Controlling the wavelength of a high power diode laser using thermoelectric cooler

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Abstract

The present work includes a design and characteristics study of a controlling the wavelength of high power diode laser by thermoelectric cooler [TEC] . The work includes the operation of the [TEC] to control the temperature of the diode laser between (0- +30) °C by changing the resistance of thermistor. We can control a limited temperature of a diode laser by changing the phase cooling between hot and cold faces of the diode, this process can be attempted by comparator type [LM –311] .The theoretical results give a model for controlling the temperature with, the suitable wavelength.

Key words

Diode laser, Thermoelectric cooler

Article info

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السيطرة على ترددات ليزر دايود عالي القدرة بأستخدام طريقة التبريد الكهروحرارية

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الخلاصة

العمل الحا لي يتضمن دراسة تصممية للسيطرة على الطول ألموجي الى نبضة اليزر المنبعثة من ليزر اشباة الموصلات ذات الطاقة العا لية بواسطة التبريد الكهروحراري . حيث يتضمن هذا العمل تشغيل المبرد الكهروحراري للسيطرة على درجة حرارة ليزر اشباة الموصلات بين 0-30 درجة مئوية، ويتم ذلك بواسة تغير مقاومة المقا وم الثيرميوني. ويمكن من خلال هذا العمل ايضأ الحصول على درجة حراره ثابتة لانتاج طول موجي ثابت وذلك بتغير طور المبرد الكهروحراري بين التبريد والتسخين، ويمكن ان تتم هذه العملية بواسطة المقارن نوع LM-311 . ومن خلال النتائج النظرية تظهر امكانيه عا لية للسيطرة على طول الموجى لنبضة الليزر من خلال هذا النوع من التبريد.

Introduction

Introducti

The increase in temperature of laser diode is one of the reasons for its failure. Small increase in temperature may lower the frequency stability of the laser output and a large increase will damages the diode. The bandgap of the diode varies with temperature [1], and as mentioned earlier, the output wavelength of the diode is proportional to its bandgap. Thus a variation in temperature [T_j] which affects the stability of the output wavelength can be expressed as follows [2]:

$$\lambda(T)= \lambda_o + K_\lambda \, (T_j- 300 \text{ K}) \qquad (1)$$

where

λ_o is the wavelength at 300 K.

K_λ is the temperature coefficient of the wavelength.

T_j is the junction temperature.

The variation of the output wavelength for diode laser if used to pump different active material is shown in Fig. (1), [3].

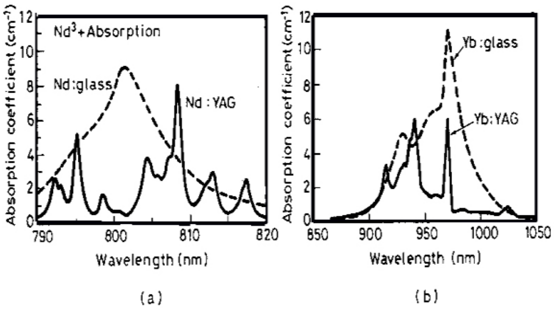

Fig.(1): Absorption spectral of (a)Nd:YAG/Glass Lasers and (b) Yb:YAG/Glass Lasers.

When the temperature increases, the absorption of the output by the facets increases. The photodiode that is present to stabilize the output detects a drop in the output and increase the drive current. Higher drive current increases the optical output and hence the temperature. This vicious cycle continues causing damage to the facets. To combat this problem, a heat sink can be used to dissipate excess heat and a thermoelectric cooler (TEC) can used to maintain a constant temperatur The laser diode is mounted on a heat sink to remove the heat generated during photon emission. The heat sink plate should have enough area to conduct the heat from the diode and dissipate it.

System Design

Our known design values are [4]: Q = 3 Watt heat load from electronic component TA= 50 °C maximum ambient air temperature TC=25°C required temperature of electronic component The first Priority is to determine which of the [TECs] is appropriate for our application. This can be made using the performance Figs. (2, 3 and 4), then we must identify the hot side temperature (TH) and the resultant temperature difference across the module (ΔT). The hot side temperature is equal to ambient temperature (TA), plus the rise in temperature which dissipates from the heat load(Q) and multiplicd by the transtation heat of the sink (RQ) and the [TEC] module power (V x I) i.e:

$$TH = TA + \{ (V \times I) + Q\} RQ \qquad (2)$$

where RQ is thermal resistance of the heat sink in°C temperature rise per Watt dissipated. In this design, we will keep the rise of the heat sink temperature to no more than about 0 .669°C above ambient. This will give us a TE module hot side temperature of about 50.669°C.

$$TH = 50°C + 0.669°C = 50.669°C \qquad (3)$$

The temperature difference across the module can now be calculated as follows:

$$\Delta T = TH - Tc = 50.699°C - 25°C = 25.669°C \qquad (4)$$

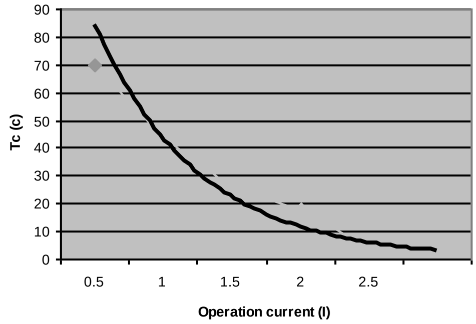

Fig.(2): The Relation between TC and operation current Q=3W, TH= 50.669c

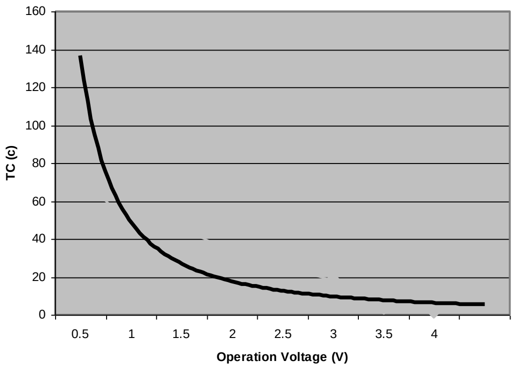

Fig. (3: The Relation between operation voltage and TC, Q=3W, Th=50.699

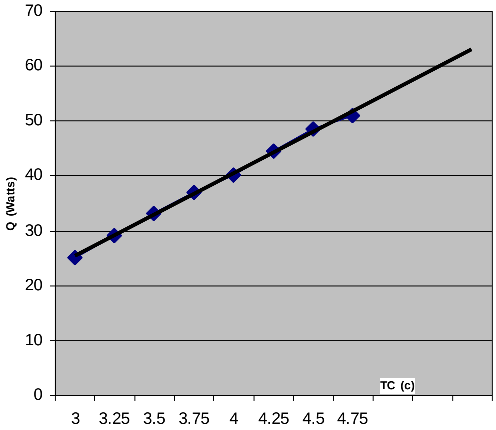

Fig. (4): The Relation between Cold temperature and heat Pumped at Cold side (Q), I=1.57 A, V=2.48 V

From this information using a "CP.0-31 -08L"module: The voltage required is 2.48VDC. The current required is 1.57A Diamentios of the [TECs] 14.86 mm* 14.86 mm * 3.99 m So the Power supplied will be 3.89 watt

Temperature control

The temperature of the laser diode is maintained within acceptable range using the cooling system, where's the components of the cooling system are shown in Fig. (5), it consists of thermistor, two aluminum plates, thermal epoxy and the [TECs] [5].

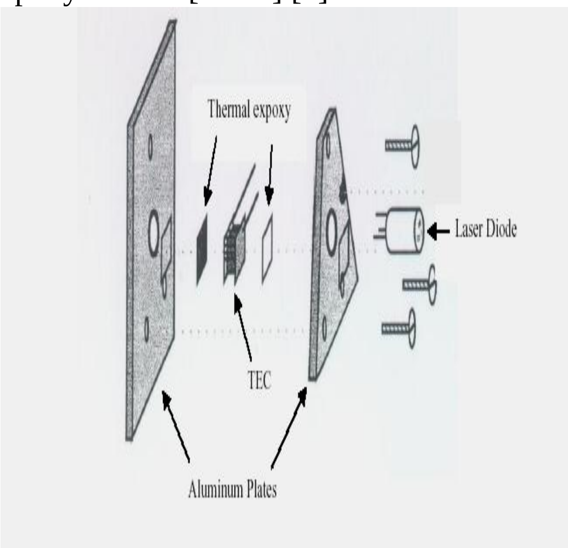

Fig. (5): Components of the cooling system

1- Thermoelectric cooler [TEC]

A typical thermoelectric module consists of an array of Bismuth Telluride semiconductor pellets that have been "doped" so that one type of charge carrier– either positive or negative– carries the majority of current. The pairs of P/N pellets are configured so that they are connected electrically in series, but thermally in parallel [6]. Metalized ceramic substrates provide the platform for the pellets and the small conductive tabs that connect them. The pellets, tabs and substrates thus form a layered configuration.

Module size varies from less than 0.25" by 0.25" to approximately 2.0" by 2.0". Thermoelectric modules can function singularly or in groups with either series, parallel, or series/parallel electrical connections. Some applications use stacked multi-stage modules. The configuration [TEC] is shown in Fig. (6).

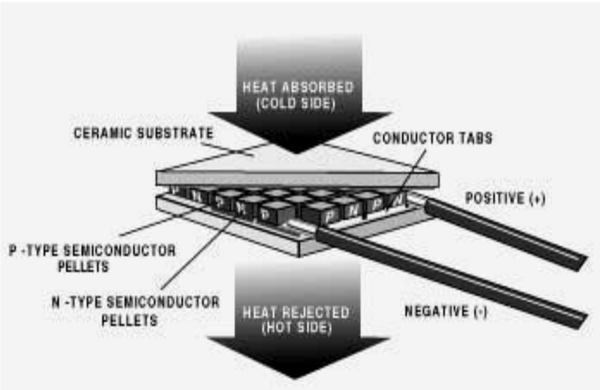

Fig.(6) Configuration of [TEC]

Thermoelectric Benefits

The choice of a cooling technology will depend heavily on the unique requirements of any given application, however , thermoelectric [TECs] offer several distinct advantages over other technologies:

•[TE Cs] have no moving parts and, therefore, need substantially less maintenance.

• Life-testing has shown the capability of

[TEC] devices to exceed 100,000 hrs. of steady state operation.
•[TE Cs] contain no chlorofluorocarbons or other materials which may require periodic replenishment.
• Temperature control to within fractions of a degree can be maintained using TE devices and the appropriate support circuitry
• [TE Cs] function in environments that are too severe, too sensitive, or too small for conventional refrigeration
• [TE Cs] are not position-dependent.
• The direction of heat pumping in a [TEC] system is fully reversible. Changing the polarity of the DC power supply causes heat to be pumped in the opposite direction– a cooler can then become a heater!

2-Thermistor

A thermistor is a two-port device, which exhibits a nonlinear relation between its resistance and temperature show in Fig.(7). Most of the commercial thermistor have Negative Temperature Coeffcients (NTC), with its resistance decreasing with increasing temperature[7]. The thermistor is used in combination with a TEC and a temperature controller circuit to provide a stable temperature for operation of the laser diode.

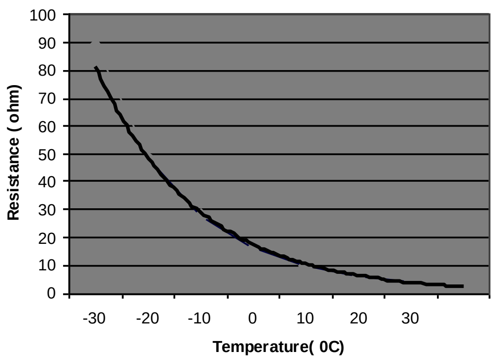

Fig. (7): The Relation between resitance and Temperature of Thermistore

3-Temperature controller

The work includes the operation of the [TEC] to control the temperature of the laser diode between (0 - 30)°C by changing the resistance of thermistor. We can control a limited temperature of a diode laser by changing the phase cooling between hot and cold faces of the diode, this process can be attempted by a comparator type [LM –311], This circuit show in Fig. (8). Calculated the applied temperature on the laser diode (ambient temperature + generated temperature) in Table (1). From this table we can limited the temperature of a diode laser at 25°C by Changing phase cooling of the [TEC] between, hot if (Vs) is equal 14 mV and cold if (Vs) is equal 9.6 mV.

Table (1): The relation between TH and sensor voltage

Hot side tem. °C	Sensor Voltage(mV)
0.669	38
10.669	21
20.669	14
25.669	12
30.669	9.6
40.669	6.2
50.669	4.3

Simulation Results and Discussion

Using Eq. (1) to draw the wavelength shift against the junction temperature, the junction temperature increased, when the junction current increased and the ambient temperature increased .Hence for certain wavelength, certain values of Voltage, current, and cooling temperature, must be chosen this parameters. Because when those parameters change the wavelength will change also. This can be shown in Fig.(9).

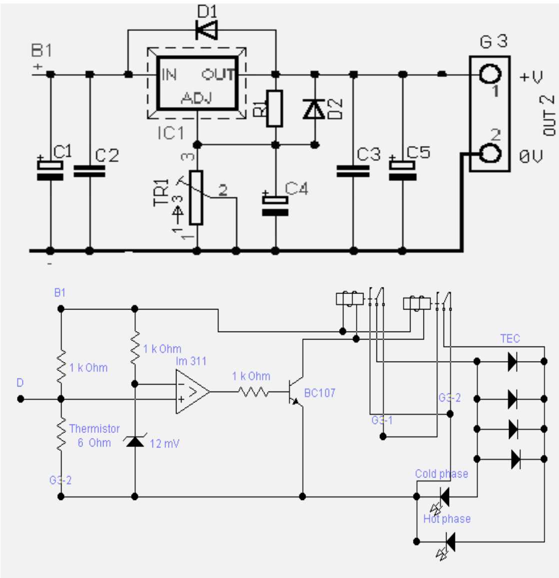

Fig. (8): Temperature controller circuit

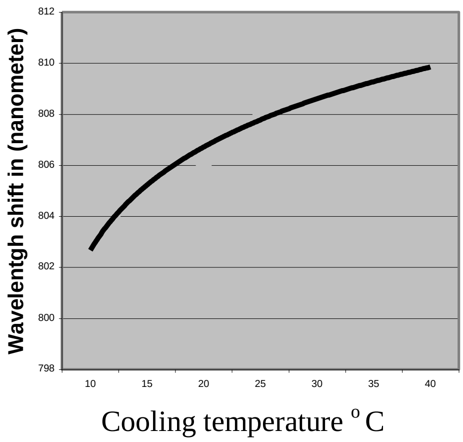

Fig. (9) The relation between wavelength shift and cooling temperature ($\Delta\lambda$= 6nm, ΔC= 30 ^{o}C).

Conclusions

This circuit demonstrates the successful application of shifted the wavelentgh of the high power laser diode (1000 mW) with varies temperature.

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