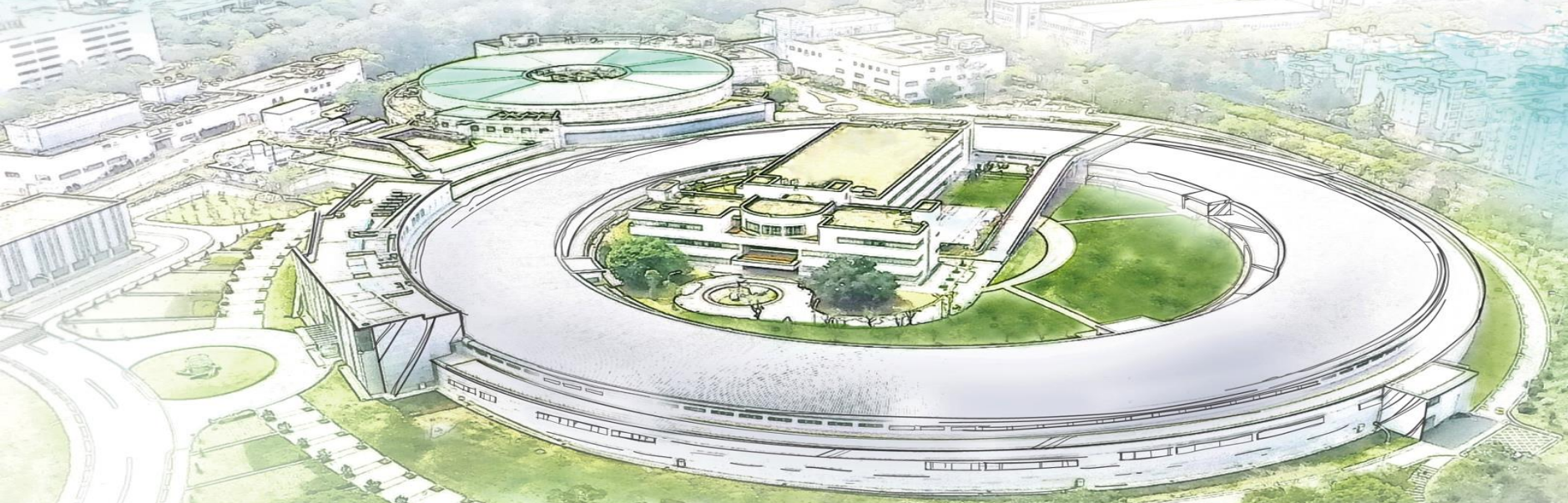
國家同步輻射研究中心
National Synchrotron Radiation Research Center

An IR Photonic Type HLS system developed at NSRRC



TSE-CHUAN TSENG / NSRRC TAIWAN

IWAA'24 OCT.9, 2024

Outline

- Introduction
- Design Concept
- Testing System Setup
- Different Sensors Testing
- Single Cell & 3 Cells IR HLS Testing
- Conclusions

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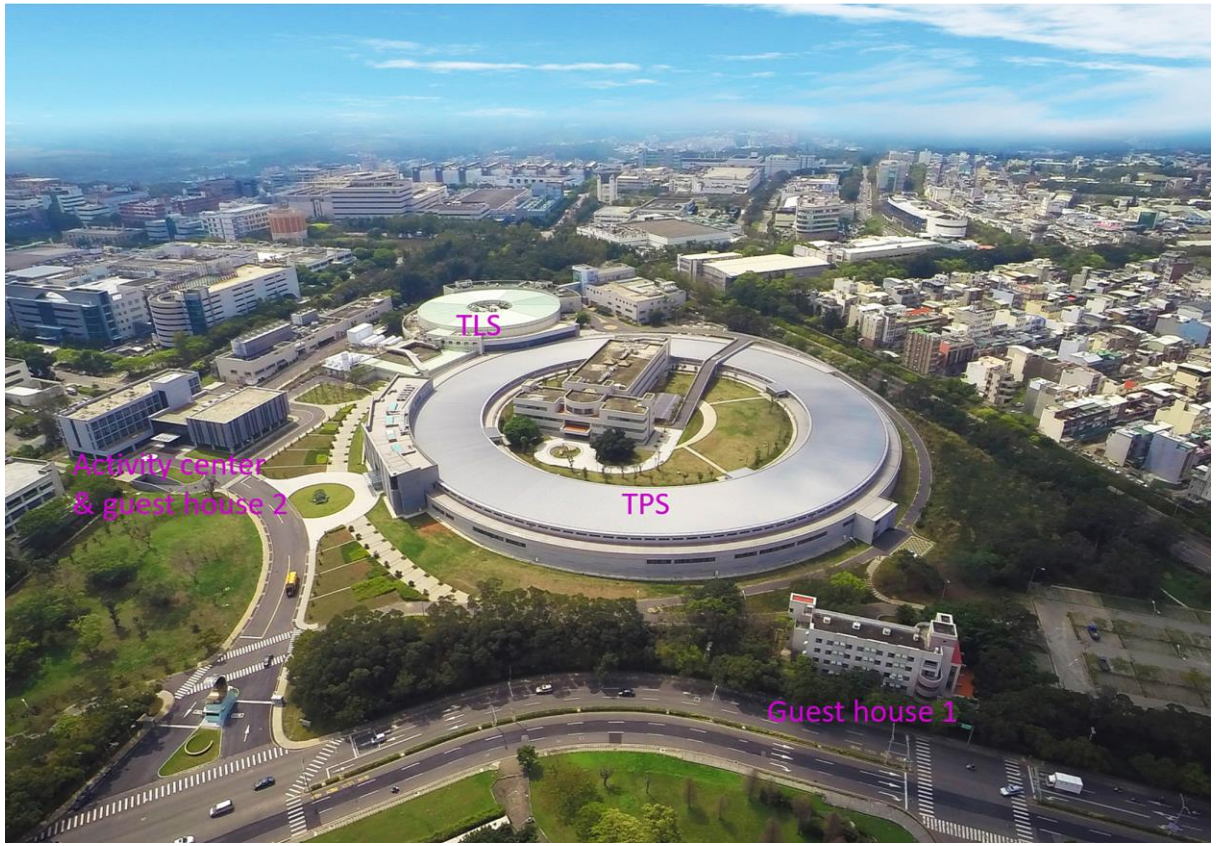
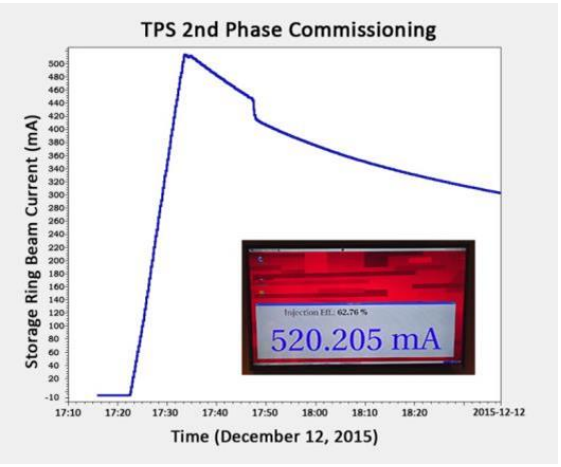
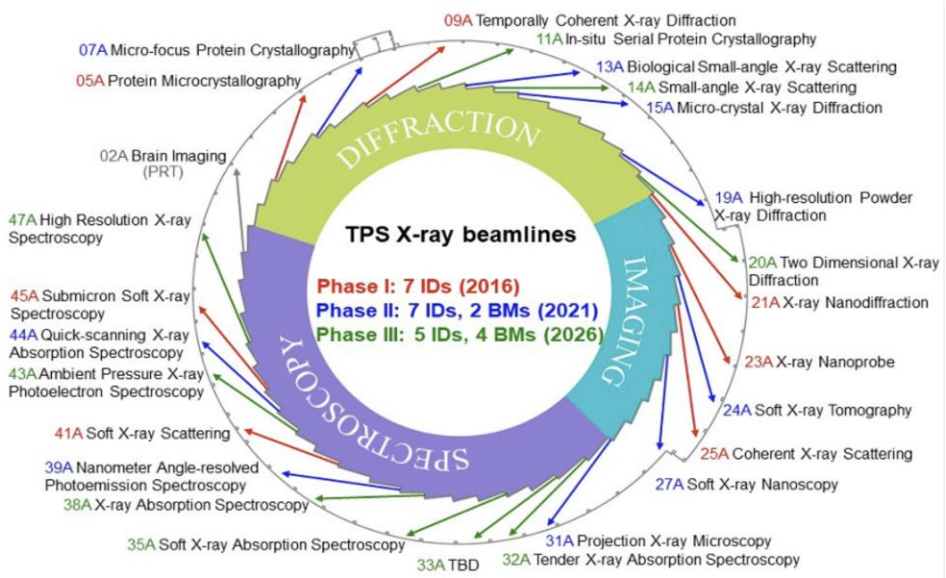
NSRRC TPS Status

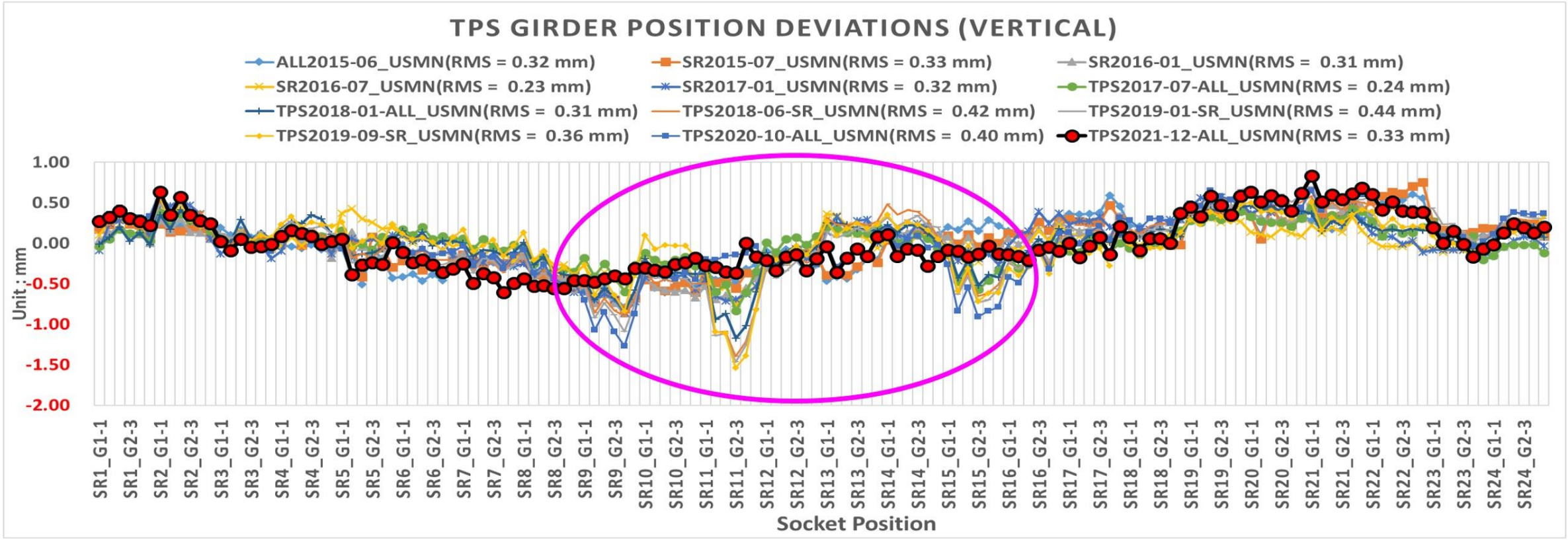






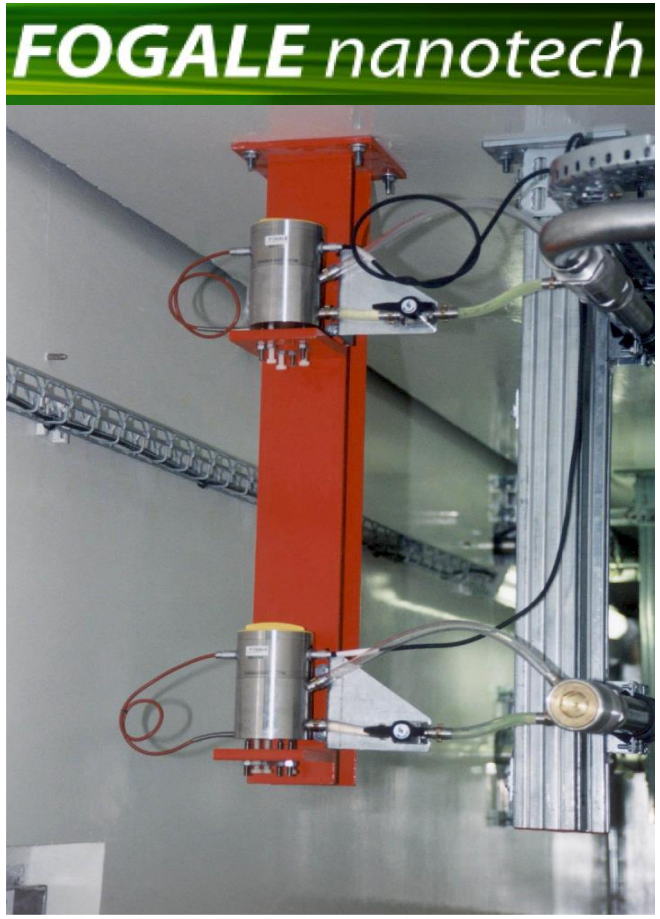
21 Beamlines open to the users now (2024)

TPS Tunnel Local Settlement



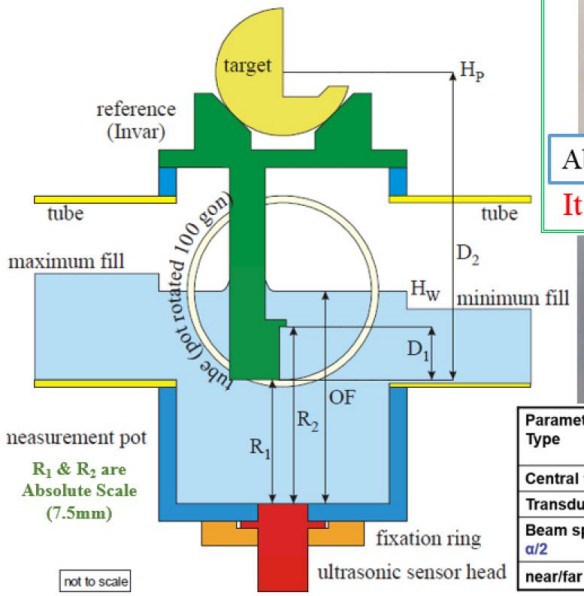
- Two locally girder system adjustments were performed in 2020 & 2021
- Some levelling sensors to keep continuously monitoring are demanded.
- There is no any settlement data in the beamline area since no survey schedule after installation.

HLS Adapted In Other Facility



The main technical parameters of ULSE

- No Drift (Self Calibrating)
- Displacement range : 5 mm (±2.5 mm)
- Precision : < 0.1 µm
- Resolution : < 0.2 µm
- Accuracy : (±5 mm range) < 3 µm
- Sampling rate : up to 10 Hz.



Material : Invar

Absolute Scale : D_1 = 7.5mm

It used for self-calibrating

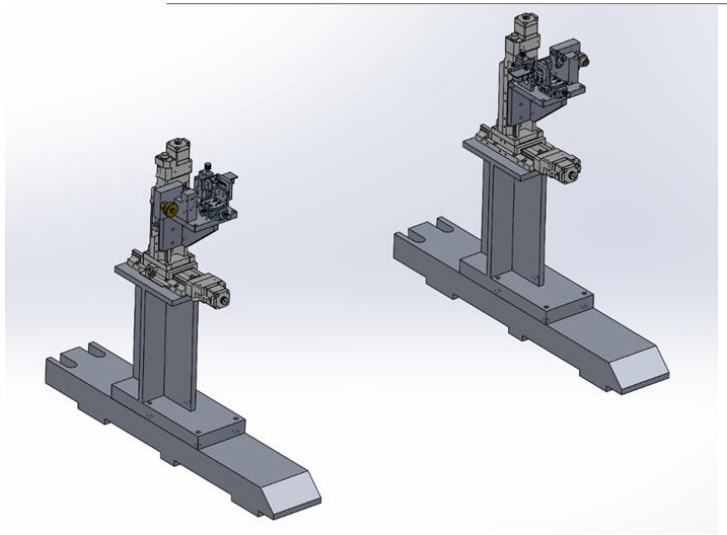
Transducer

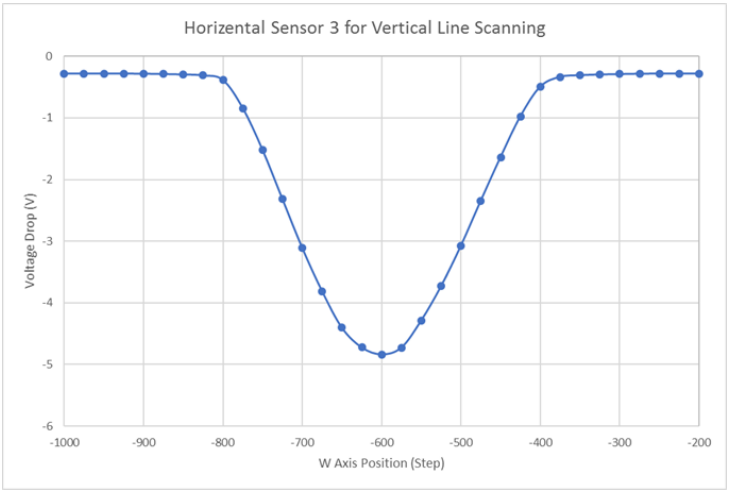
Parameter \ Transducer Type	Units	H10 KB 3T General Electric (Krautkraemer)
Central frequency f	MHz	7.0
Transducer diameter D	mm	5.0
Beam spread angle α/2	Degree (rad)	1.263 (0.022)
near/far distance N	mm	29.2

BINP Ultra sonic (ULS) sensor.

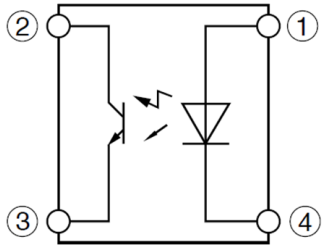
No budget for high resolution system, 10um seems enough

Concept From The Vibration Wire Alignment System





Top view



① Anode
② Collector
③ Emitter
④ Cathode

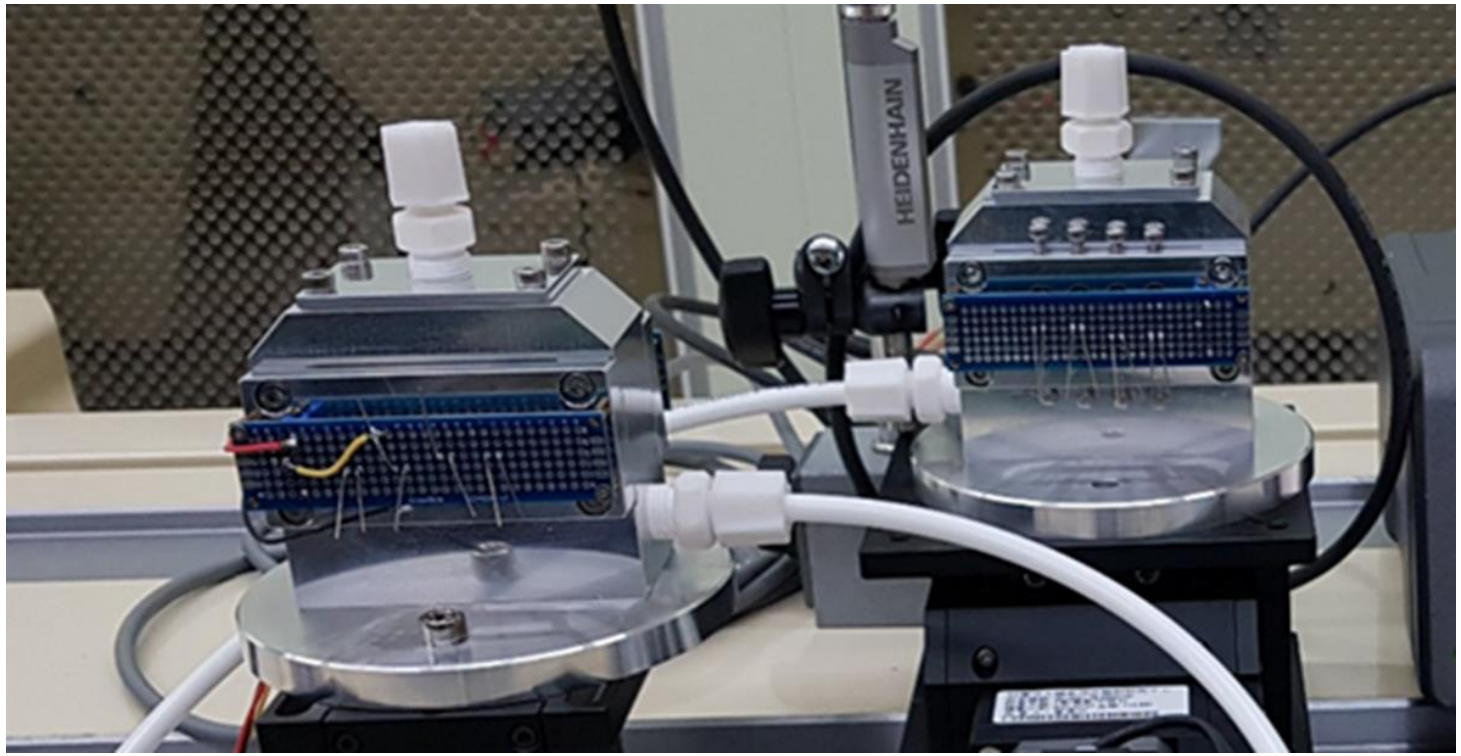
SHARP GP1S094HCZ0F

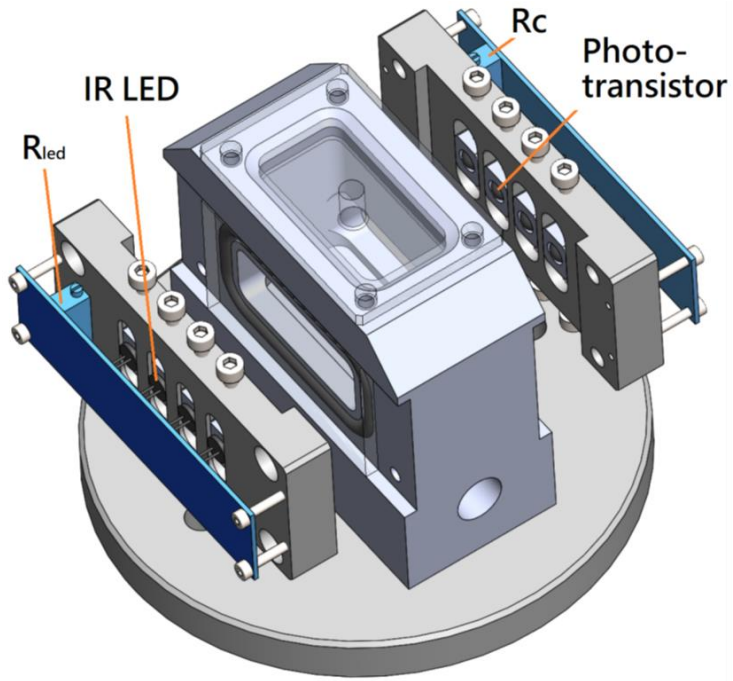
Everlight PT334-6B
940nm phototransistor

Vishay-TSAL6200
940nm IR led

- The photointerrupter adapted to detect the variation of the wire is quite sensitive, reliable, simple and also cheap.
- To place one pair of isolated IR led & phototransistor aside of the water gap to transform the light intensity variation interfered by water level deviation to voltage variation.

IR Photonic HLS Prototype Constructing

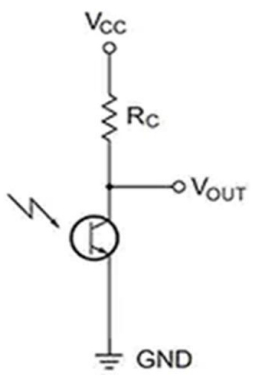




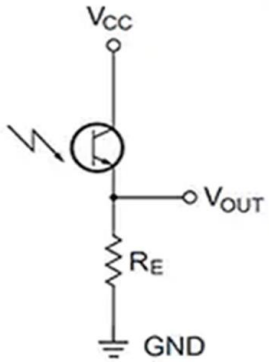
- Three pairs of led & phototransistor in one cell seems interfere each
- Two HLS bodies connected with thin pipe seems not easy to maintain steady

Poster in IWAA 2022

Phototransistor Circuit Mode & Testing

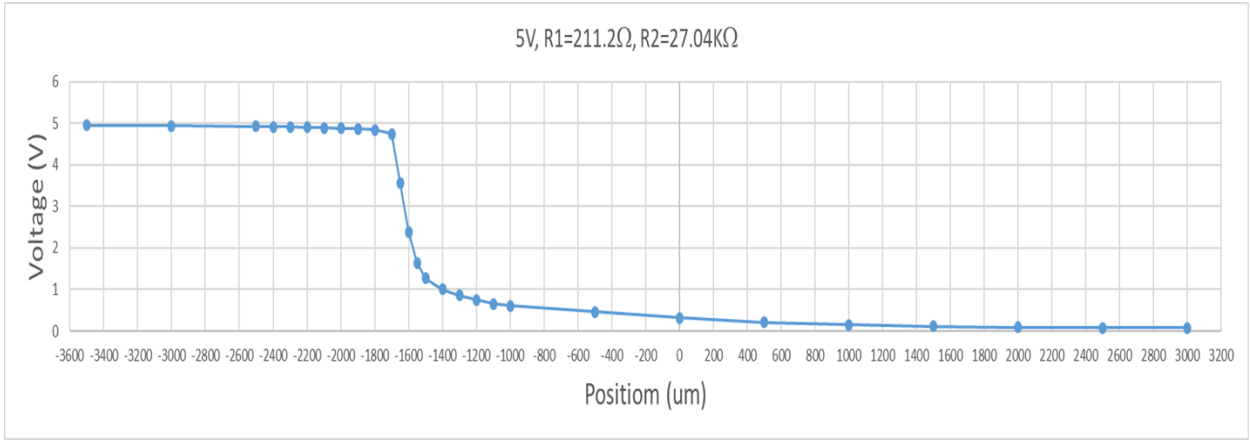


Common Emitter

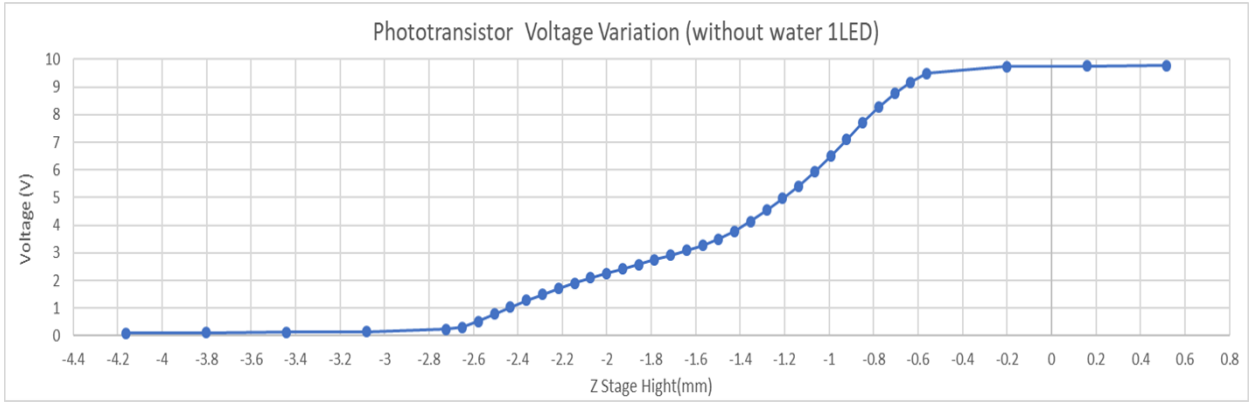


Common Collector

- At common collector mode, it acts as a switch and the sensing range is narrow but high resolution.
- At common emitter mode, it acts as an amplifier and the sensing range is wider but lower resolution according to the applied voltage.
- Since the AD module can only read voltage less than 10V voltage, for 3mm levelling rage, 2~3 mV indicating 1um deviation is still detectable and also meet the requirement for 10um resolution.

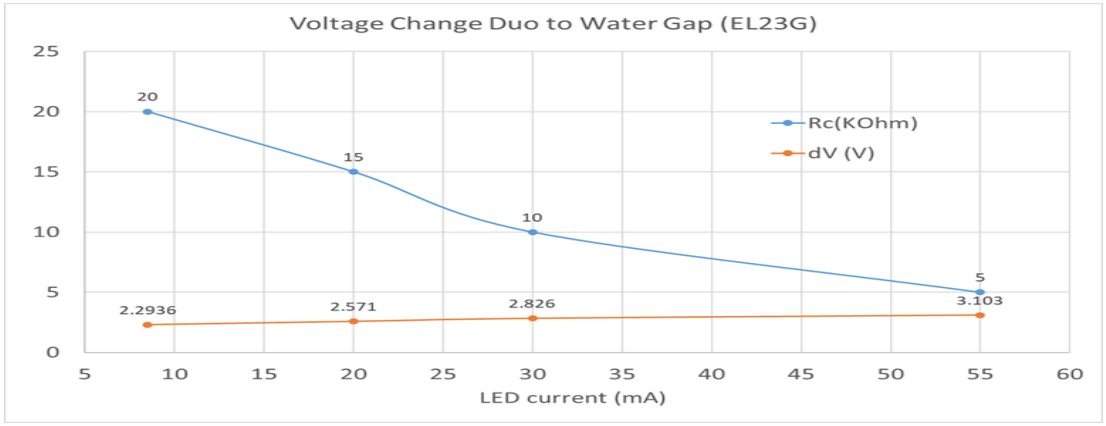


Phototransistor at common collector mode(narrow range)

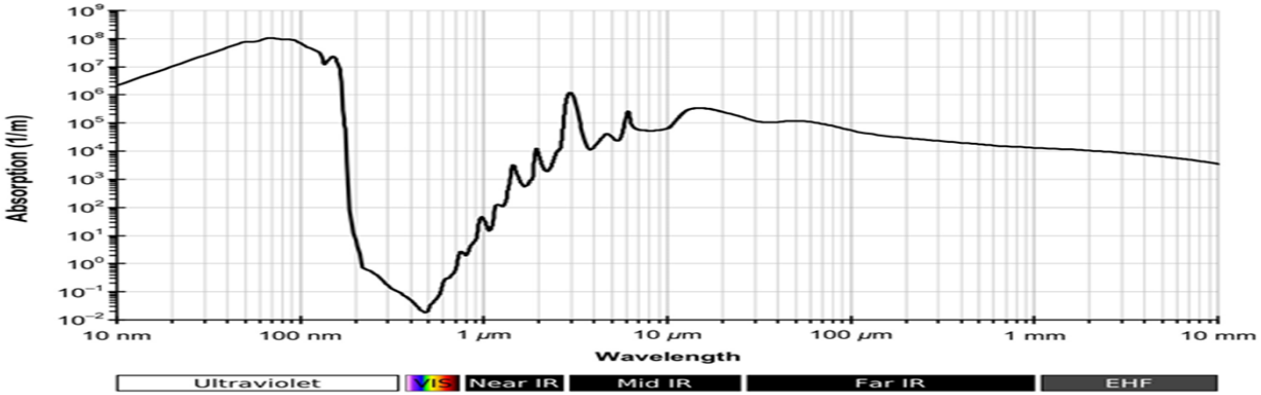


Phototransistor at common emitter mode

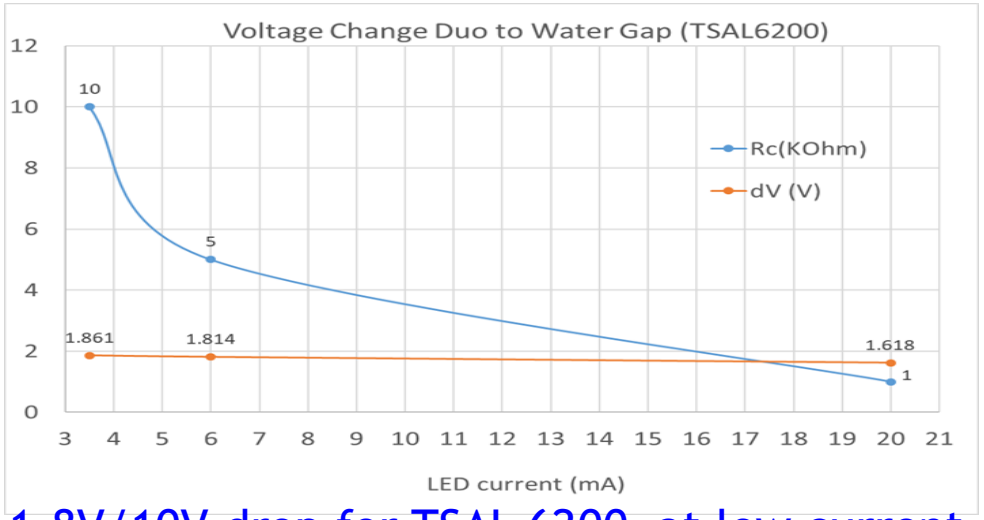
Absorption Testing With Water



3V/10V drop for EL32G with 20mm water gap



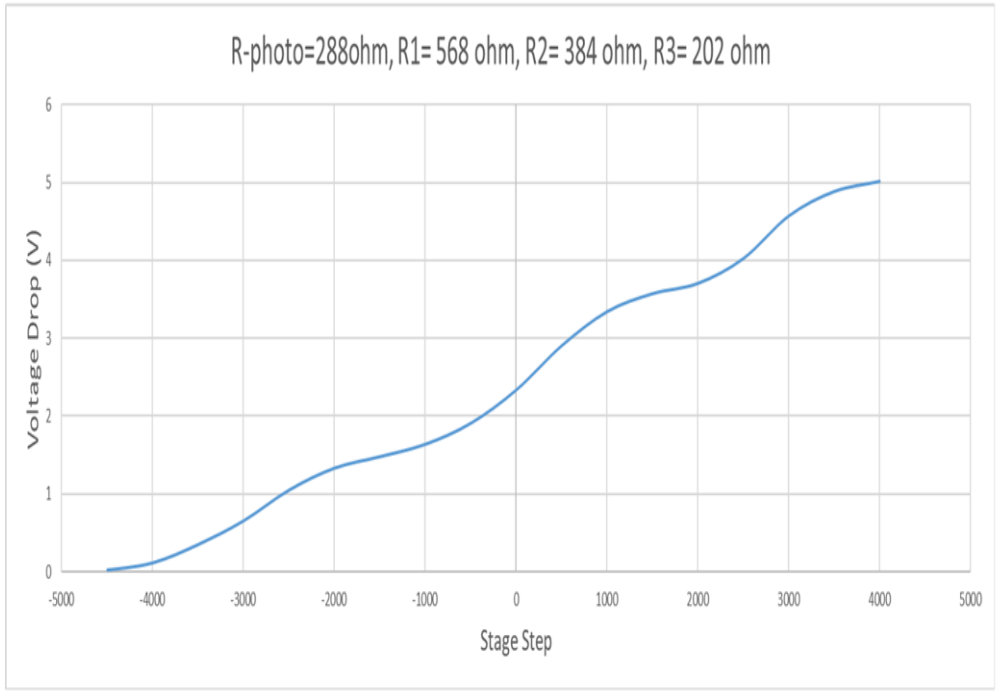
Absorption spectrum of liquid water
(From Wikimedia Commons)



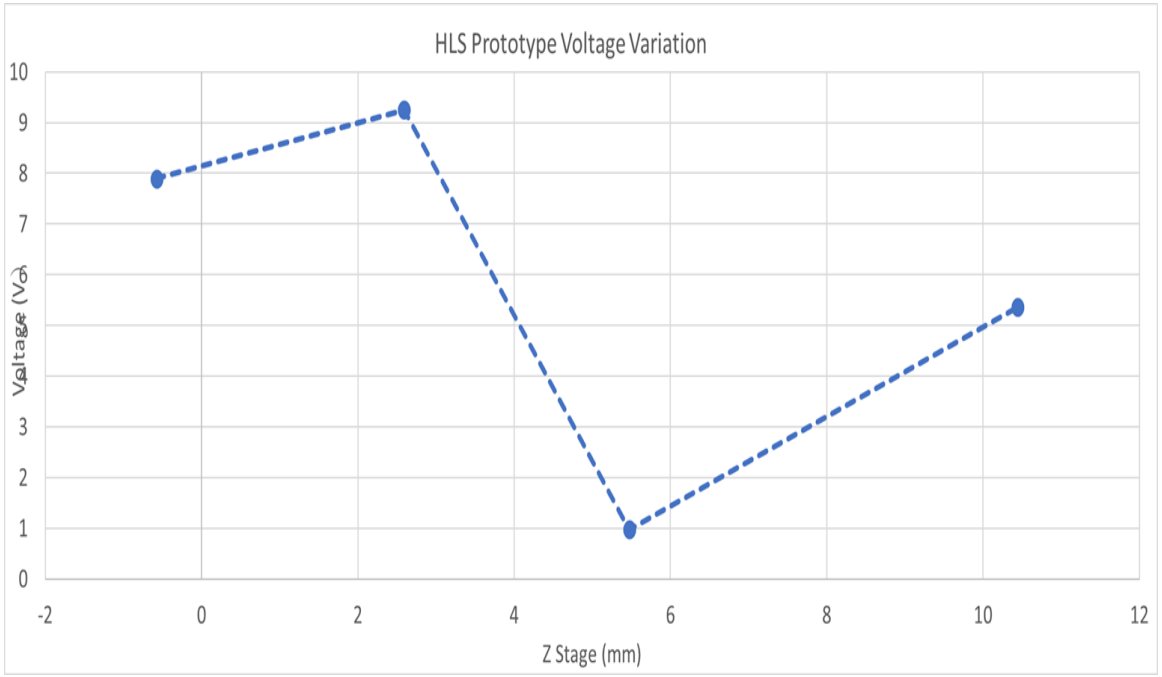
1.8V/10V drop for TSAL 6200 at low current

- The water gap will not fully block the 940nm IR light
- The voltage deviation range due to water gap change is not enough (0~10V)

IR Photonic Type HLS Prototype Testing



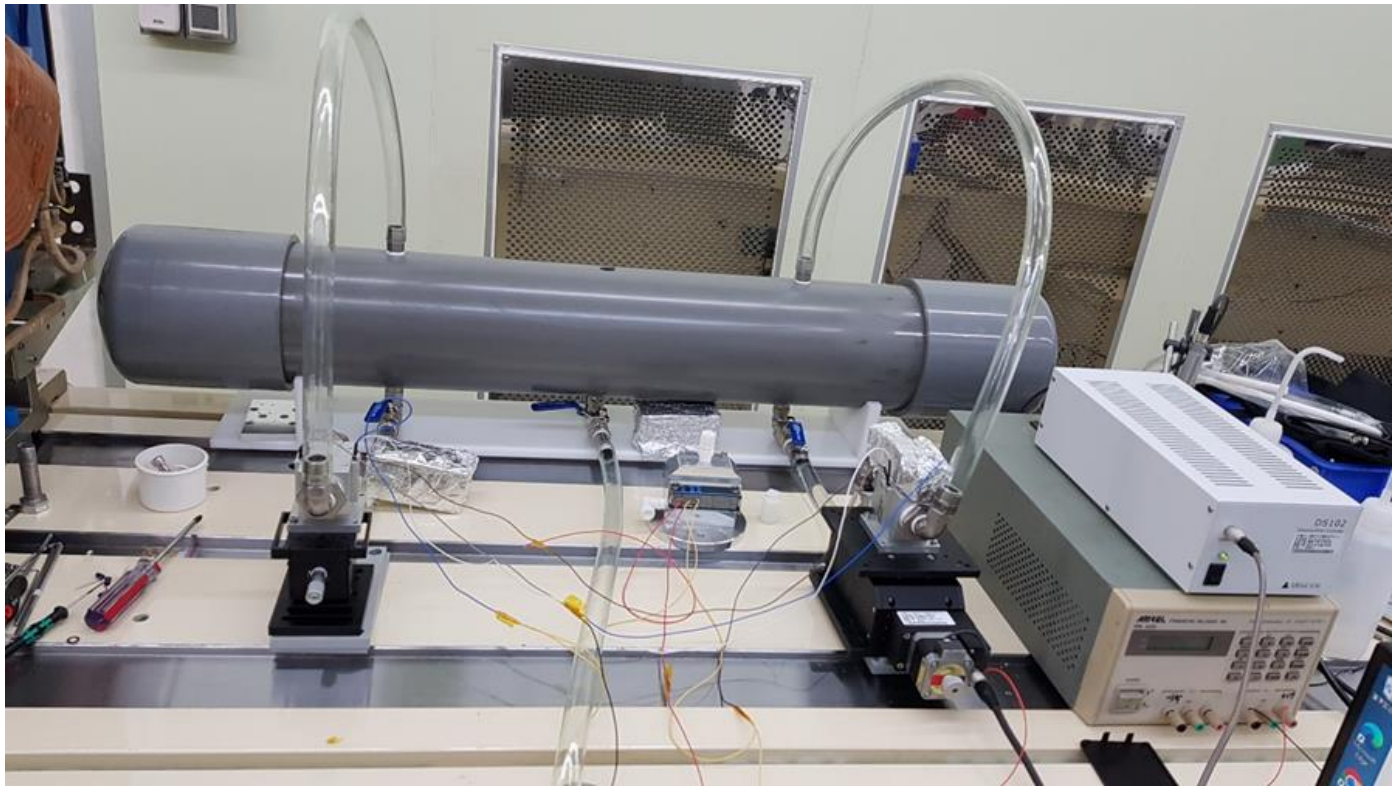
Combination of 3 phototransistors at CE mode

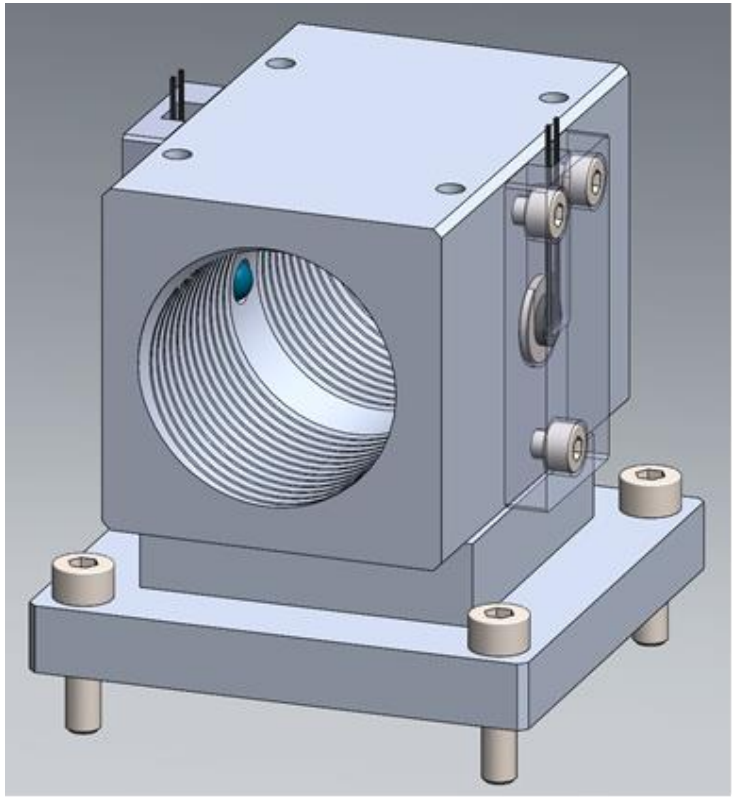


Voltage drop about 8V/10V as water surface around the phototransistor (EL23G)

The viscosity of the water restricts the short time repeatability and demands more lasting tests

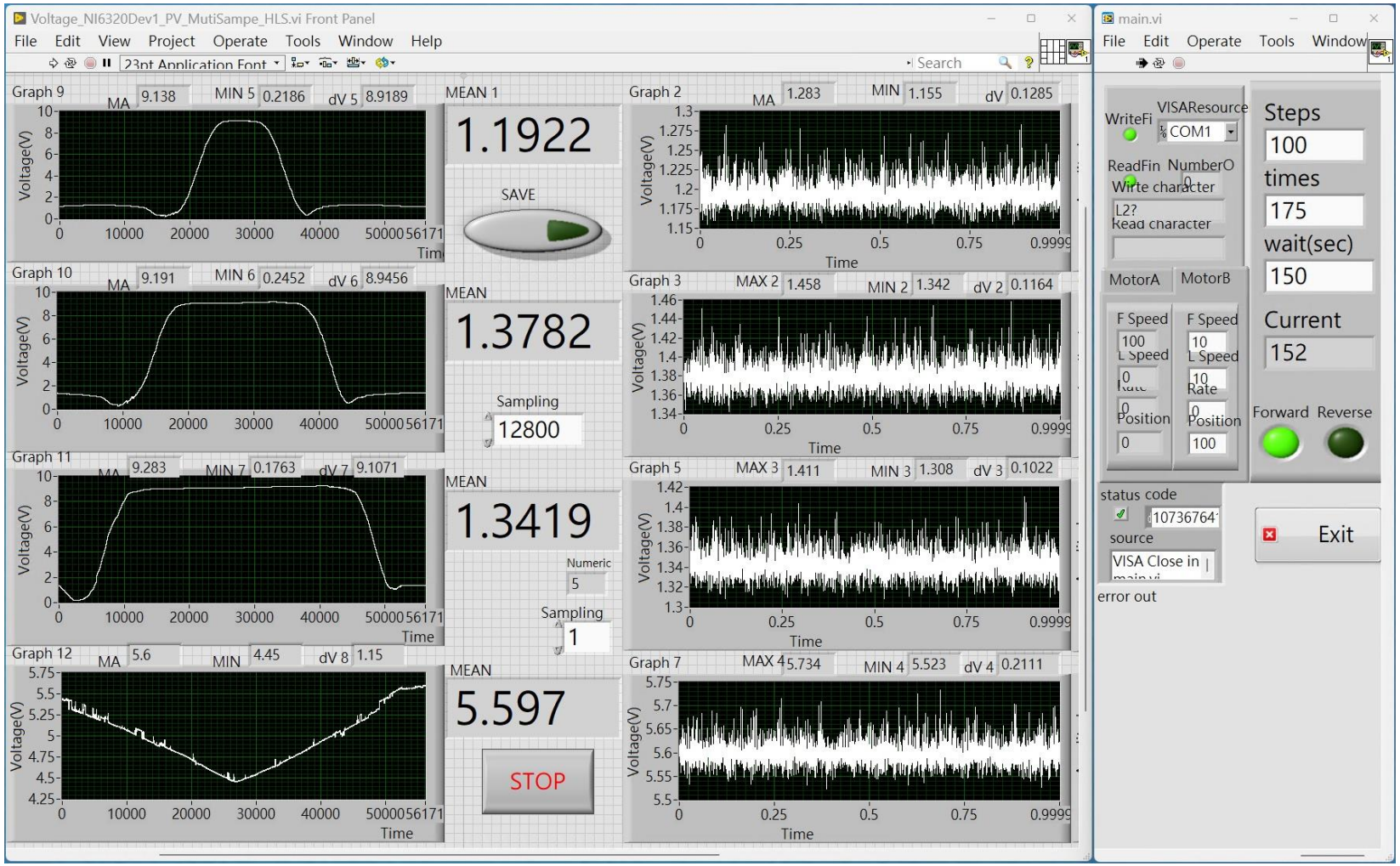
Testing System Setup



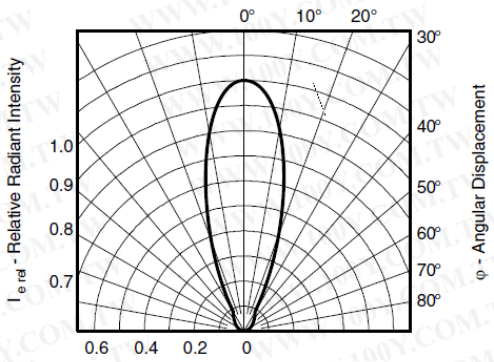


- A plastic water pipe tank was setup as a buffer tank to maintain stability.
- Two Simple HLS Bodies with a single pair of led & phototransistor for testing.
- One HLS moving with elevating stage, the other one to indicate the deviation of the buffer tank as a compensation.

Labview program for signals collecting & Stage control

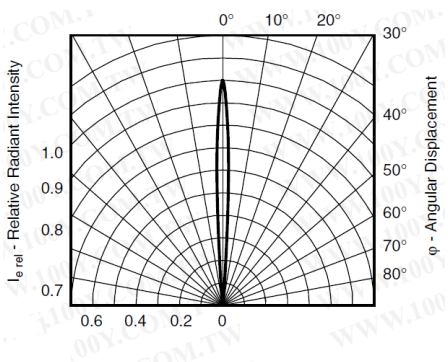


IR LED & Phototransistor Tested



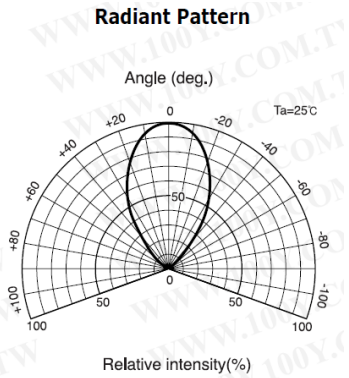
Relative Radiant Intensity vs. Angular Displacement

VISHAY-TSAL6200

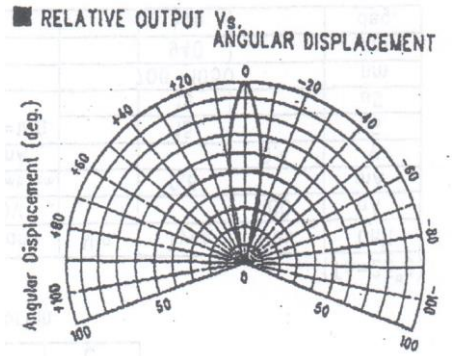


Relative Radiant Intensity vs. Angular Displacement

VISHAY-VSLY5940

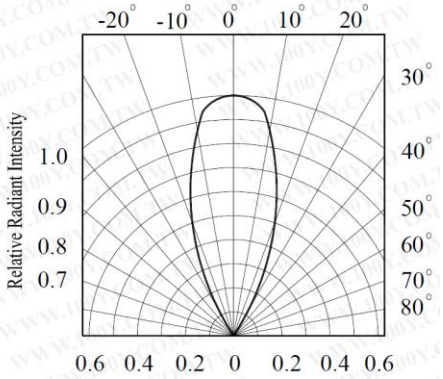


KODENSHI EL-23G



KODENSHI-ST-2L2B

Relative Radiant Intensity vs. Angular Displacement

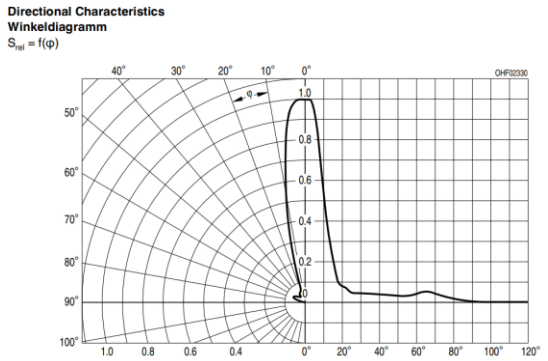


EVERLIGHT-IR333C

5. Electro-optical Characteristics (Ta=25°C)

Parameter	Symbol	Testing Conditions	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	I_F=100mA		1.4	1.7	V
Reverse Current	I_R	V_R=5V			10	μA
Radiant Intensity	Ie	I_F=100mA	30	50		mW/sr
Terminal Capacitance	C_t	f=1MHz		20		pF
Half Power Beam Angle	Δθ			±30		deg.
Peak Emission Wavelength	λp	I_F=50mA		940		nm
Spectral Bandwidth at 50%	Δλ	I_F=50mA		50		nm

KODENSHI EL-1L7

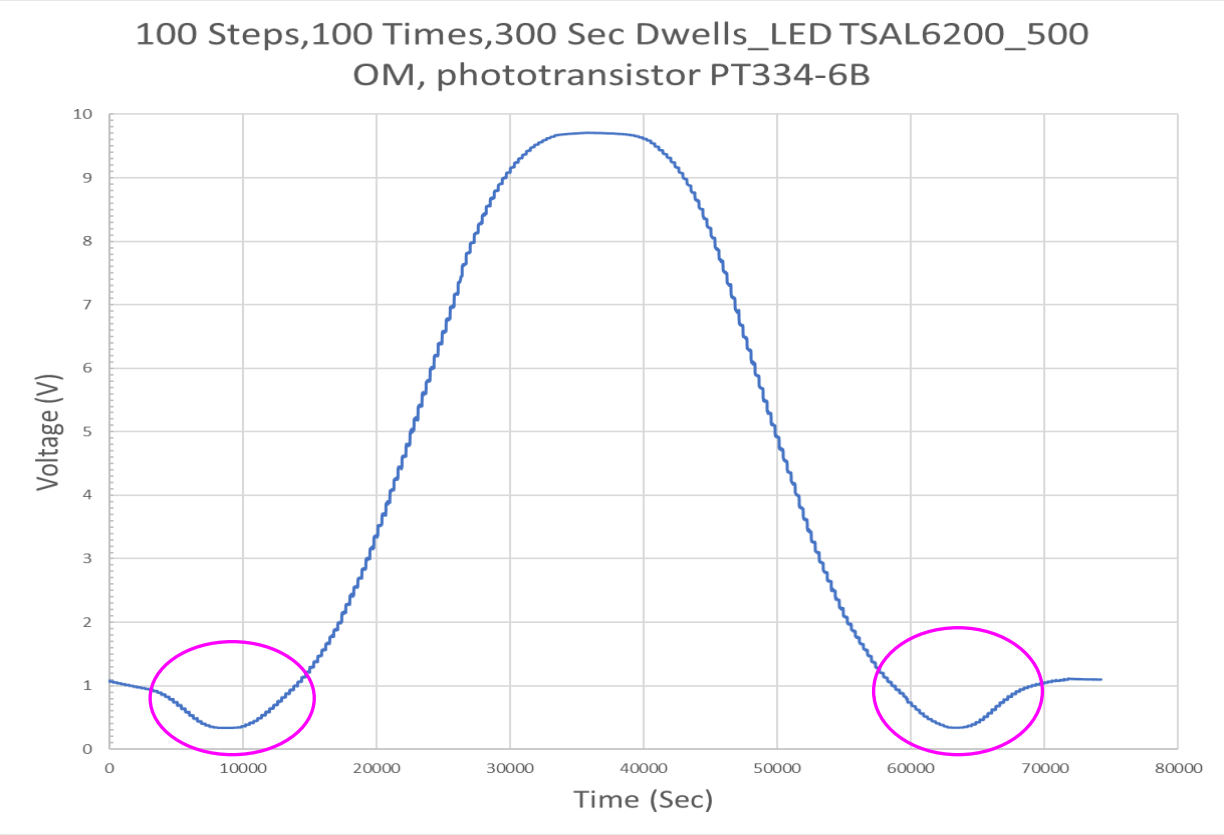


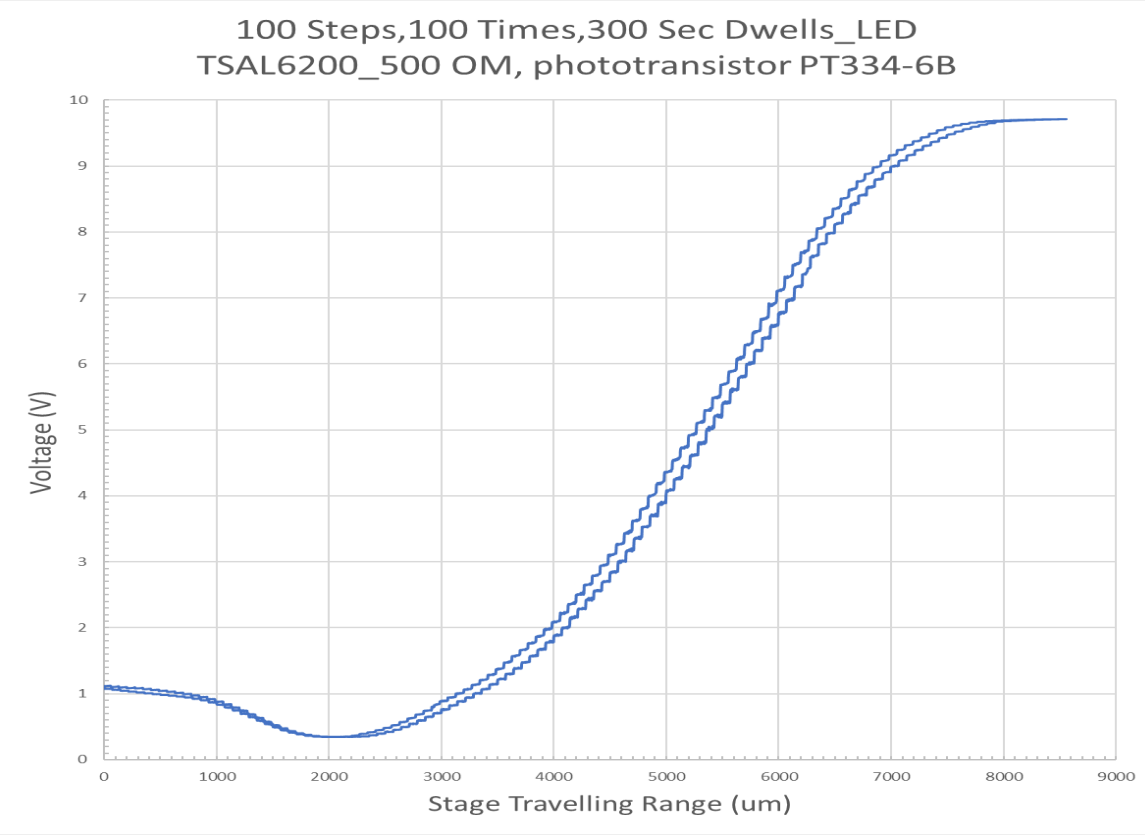
OSRAM-SFH313FA-2

TSAL6200 & IR333C with PT334-6B are better

No receiving angle data
Everlight PT334-6B

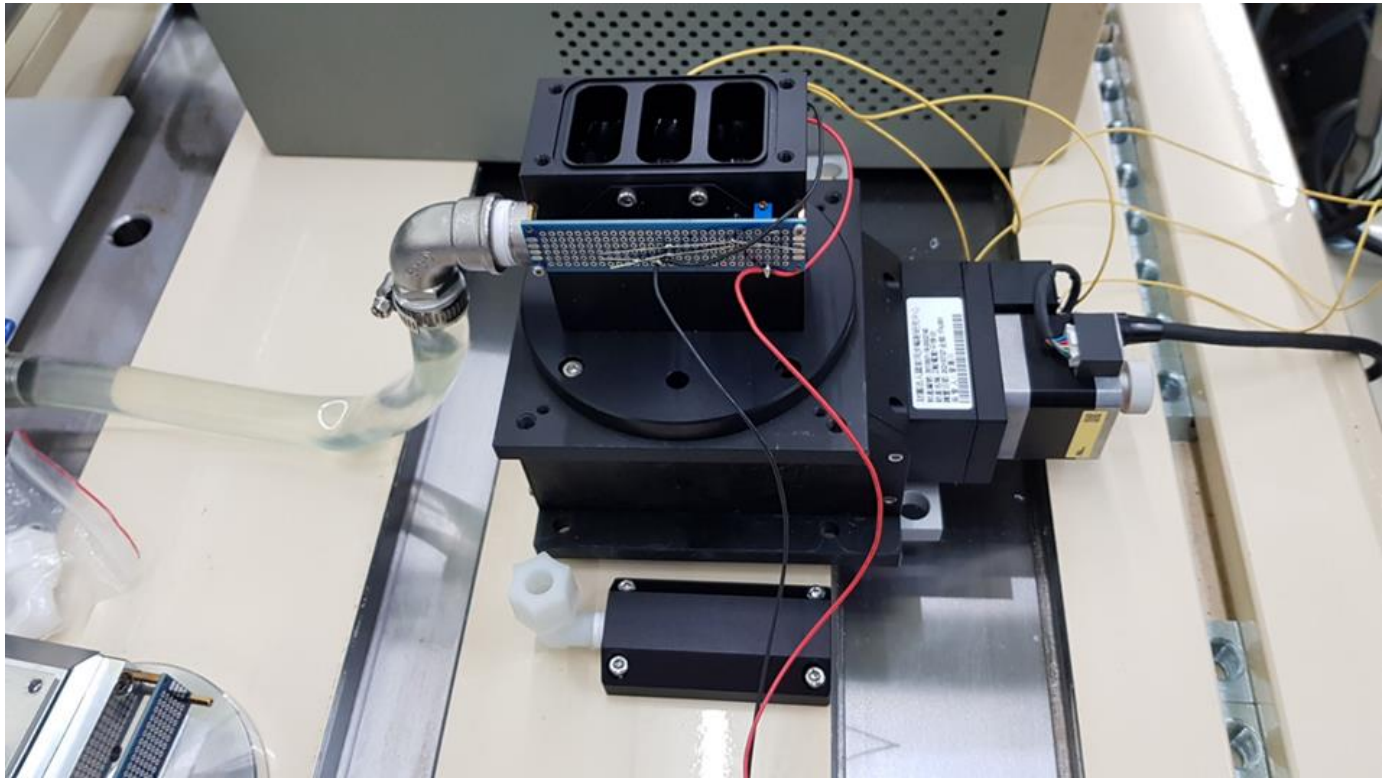
Single Cell HLS Testing

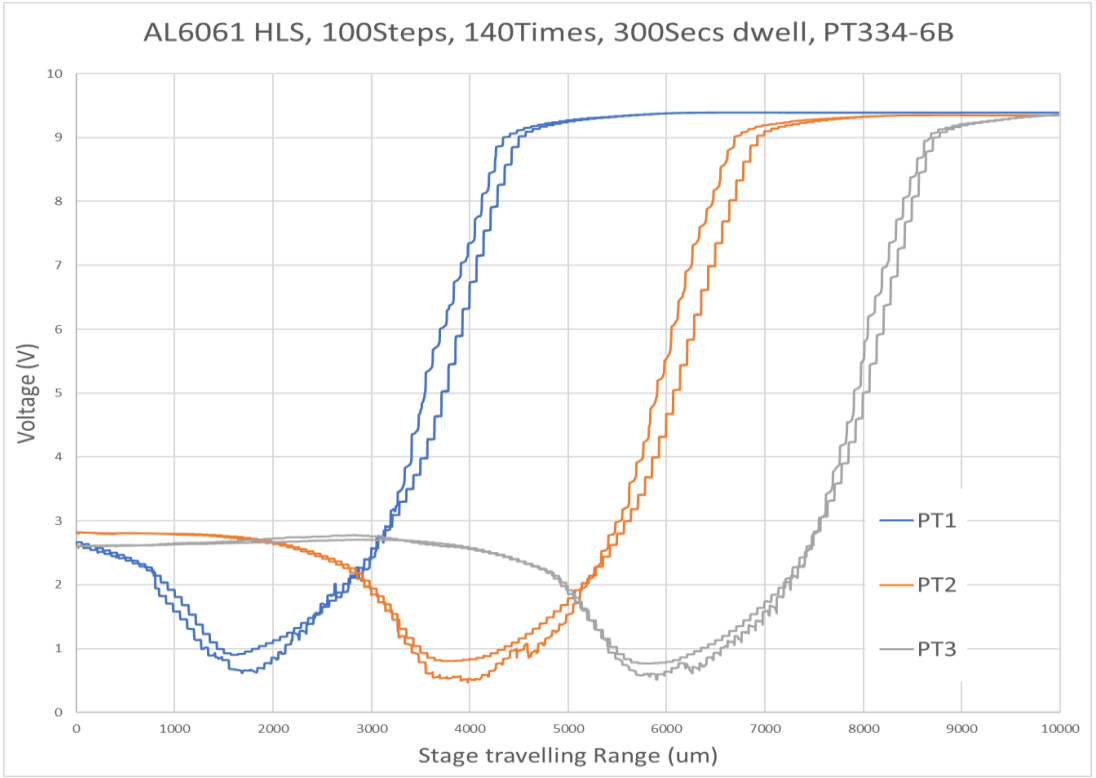




- A most blocking situation as the water surface approach the top of led and phototransistor
- The sensing range is better than 5mm
- A hysteresis phenomenon observed

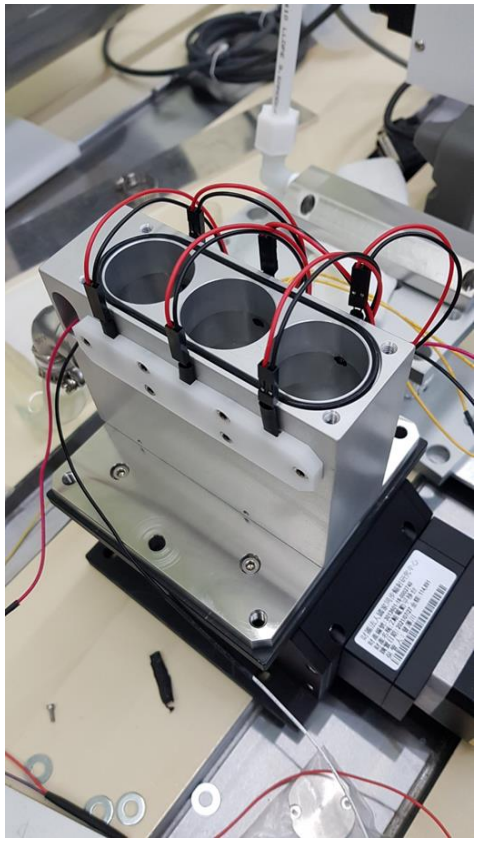
Three Racetrack Cell HLS Testing



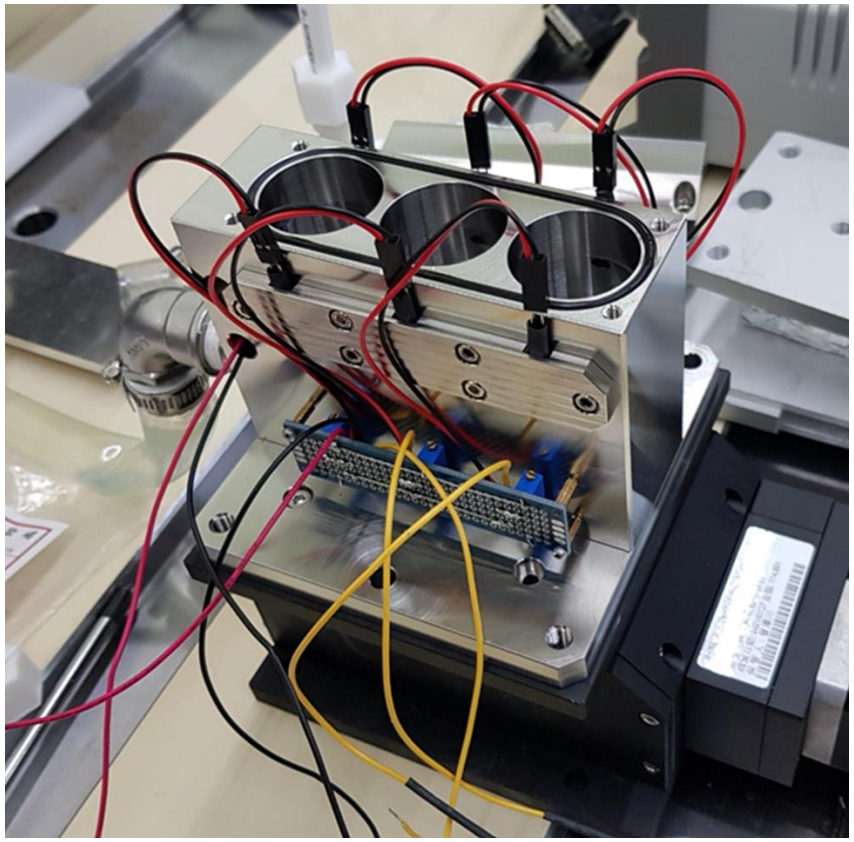


- Combined with three cells can extend the rage to 10mm (each pair 3mm apart in elevation)
- The sensing range is Almost less than 3mm due to the racetrack shape cell (?)
- A hysteresis phenomenon observed

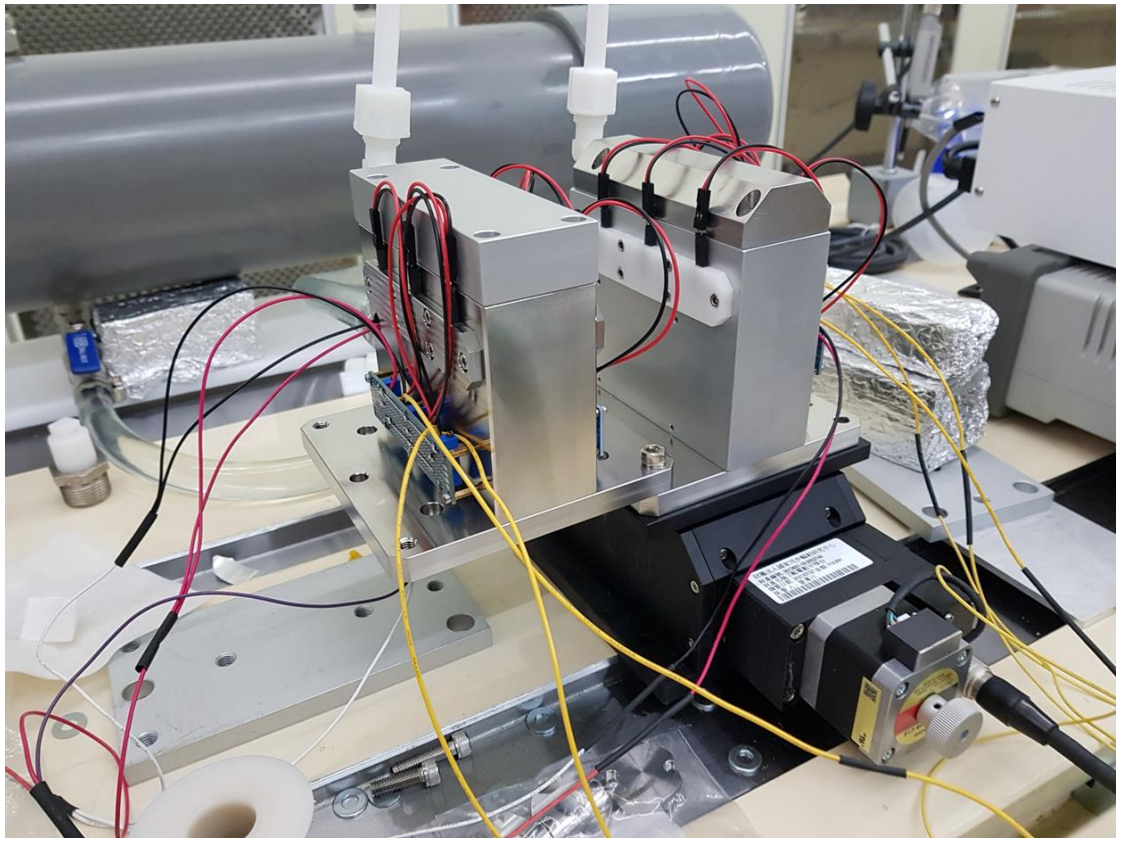
Three Circle Cell HLS Testing



Anodized AL5086 HLS

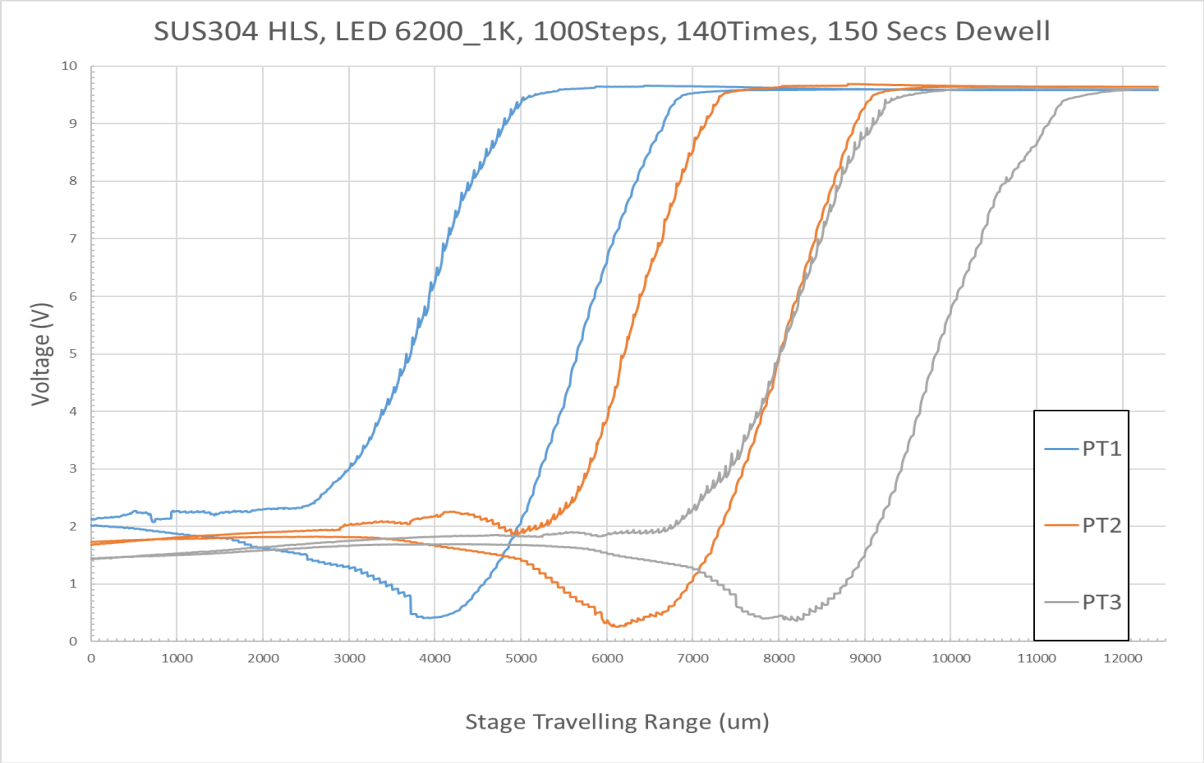


SUS304 HLS

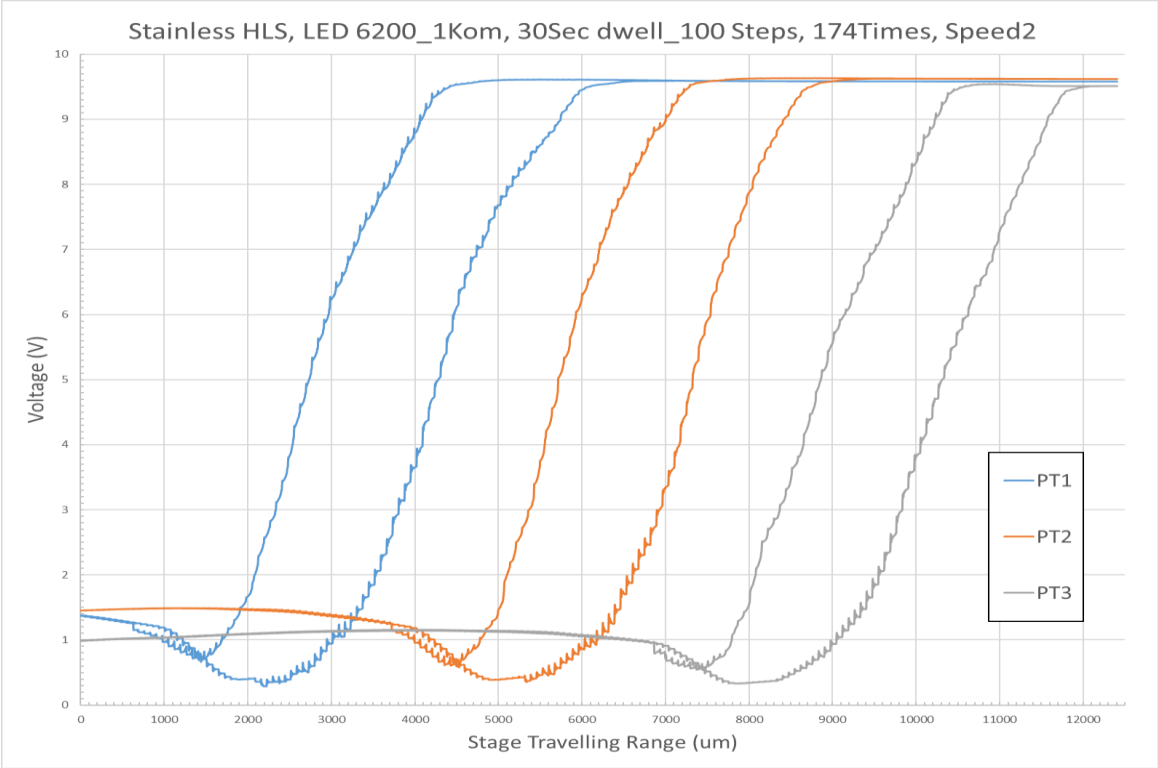


Two HLS combined testing

Three Circle Cell Stainless HLS Testing



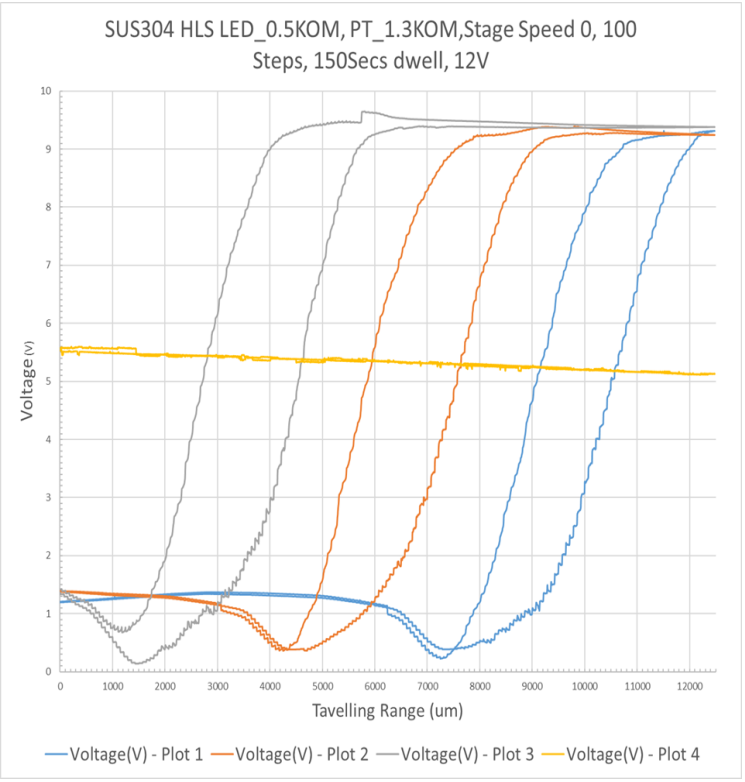
Finely machined inside surface of cells

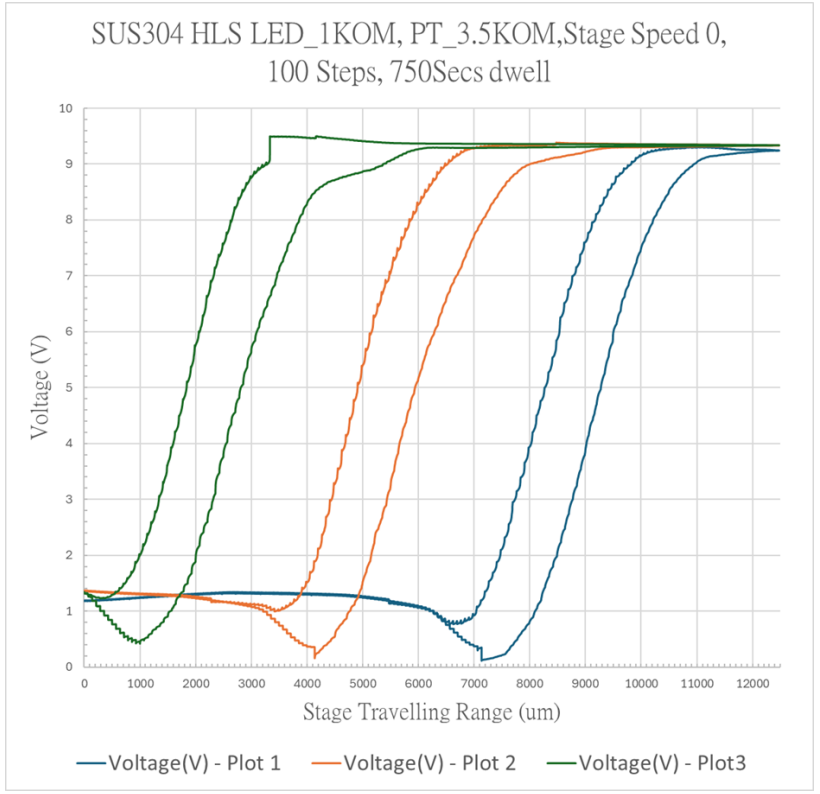


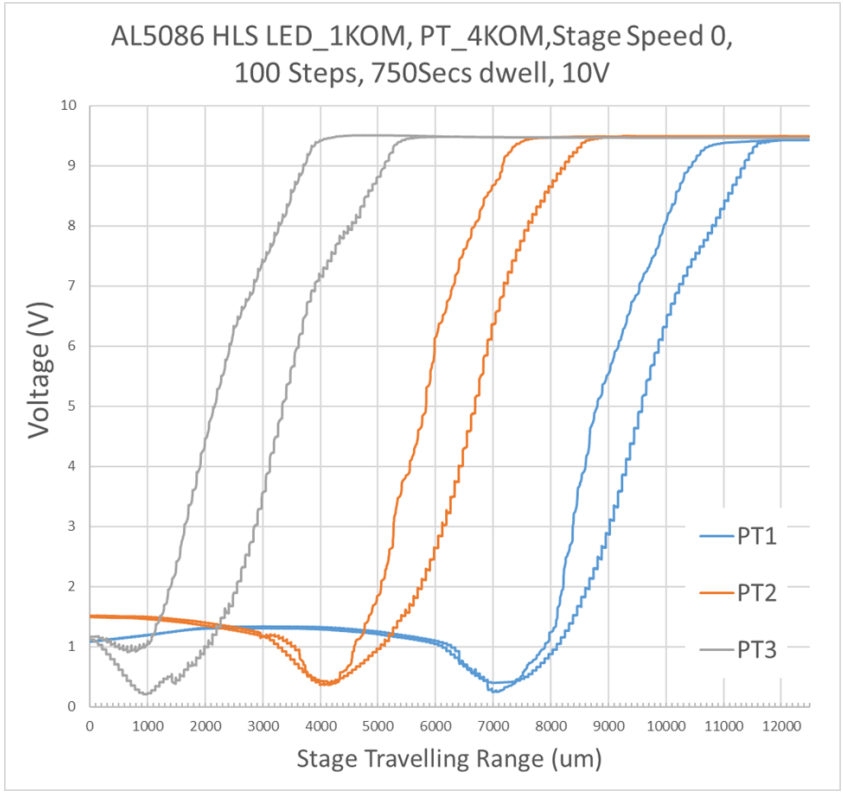
Cell inside surface sand blasted

- Sensing range of finely machined HLS is almost less than 3mm and after sand blasted is better
- The hysteresis phenomenon is worse with stainless body HLS

AL5086 & SUS304 HLS combined test

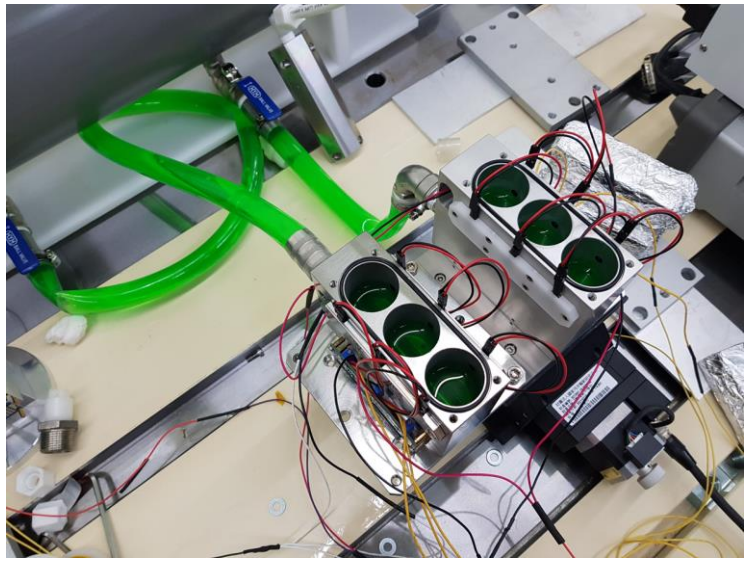




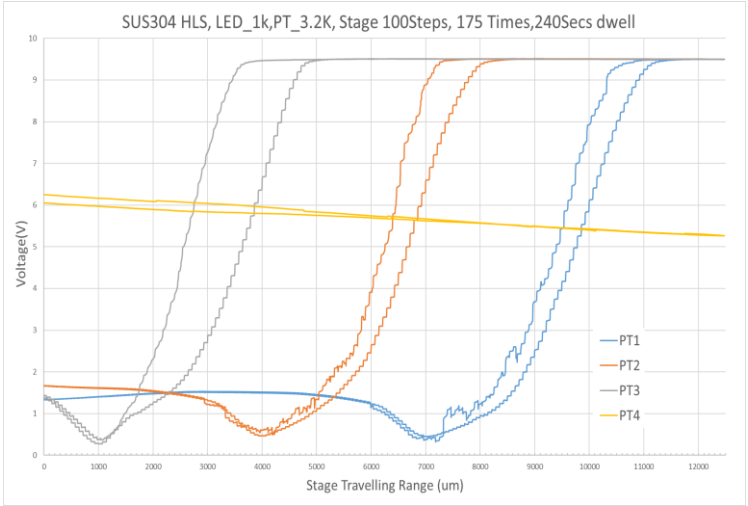


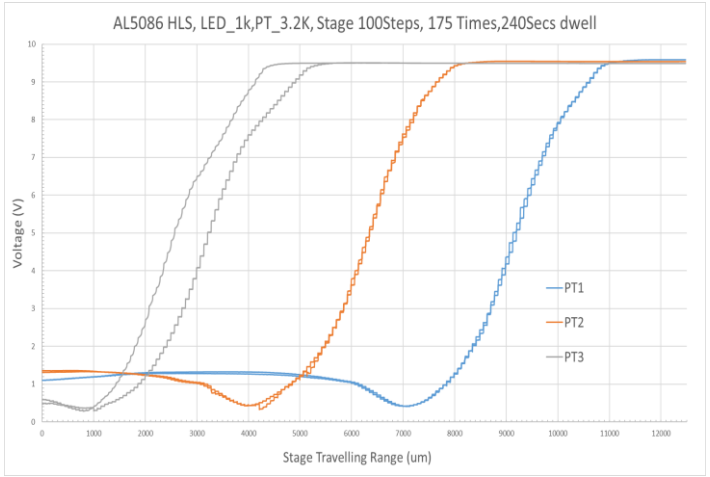
- Sensing range of both type HLS are better than 3mm
- The hysteresis phenomenon is still worse but seems to decrease with dwelling time
- The hysteresis phenomenon of anodized AL5086 HLS is worse than AL6061 HLS

AL5086 & SUS304 HLS combined test with antifreeze

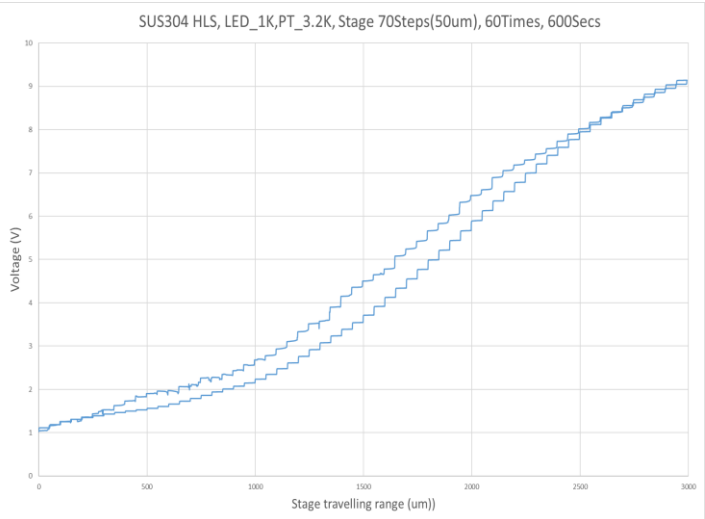


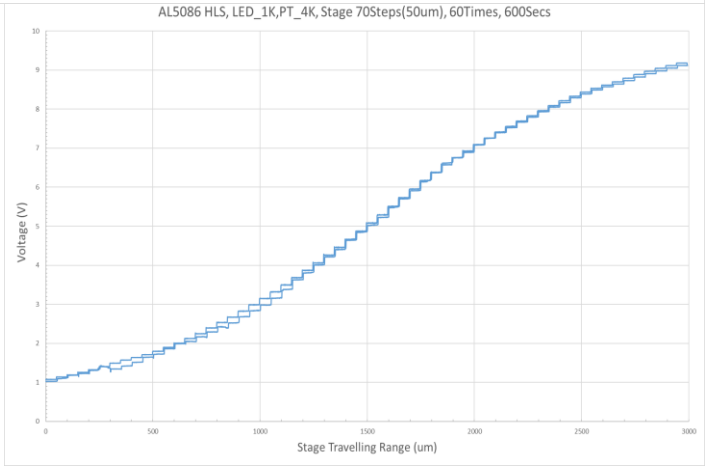
- Antifreeze added can reduce the viscosity or adhesivity of water.
- Anodized aluminum alloy HLS body has less hysteresis.
- Obvious hysteresis phenomenon of PT3 may be due to the large travelling of stage or interference between two HLS, still need to investigate.





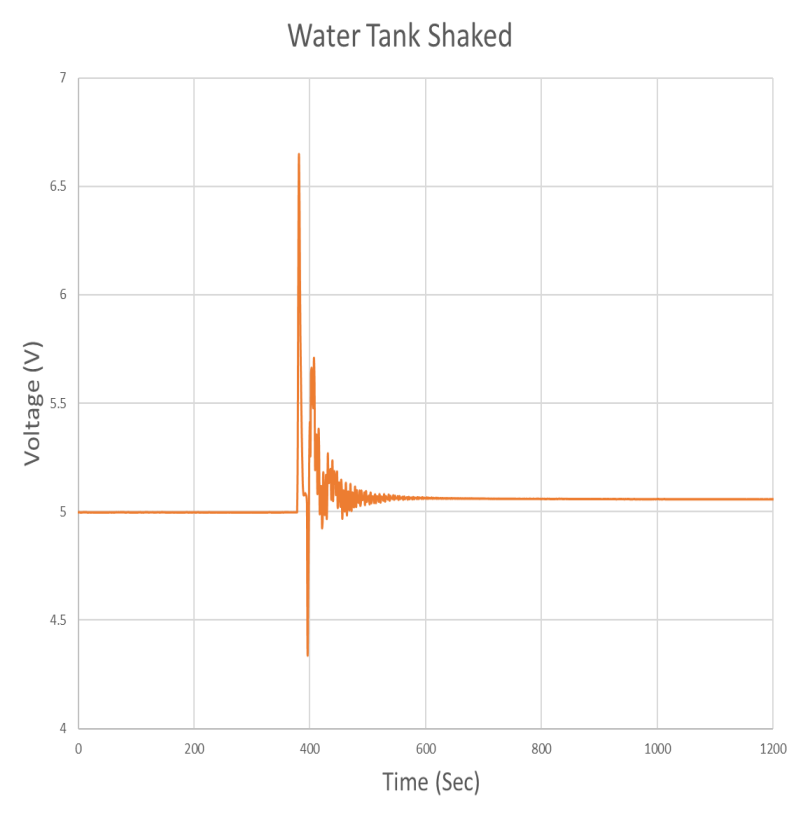
12.5mm stage moving range

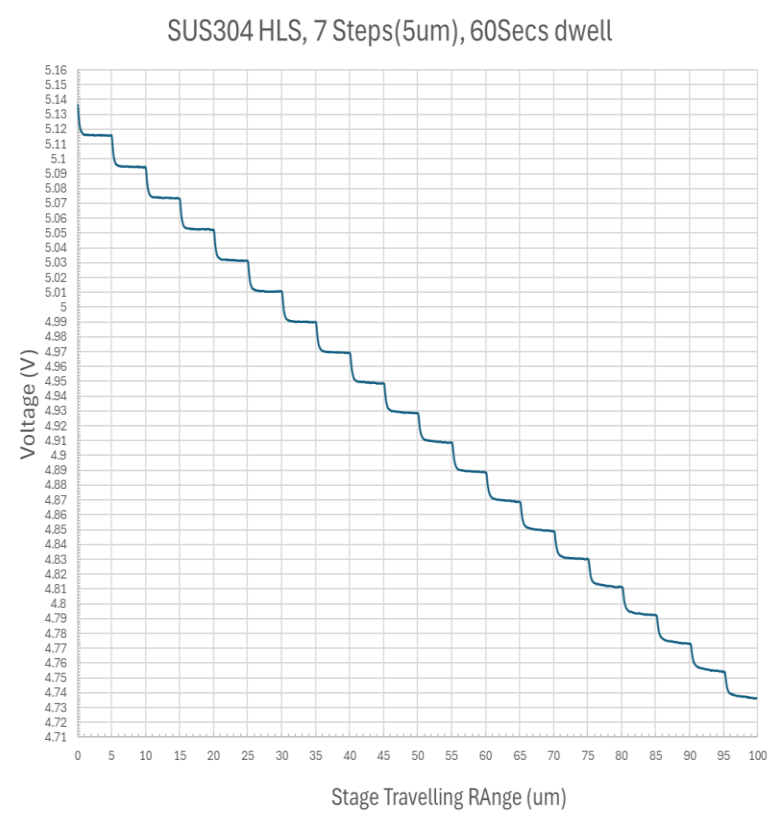


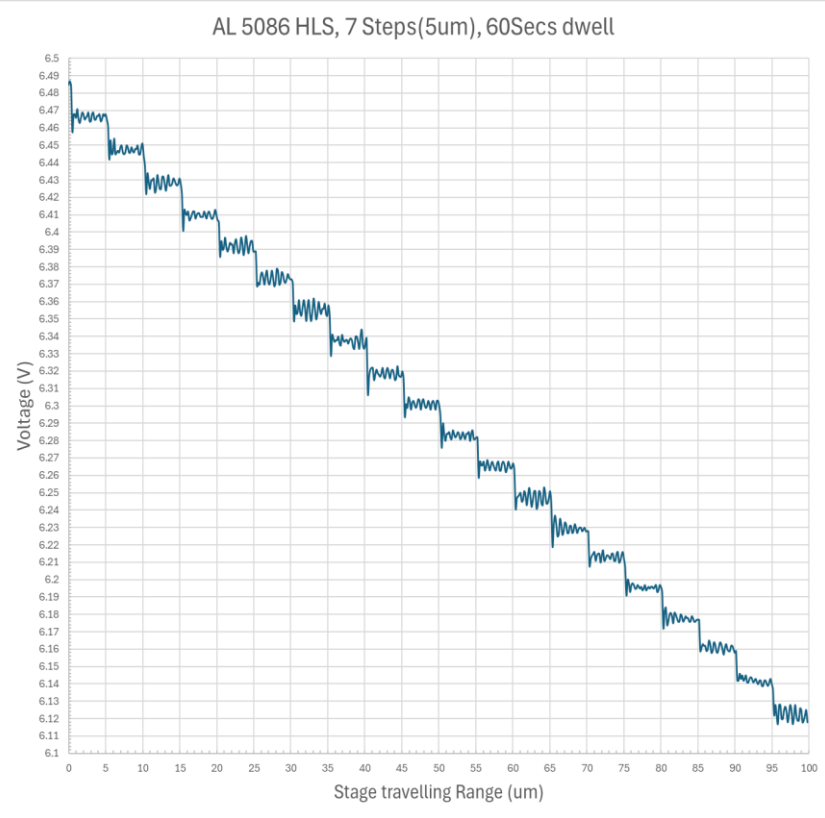


±1.5mm sensing range

Stability Resuming & Resolution Tests



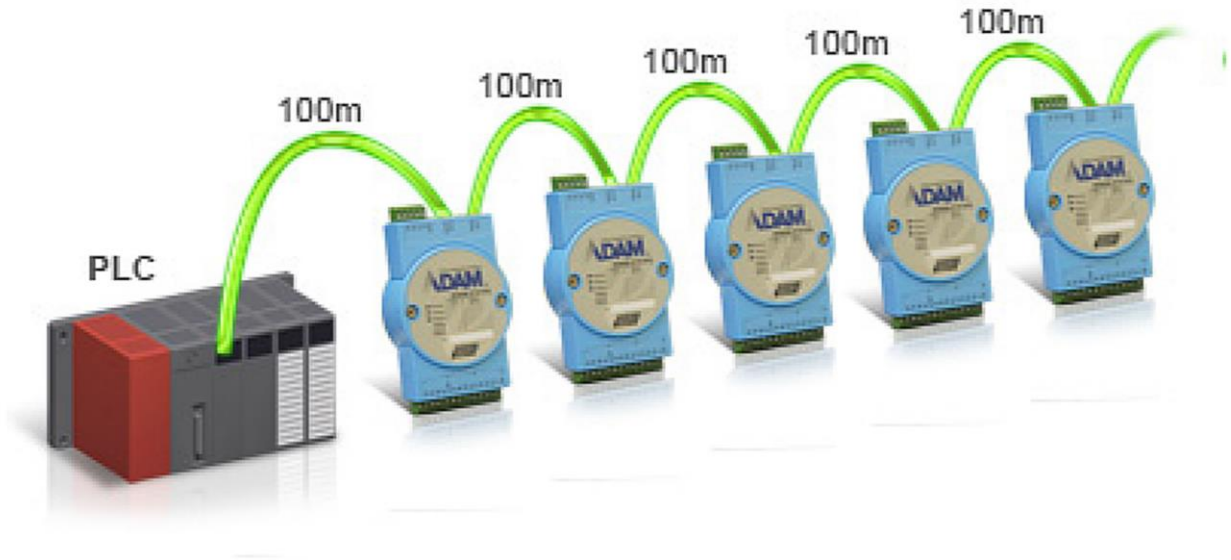




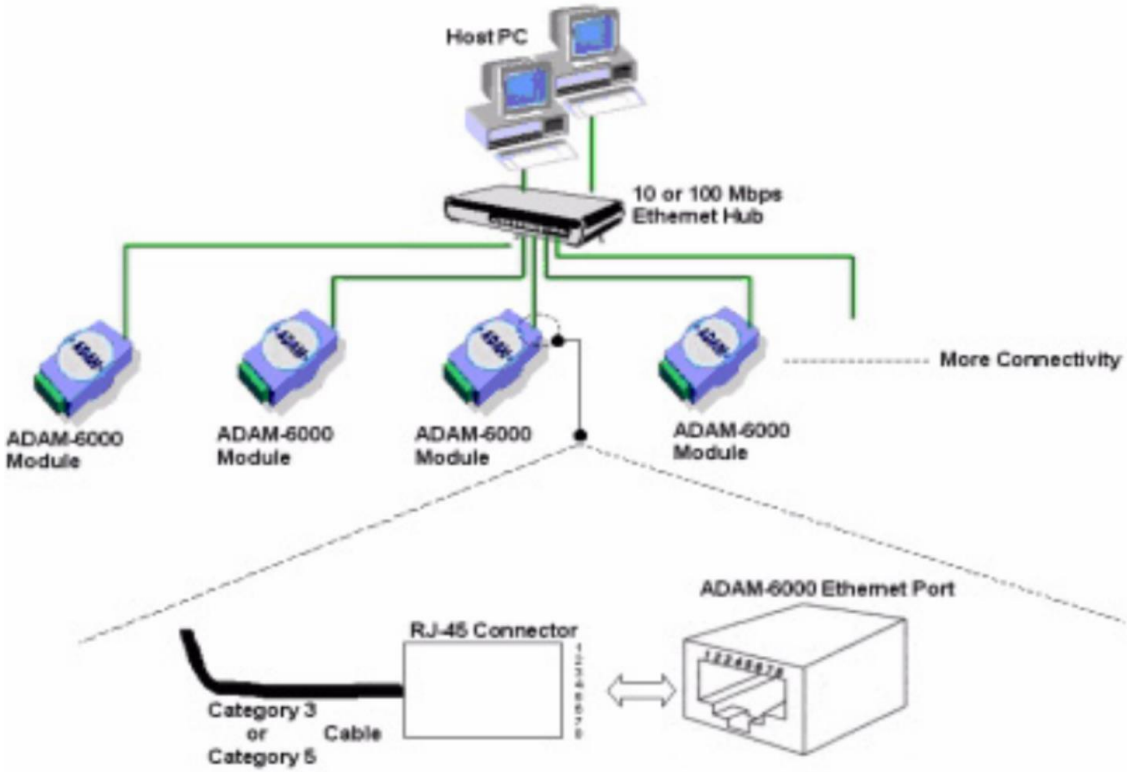
- A sudden shake of the water tank takes 4 minutes to resume stable (offset may be due to the stage also shaked)
- 5 um stage moving is detectable

AD Module Adopted In Future System

ADAM-6100EI series modules can be daisy-chained in an Ethernet network, making it easier to deploy, and helping improve scalability. You can refer to the figure below to see how a daisy-chain connection works in the network.



ADAM-6100EI Daisy Chain Connections



ADAM-6017 Ethernet Terminal and Cable Connection

- Two types of Ethernet AD module from Advantech are investigated (now NI-PCIe6320 for testing)
- With a simple power supply, the cost of each IR HLS system should be less than 1,000 USD (30,000 NTD)

Conclusion

1. A simplified & low-cost IR photonic Hydraulic Level Sensor (HLS) system by sensing the water surface floating is developed & tested.
2. The anodized aluminum alloy HLS shows better condition than stainless one with antifreeze added in the water duct.
3. The sensing range of one cell system can be better than 5mm.
4. HLS with three cells can be combined to extend the sensing range to 10mm.
5. The resolution can be better than 5um.
6. The hysteresis phenomenon still need to be investigated to improve the accuracy.

Thank you for your attention!

Welcome to Taiwan 2025 IPAC