# Development of Radiation Resistant In-water Transmission System

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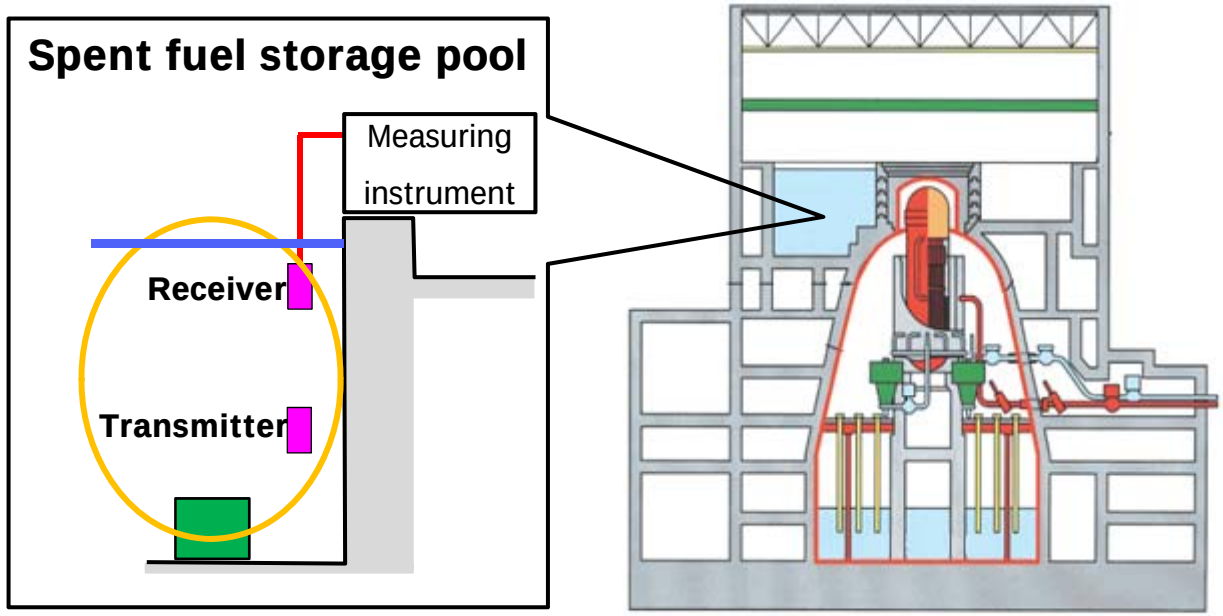
# Background

- Selection of important information about the nuclear facility.
- Development of transmission system which available under severe accident.
- Selection of important elements for observation system in the nuclear facility, and demonstration of it.




**Wireless transmission technology (underwater)**

Development of transmission system which available with small electrical voltage in severe condition.

# Introduction

We started from 2012 a research and development so as to monitor the NPPs situations during severe accidents. Considering that reactor buildings could be filled with water under the severe accidents, a development of an in-water wireless transmission system was started.

Our group completed the basic design of the system and the radiation-resistant tests of the candidate transmitting and receiving devices by the end of FY2013. In this presentation, the results of the gamma irradiation tests of the devices, and preliminary of a developed transmission test system will be reported.

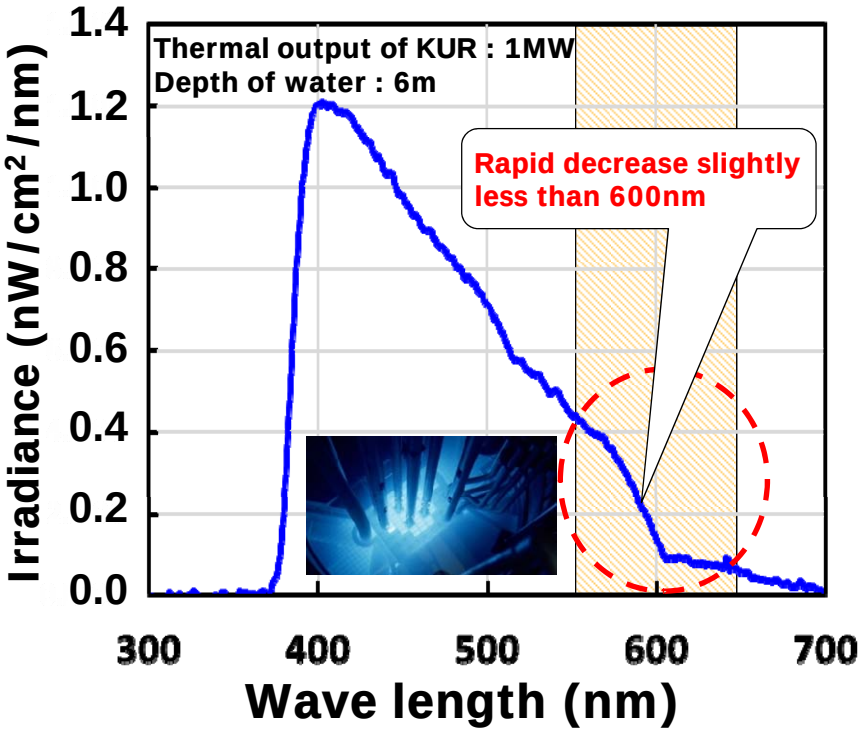
# Comparison of Transmitting Method under Water

| Item \ Method | Radio wave | Visible light | Sonic wave |
|---|---|---|---|
| Transmitting Status | △ | ○ | ○ |
| Range | Several meters | Unknown | Several hundred meters |
| Advantages | ・Existence of many general purpose components<br>・Fast Transmission | ・Resistant to EM-noise<br>・Small Attenuation in the water<br>・Fast transmission | ・Long Range |
| Disadvantages | ・Large electricity consumption<br>・Available only low frequency | ・Influence of the other light noise<br>・Large scattering | ・Slow transmission<br>・Large transmitter |
| Examples of use In water | Underwater Transceivers | Communication device | Underwater Transceivers |

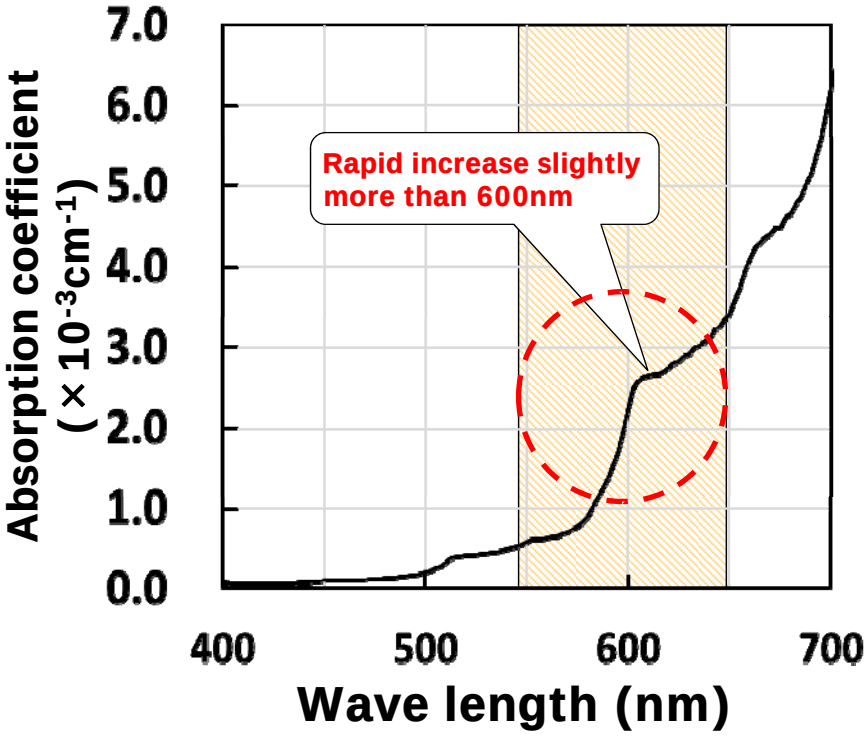
Visible light has low attenuation coefficient in water and enough transmission rate. Thus, we use visible light against underwater wireless transmitting system.

# Considering Suitable Light Wavelength

## Influence of Cherenkov light



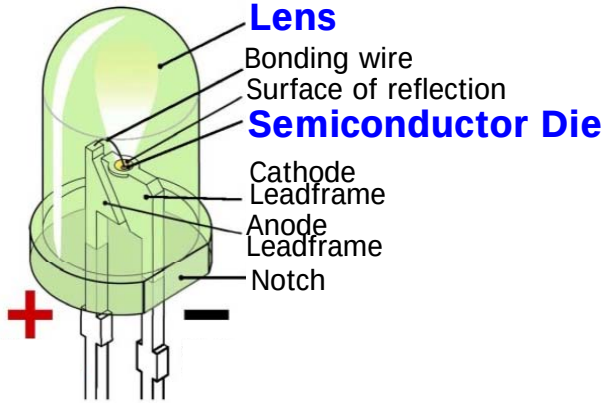

## Optical absorption coefficient of distilled water




The results suggest that suitable light wavelength is about from 550-650 nm.

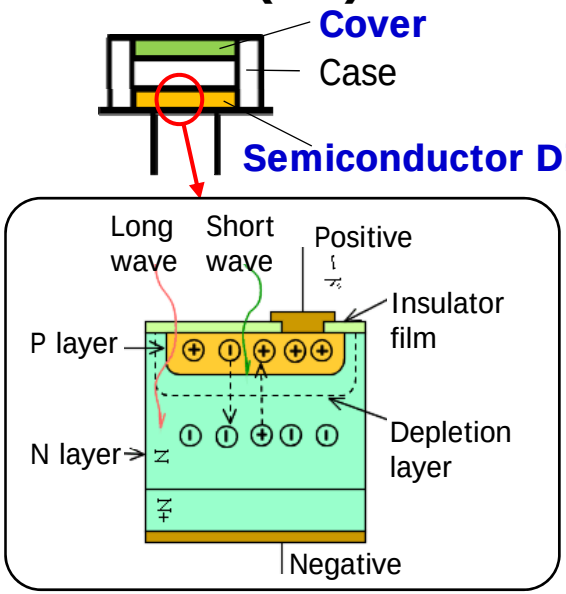
# Samples of LED and PD

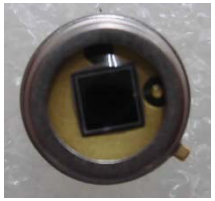
## 【Light Emitting Diode (LED)】




| Item \ Sample | LED-A | LED-B | LED-C |
|---|---|---|---|
| Externals |  |  |  |
| Material | Epoxy resin | | |
| Wave length | 575nm | 609nm | 635nm |
| Emitting Power | 0.31mW | 2.48mW | 4.64mW |

## 【Photo Diode (PD)】




| Item \ Sample | PD-A | PD-C |
|---|---|---|
| Externals |  |  |
| Material | Quartz glass | Borosilicate glass Silicone resin |
| Receiving area | 33mm$^2$ | 7.26mm$^2$ |

# Outline of Gamma-rays Irradiation Tests

## Experiment Flow

Characteristic tests of un-irradiated samples

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Gamma-rays irradiation (1)

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Characteristic test of irradiated samples

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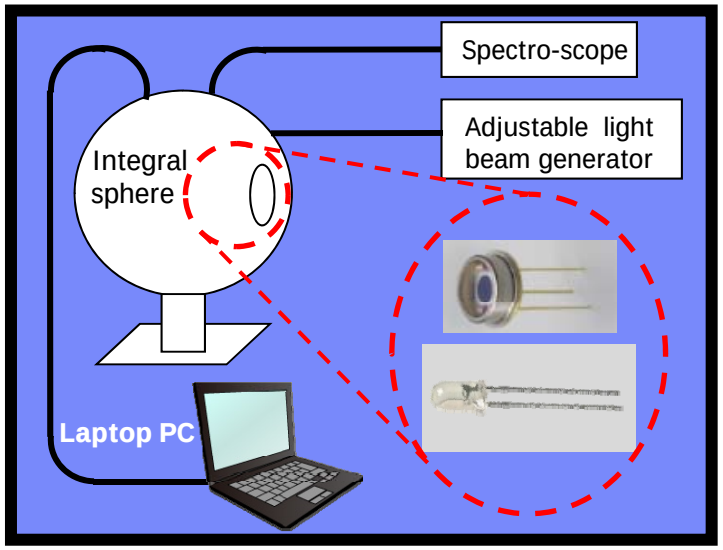
Gamma-rays irradiation (2)

⋮

Characteristic tests of irradiated samples

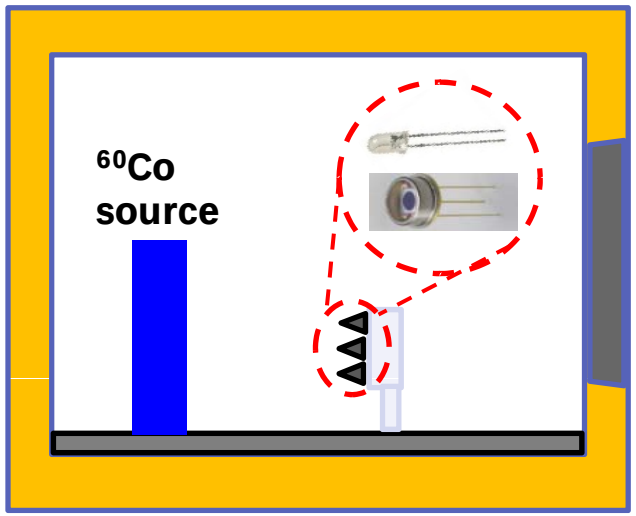
## Characteristic Tests




LED
- Total luminous flux
- Current-voltage curve

PD
- Light sensitivity

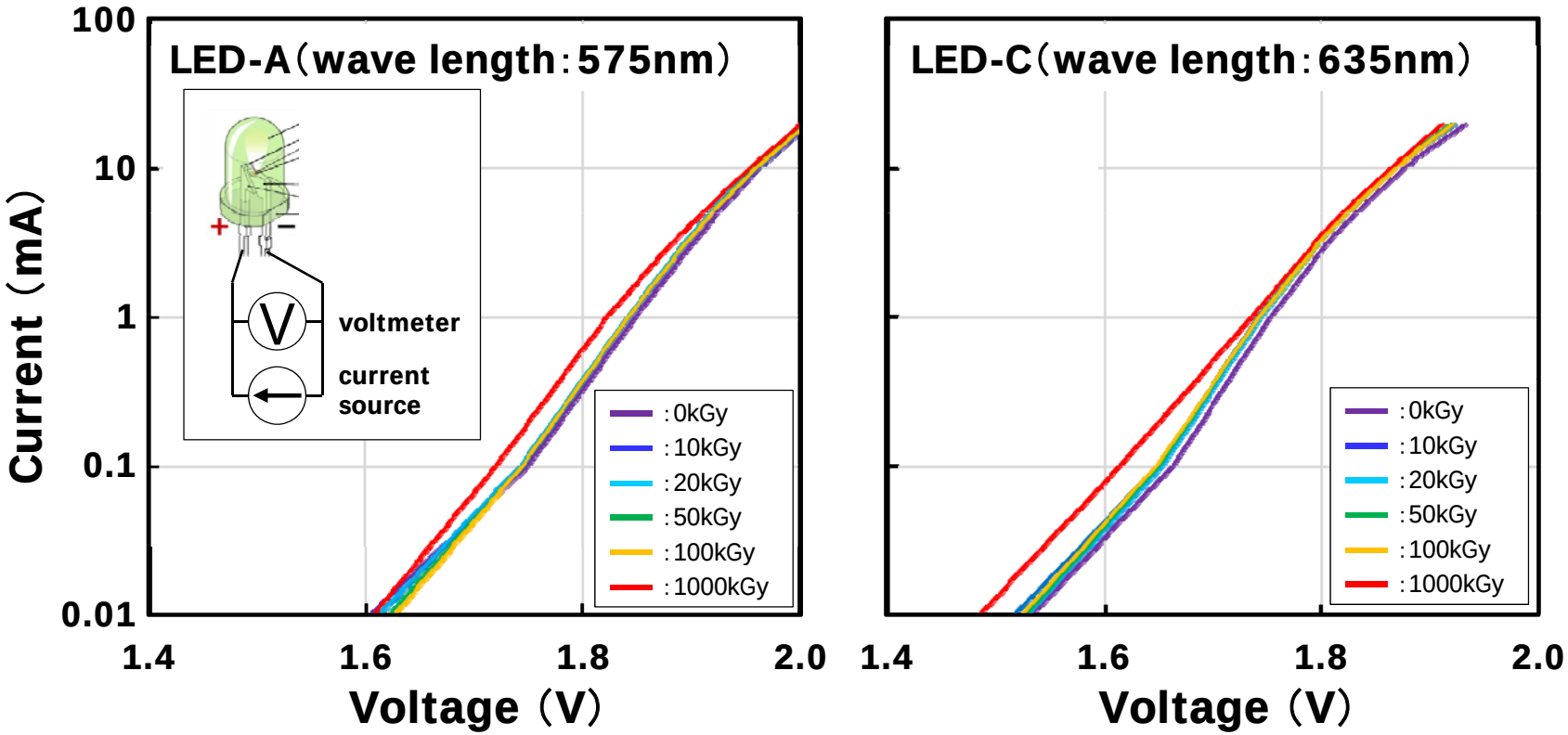
## Gamma Irradiation Field




| | |
|---|---|
| Total dose (kGy) | 10,20,50, 100,1000 |
| Dose rate (kGy/h) | 10 |
| Temp. (˚C) | ~20 |

# Irradiation Effect on LEDs (1/2)

## Current-voltage curves of LEDs

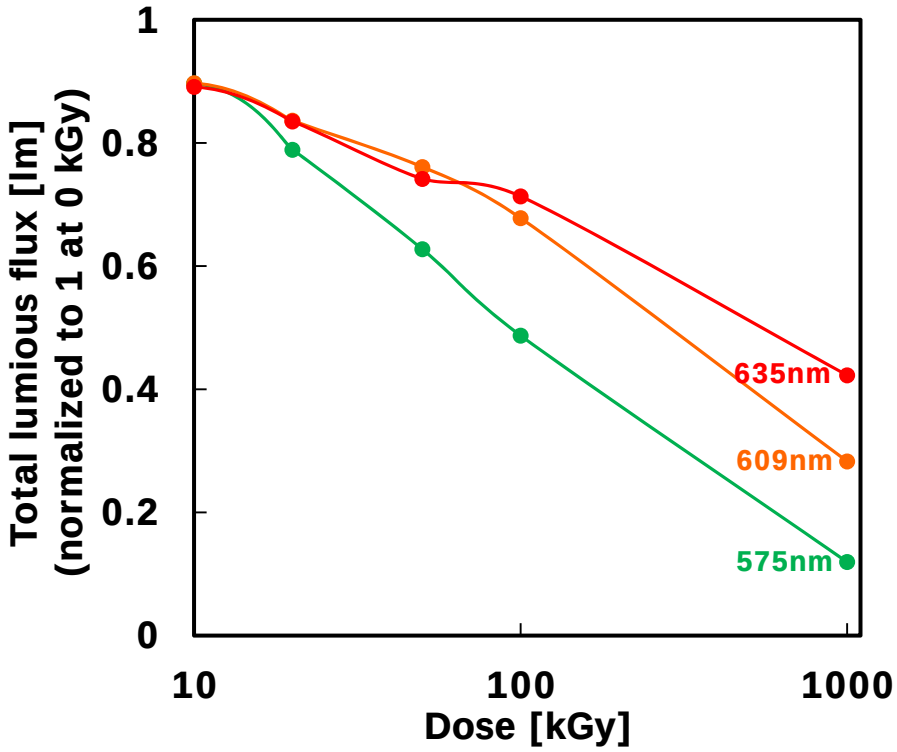



Properties between current and voltage are almost stable up to 1000kGy.

No significant difference about electrical properties for total dose

# Irradiation Effect on LEDs (2/2)

**Degradation of total luminous flux with total dose**




**Appearance**

| Sample \ Dose | 0kGy | 50kGy | 1000kGy |
|---|---|---|---|
| LED-A (575nm) |  |  |  |
| LED-B (609nm) |  |  |  |
| LED-C (635nm) |  |  |  |

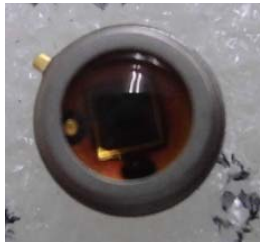
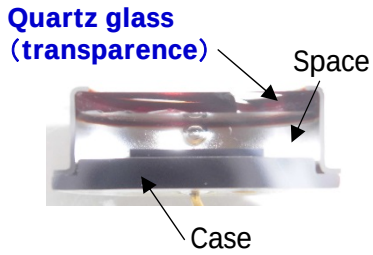
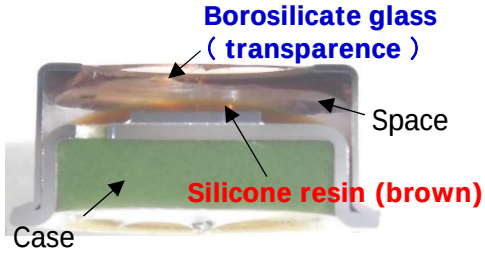
The total luminous flux reduced with increasing of dose.

Epoxy resin of LED changed brown.

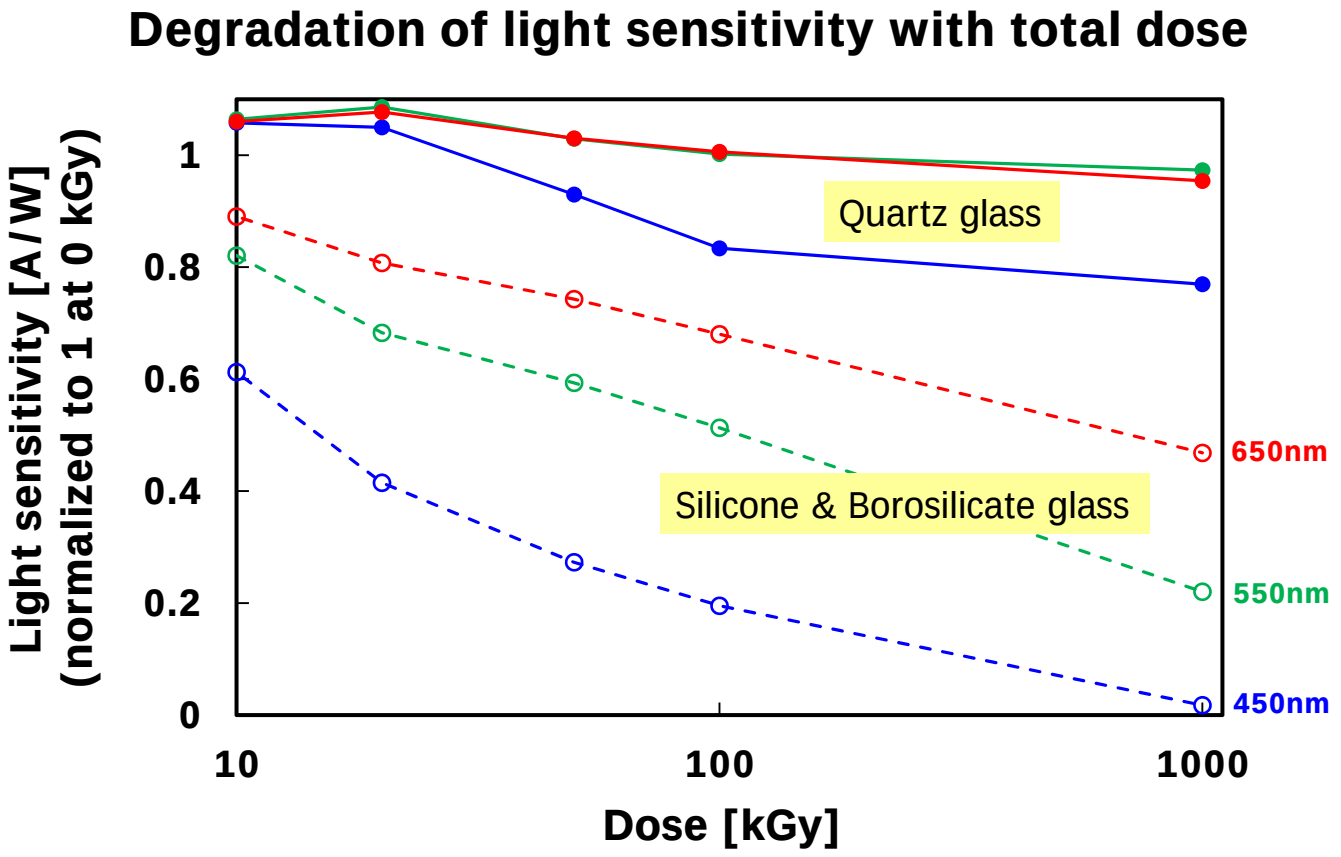
Colored epoxy resin of LED lenses absorb light.
⇒Total luminous fluxes decrease.

# Irradiation Effect on PDs (1/2)

## Appearance of PDs after 1000kGy irradiation

| Item \ Sample | PD-A | PD-B |
|---|---|---|
| Window material | Quartz glass | Borosilicate glass<br>Silicone resin |
| Appearance |  |  |
| Cross section inspection |  |  |
| Result | Quartz glass did not change even at 1000kGy. | Silicone resin was colored to brown. |

# Irradiation Effect on PDs (2/2)

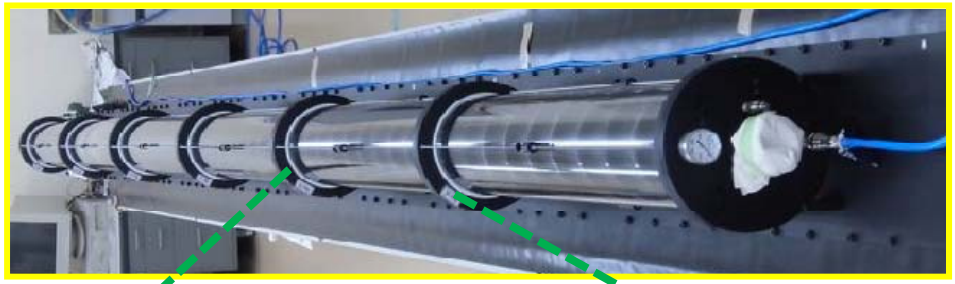


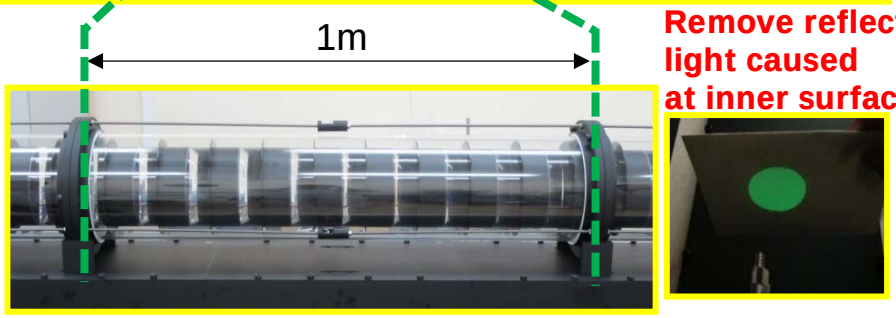

Browning of the silicone resin makes the light sensitivity decrease.

Quartz glass is desirable for window material of PD.

# Underwater Transmitting Testing System

## Testing System





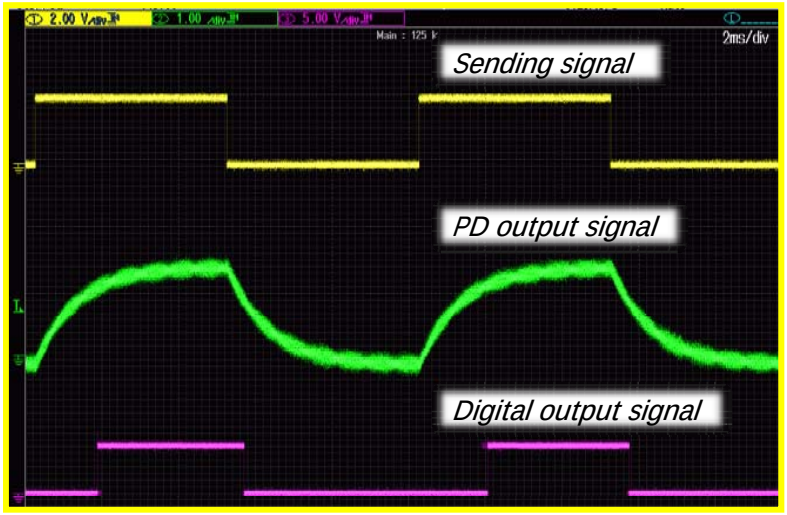

Remove reflected light caused at inner surface



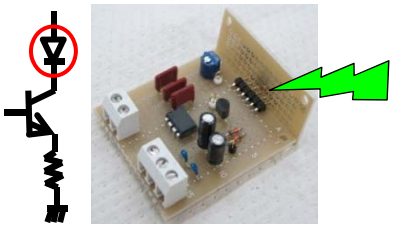
Connectable 6 units (max 6m)

## Waveform of Transmit and Receive

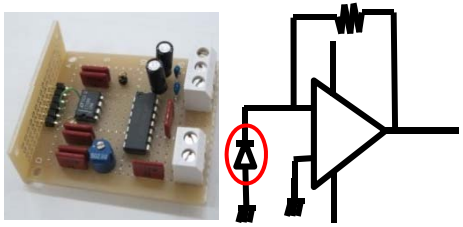
| Experimental Condition | |
|---|---|
| Range | 6m |
| Frequency | 100Hz |
| Duty | 50% |




**LED sender circuit**



**PD receiver circuit**



This testing system reduces light reflection at the inner surface.
⇒ This system simulates infinity water space.

# Summary

(1) Transmission with red light have advantage in point of radiation-resistant while the attenuation coefficient is low.

(2) Gamma irradiation does not significantly cause the degradation of the semiconductor parts of LEDs and PDs up to 1000 kGy.

(3) Glass is more suitable than resin for light window materials of LEDs and PDs under radiation environment.

# *Future Plan*

*(1) Design and fabrication of higher-integrity transmission system*

*(2) Transmission confirmation tests using in-water environment simulator which simulates under severe accident environment*