Reduction of Temperature in Layered Structure of Transceiver by Heat Conduction Through Thermal Simulations

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***Abstract*-- Transceivers consist of electronic and photonic components developed on silicon-on-insulator (SOI) technology. While operating, the device gets heated up due to temperature sensitivity of photonics components, and the temperature of the device increases. This increases the temperature to heat power supplied to the layered structure of laser, electronic drivers, and trans-impedance amplifiers (TIAs). To keep the device cool, heat must be transferred from source to sink at a faster rate. In this research, using conduction of heat through thermal simulation, heat transfer rate is increased from source to sink. The temperature per heat power supplied to the laser decreases from 2.0 K /mW to 1.7 K/ mW by decreasing the thickness of the thermal interface material (TIM) having low thermal conductivity.**

Keywords—transceiver temperature, thermal simulations, solidworks simulation, heat management, thermal issues, electronic components temperature, photonic components temperature, thermal management of temperature, electro-optic devices, thermal issues in electro-optic devices, optical components heating, thermal issues in optical components, thermal issues in electronic components, electronic components heating, optics, photonics, photonic components temperature management, silicon photonic, silicon photonic sensitivity, telecommunication.

I. INTRODUCTION

Transceivers are widely used to transmit and receive data signals over long distance worldwide. With the rapid increase in demand for personal computers, cell phones, 5G networks, information and technology, a very fast data transfer rate is required to send and receive the information signals [1]. It is predicted that data transfer rate will grow exponentially and reach up to 175 Zettabyte in 2025.We need to work on devices to increase their efficiency of transferring data signals [2].

Transceiver consists of electronic and photonic components such as lasers, transimpedance amplifiers (TIAs), electronic drivers, and silicon photonic integrated circuits (Si-PIC) etc. When it operates, its transmitter part, transmit optical sub assembly (TOSA), converts electrical signals into optical signals and transmit them through transmitter. The other part of transceiver is receiver, Receiver optical sub assembly (ROSA), that receives transmitted optical signals and convert them back into electrical signals. During its operation, transceiver gets heated up due to working of active components [3,4]. Increase in demand of high data transfer rates has increased our interest in integrated photonics technology. Technologies has already made possible hybrid integration of photonic and electronics components on SOI. This technology gives efficient results but still there exist a difficulty in controlling temperature of components of transceiver. This happens due to high temperature sensitivity of photonic components which causes extra heat. This heat affects working of components and reduces efficiency of transceiver of data transfer rate [5].

Usually, the temperature control is achieved by fan blowing close to operating device. However, due to miniaturization in electronic and photonic components that have different operating temperatures, uniform air flow to the operating components is not possible which leads to extra unwanted heat generation and more power consumption of devices [6]. In this paper we designed layered structure of transceiver using SolidWorks software. With the help of finite element analysis (FEA) various thermal simulations are performed. Considering the conduction of heat methodology, flow of heat from source to sink is observed. It is found that variation in thickness of Thermal Interface Material (TIM) has largely impacted the heat transfer rate and hence temperature of device. By considering the concept of thermal conductivity of materials, ttemperature per heat power of lasers, TIAs and drivers have been reduced. The overall temperature of device was reduced.

II. METHODOLOGY

Conduction is a process of heat transfer that occurs within a same solid body or between two bodies which are in thermal contact. Transfer of heat depends upon different factors such as temperature difference between hotter and cooler regions, area of conducting material and length of thermal contact between two bodies. Rate at which heat transfers is known as heat conduction and is given by [7].

$$H = \frac{kA\,(T_H - T_C)}{L} \tag{1}$$

Where H is heat transfer rate by conduction in [J/s], k represents thermal conductivity of a material in [W/m.K], A denotes area of body [m2], and L is length of body [m]. (TH-TC) is temperature difference between hotter body and cooler body. Different materials have different thermal conductivities which means each material has different rate of heat transfer. Thermal conductivity of silicon (Si) material is 142 W/m.K while on the other hand thermal conductivity of silicon dioxide (SiO2) material is 1.15 W/m.K. This shows rate of heat transfer from hotter region to cooler region in Si is higher than SiO2. This is fundamental concept that we have used in thermal simulation for temperature management in layered structure of transceiver.

III. STRUCTURE DESIGN

First schematic diagram is designed as in Fig. 1 (a). On the top and bottom layers, thermal boundary conditions are applied (copper case). Thermal gap pads are sandwiched between coper case and heat spreaders. These are made up of silicon origin material but with changed thermal properties. Voids and air pockets are barriers for heat transfer, so pads facilitate between source and sink for heat conduction. Heat spreaders are used to spread the heat as suggested by its name. Then the assembly of Transceiver consisting of TIAs, drivers and lasers is designed on Si-PIC. Glue act as thermal interface material which is made up of arctic silver 5. All sub-assemblies are mated and furnished on Printed Circuit Board (PCB). Each component is designed as a part separately and then these parts are mated to form sub-assemblies. These subassemblies are further mated to make a complete layered structure of transceiver as shown below.

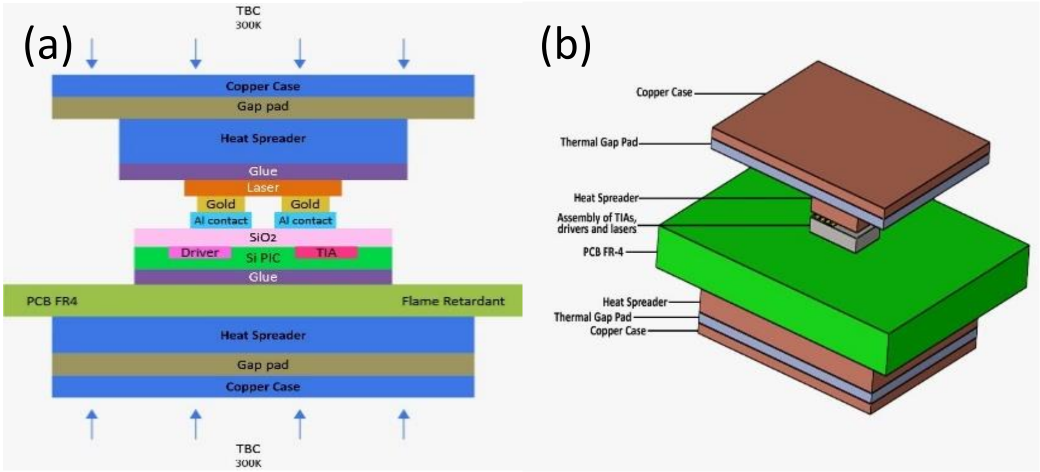

Figure 1. (a) A schematic diagram of Transceiver (b) A layered structure of transceiver designed in SolidWorks.

TABLE I. DIMENSIONS AND THERMAL CONDUCTIVITIES OF MATERIAL

Component Name	**Material**	**Dimensions (LxWxH) (mm)**	**Thermal conductivity (W/m.K)**
Metal cases	Copper	15x15x0.5	398
Thermal Gap pads	(Si-Origin)	15x15x0.5	5.2±0.52
Heat Spreader below PCB	Copper	15x15x2	398
Printed Circuit Board	FR-4	20x20x2	0.4
Glue or Thermal interface material layer	Arctic Silver	4x3.3728x0.05	8.9
Silicon PIC	Silicon	4x3.3728x0.70	142
Transimpedance amplifier & electronic drivers	Silicon	0.7x0.36x0.005	142

Oxide layer	Silicon dioxide	4x3.3728x0.003	1.15
Lasers	Indium Phosphide	0.310x0.25x0.0995	68
Aluminum contacts	Aluminum	0.865x0.865x0.003	247
Gold Contacts	Gold	0.05x0.05x0.02	315
Heat spreader above lasers	Copper	4x3.3728x2.7795	398

After designing four TIAs, four electronic drivers and four lasers in the structure, thermal simulations were performed in software using different parameters. These were the initial conditions on which simulations were performed. The thickness of glue or thermal Interface material (TIM) is kept 50 µm . The thermal boundary conditions (TBC) of 300 K are applied at the top and bottom of copper cases. Heat Power supplied to each TIA is 80mW. Heat power supplied to drivers per item is 200mW. Heat power supplied to each laser varies from 100mW, 150mW to 200mW.Although other values can be used depending upon requirements. Here we found the following results.

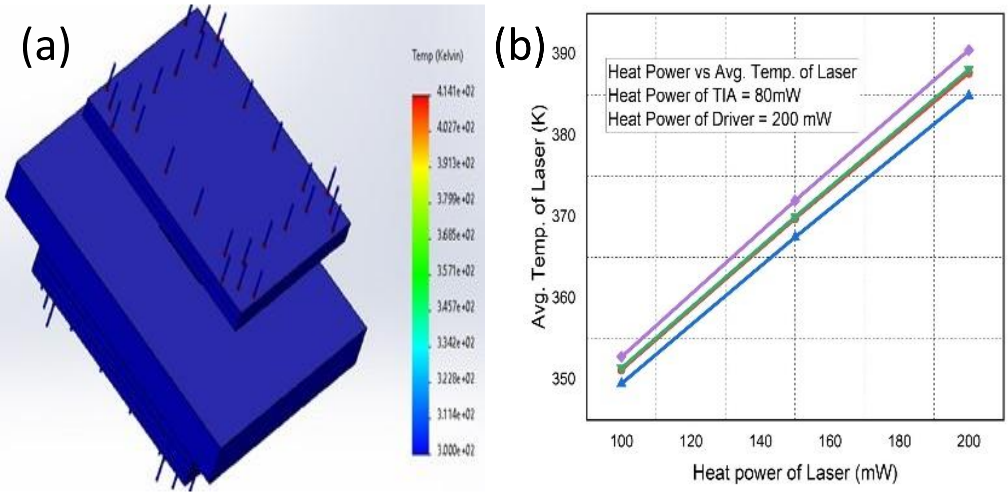

Figure 2. (a) Simulation results at 50 µm thickness of TIM (b) Average Temperature of Laser vs Heat Power

Above four curves in fig 2.(b) show temperature of lasers. Two curves overlap while others not perfectly. This happens because they are placed at different locations some of them are near to each other and they may go in thermal equilibrium. These components are assembled between thermal interface material (TIM). TIM is made up of arctic silver 5 having thermal conductivity of 8.9 W/m.K. The arctic silver has relatively high value of thermal conductivity as compared to others TIM. This means, if we reduce the thickness of TIM from 50 µm to 25 µm and further to 5µm, temperature of device may reduce.

IV. RESULTS

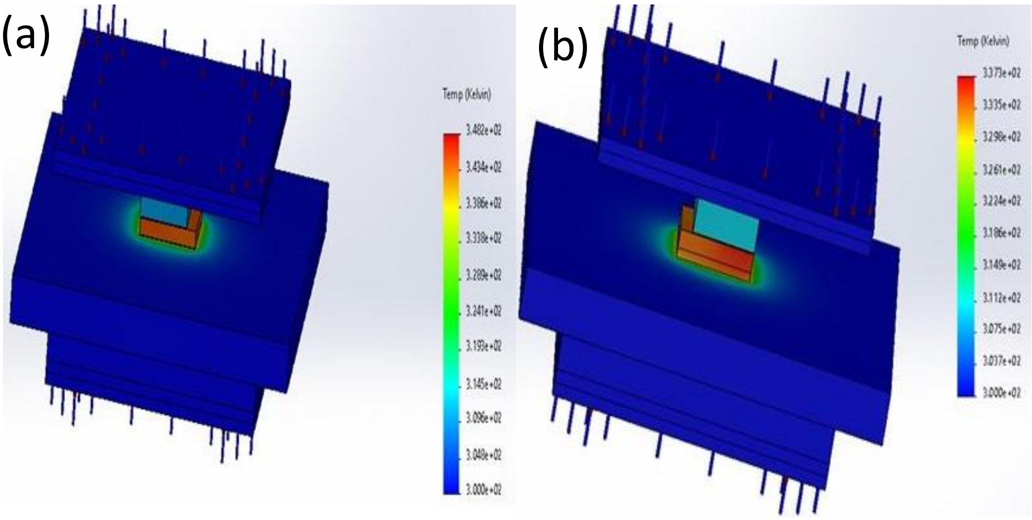

Figure 3. (a) Simulation results at 25 µm thickness of TIM (b) Simulation results at 5 µm thickness of TIM

Simulation study in Figure 3(a) shows that device temperature per heat power has been reduced from (414.1k/200mW=2.07K/mW) to (348.2K/200mW=1.74K/mW) and finally (337K/200mW=1.68K/mW) at 200 mW heat power. The temperature per heat power of device decreases from 2.0 K / mW to 1.68 K / mW. This shows that the device temperature is reduced because the thickness of TIM is decreased. A comparison of decrease in temperature of all active components such as TIAs, drivers, and lasers with respect to 50 µm, 25 µm and 5 µm thickness of TIM is given below.

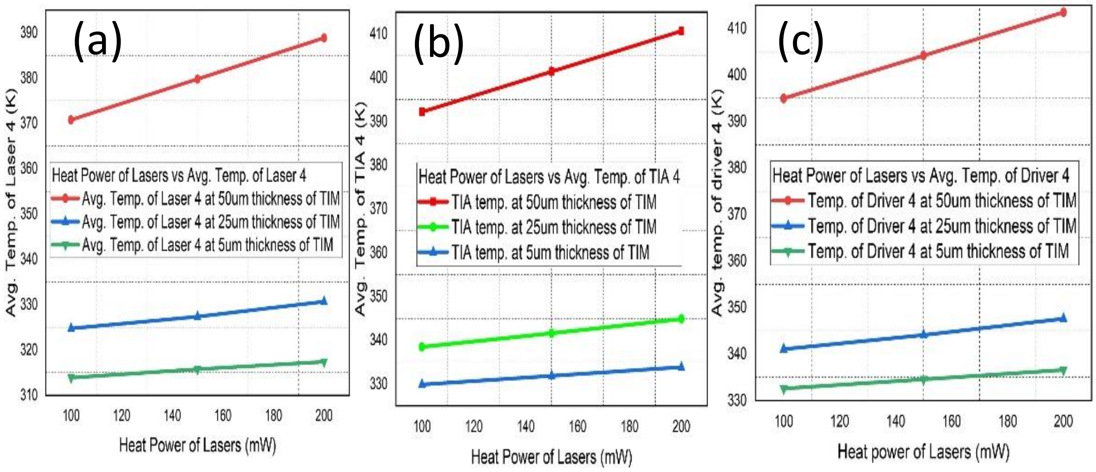

Figure 4. (a) Average temperature of laser vs heat power of lasers. (b) Average temperature of TIAs vs heat power supplied to lasers. (c) Average temperature of electronic driver's vs heat power supplied to lasers.

V. DISCUSSION

Heat transfer from source to sink is increased when the thickness of TIM material is decreased. The temperature of device remains lower, and it can operate in cooler environment. Materials that are poor conductor of heat are likely to decrease heat transfer rate due to lower thermal conductivity. Arctic silver has relatively high thermal and low electrical conductivity as compared with others thermal interface materials. It decreases temperature per heat power supplied that decrease the temperature of device. The temperature per heat power of laser decreases from 1.9 K / mW to 1.6 K / mW. The temperature per heat power of TIA decreases from 2.0 K / mW to 1.7 K / mW. The temperature per heat power reduces from 2.06 K / mW to 1.7 K / mW. The different thickness 50 µm, 25 µm, and 5 µm of TIM was used. The fixed heat power 80mW and 200Mw supplied to each TIA and electronic driver respectively.

VI. CONCLUSION

By decreasing the thickness of thermal interface materials (glue), we can increase heat transfer from our working components (Source) to sink. The temperature per heat power supplied to laser decreases from 1.9 K/ mW to 1.7 K/mW. Increase in heat transfer rate means heat will not be stored and obstructed near source instead it will move from source to sink at faster rate and device temperature due to working components may remain down.

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