

# Design of the Laser Acupuncture Therapeutic Instrument

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**Abstract**—Laser acupuncture is defined as the stimulation of traditional acupuncture points with low-intensity, non-thermal laser irradiation. It has been well applied in clinic since the 1970s; however, some traditional acupuncture manipulating methods still cannot be implemented in the design of this kind of instruments, such as lifting and thrusting manipulating method, and twisting and twirling manipulating method, which are the essential acupuncture method in traditional acupuncture. The objective of this work was to design and build a low cost portable laser acupuncture therapeutic instrument, which can implement the two essential acupuncture manipulating methods. Digital PID control theory is used to control the power of laser diode (LD), and to implement the lifting and thrusting manipulating method. Special optical system is designed to implement twisting and twirling manipulating method. MSP430 microcontroller system is used as the control centre of the instrument. The realization of lifting and thrusting manipulating method and twisting and twirling manipulating method are technological innovations in traditional acupuncture coming true in engineering.

## I. INTRODUCTION

Since the first laser-needles acupuncture instrument was introduced in therapy, this kind of instruments has been well used in laser biomedicine, as its non-invasion, free-pain, non-bacterium, safety, smart application and convenient operation [1-2]. However, most laser acupuncture therapeutic instruments cannot adopt the reinforcing and reducing manipulating methods at present, which influences the therapeutic effect of laser acupuncture.

Over centuries, because of the great therapeutic effect, reinforcement and reduction are deemed as the gist of

acupuncture and moxibustion in many books written on acupuncture and moxibustion from Huang Di Nei Jing, the earliest extant medical classics and the first summary of acupuncture, and Zhen Jiu Jia Yi Jing, a monograph of acupuncture in the Jin Dynasty, to Zhen Jiu Da Cheng in the Ming Dynasty. Reinforcement and reduction are conducted to stimulate the channel Qi by puncturing the points with specific manners so as to regulate the functional activities of the internal organs [3-4].

To achieve better therapeutic effect of laser acupuncture, the objective of this work was to design a low cost portable laser acupuncture therapeutic instrument, which can implement two essential reinforcing and reducing acupuncture methods, lifting and thrusting manipulating method and twisting and twirling manipulating method.

This paper is organized as follows. In the second section, system structure of the instrument is introduced. In the third section characteristics of laser diode and how to implement the lifting and thrusting manipulating method are given. The digital PID control algorithm is introduced in the forth section to adjust the power output of the laser diode. The optical circuit design and how to implement twisting and twirling manipulating method are introduced in the fifth section. The conclusion is in the last section.

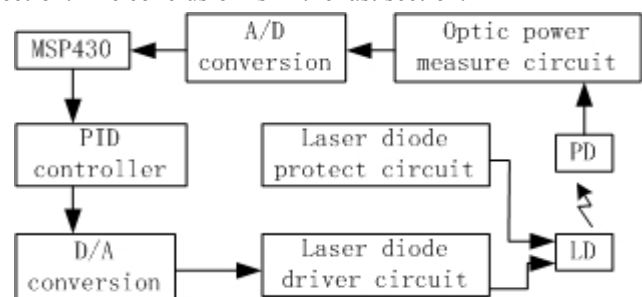


Fig.1. Schematic diagram of the system structure

## II. SYSTEM STRUCTURE OF THE INSTRUMENT

The instrument is designed based on the MSP430 microcontroller system, and PID algorithm is used to adjust the power output of laser diode. The schematic diagram of the system structure is shown in Fig.1. The system operates as follows. When power is applied, the light from the laser diode falls on the monitor photodiode, generating a photocurrent. Then the photocurrent is converted into digital signal. After the signal is processed by the PID control algorithm, voltage signal is exported to laser diode driver circuit by the D/A conversion to control the power output of laser diode.

## III. CHARACTERISTICS OF LASER DIODE AND IMPLEMENT OF LIFTING AND THRUSTING MANIPULATING METHOD

The laser diode used in the design is 30mw AlGaInP laser diode with an emission wavelength of 655nm. The threshold current is 40mA at 25°C. A photodiode is used to monitor the light output on the rear facet of the laser. The current from the photodiode changes with variations in light output and provides feedback of adjust the laser drive current.

The light characteristic curve is shown in Fig.2. Light is emitted when the electrical current input is above the threshold. And the optical power output is proportional to the current above the threshold, while the temperature keeps unchanging. Linearity of the laser diode is applied in this design to implement lifting and thrusting manipulating method.

In traditional acupuncture, the reinforcement and reduction of lifting and thrusting is as follows [3].

**Reinforcement:** The needle is lifted and thrust up and down first superficially and then deeply. Lift the needle gently and slowly; thrust it heavily and rapidly, with small amplitude and slow frequency as is shown in Fig.3 (a)

**Reduction:** the needle is lifted and thrust first superficially, thrust the needle gently and slowly; lift needle heavily and quickly with large amplitude and quick frequency as is shown in Fig.3 (c).

In this design, value of optical power output is the amplitude of the needle. Decreasing of power output is lifting. And the increasing is thrusting. Changing rate of the

power output is the frequency of the needle. As shown in Fig.3 (b) and (d).

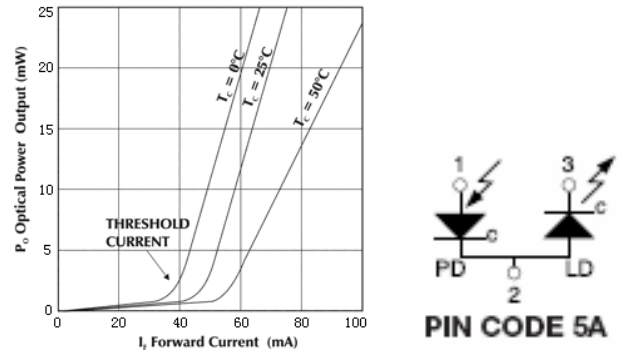


Fig.2. Light characteristic curve of the laser diode

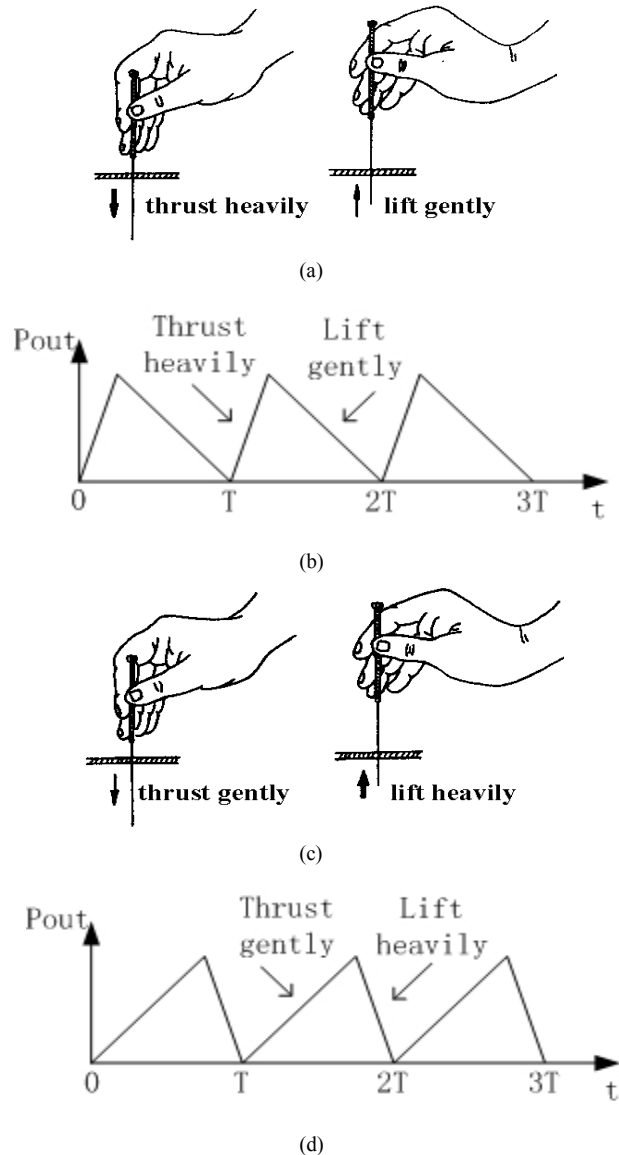


Fig.3. Lifting and thrusting

#### IV. DIGITAL PID CONTROL

The structure of the control system with PID controller is shown in Fig.4. According to analogical PID algorithm, position form PID expression is as follow [5-6].

$$u(t) = K_p e(t) + T_I \int_0^t e(t) dt + T_D \frac{de(t)}{dt} \quad (1)$$

Where  $u(t)$  the control output

$e(t)$  Difference between the set point  $r(t)$  and

the plant output  $y(t)$

$K_p$  Proportional gain

$T_I$  Integral time constant

$T_D$  Differential time constant

If we set  $t = kT$  ( $k = 0, 1, 2, 3, \dots$ ), then

$$\int_0^t e(t) dt \approx T \sum_{j=0}^k e(jT) = T \sum_{j=0}^k e(j) \quad (2)$$

$$\frac{de(t)}{dt} \approx \frac{e(T) - e[(k-1)T]}{T} = \frac{e(k) - e(k-1)}{T} \quad (3)$$

And then digital PID expression is getting.

$$u(k) = K_p \left\{ e(k) + \frac{T}{T_I} \sum_{j=0}^k e(j) + \frac{T_D [e(k) - e(k-1)]}{T} \right\} \quad (4)$$

$$e(k) = r(k) - y(k) \quad (5)$$

Where  $u(k)$  the k-th control output

$e(k)$  Deviation value of the k-th sampling

$r(k)$  the k-th set point

$y(k)$  the k-th plant output

$T$  Sampling period

Program flow chart of position form PID algorithm is shown in Fig.5. After PID algorithm processing,  $u(k)$  is exported to laser diode drive circuit by D/A conversion to control the laser diode.

#### V. OPTICAL CIRCUIT DESIGNS AND IMPLEMENT OF TWISTING AND TWIRLING MANIPULATING METHOD

The beam divergence in the horizontal and vertical directions is  $7^\circ$  and  $23^\circ$ , respectively. Because of the large divergence angle of the laser diode, which made the power output fail to be focused, special optical circuit is designed, as is shown in Fig.6, and the optical fiber special for medical use is used to transmit the light for convenient operation.

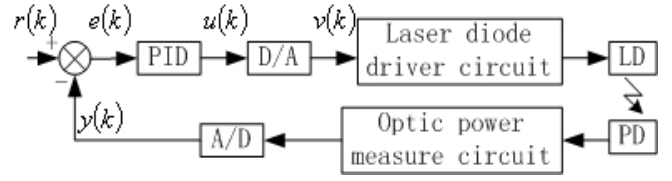


Fig.4. Structure of the control system with PID controller

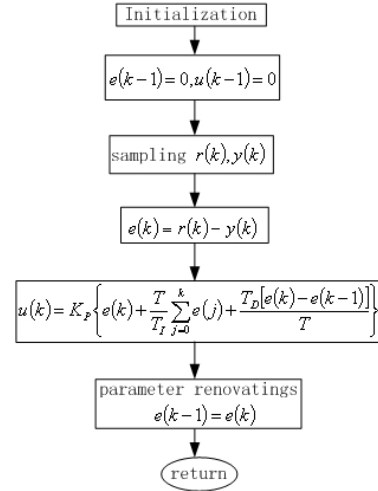


Fig.5. Program flow chart of position form PID algorithm

In traditional acupuncture, reinforcement and reduction of twisting and twirling is shown as follows [3].

Reinforcement: Twirl the needle gently and slowly with small amplitude, as is shown in Fig.7 (a).

Reduction: Twirl the needle heavily and quickly with large amplitude, as is shown in Fig.7 (b).

In this design, as shown in the Fig, the light passes through a 1/4 wave plate and a linear polarizer, then its luminous intensity is invariable, and its electric vector is rotating followed the rotation of the polarizer. According to the electromagnetism effect of laser acupuncture and action mechanism, the twirling of the needle is achieved by the rotation of the electric vector.

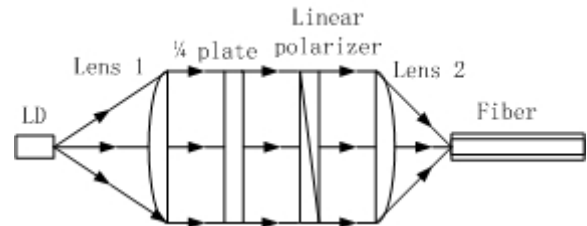


Fig.6 Optical circuit

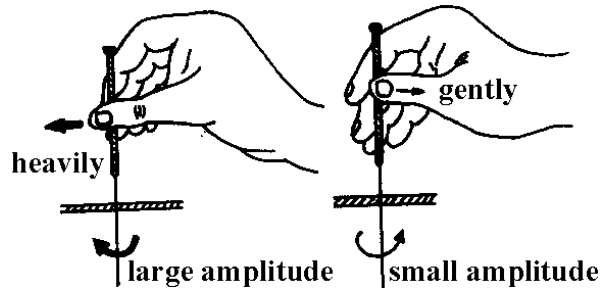


Fig.7 (a) Twisting and twirling (Reinforcement)

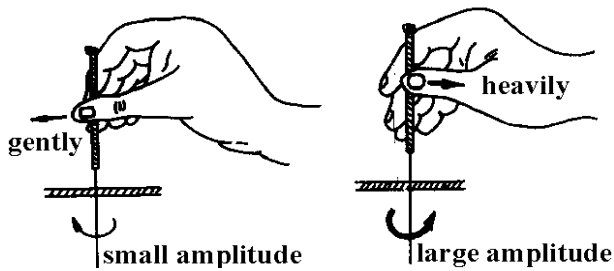


Fig.7 (b) Twisting and twirling (Reduction)

## VI. CONCLUSION

The laser acupuncture instrument designed in this paper can implement two essential acupuncture manipulating methods. And laser acupuncture based on this novel design

can get lifting and trusting manipulating method and twisting and twirling manipulating method are technological innovations in traditional acupuncture coming true in engineering. Further work will be done to implement more acupuncture manipulating methods.

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