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# On-Line Gamma Irradiation Test of High Speed Fiber Optic Transceiver

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## 1. Introduction

The field data communication based on the fiber optics is considered for application in nuclear environments. The nuclear facilities, including nuclear power plants, high radioactivity waste disposals, reprocessing plants and thermonuclear fusion installations can benefit from the unique advantages of the fiber optic data communication for the smart field instruments and controls. A major problem which arises when dealing with fiber optic data communication in these environments is the presence of high dose-rate gamma irradiation fields[1]. Radioactive constraints for the DBA(design basis accident) qualification of the RTD transmitter installed in the inside of the RCS pump are typically on the order of 4kGy/h with total doses up to 10kGy[2]. In order to use fiber optic communication system as an ad-hoc sensor data link in the vicinity of the reactor area of the nuclear power plant, the robust survivability of these system in such intense gamma-radiation fields therefore needs to be assessed. We have conducted high dose-rate (up to 1.5kGy) gamma irradiation experiments on a COTS fiber-optic transceiver module for the USB2.0 interface data link. In this paper we describe the evolution of its basic characteristics with high dose-rate gamma irradiation and shortly explain the observed phenomena.

## 2. Experiment

A block diagram of a typical gamma irradiation set up for the fiber optic data link is shown in Fig. 1.

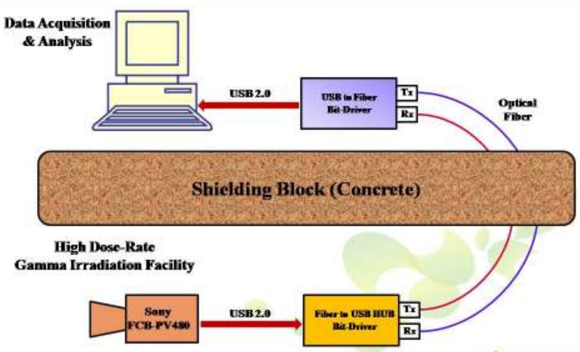

Fig. 1. A schematic diagram of the gamma irradiation test

In order to evaluate performance of high speed & wide bandwidth fiber optic data link, progressive scan-typed CCD camera was used as the USB2.0 interface signal source. The progressive scan-typed CCD camera transmits high speed digital data up to 160Mbits/s (659×494×8×60Hz). Compared to the conventional method using function generator, the experimental set-up is simplified. As shown in Fig. 1, an image variations were monitored using image processing system embedded in the data acquisition & analysis system. Using an entropy-based image processing algorithm, high dose-rate gamma radiation induced degradation of the fiber optic data link is easily observed.

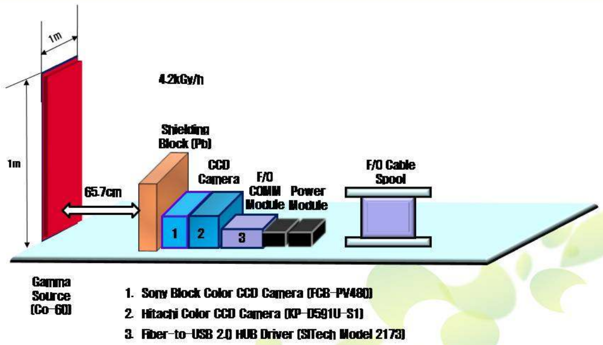

Fig. 2. Layout of gamma irradiated devices.

Fig. 3. A fiber optic communication system placed in the high dose-rate gamma irradiation facility.

Fig. 4. Experimental setup for data acquisition system

The experimental setups for gamma irradiation test for the high speed fiber optic data link are shown in Fig. 2, 3 and 4. Fig. 5 shows gamma irradiation results of the fiber optic communication system.

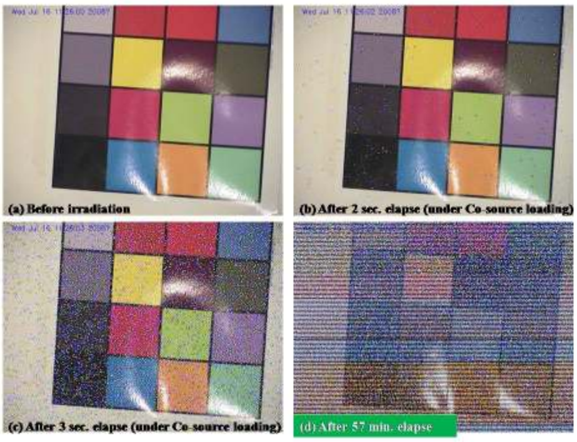


Fig. 5. Image frames transmitted over fiber optic data link during the high dose-rate gamma irradiation.

After 57 minutes elapse, the high speed data transmission performance is severely degraded shown in Fig. 5(d). It is estimated that the USB2.0 interface driver embedded in the fiber optic transceiver module is damaged. As compared to fiber optic source (LED and PD) made of GaAs device, the USB 2.0 interface driver chip based on Si-CMOS FPGA is more weak when exposed to the high dose-rate gamma irradiation field. After gamma irradiation test, we conducted recovery test of the fiber optic communication systems. Table 1 summarized the recovery test of the devices shown in Fig. 2.

Table 1. Recovery test results of active devices

| | Sony FCB-PV480 | Hitachi KP-D591U-S1 | S.I. Tech Fiber Optic Data Link 2173) |
|---|---|---|---|
| **Dose Rate (kRad/h)** | **2.55** | **69.6** | **160** |
| Distance (cm) | 74.1 | 81.1 | 87.5 |
| Diagonal distance (cm) | 120.82 | 125.97 | 132.88 |
| Shielding thickness | 8.5mm | 2.75mm | - |
| Recovery test | Normal | Fail | Normal (time reduced) |

Table 2 shows recovery performances of fiber optic data link after gamma irradiation as the elapsed time. As the elapsed time increases in the recovery test, the normal operation time of fiber optic data link increase also.

Table 2. Recovery performance of fiber optic data link (2173)

| Day | Normal operation | Time (min) |
|---|---|---|
| 1st (7.20) | | 3 |
| 2nd (7.21) | | 12 |
| 3rd (7. 22) | | 28 |
| 4th (7. 24) | | 45 |

As shown in Table 2, single green block represents normal operation time (1 minute). And green block means that image quality transmitted over the fiber optic communication system is the same as the one shown in Fig. 5(a) also. From the table 1 and table 2, it is concluded that high speed fiber optic data link is a robust communication link applicable to the harsh environments such as the reactor pressure vessel area. If the Si-CMOS FPGA chip, functioned as USB2.0 interface signal driver, is effectively shielded by lead material (about 8.4mm thickness), the high speed fiber optic transceiver module (USB 2.0 converter unit) shows robust survivability in the gamma-irradiation requirement during design base accidents.

## 3. Conclusions

In order to use fiber optic communication system as an ad-hoc sensor data link in the vicinity of the reactor area, the robust survivability of its system in such intense gamma-radiation fields needs to be assured. We have conducted high dose-rate (up to 1.5kGy) gamma irradiation experiments on a industrial fiber-optic transceiver module for the USB2.0 interface data link. The evolution of its basic characteristics with high dose-rate gamma radiation field and the observed phenomena were described in this paper. If the Si-CMOS FPGA chip, functioned as USB2.0 interface signal driver, is effectively shielded by lead material (about 8.4mm thickness), it is concluded that the high speed fiber optic transceiver module (USB 2.0 converter unit) can be survived robustly in the gamma-irradiation requirement during design base accidents.

## REFERENCES

[1] R.E. Sharp, "Radiation effects on electronic equipment, a designers'/users' guide for nuclear power industry", AEA-D&W-0691, 1994
[2] Weed Instrument, "Nuclear Qualified N4000R-99 Series RTD Temperature Transmitter", Datasheet