Rhinitis phototherapy prototype with timer based on light energy

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ABSTRACT

The set of timers in using phototherapy is major problem which has to be resolved to get a good performance of rhinitis phototherapy. This research aims to develop a prototype of phototherapy for allergic rhinitis, incorporating a timer based on light energy. The prototype utilizes a laser diode as a visible light source, specifically with a wavelength of 650 nm. The recommended safe and effective dose of light energy ranges from 1 to 10 Joules, which has been converted into minutes. Measurement tests indicate an average wavelength of 652.40 nm for the right laser, with a measurement uncertainty of ±0.11, and 653.23 nm for the left laser, with a measurement uncertainty of ±0.05. The laser diode source has an average voltage of 1.91 volts and an average current of 1.89 milliamperes, with a measurement uncertainty of ±0.00 and ±0.01, respectively. Additionally, the average discrepancy in the timer is 0.082 minutes for the 10-minute setting and 0.082 minutes for the 20-minute setting. These results confirm the effectiveness and suitability of the developed tool for practical use. The proposed method was useful for rhinitis therapy by using light energy.

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1. INTRODUCTION

Allergic rhinitis is a prevalent inflammatory condition of the nasal mucosa triggered by Immunoglobulin E (IgE) due to exposure to allergens. The condition is marked by symptoms like sneezing, nasal congestion, runny nose (rhinorrhea), and watery eyes [1], [2]. The prevalence of allergic rhinitis varies, with doctor-diagnosed cases reported at 15% in the United States and self-reported cases as high as 30% [3]. A study conducted in 2019 in Budapest, Hungary focused on school-aged children and randomly selected 21 schools as the sample. The study distributed 3,836 questionnaires to the participants, and the findings revealed a prevalence of allergic rhinitis at 29.3% (1,043 cases), doctor-diagnosed allergic rhinitis at 9.7% (373 cases), and cumulative allergic rhinitis at 36.2% (1,289 cases) [4]. Considering these statistics, one of the methods to cure the allergic rhinitis is phototherapy [5], [6].

Phototheraphy has emerged as a treatment option for allergic rhinitis due to its ability to directly apply light to the nasal cavity with minimal side effects [7], [8]. Allergic rhinitis phototherapy devices available on the market have varying wavelengths and no time limit for the cleansing process to be carried out. A patent with the number US 2012/0232618 A1 describes a device that utilizes two pairs of red LEDs placed inside a probe to dry the mucus in the nasal mucosa. The device is adjustable to fit the size of the patient's nostrils [9]. Another patent, US 009744375B2, employs visible light with a wavelength ranging from 600 nm to 700 nm. The light is generated by a xenon flash lamp equipped with a light filter and transmitted through an optical fiber measuring 10 mm to 20 mm in length. The recommended safe and effective energy dose falls within the range of 1 Joule to 10 Joules [10]. Furthermore, a study conducted by Jiang and Wang [11] involved the use of three different devices for rhinitis treatment. The first device released visible red light at a single wavelength of 660 nm; the second released infrared light at two different wavelengths: 652 nm and 940 nm; the third released composite light, which was made up of seventy percent visible light, twenty-five percent ultraviolet light-A, and five percent ultraviolet light-B. These studies demonstrated positive effects in improving rhinitis symptoms. However, there have been reports of patients experiencing a burning sensation in the nose during and after phototherapy sessions due to the use of unsafe doses. Currently available allergic rhinitis phototherapy devices on the market feature varying wavelengths and do not specify a time limit for the irradiation process. Exceeding the recommended time can result in dry nasal cavities and a burning sensation, while using phototherapy for a shorter duration may delay the healing process and potentially worsen allergic rhinitis symptoms [12], [13].

To address the aforementioned issues, this research aims to develop a tool that can assist patients in determining the appropriate energy dose for phototherapy. The proposed tool utilizes a diode laser with a specific wavelength of 650 nm, the light is emitted directly and the heat is high, such characteristics can be used for a variety of purposes in the application of laser technology [14], which is effective in drying mucus and eliminating bacteria and fungi present in the nasal mucosa [15]-[18]. The energy dose is set within the range of 1 to 10 Joules, and it has been converted into corresponding time intervals. The research proposes three timer settings for the phototherapy sessions: 10 minutes with an energy dose of 2,060 Joules, 20 minutes with 4,121 Joules, and 30 minutes with 6,182 Joules. These settings have been determined to be both safe and effective for performing phototherapy [19]. By implementing this timer-based system, the tool aims to facilitate operators and patients in accurately determining the appropriate dose required for their treatment. Through the development of this tool, it is expected that patients will have a more convenient and reliable means of administering phototherapy for allergic rhinitis, ensuring that the therapy is administered within safe and effective parameters.

2. METHOD

The method contains the design of the system that will be made by the researchers so that the research can run as desired. Besides, the method also responds to the problems that have been raised in the background. The proposed tool utilizes a diode laser with a specific wavelength of 650 nm, which is effective in drying mucus and eliminating bacteria and fungi present in the nasal mucosa [14]-[17]. To answer the problem, researchers have created a system that can help allergic rhinitis patients using visible light. The rhinitis phototherapy prototype system with a timer based on light energy has a system as shown in Figure 1.

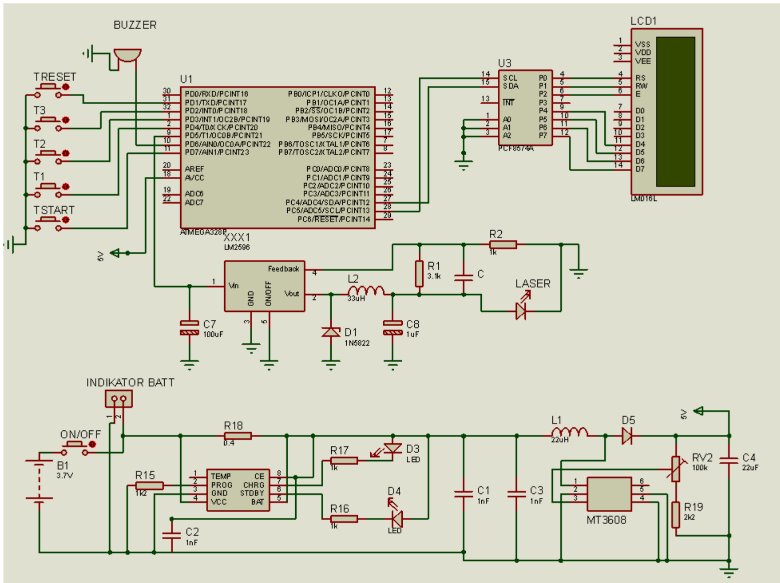


Figure 1. The system of rhinitis phototherapy

Based on Figure 1, a 3.7-volt battery powers the device. To activate the AT-Mega 328 microcontroller circuit, a step-up circuit is utilized to raise the voltage to 5 volts. Pressing the On/Off button initiates the device, which undergoes a brief waiting period before becoming operational. To begin therapy, users select the appropriate timer setting based on their needs. Pressing the start button triggers the therapy session. In case of an incorrect timer selection while the device is running, pressing the reset button restarts the timer setting process. The timer setting that has been selected will be sent to the microcontroller to be processed and the timer setting results will be displayed on the display to make it easier for users to see the therapy time. As the timer runs, the laser diode automatically activates and deactivates upon completion. When the timer concludes, a buzzer alerts users, and the LCD display returns to the initial timer setting menu. The duration of use the device based on laser diode voltage and current measurements using some formulas. In Figure 2 is the system flow diagram of the device.

$$V = \frac{hc}{\lambda q} \tag{1}$$

$$W = P \times t \tag{2}$$

$$P = V \times I \tag{3}$$

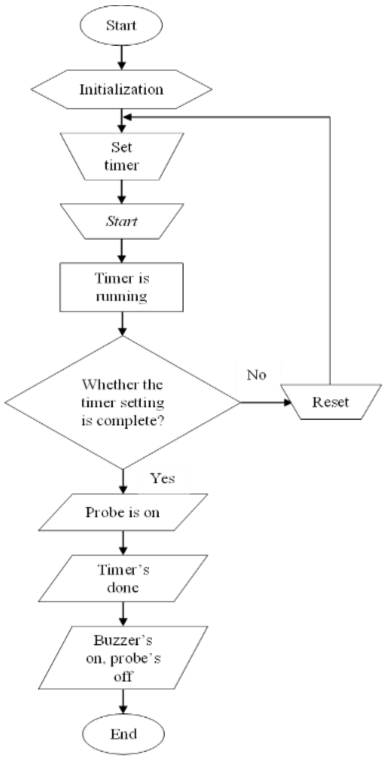


Figure 2. Flowchart of the rhinitis phototherapy prototype

Based on the process flow diagram in Figure 2, when the tool is turned on it will start the initialization process. Initialization is the process of tool declaration, in the form of tool name, identity, and heading to the main menu, namely the selection of timer settings. In the main menu, users can choose the desired timer setting based on their therapy requirements. The available options are 10 minutes, 20 minutes, and 30 minutes. Once the appropriate timer setting is selected, the user can press the start button to begin the therapy session. During the therapy session, if the user realizes they have chosen the wrong timer setting, they can press the reset button to repeat the timer setting process and make the necessary adjustments. Once the timer reaches its set duration, the buzzer will sound, signaling the completion of the therapy session. Simultaneously, the laser probe will automatically turn off, indicating that the therapy has been successfully completed. In Figure 3 is a mechanical diagram of the allergic rhinitis prototype with a timer based on light energy.

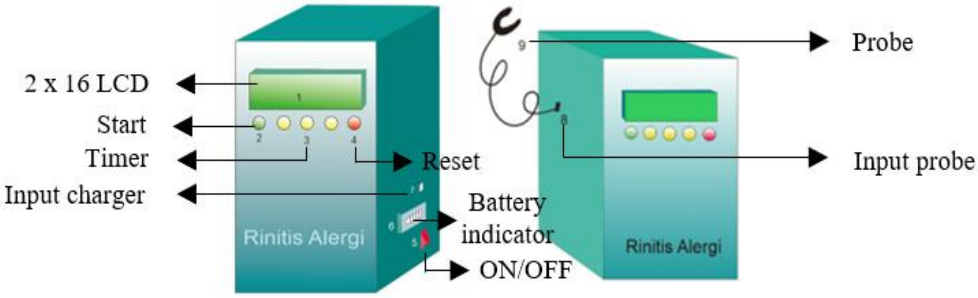


Figure 3. Mechanical diagram of the rhinitis phototherapy prototype

3. RESULTS AND DISCUSSION

3.1. Wavelength testing

The data obtained from tests conducted by PT. Adi Multi Kalibrasi, in collaboration with researchers, for the collection of wavelength data during the operation of the timer until the buzzer sounds is presented in Table 1. The tests were performed using a Spektroradiometer type LMS-6000 Lisung measuring instrument. Table 1 presents the results of the wavelength test, comprising 15 data points. The average measurements for the right laser were found to be 652.4 nm, while for the left laser, it was 653.23 nm. These measurements were influenced by factors such as room lighting, the precision of laser diode placement, and the measuring instrument used [20]–[22]. It is worth noting that the specifications of laser diodes available in the market can vary, resulting in slight differences in wavelength, such as 2.4 nm for the right laser and 3.23 nm for the left laser. However, this variation does not impact the research findings, as the wavelength range used in allergic rhinitis therapy falls within the broader range of 400 nm to 700 nm [23]. Besides, based on a journal review stated that the use of 650nm visible light can have a positive impact on allergic rhinitis patients [5]. The measurement uncertainty for the right laser diode was ±0.11, while for the left laser diode, it was ±0.05. These findings indicate that the tool performs well and is suitable for practical use [24], [25].

Table 1. Wavelength testing data

No.	Wavelength (650nm) right laser (nm)	left laser (nm)	Laser probe condition
1	652.71	652.99	ON
2	652.58	653.05	ON
3	652.57	653.18	ON
4	652.54	653.15	ON
5	652.35	653.13	ON
6	652.4	653.23	ON
7	652.58	653.22	ON
8	651.99	653.27	ON
9	652.4	653.23	ON
10	652.27	653.21	ON
11	652.46	653.39	ON
12	652.36	653.36	ON
13	652.27	653.38	ON
14	652.28	653.27	ON
15	652.24	653.39	ON
Total	9786	9798.45	ON
Average	652.4	653.23	ON
Measurement uncertainty	±0.11	±0.05	-

3.2. Voltage and current of laser measurement

The following information was gathered from voltage measurements taken by PT. Adi Multi Kalibrasi using a Hantek Handheld Oscilloscope measuring device ten times until the device's buzzer sounded. The measurements were compared using a multimeter and computation. Data comparison of llaser's voltage measurement can be seen in Table 2 and to facilitate the reader, the authors put the data in Table 2 into the form of a graph shown in Figure 4. especially subfigures of Figure 4(a) that explain of laser's voltage measurement data.

Table 2. Voltage measurement data

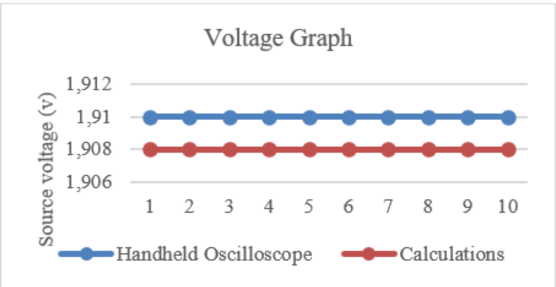
Measurement no	Handheld oscilloscope	Calculations
	Source voltage (V)	
1	1.91	1.908
2	1.91	1.908
3	1.91	1.908
4	1.91	1.908
5	1.91	1.908
6	1.91	1.908
7	1.91	1.908
8	1.91	1.908
9	1.91	1.908
10	1.91	1.908
Average	1.91	1.908
Measurement uncertainty	±0.00	±0.00
Error	0.001	

Table 2 and Figure 4(a). presents the data obtained from measuring the laser source voltage using the Hantek Handheld Oscilloscope, along with a multimeter and subsequent calculations. The average measured value using the Hantek Handheld Oscilloscope tool is 1.91 Volts. The laser source voltage was also calculated using the formula (1). Based on (1), the measured laser diode source voltage is 1.908 Volts. A voltage error of 0.1% is calculated by comparing this measurement with the value obtained using a Handheld Oscilloscope and the subsequent calculation. The voltage measurement results play a crucial role in determining the duration of the phototherapy process based on light energy. The measurement uncertainty for the laser source voltage, determined using the Hantek Handheld Oscilloscope tool, is ±0.00. Similarly, the uncertainty for the laser source voltage calculation is ±0.00. These values indicate a high level of precision and reliability in measuring the laser source voltage. And the results of these tests indicate that the components used are safe for patients.

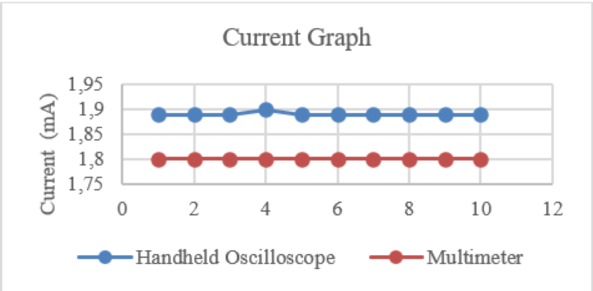
The data in Table 3 is derived from measurements conducted by PT. Adi Multi Kalibrasi for current data collection. The timer is set to run for 10 measurements using a Hantek Handheld Oscilloscope, and the measurements are compared with those obtained using a multimeter. To facilitate the reader, the authors put the data in Table 3 into the form of a graph shown in Figure 4. especially subfigures of Figure 4(b) that explain of laser's current measurement data.

Table 3. Current measurement data

Measurement no.	Handheld Oscilloscope	Multimeter
	Curent (mA)	
1	1.89	1.8
2	1.89	1.8
3	1.89	1.8
4	1.9	1.8
5	1.89	1.8
6	1.89	1.8
7	1.89	1.8
8	1.89	1.8
9	1.89	1.8
10	1.89	1.8
Average	1.89	1.8
Measurement uncertainty	±0.01	±0.00
Error	4,8%	



(a)



(b)

Figure 4. Data comparison of (a) voltage graph and (b) current graph

Table 3 and Figure 4(b) is the data from the measurement of the laser source current using the Hantek Handheld Oscilloscope and multimeter. The average measured using the Handheld Oscilloscope tool is 1.89 mA and measurements using a multimeter average is 1.8 mA. Measurement uncertainty measured using Handheld Oscilloscope Merk Hantek obtained laser source current is ±0.01 and uncertainty of laser source current calculation is ±0.00. While the current error measured using Handheld Oscilloscope and multimeter as a comparison is 4.8%. The voltage and current of the laser diode source are measured in order to calculate the energy produced by the laser and to establish a safe dosage and duration of use for the researcher's device.

3.3. Timer measurement

The data below was collected by measuring timer settings with a stopwatch at 10 and 20 minutes intervals. The timer was set to run until the tool's buzzer sounded after 15 measurements. The data with settings of 10 minutes can be seen in Table 4.

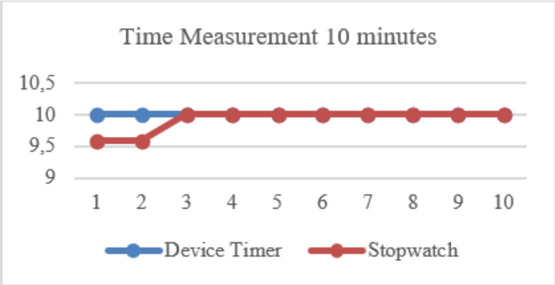
Table 4. Timer measurement data in 10 minutes

Measurement No.	Time measurement 10 minutes	
	Device timer	Stopwatch
1	10	9.59
2	10	9.59
3	10	10
4	10	10
5	10	10
6	10	10
7	10	10
8	10	10
9	10	10
10	10	10
Average	10	9.918
Error	0.82%	

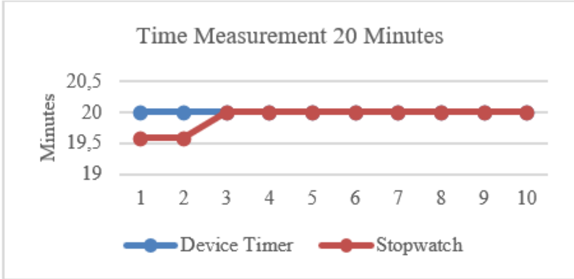
The authors have converted the data from Table 4 into a graph in Figure 5, presented in Figure 5(a), for better visualization and comprehension by readers. Table 4 and Figure 5(a) displays the measurement data comparing the 10-minute device timer with a stopwatch. The average measurement on the device timer is 10 minutes, while the stopwatch measurement records 9.918 minutes. The error between the tool timer and stopwatch is 0.82%. The disparity in the 10-minute timer data is visualized in Figure 5(a).
The authors have converted the data from Table 5 into a graph in Figure 5, presented in Figure 5(b), for better visualization and comprehension by readers. Table 5 and Figure 5(b) is the measurement data of the 20-minute timer tool compared to the stopwatch. The average measured on the tool timer is 20 minutes and the measured using a stopwatch is 19.918 minutes. While the error measured on the tool timer and stopwatch is 0.82%. The researchers created the energy that used in duration of using the device based on (2) and (3). In a 10-minute timer setting with an energy of 2,060 Joule and a 20-minute setting with a energy of 4,121 Joule, that is safe but effective in performing phototherapy so it can make easier for both operators and patients to determine the dose of use [26].

Table 5. Timer measurement data in 20 minutes

Measurement no.	Time measurement 20 minutes	
	device timer	stopwatch
1	20	19.59
2	20	19.59
3	20	20
4	20	20
5	20	20
6	20	20
7	20	20
8	20	20
9	20	20
10	20	20
Average	20	19.918
Error	0.82%	



(a)



(b)

Figure 5. Data comparison of (a) time measurement 10 minutes graph and (b) time measurement 20 minutes graph

4. CONCLUSION

After conducting the design, production, experimentation, testing, data collection, and analysis processes, the author has arrived at the following conclusions: The development of an allergic rhinitis phototherapy prototype incorporating a timer based on light energy and utilizing a laser diode as the light source has been successfully accomplished. Through testing PT. Adi Multi Kalibrasi and the Electro-medical Technology laboratory, it can be concluded that the prototype operates effectively. Wavelength measurement provide a reliable understanding of the tool's wavelength performance and its associated measurement uncertainties. A total of 10 voltage and current measurements were conducted using a Hantek Handheld Oscilloscope, findings provide a comprehensive note of the voltage measurements obtained from different methods, highlighting the accuracy and consistency of the voltage values recorded and determine the safe dosage of the duration of use of the device. Besides, the measurement errors for the 10-minute and 20-minute timers were found to be 0.82%, indicating a small deviation from the stopwatch measurements. In further research, it is expected to be able to use other sources of light without having to insert it into the nostrils to keep the device sterile.

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