Development of thermoelectric cooling system for the PERCIVAL

IFDEPS VT

April 8, 2021

HyoJung Hyun[1], Seonghan Kim[1],

Kee Hyuk Sung[2], Chan Park[2] and Young Gyoon Yoon[2]

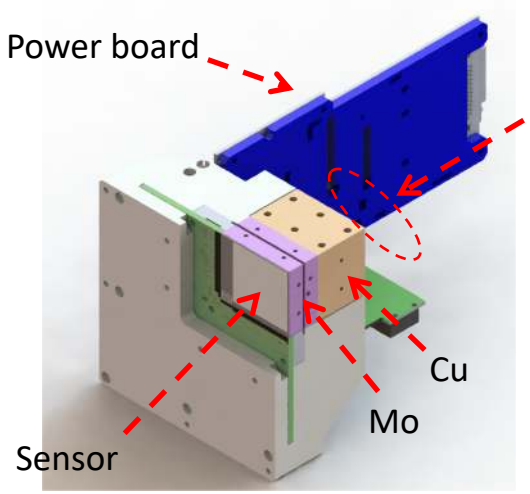
[1] Pohang Accelerator Laboratory, Pohang, Gyeongbuk 37673, Republic of Korea

[2] LIVINGCARE R&D Center, Gunpo, Gyeonggi 15850, Republic of Korea

Specification of PERCIVAL & Requirements for the Cooling System

Energy range [keV]	0.25 ~ 1
Pixel size [µm]	27
Number of pixels	2M – 1408 × 1484
Imaging area [mm × mm]	40 × 40 uninterrupted
Full well [e-]	3.5×10^6
Dynamic range [photons/pixel]	5.0×10^4 at 250 eV
Noise [e-rms]	**<15**
Quantum efficiency	>85%, uniform over pixel and over energy range
Frame rate [Hz]	Up to 300
Sensor output	**Digital, LVDS**
Buttability	**2-side (adjacent edges)**
Exposure modes	Either quasi-continuous or single shot illumination

- There are Mo and Cu blocks between the sensor and the thermoelectric element



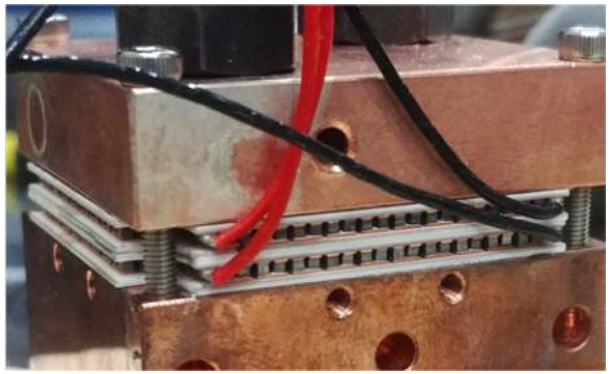
[BSI detector head]

- Detector should be operated at low temperature (from –20 ℃ to –40 ℃)
- Estimated power consumption of the sensor is about 10 W
- Area of the thermoelectric element should be limited to 50 mm × 42 mm

Fabrication of Thermoelectric Elements

- To meet the requirements, **thermoelectric elements are designed and manufactured**
- In case of **2nd new elements**
  - It covers the entire cross-sectional area of Cu block as much as possible
  - The degree of integration increases about 20 % compared to 1st new element

	Commercial Element		1st New Element		2nd New Element	
Model name	LM-4040-3.4-23.9		LM-4040-3.4-28.9		LM-5042-3.0-37.3	
T_h [℃]	27	50	27	50	27	50
Q_{MAX} [W]	81.9	92.1	99.2	111.5	128.0	144.0
I_{MAX} [A]	6.0	6.0	6.0	6.0	6.0	6.0
V_{MAX} [V]	**23.9**	25.7	**28.9**	31.1	**37.3**	40.2
ΔT_{MAX} [℃]	70	79	70	79	70	79
Resistance [Ω]	3.4	-	4.0	-	5.1	-
Dimension [mm^3] (A × B × H)	40 × 40 × 3.4		40 × 40 × 3.4		42 × 50 × 3.0	



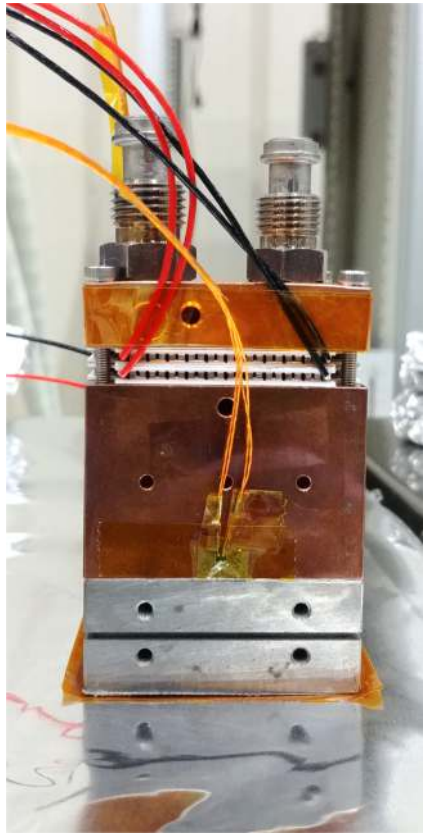
Efficiency of Heat Transfer

- Heat transfers by **conduction** in vacuum

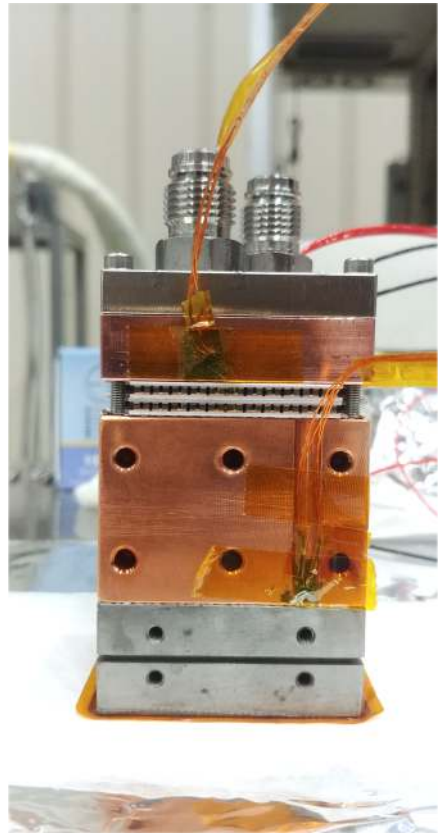
  → **There should be NO gap at every interface**

  - Indium sheet is used at every interface
  - Bolts holes on the copper block are molded with indium
  - Over torque (22 kgf·cm) for the assembly bolts is applied
  - Water jacket consists of only copper is replaced to new water jacket made of copper and stainless steel

- Any other parameters
  - Number of thermoelectric elements is two
  - Set temperature for water chiller is determined to be +10 ℃



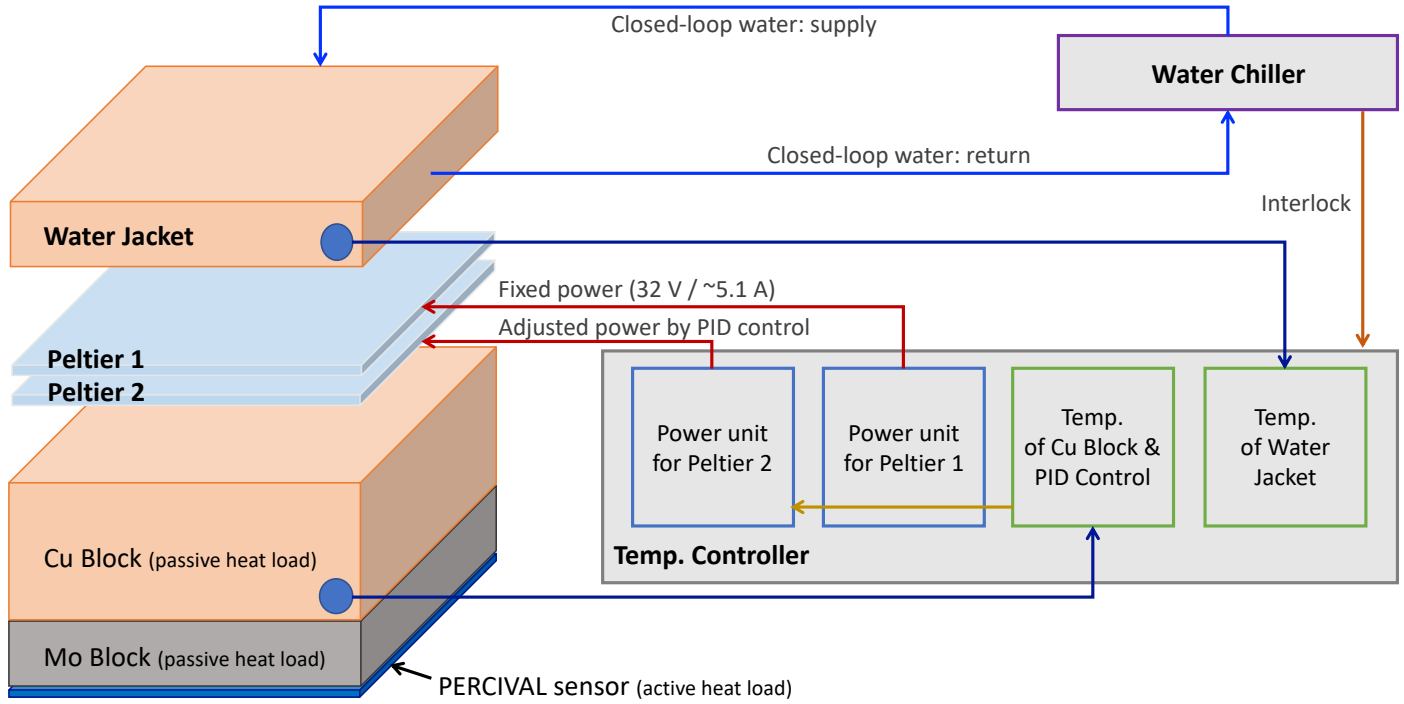
[Dummy test block with original water jacket]



[Dummy test block with new water jacket]

Configuration of Thermoelectric Cooling System and Result

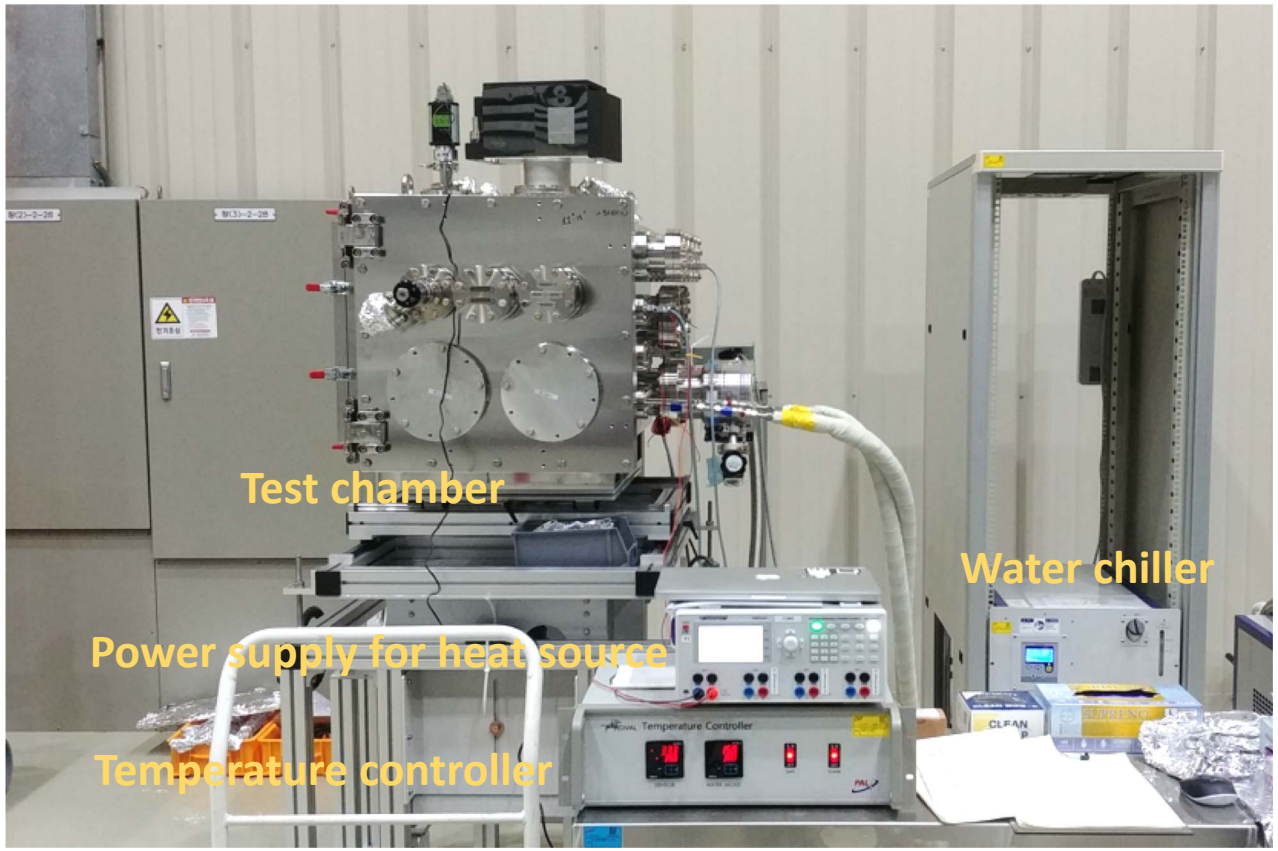
- The cooling system consists of two thermoelectric elements, water jacket, temperature controller and chiller
- The set temperature can be achieved by adjusting power to the second element with PID control

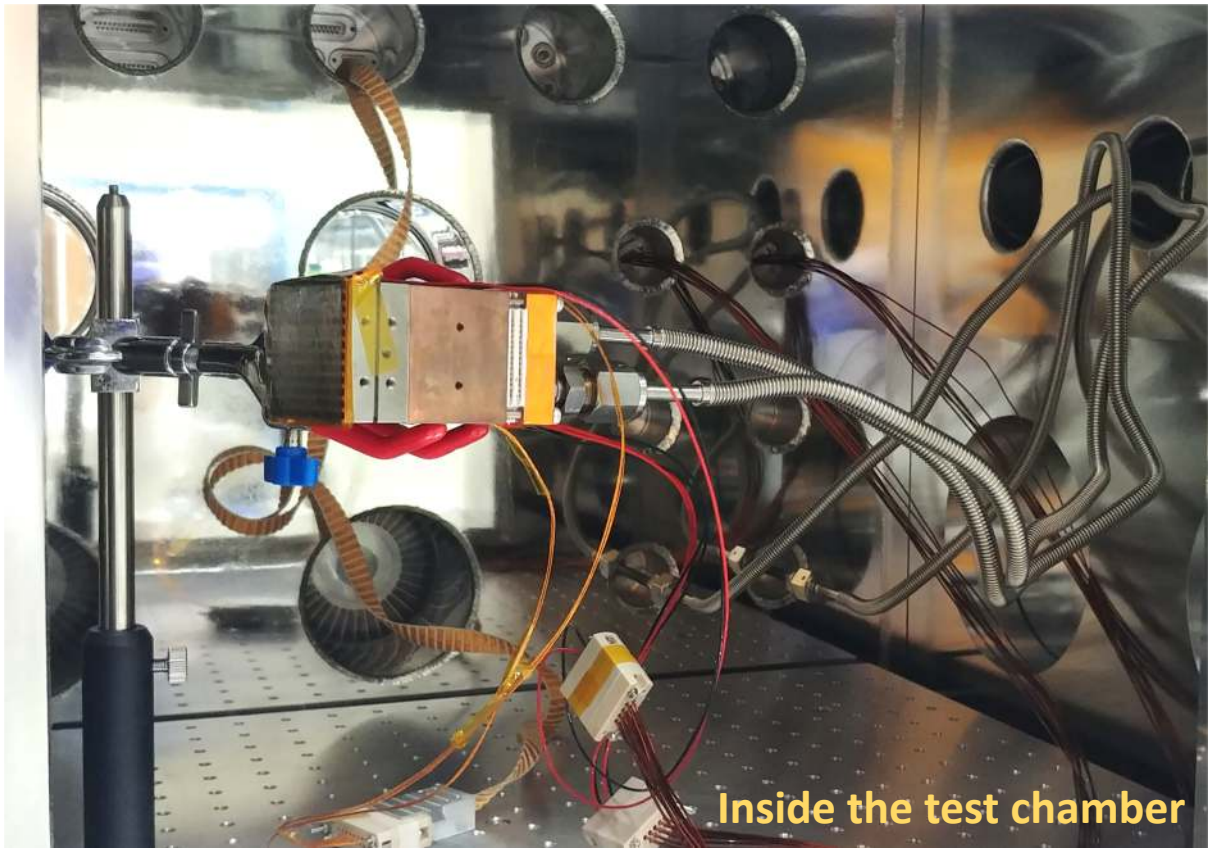


Set temperature for feedback : -35 ℃			
Heater power	Time after Peltier ON [min]	Temperature [℃]	
		Water jacket	Cu block
0 W	4	+16.4	-14.5
	6	+16.1	-22.4
	8	+16.0	-30.2
	10	+15.6	-35.1
13 W	12	+15.8	-35.0
	14	+15.7	-35.0
14 W	16	+15.8	-35.0
	18	+15.8	-35.0
	20	+15.8	-35.0
15 W	22	+15.8	-34.8
	24	+15.8	-34.9
	26	+15.8	-35.0
	28	+15.8	-35.0

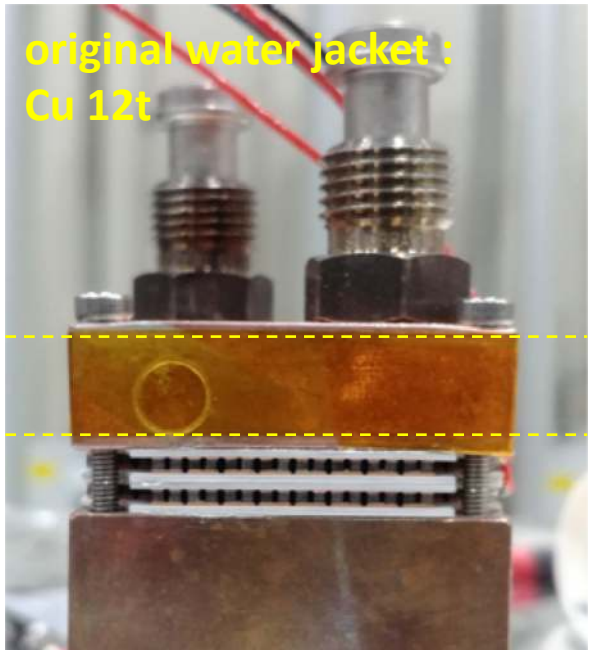
BACKUP SLIDES

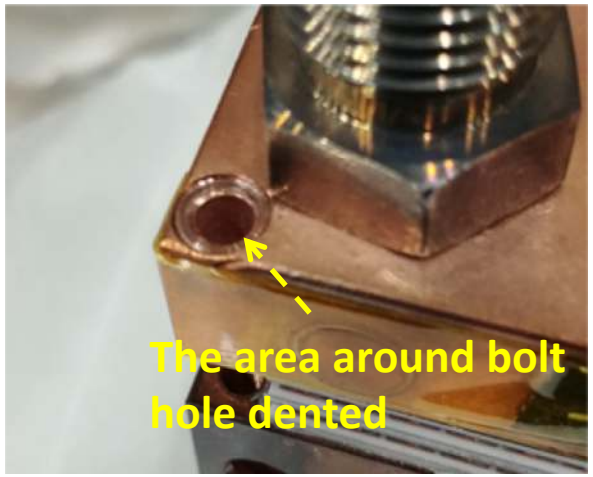
Test Setup


Test chamber
Water chiller
Power supply for heat source
Temperature controller


Inside the test chamber

New Water Jacket





- Water jacket structure simulated by using **ANSYS** :
  22 kgf·cm torque applied to the bolts → Deformation checked
- When Cu thickness increased
  → The maximum value of the deformation is decreased, but the effect is not big
- **When stainless steel cover used together Cu**
  → The cover helps to decrease the maximum deformation value
  → However, the thickness of the cover does not matter much
- The stainless steel cover is more important than Cu being thicker