

EXPERIMENTAL STUDY OF THERMOELECTRIC COOLER FOR DIODE PUMPED SOLID STATE LASER*

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ABSTRACT

Thermoelectric cooler (TEC) is a solid state heat pump. It normally used for a Diode Pumped Solid State (DPSS) laser. It is used to control and stabilize the temperature of pumping source of Laser Diode (LD) and the frequency doubled of Kalium Titanyl Phosphate (KTP) crystal. The aim of this study is to diagnose the performance of TEC in DPSS system. High power Laser Diode driver circuit was utilized as a pumping source. The current of the driver circuit was verified and the temperature of the LD and KTP were measured. The result obtained indicates that, the temperature of LD linearly increased upon the current in the initial stage. After achieving a threshold current of 7 A the temperature remained constant at 25.4 °C. Unlike in KTP crystal, initially the temperature was nonlinearly decreased down to the minimum of 14.8 °C at threshold current. The temperature was then nonlinearly increased up to maximum of 25.7 °C at 15 A. Beyond 18 A, the temperature slightly dropped and remained constant at the same value of LD temperature of 25.4 °C. Hence the TEC was stabilized and controlled the temperature of DPSS laser at 25.4 °C. The best performed of TEC when the pumping current exceeds 18 A.

Keywords: Thermoelectric cooler, DPSS, KTP, temperature

INTRODUCTION

In recent years, the electronic industry has developed rapidly and the miniaturization of electronic components has been ongoing. As components have shrunk, the chip-level power density has continued to rise greatly. Therefore, thermal management is becoming a critical issue in system performance. Moreover, the electrical stability of many pieces of electronic equipment, such as Laser Diode, semiconductor optical devices, infrared detectors, and others, should be improved, to ensure electrical stability and rapid electrical–optical transmission. Thermoelectric Cooler (TEC) is therefore employed to control the thermal and electrical stabilities [1].

TEC has been practical for specialized application since the late 1960s. Recent reports of material improvement through novel processing techniques may make TEC practical for more everyday application [2]. TEC is usually used for thermal management in smaller units where precise temperature stability is critical. This cooler not only provide a way to remove excess heat efficiently, but are also solid state devices that can be incorporated in feedback control loops [3].

Most of the times raise of temperature causes some problems which affect the function of the device. Lasers are devices which require current to produce some Watt or miliWatt of light. In the DPSS laser system, thermal management of the pump lasers is very important, it is critically affects laser wavelength, output power, threshold current, slope efficiency and operating lifetime [4]. By using cooling elements, temperature is

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roughly regulated. Therefore by controlling the temperature of the Laser Diode we can improve the system stability.

THEORY

Thermoelectrics are based on the Peltier Effect, discovered in 1834 [5]. Peltier discovered that when an electric current cross the junction between two dissimilar conductors, heat is absorbed or liberated at the junction. If the direction of current flow is reversed, the effect also reverses [6]. It is also described as a solid state method of heat transfer generated primarily through the use of dissimilar semiconductor material (P-type and N-type) like conventional laws of thermodynamics.

The typical thermoelectric module is manufactured using two thin ceramic wafers with a series of P and N doped bismuth-telluride semiconductor material sandwiched between them. The ceramic material on both sides of the thermoelectric adds rigidity and the necessary electrical insulation. The N type material has an excess of electrons, while the P type material has a deficit of electrons. One P and one N make up a couple.

As the electrons move from the P type material to the N type material through an electrical connector, the electrons jump to a higher energy state absorbing thermal energy. This part of the TEC is referred as cold side. Continuing through the lattice of material, the electrons flow from the N type material to the P type material through an electrical connector, dropping to a lower energy state and releasing energy as heat to the heat sink. The part in TEC whereby the heat released is namely as hot side.

METHODOLOGY

A DPSS model LYDPG-1 was employed as a source. DPSS comprised high power Laser Diode which is used as a pumping source. The wavelength of the Laser Diode was 808 nm. The heat liberated during pumping process was controlled by TEC 1.

Laser Diode was used to pump active medium which is consist of Nd:YAG crystal. The laser material emitted IR beam of 1064 nm wavelength. A KTP crystal was employed as a second harmonic generator which responsible to convert the original beam into half wavelength and produce visible light of 532 nm.

In order to maintain the output remain constant, both crystals (Nd:YAG and KTP) are placed on the TEC 2. The DPSS also provided with fan cooling to extract the wasted heat out of the system. In this experiment, LD and KTP temperature current were taken by the increasing of the LD current. The schematic diagram of the whole experimental setup is shown in Figure 1.

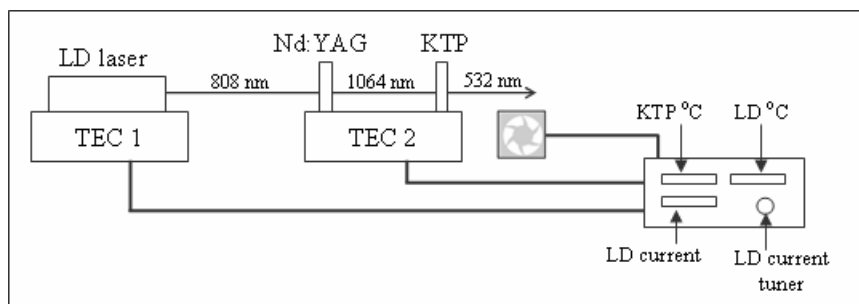


Figure 1: Schematic diagram of the whole experiment setup.

RESULT AND DISCUSSION

The performance of thermoelectric cooler for diode pumped solid state laser was studied by measuring the Laser Diode (LD) and KTP temperature with the increasing of the LD current with the increment of 1 A. The experiment was carried out 3 to 4 times and the average of the reading was calculated. The obtainable data was used to plot graph as depicted in Figure 2.

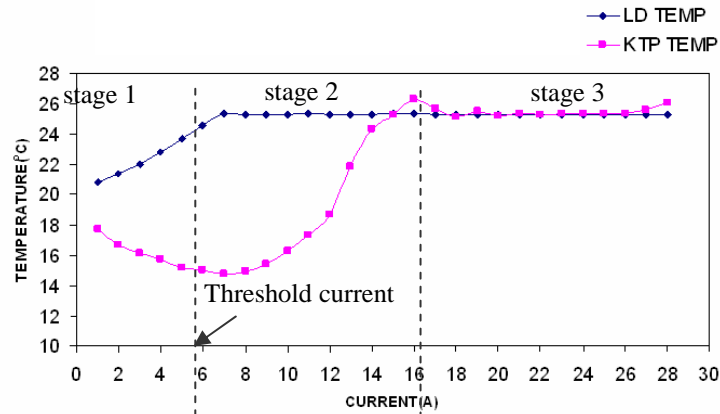


Figure 2: LD and KTP temperature as a function of LD current.

Two curves are shown in Figure 2, owing to the LD and KTP profile respectively. Initially the temperature of LD was found proportional to the LD current. However after pumped with 7 A the temperature is remained constant at 25.4 °C. This is because the TEC starting its operation, thermal energy (heat) from Laser Diode is absorbed by electrons as they pass from a low energy level in the p-type semiconductor element, to a higher energy level in the n-type semiconductor element. Meanwhile, power supply from TEC provides energy for electron to move from higher energy level in N type to lower energy level in P type. In the junction from N to P, the electron was absorbing thermal energy while the junction from P to N, the electron was releasing thermal energy.

In contrast with the temperature profile in KTP, the configuration of the curve was divided in three stages. In the first stage the temperature was gradually decreased down to a minimum temperature of 14.8 °C corresponding to the threshold current of 7A. This is because the current pumped diode is not enough to pumped the Nd:YAG medium in the early stage. Consequently no infrared beam of 1064 nm is emitted. As a result, KTP crystal has not been exposed by infrared beam. Before Nd:YAG crystal was lased, any heat liberated from optical component was extracted by the fan. In this stage the fan cooling dominates the heat transfer in the laser system. As a result the temperature of KTP crystal was drop lower than ambient.

In the second stage, the temperature is gradually increased with respect to the pumping current. However the increasing temperature was subjected due to illumination of infrared (IR) beam from Nd:YAG crystal. The nonlinear KTP crystal absorbed the IR beam and emitted visible of green light. Not all the IR beam exposed to KTP is converted to half wavelength. Some of them will liberate as energy and heating KTP crystal.

Thirdly, temperature of the KTP crystal in Figure 2 was found almost constant. At this stage, TEC dominantly controlled the temperature. The power of IR laser is high enough to initiate the TEC. In this case the electron from high energy level from N-type semiconductor move toward lower energy level of P-type semiconductor a hot junction,

the energy released to the heatsink. When, such motion continuously occurred, that controlled temperature and remained constant at 25.4 °C. As a result the temperature of the KTP crystal at this stage is the same level with LD source.

However, the temperature of the KTP crystal was found fluctuated at the high end pumping current. This is possibly due to high power produce from the infrared beam and additional contribution from heat transfer either by radiation, convection and conduction.

CONCLUSION

TEC performance in DPSS system was successful studied. TEC was installed at the optical pumped source that is Laser Diode and optical components including active medium of Nd:YAG and second harmonic generation of KTP. Fan extractor also used as external cooling in DPSS system. The result of investigation showed that the TEC was controlled the maximum temperature at 25.4 °C. It was operating faster in Laser Diode compared to KTP crystal. This is because current was directly applied to the Laser Diode whereas KTP was only heated when Nd:YAG was started lasing. In additional, the existing of fan cooling, also retarded the heating process, as well as desire higher pumping current of 18 A to initiate the TEC to control and stabilize the temperature of DPSS laser .

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REFERENCES

- [1] Y. H. Cheng, W. K. Lin. *Geometric Optimization of Thermoelectric Coolers in a Confined Volume using Genetic Algorithms*. *Applied Thermal Engineering*, submitted to be publish in Journal of Applied Thermal Engineering (2005) 1-15
- [2] P. J. Taylor, W. A. Jesser, F. D. Rosi and Z. Derzko. *A Model for Non Steady State Temperature Behaviour of Thermoelectric Cooling Semiconductor Devices*. *Semiconductor Science Technology*. 12 (1997) 443-447.
- [3] K. Kuhn. *Laser Engineering*. Prentice Hall, Inc.1998. 332.
- [4] M. Labudovic. *Modeling of TEC Cooling of Pumping Lasers*. *IEEE Transaction on Component and Packaging Technologies* (2004) 724 – 730.
- [5] R. E. Simons and R. C. Chu. *Application of Thermoelectric Cooling to Electronic Equipment: A Review and Analysis*, *Proc. Sixteenth IEEE SEMI- THERMTM Symposium* (2000) 1-9.
- [6] C. Shafai, *Fabrication of a Micro-Peltier Device*. *Thesis for degree of Doctor of Philosophy, University of Alberta*. Spring (1998) 15.