# An Integrated Thermal Dissipation Micro Structure for 400Gbit/s Optical Module

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***Abstract*— *400Gbit/s optical module will soon be commercially deployed on a large scale due to the need for high capacity information transmission. It has much higher power density than that of 100Gbit/s and 40Gbit/s and therefore the thermal management still remains an obstacle. An integrated thermal dissipation micro structure (ITDMS) including µ-channel, µ-pool, graphene thermal pad with lateral and longitudinal transfer paths proposed and numerically validated for effective heat dissipation of CDFP optical modules.***

## I. INTRODUCTION

The needs of consumers for information transmission are staggering and continuing to grow which requires significant increases in the capacity of communication network and bit rate of data center [1, 2]. The CDFP optical module is defined by CDFP-MSA protocol which supports both 400Gb/s transmission and interconnection. So it is preferable for wide range of transceiver vendors and communication carriers.

CDFP optical module needs a more efficient cooling solution due to higher power density and has a more compact mechanical structure than previous optical modules. With the development of materials science, graphene has been found to has excellent optical and thermal properties. The thermal resistance is much lower than metals such as copper and aluminum [3]. Liquid cooling is often used for equipment-level cooling. With the development of PCB processing technology, it is possible to directly etch the µ-channels on the substrate to achieve device-level liquid-assisted heat dissipation. From a thermal perspective, µ-channels are of particular interest due to the extremely large surface area which provide for heat transfer [4]. Traditionally, the power densities of optical transceiver modules such as CFP4, XFP and SFP+ are less than 0.30 W/cm$^2$. Due to the smaller mechanical structure and higher power of the 400G optical module, the CDFP pluggable optical module has a higher power density. The power density of 400G optical modules tends to be higher than 0.5W/$cm^2$ for their high power class. Based on integrated thermal dissipation micro structure (ITDMS) including µ-channel, µ-pool, graphene thermal pad with lateral and longitudinal conduction path, we numerically investigate the thermal distribution for a 6-Watts CDFP Style3 module with power density of 0.91 W/$cm^2$ to verify such thermal management can still keep the temperature below 70℃ which can guarantee module functionality and reliability [1].

## II. THERMAL DESIGN

Since the CDFP-MSA protocol does not specify the internal structure of the CDFP optical module. This simulation model designs the layout inside the CDFP Style3 optical module. The main heat sources such as TOSA, ROSA and Controller are placed at the rear of the optical module to facilitate fiber access and photoelectric signal conversion [5]. The power distribution is shown in Table 1.

Table 1: Power Distribution of CDFP Style 3 Optical Module

| Power distribution of CDFP optical module | | |
|---|---|---|
| TOSA | ROSA | Controller |
| 3W | 2W | 1W |

However, the pluggable optical module itself does not have a direct external heat dissipation structure, so heat cannot be emitted directly through pluggable optical module. and the upper heat sink can be used only after the front half of the optical module is inserted into the interface cage. As it shown in Fig.1, it is necessary to construct an efficient lateral heat transport channel to conduct the heat generated by devices in rear of PCB to the front of the optical module and dissipate the heat to the outside through the pin fin heat sink.

Graphene thermal pad and flowing liquids have higher heat transport properties [4], so a µ-pump is required to drive the fluid on the PCB, the design of the µ-pump is no longer discussed in this paper.

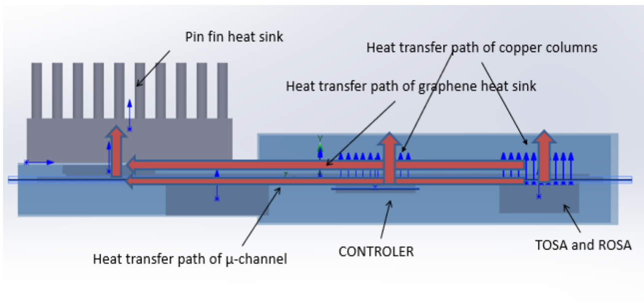


Fig.1. Heat transfer path in PCB

## III. SIMULATION & DISCUSSION

If only µ-channels and graphene are used for heat dissipation without constructing a longitudinal heat transfer channels, µ-channels need many bends in the region with high power density to increase the heat exchange area,

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which needs higher flow velocity of liquid in μ-channels. We propose a more efficient thermal management scheme of a μ-pool on the PCB beneath the TOSA, ROSA and Controller. Some copper columns support the devices and construct longitudinal heat transfer channels [6]. The water flows in pools and exchanges heat with the copper columns which also exchange heat with the graphene thermal pad on the other side of the PCB, as shown in Fig. 2.

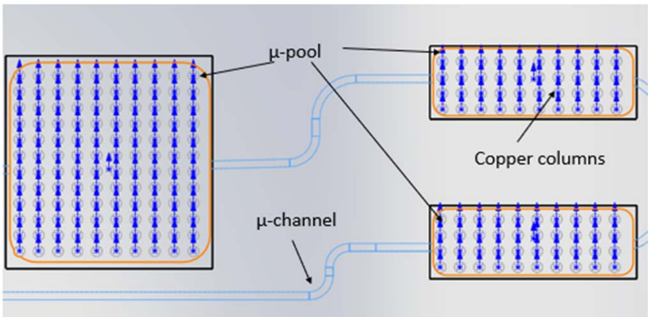



Fig.2. Heat dissipation structure with μ-channels, μ-pools and copper columns

The model is simulated by using SOLIDWORKS Flow Simulation and using 10℃ water as the fluid. In Fig.3, the thermal management with ITDMS can reduce the maximum temperature of the optical module to 34.73℃ with slow flow velocity. But the heat dissipation scheme only with μ-channels and graphene only can reduce it to 45.18℃. It can be observed in Fig. 4. Both of these cooling solutions are far superior to module without any thermal assistance, in which the maximum temperature will melt the PCB. ITDMS can also reduce the power consumption of the μ-pump.

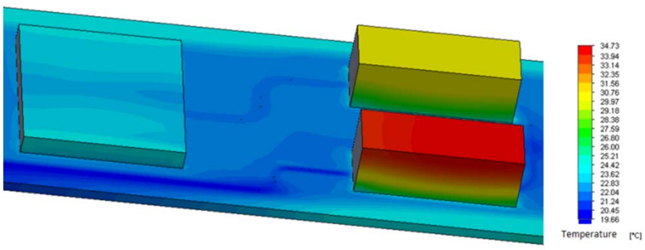
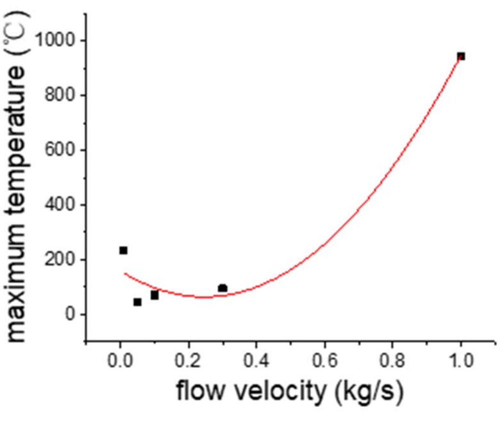
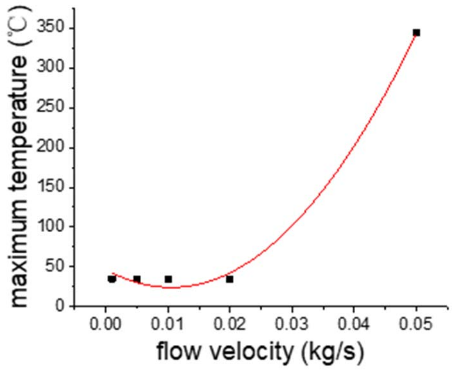



Fig.3. Thermal field distribution in module




(a)




(b)

Fig.4. Analysis of flow velocity and maximum temperature of module, *(a)* only with μ-channels and graphene, *(b)* with ITDMS

It can be analyzed from the Fig.4 that the flow velocity change has a direct influence on the maximum temperature of the module. For the incomplete heat dissipation scheme which only with μ-channels and graphene, the heat transfer between the devices and the fluid is sufficient, but the heat lateral conduction efficiency is low when the flow rate is relatively low. However, when the flow velocity is high, heat transfer is insufficient and meanwhile lateral conduction efficiency is high (Fig.4a). Based on the ITDMS featured by the efficient longitudinal thermal conductivity of the copper columns and the heat storage characteristic of the μ-pools, the heat transfer can be sufficient and hence the flow velocity requirement is relatively low (Fig.4b).

## IV. CONCLUSION

The CDFP optical modules defined by CDFP-MSA protocol are widely used in telecommunication and data communication by a wide range of transceiver vendors and communication carriers. Such module needs a more effective cooling solution where properly designed heat dissipation paths are of priority. Integrated thermal dissipation micro structure including μ-channel, μ-pool, graphene thermal pad with lateral and longitudinal transfer is presented and numerically verified to serve as an efficient thermal management scheme which reduces requirements on the flow velocity and the application of μ-pump in PCB.

## ACKNOWLEDGMENT

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