Design and Thermal Simulation of the Front-end Module for STARLIGHT

Han Wang[1], Peng Peng[1], Jie Zhang[2], Zhi Liu[1], Xudong Ju[1], Xining Jia[1], Wei Li[1], Peng Liu[1], Tao Sun[3], Zhen Sheng[3], Fang liu[1]

1 ShanghaiTech University, Shanghai China. 2 Institute of High Energy Physics, Chinese Academy of Science.

3 Shanghai Institute of Microsystem and Information Technology,Chinese Academy of Science.

Email：wanghan98@ihep.ac.cn

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Introduction

Figure 1 Location of SHINE (Top View)

- SHINE (Shanghai HIgh repetition rate XFEL aNd Extreme light facility) is the first hard-Xray Free Electron Laser facility in China.
- Photon Energy: 0.4~25 keV
- Pulse Duration: 20~50 fs (5~200 fs)
- Repetition Frequency: 10 kHz (1 MHz)
- Peak Brightness: 10^{32} ~10^{33} photons/μm²/rad²/s/0.1% BW

- **To make use of the excellent properties, a pixel detector system is being developed, named STARLIGHT. The Specifications of the detector is shown in table 1.**

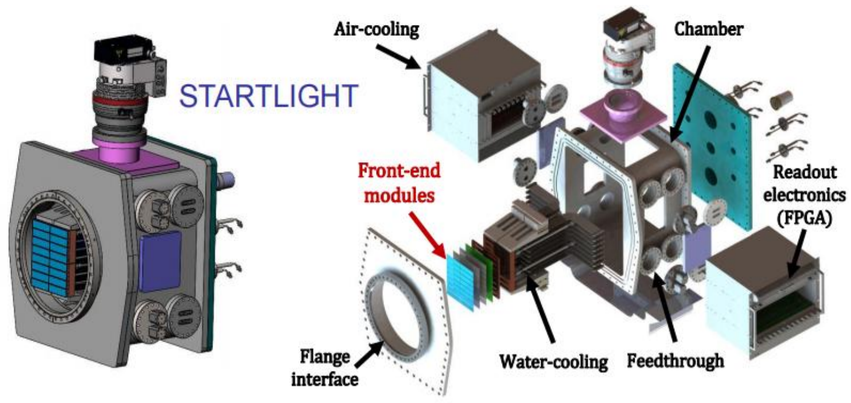

Figure 2 The STARLIGHT Detector System

- **The front-end module is the core part of STARLIGHT, As shown in Figure 3, including sensor, readout chip, front end printed circuit board (PCB) and support heat dissipation structure.**

Table 1 Specifications of the STARLIGHT Detector System

Specs	Parameters
Pixel Array	128 × 128
Energy range	5 - 25 keV
Pixel size	100 μm × 100 μm
Dynamic range	1 ~ 10000 photons/pulse @12 keV
Frame rate	10 kHz (continuous readout)
Quantum efficiency	90 % @ 7 keV
Cavity vacuum degree	10^{-6} mbar

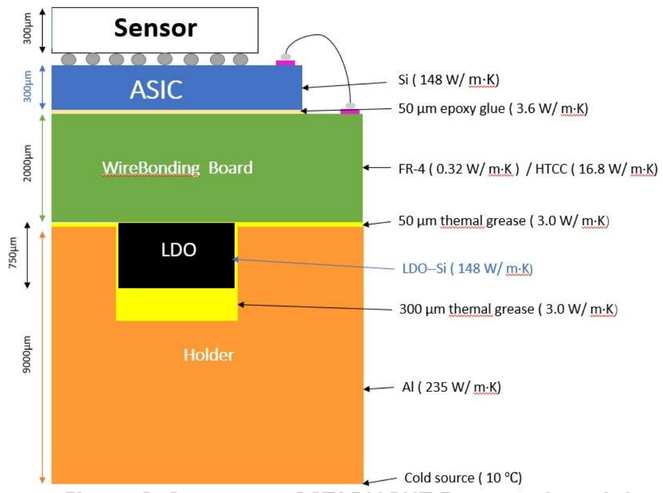

Figure 3 Structure of STARLIGHT Front-end module

Design of the Thermal_emulator

- In STARLIGHT, each chip has a 128×128 pixel array with a single pixel power consumption of 50 μW. The total power consumption of a chip is 0.82 W, with the LDO consuming 0.273W. The total heat flux is 5.443 mW/mm².

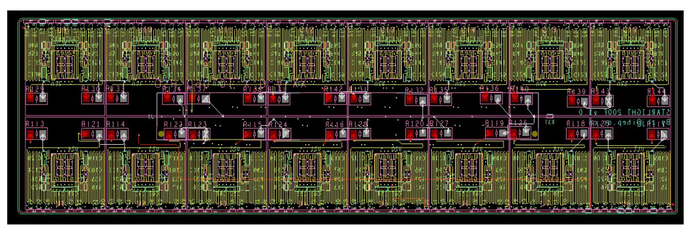

Figure 4 Distribution of simulated ASIC heat-producing copper wires

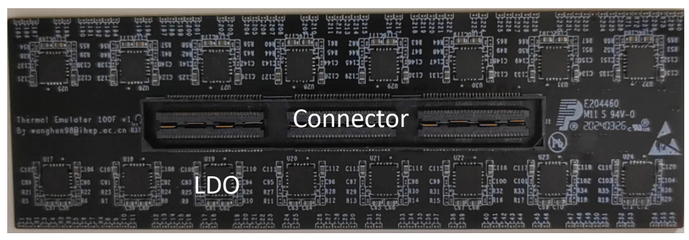

Figure 5 The dimensions of thermal_emulator

Table 2 The design parameters of Thermal_emulator

Para.	thickness	width	length
VDDA	0.5 oz	5 mil	16998 mil
VDDD	0.5 oz	5 mil	16998 mil

Thermal simulation of the front-end module

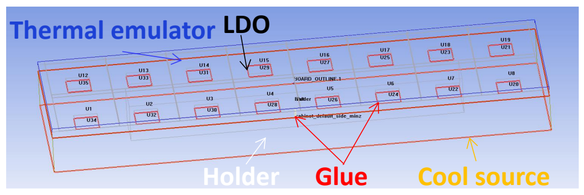

Figure 6 Front-end module model diagram in ICEPAK

- It predicts airflow, temperature and heat transfer in IC PCBs.

Figure 7 Temperature distribution cloud map (Top view)

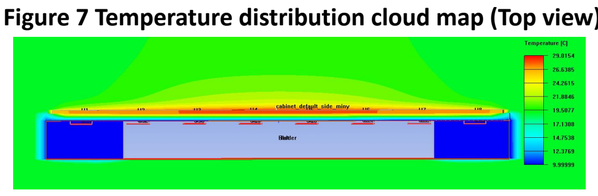

Figure 8 Temperature distribution cloud map (Front view)

- The model is established, meshed, material properties and boundary conditions are set, and calculations are performed. The simulation results in Figure 6 show a temperature rise of 18.8187 ℃.

Test Results and Summary

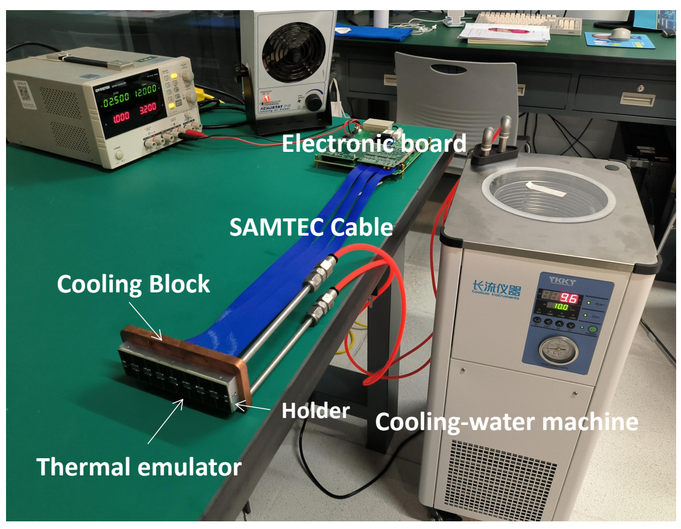

Figure 9 Thermal emulator test environment

Table 3 The Test Results of Thermal_emulator

	Design	Test
Voltage/V	1.4	1.393
ASIC power/W	0.82	0.900
LDO power/W	0.273	0.261

- The test results of the Thermal emulator are given in Table 3.
- Thermal imaging results of the front-end module are shown in Figure 10,the temperature rise is 21.9 ℃,which is close to the simulation.

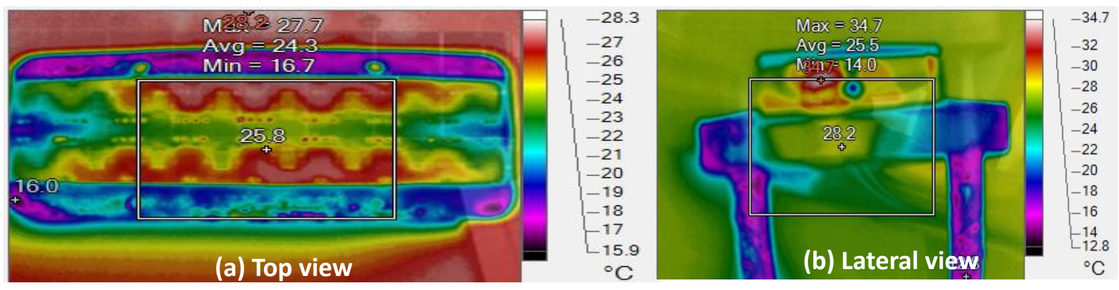

Figure 10 Thermal image of Thermal emulator front end module

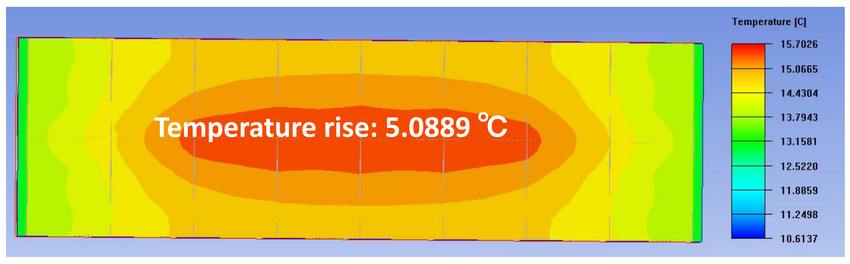

Figure 11 Temperature distribution cloud map (Top view)

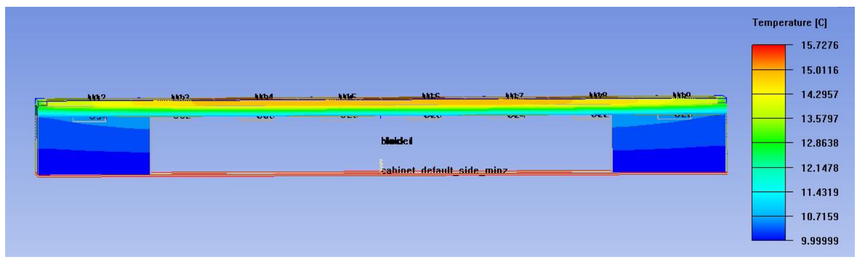

Figure 12 Temperature distribution cloud map (Front view)

At present, the FR-4 heat dissipation effect used in STARLIGHT's front-end module PCB is not very good, and HTCC (High-temperature co-fired ceramics) is intended to be used in the future, the thermal simulation results are shown in Figure 11. The temperature rise is 5.0889 ℃.

中国科学院高能物理研究所 Institute of High Energy Physics Chinese Academy of Sciences

上海科技大学 ShanghaiTech University

中国科学院 上海微系统与信息技术研究所 SIMIT