Proceedings of the 2nd International Conference on Mathematical Physics and Computational Simulation
DOI: 10.54254/2753-8818/36/20240536

# Design of a 1900nm thulium-doped laser emitter

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**Abstract.** In recent years, laser emitters have developed rapidly, been used in many fields, and have also brought great development to many industries such as communications and medical treatment. Thulium as a rare earth ion has a long service life and laser conversion efficiency, so the study of thulium-doped fiber lasers is of great significance for the development of the laser industry, but there is still a gap in the research in the field of 1900nm thulium-doped fiber lasers, Therefore, this experiment uses the physical model and quantum electric model to study 1900nm thulium-doped fiber lasers. The conclusion that the pump optical power decreases with the increase of distance and the pump optical power increases with the increase of laser power is processed, and the relationship between the pump optical power and the laser power, the relationship between the distance length and the pump optical power and the lasing optical power is shown with images.

**Keywords:** 1900nm, thulium ion, fiber laser, power

## 1. Introduction

Fiber laser is a laser using fiber as a gain medium, which has the advantages of high efficiency, good stability, high output beam quality, and has been applied in many fields. In the medical field, it is used in medical laser devices, such as laser surgery, laser treatment, laser diagnosis, etc. Baalbaki et al. have used copper vapor laser to transform medical devices [1]. Lasers can be used for high-precision tissue cutting, cancer treatment, ophthalmic surgery, etc. Wang and You et al. used lasers to enhance in situ vaccines and enhance cancer immune circulation [2]. In the field of communication, lasers are used in optical communication systems, including fiber optic communication, laser radar, fiber optic sensing, etc. Andrew used laser radar to study yellow pine [3]. Laser devices can also be used in optical fiber communication as a light source and optical amplifier to provide stable and efficient laser output. In the field of optical fiber communication, Xin et al. conducted a division study on optical fiber communication based on intelligen [4]. In the field of material processing, laser cutting, laser welding, laser marking, and other material processing applications are used. In addition, laser emitters have important applications in the field of laser processing with high power and high energy density, which can realize high precision and material processing. Zhang and Li studied a laser technology applied to precision material processing for processing brittle and hard materials [5]. In the field of scientific research, it is applied to scientific experiments, spectral analysis, laser spectroscopy, etc. Zhang and Feng et al. conducted a spectral analysis of a laser array beam combination system based on smile effect [6].

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Fiber laser is made of glass mixed with various rare earth ions. As a rare earth ion, thulium particles are suitable for excitation of various wavelength pump light sources, with long laser service life and high laser conversion efficiency and have been widely used in the design and research of various laser emitters for many years. Hayward et al. greatly improved the luminous efficiency of thulium-doped fiber [7], which greatly promoted the research on thulium-doped fiber. Shaoxiang Chen and Mingjun Yong et al studied the application of thulium-doped particles in laser emitters in the band of 1660nm to 2050nm [8], indicating that thulium particles can be better applied in laser emitters in large bands. 1900nm laser belongs to near-infrared laser and is mainly used in the medical field. G. Yu, J. Chang, Q. Wang, et al conducted experiments on a 1900nm laser in 2010 [9], and Z-Y.H and P.Yan et al also conducted experiments on a 1908nm laser[10]. However, there is still a lack of research on 1900nm laser emitter doped with thulium particles, so this experiment aims to design a laser emitter doped with thulium rare earth ions.

The objective of this experiment is to improve and design a 1900nm fiber laser using thulium-doped rare earth particles. First of all, this experiment adopts physics-driven simulation, uses the physical model for theoretical calculation, uses the rate equation and power equation of the laser to solve, and uses the result graph obtained from the physics simulation.

## 2. Method

In the 1900nm laser emitter, thulium-doped fiber is the most important part, the approximate model diagram is shown in Fig.1. Thulium ion is a rare earth ion with multiple energy levels, and two-level thulium ion is the most suitable rare earth ion. Therefore, the rate equation of the two-level structure was selected in this experiment when the model was established. In this experiment, N1 and N2 were assumed to be the bulk densities of ions with electrons in the first and second energy levels, which would undergo energy level transitions when excited by pump light, as shown in Fig.2.

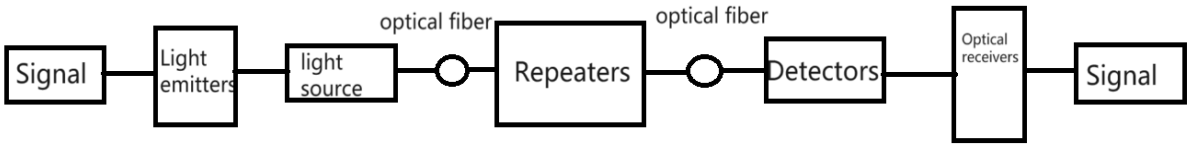


**Figure 1.** Fiber optic system diagram (Picture credit : Original)

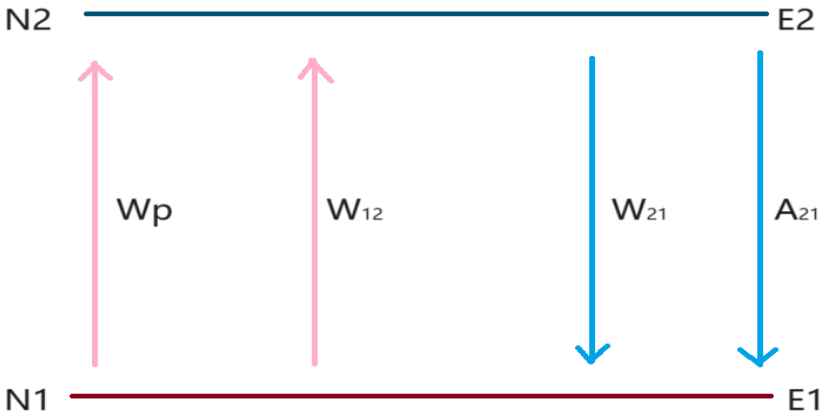


**Figure 2.** Schematic diagram of thulium ion energy levels (Picture credit : Original)

Wp is the pump light absorption rate, W12 is the signal light absorption rate, W21 is the signal light stimulated emission rate, A21 is the radiation transition probability, and the rate equation related to the two levels can be listed. The specific expressions of pump light absorption rate, signal light absorption rate, signal light stimulated emission rate, and radiation transition probability can be obtained by solving the rate equation.

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After retaining this result, the equation of power propagation in optical fiber can be listed, as shown in Fig.3, a schematic diagram of power propagation in optical fiber.

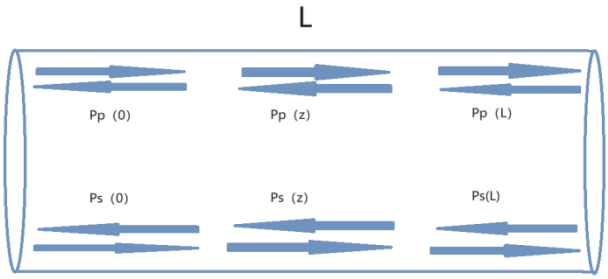


**Figure 3.** Schematic diagram of power propagation within optical fibers (Picture credit : Original)

In this experiment, the power of Pp+ pump light incident from the left, P-p is the power of pump light incident from the right, P+s is the power of laser incident from the left, P-s is the power of laser incident from the right, and the power propagation equation is listed. Next, the pump power threshold is calculated in this experiment, the equation of threshold and gain coefficient is listed, and the output power of the fiber laser can be solved. The above steps are the preparation part of the formula of this experiment. Theoretically, the ideal value can be calculated by bringing in the data. This experiment is based on the experimental data of Khamis et al and the data of this experiment is obtained after calculation, which is listed in Table 1[11].

**Table 1.** Data from this experiment[11]

| Symbol | Physical parameter | Numerical value | Unit |
|---|---|---|---|
| $\lambda_{sp}$ | Central wavelength of pump light | 1900 | nm |
| $\lambda_s$ | Fiber laser center wavelength | 1600 | nm |
| $\tau$ | Thulium particle energy level lifetime | $12\times10^{-3}$ | s |
| $\sigma_{ap}$ | Pump light absorption cross section | $2.1354\times10^{-23}$ | $m^2$ |
| $\sigma_{ep}$ | Pump light emission cross section | 0 | $m^2$ |
| $\sigma_{as}$ | Fiber laser absorption cross section | $6.5\times10^{-24}$ | $m^2$ |
| σes | Fiber laser emission cross-section | $1\times10^{-23}$ | $m^2$ |
| $A_c$ | Fiber cross section | $3.01\times10^{-11}$ | $m^2$ |
| N | Thulium particle impurity concentration | $4.683\times10^{22}$ | $m^3$ |
| $\alpha_p$ | Pump light loss | $2\times10^{-3}$ | $m^{-1}$ |
| $\alpha_s$ | Laser loss | $4\times10^{-4}$ | $m^{-1}$ |
| L | Length of optical fiber | 1 | m |
| $\tau_p$ | Pump optical power fill factor | 0.73 | |
| $\tau_s$ | Laser power filling factor | 0.82 | |
| $R_1$ | Reflectance of front cavity mirror | 99 | |
| R2 | Reflectance of posterior cavity mirror | 635 | |

After clarifying the data of this experiment, this experiment uses MATLAB software to conduct numerical simulation experiment. The appendix is the code used in the experiment.

## 3. Result and discussion

After the input of the experimental data, the specific images of the experiment are obtained, which are the relationship diagram between the pump optical power and the laser power, the relationship diagram

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between the distance length and the pump optical power and the laser optical power. This will be shown in Fig.4 and Fig.5 below.

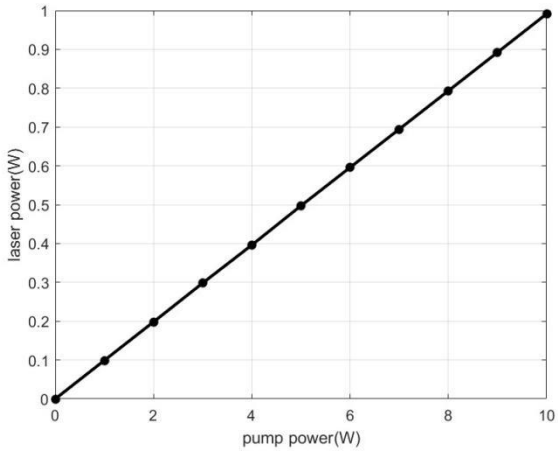


**Figure 4.** Diagram of the relationship between pump light power and laser power (Picture credit : Original)

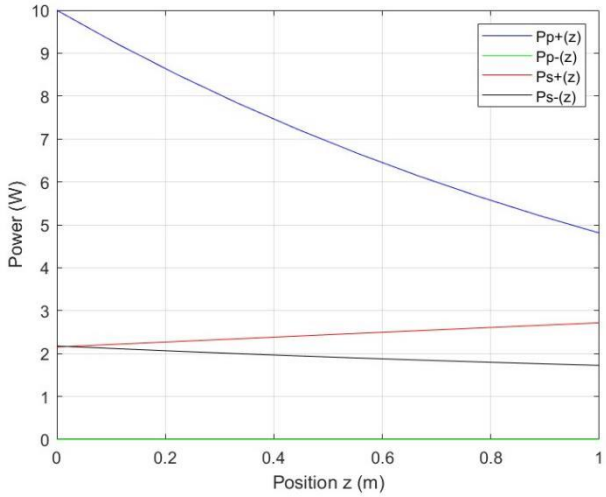


**Figure 5.** Diagram of pump light power, laser light power and time relationship (Picture credit: Original)

It can be seen from Fig.5 that the pump optical power increases with the increase of the laser power, and the relationship does not show a linear relationship. The values of the pump optical power and laser power both approach 0 and increase successively. Although the relationship is nonlinear, the laser power is also close to these two values at several key nodes, such as when the pump optical power approaches 4w and 6w. This shows that the quantitative relationship between the two will hardly change.

It can be seen from Fig.5 that the pump light power decreases with the increase of distance, and the lasing light power increases with the increase of distance. Among them, the pump optical power decreases with the increase of distance, so the curve gradually becomes gentle, while the lasing optical power slowly increases with the increase of distance, and the curve becomes steeper. At present, this picture only depicts the position where the distance is 1m, and it is believed that with the increase of distance, the pump optical power will still decrease while the lasing optical power will still increase.

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## 4. Conclusion

This study starts with the introduction of laser emitters, briefly introduces the development background of laser emitters and the development status of thulium-doped laser emitters, and then studies the 1900nm thulium-doped fiber laser by establishing the formula, calculating the data, and establishing the numerical model, and draws the pumping power. The relationship between lasing light power and time, and the relationship between pumping light power and laser power. Finally, it is found that the pump optical power decreases with the increase of distance and the pump optical power increases with the increase of laser power.

At present, fiber lasers are in rapid development, with the continuous improvement of technology, fiber lasers will be toward higher power and smaller volume development, to be used in more fields, for the network, communication, medical and other professional fields have a strong role in promoting.

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