDR) has a response curve shown in Figure 3. A quick analysis of Figure 3 shows that the receiver should work properly with both light sources despite their optical spectrum differences.

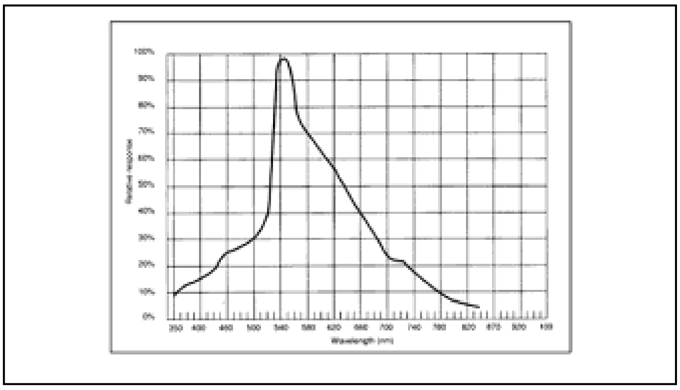


Fig. 3. CdS LDR response curve. [2]

Figure 4 shows the transmission circuit driver, which was coupled to an HP Wave generator set to operate at 4kHz maximum frequency, emulating a baseband voice channel.

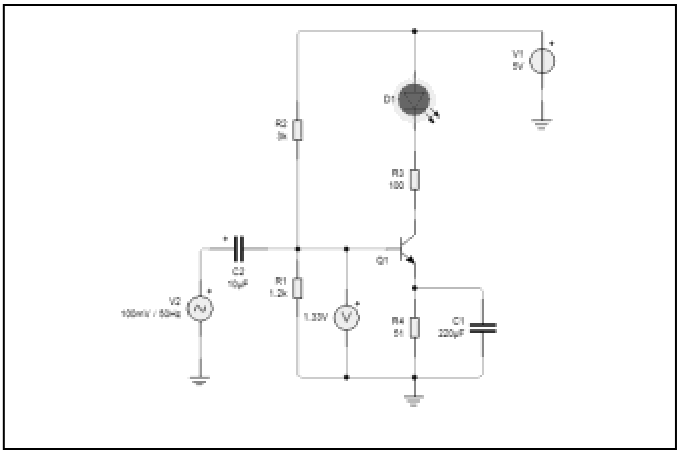


Fig. 4. Transmission circuit driver

The LRD detector, on the other hand, was coupled to an electric circuit compounded of a voltage divider coupled to a push-pull amplifier as shown in Figures 5 and 6, respectively.

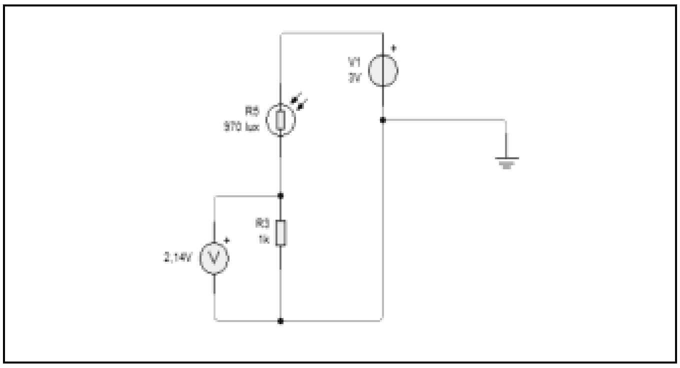


Fig. 5. Reception voltage divider circuit

The amplifier output was then fed to an oscilloscope in order to verify the system's receiving optical signal.

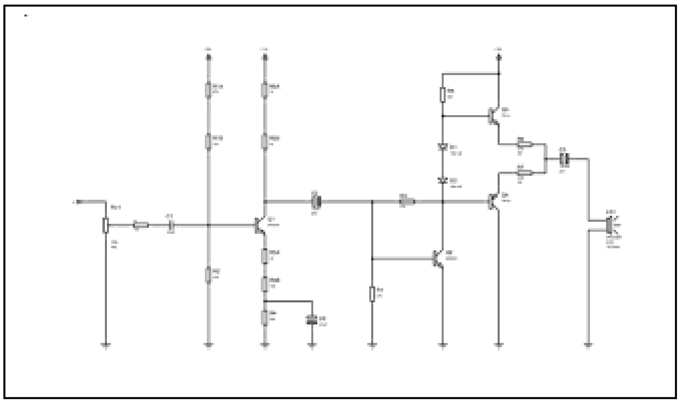


Fig. 6. Push-pull amplifier

The light pipe was a 30 cm long fuzzed quartz glass rod, having an 8mm diameter, with both ends surfaces fully polished.

III. METHOD

The experimental arrangement was set-up at the PUC-Campinas Transmission Media Laboratory. The first step was to verify the Lux Meter calibration using a light-shielded box and measuring the light intensity emitted by an incandescent light bulb at different distance separations. Next, the LED and LASER light responses were characterized in a similar way. The light pipe acceptance angle was verified employing the LASER source.

The system response to a sine wave with a maximum frequency of 4kHz, either in open-air or transmitted trough the quartz fused light pipe, was then measured in the same light-shielded environment. The input and output signals were then compared on a scope screen.

All the data results reported here were linearly averaged after six times measures which resulted in less than 5% uncertainty in all obtained results.

Finally, the system's flexibility was demonstrated by transmitting an audio signal with bandwidth from 20 to 2.000 kHz and subjectively evaluating the audio quality.

IV. Results

A. *Lux Meter Calibration*

Table I, bellow, shows the obtained number of Lumens during the Lux Meter calibration in open-air as a function of the distance between the light source and the meter.

TABLE I. Lux Meter Calibration

Lux Meter Calibration	
Distance (cm)	***Light Inte. (L)***
10	10230
20	3060
30	**2460**
60	980
90	670
120	480

The bold-faced distance was used for the light pipe length. Figure 7 shows the Table I results graphically.

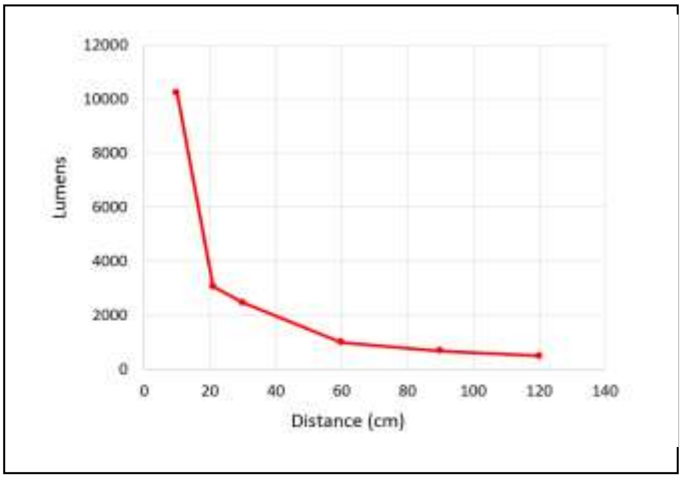


Fig. 7. Lux Meter response

B. *LDR calibration*

The LDR characterization was performed once the Lux Meter response was verified, Figure 8 shows the obtained results.

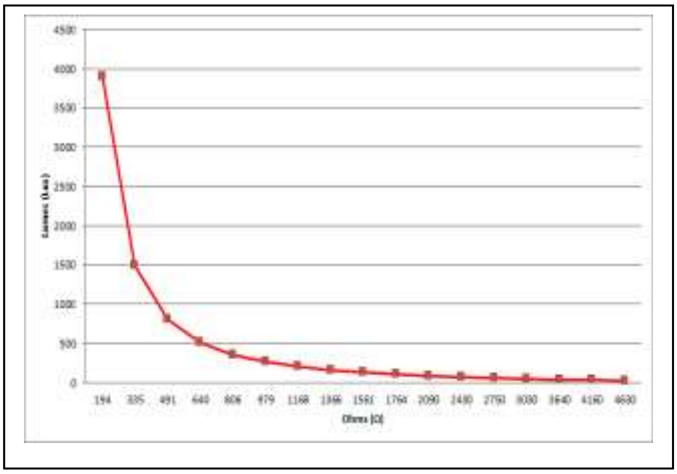


Fig. 8. LDR response.

One can see that the LDR responds almost linearly for the light intensity range 200 Lumens for the open-air arrangement, were the resistance also changes likewise between 1000 and 100 ohms, approximately.

C. *Light pipe acceptance angle*

With the receiving end optically characterized the next step was to measure the acceptance angle of the 8mm diameter light pipe. In order to do so, the light intensity at the far end of the lite pipe was measured for different incidence angle of a LASER beam [3]. Table II shows the obtained results.

TABLE II. Acceptance Angle Measurement

Acceptance angle measurement	
Angle (degrees)	***LDR tension (V)****
0	1,6(1)
10	1,6(1)
20	1,6(1)
30	1,6(1)
40	1,8(1)
50	1,6(1)
60	1,4(1)
70	0,1(1)
80	0,1(1)
90	0,1(1)

* - LDR voltage drop at the voltage divider (Figure 5).

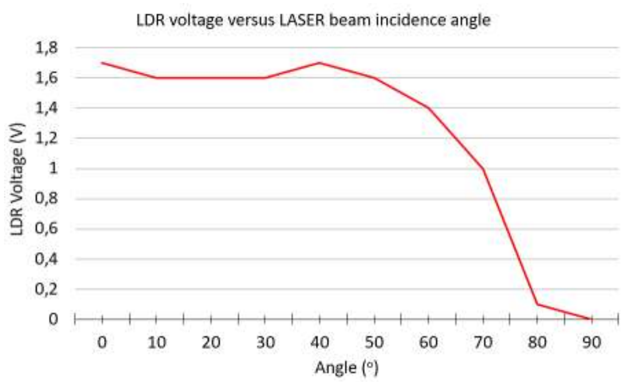
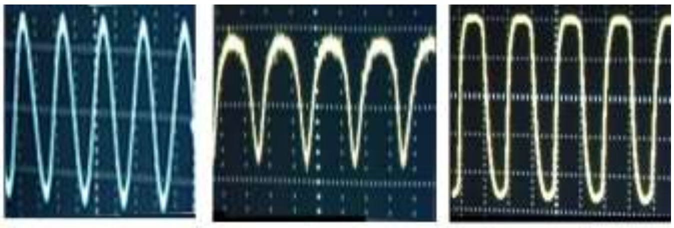


Fig. 9. Acceptance angle measurement

Figure 9, above, summarizes the Table II results. The curve shows the acceptance angle of the light pipe is 35 degrees or more. This indicates that at least 90% of the light emitted by the LED will be injected into the light pipe, by placing the LED right at the entrance face.

D. *Transmitted signals measurements*

Figures 10 (a) through (c) shows the input electrical signal driving the light sources and the signal detected by the LDR at the far end for the LASER and the LED, respectively, when using the light pipe as transmission media.



(a) (b) (c)

Fig. 10. (a) driving signal, (b) LASER signal at RX (c) LED signal at RX

No signal was detected by the LDR when the LED was used to transmit the signal through open air at a distance of 30 cm.

V. Final Remarks

A very basic optics experiment set up, with off the shelf components, was used to demonstrate the transmission of 4kHz bandwidth signal using an LED and a light pipe as a transmission media. This low-cost arrangement (bill o materials less than US$40,00) allowed the students to understand de basic principles of light transmission in confined media. Furthermore, the students successfully transmitted music with the same set-up showing the system's capability to work in a much broader bandwidth.

Acknowledgment

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