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AN ACCELERATED GAMMA IRRADIATION TEST OF LOW DOSE RATE FOR A SINGLE MODE FIBER

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I.INTRODUCTION

Conventional single mode fiber (SMF), due to its electromagnetic interference immunity, light weight, physical flexibility and broad bandwidth for data transmission, has been well employed in space, such as optical communication [1], structural health monitoring of spacecraft [2], and attitude determining applications, e.g. interferometric fiber optic gyroscope (IFOG).

However, the SMF will suffer radiation induced attenuation (RIA) in space. The RIA will result in the decay of light power in the SMF. Thus the SMF-based device will have gradually-decreasing signal-to-noise ratio (SNR). To qualify the radiation specification of the SMFs, the radiation tests are usually performed on the ground.

The space radiation has a low dose-rate of ~10^{-4} to 10^{-2} rad/s depending on the missions. However the mission durations may be several years, therefore, the total dosages are usually accumulated up to the order of 10^5 rad or higher [3]. To perform the influence of total dosage, the radiation tests on the ground usually use a high dose-rate for saving test time. Besides, It has been well known that enhanced low dose-rate sensitivity (ELDRS) is observed on devices, such as linear bipolar circuits [4] and erbium-doped fibers (EDFs) [5]. When the dose-rate is not low enough, the ELDRS effect will cause under-estimated RIA results. Thus, the dose-rate is often set less than 0.01 rad/s to relatively reduce the ELDRS effect.

However, if we choose 0.01 rad/s as the dose-rate and 100 Krad as the total dosage, the test duration will be over 2778 hours which is too long. Thus, we adopted the "switching dose-rate method" [5] to reduce the test duration. In this paper, we will present an accelerated irradiation test of the low dose-rate to reduce test duration efficiently and show the SMF ELDRS effect.

II. EXPERIMENT

A. Devise Under Test

The three coils of single mode fiber (GGP80/90/130, POFC (Success Prime Co.), Taiwan) are used in this test. Each coil has 200 meters in fiber length.

B. Irradiation Facilities

The Co^{60} radiation test was performed in the Radioisotope Laboratory of National Tsing Hua University. Because the dose-rate is inversely proportional to the distance between the radiation source and the coils, the dose-rate can be adjusted by changing the positions of the SMF coils. In this test, we adopted 1.01 rad/s, 0.53 rad/s and 0.0078 rad/s for the three coils.

C. Experimental Setup

According to the RIA measurement setup in Fig.1, the 6 pieces of SMF-28 were fusion spliced to the three coils for the connections to the instruments and the light source, which were set outside the irradiation area. The 6 pieces of SMF-28 (4 meters) were much short than the three coils (200 meters), so the 6 RIAs of the SMF-28 fibers would not much contribute to the measuring RIAs in this test. By using the power meters (S380 Dual Channel Optometer, UDT INSTRUMENT), whose responsivity was previously calibrated by a stable laser, we could measure the optical power of 1550-nm light which emitted from the light source and went through the three coils. The light source used a tunable laser (Tunable Laser TSL-510, SANTEC CORPORATION), which had a power stability of ±0.01 dB and a wavelength stability of ±5 pm, the wavelength and power of the laser light are set to 1550 nm and 20 mW, respectively. The laser light was split by two 2x2 single mode fiber couplers (CORETECH OPTICAL CO., LTD, Taiwan) which was set 2-meter far from the radiation source, and the accumulating total dosage of the fiber couplers was 3.2 Krad. According to our previous irradiation test, the RIA of the fiber couplers was less than 0.01dB at a total dosage of 3.2 Krad, thus, it could be neglected its

contribution in the measuring RIAs of the coils. The measurement data of power meters were recorded by the computer (PC). The irradiation test was performed at room temperature.

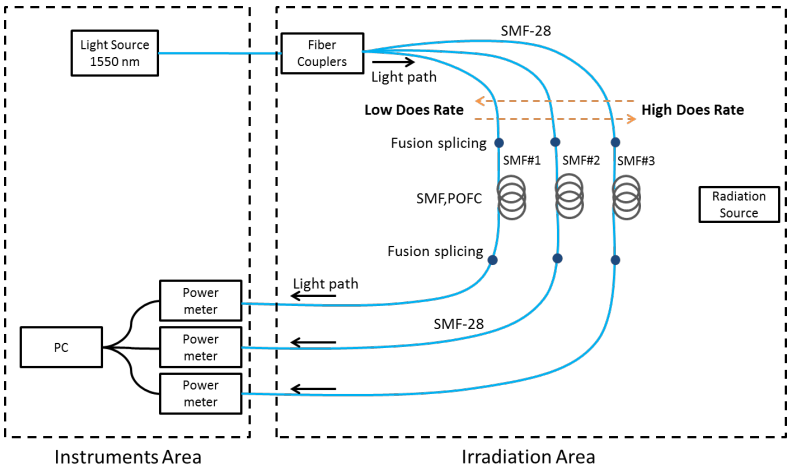

Fig.1 Schematic diagram of coil's RIA measurement setup

For accelerating irradiation test, we adopt three different dose-rates from the beginning until each coil has accumulated to the given doses based on the switching dose-rate method, and the RIAs of the three coils of SMFs were measured at the same time. Fig.2 (a) shows the irradiation treatments of total dosages and dose-rates for the three coils. The first coil (SMF#1) was gamma-irradiated with a dose-rate of 0.0078 rad/s up to a total dosage of 6 Krad. The second coil (SMF#2), at the beginning, was gamma-irradiated with a dose-rate of 0.53 rad/s up to a total dosage of 7.2 Krad, then SMF#2's dose-rate was switched to 0.0078 rad/s and SMF#2 continues accumulating the total dosage up to 10.2 Krad. The third coil (SMF#3) was first gamma-irradiated with a dose-rate of 1.01 rad/s up to a total dosage of 14 Krad, then SMF#3's dose-rate was switched to 0.0078 rad/s and SMF#3 continued accumulating the total dosage up to 18 Krad.

In Fig.2(b), the RIAs of three coils can be calculated by analyzing measurement data. By horizontally translating the low-dose-rate curves of SMF#2 and SMF#3 to fit the extended curve of SMF#1, we can construct a new low-dose-rate RIA curve on an equivalently wide dose range. The combined RIA curves depict the overall low dose-rate curve up to 620 hours.

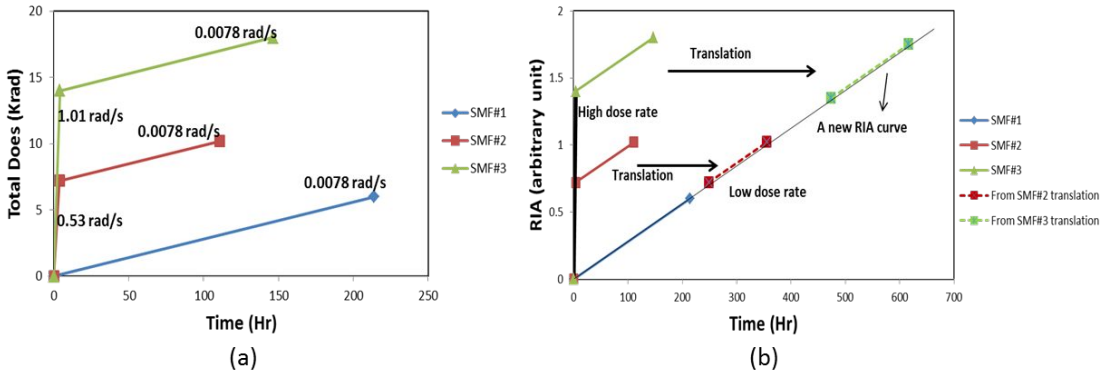

Fig.2. (a) The irradiation treatments of total dosages and dose-rates for the three coils. (b) Acquiring a new RIA curve with low dose-rate by the switching dose-rate method

III. RESULTS AND DISCUSSION

The Fig. 3 shows the accelerated Co^{60}-irradiated test results of the SMFs. The L1 is the linear fitting of SMF#1's RIA curve (black) whose dose-rate is 0.0078 rad/s. The L2 and L3 are the RIA curves of SMF#2 and SMF#3 whose dose-rates were switched to 0.0078 rad/s, respectively. Because the slopes of L2 and L3 are similar to the slope of L1, L2 and L3 can move to the positions in which L2 and L3 are fitted to L1, respectively. Thus, we combined a new RIA curve which depict the overall low dose-rate curve up to 10 Krad. Without using switching dose-rate method, it would take about 356 hours to accumulate 10 Krad in total dosage when the

dose-rate is 0.0078 rad/s. In this test, We only took about 214 hours obtain the low dose-rate 10-Krad RIA curve. We successfully reduced the test duration of 40%.

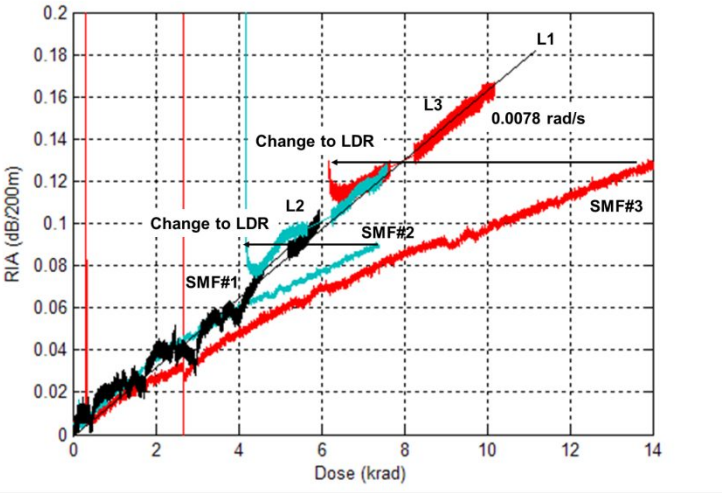

Fig.3.The result of an accelerated gamma irradiation test of low dose-rate (LDR) for SMF

When comparing the RIA curves of three coiled SMFs in Fig.3, we can observe that their slopes are different. Fig.4 shows the estimated RIAs of three coiled SMFs at a total dosage of 10 Krad. The R1 is 0.166 dB/200m which is estimated by fitting the combined RIA curve in Fig.3. The R2 is 0.11 dB/200m which is estimated by fitting the curve of SMF#2, and the R3 is 0.097dB/200m which is estimated by the curve of SMF#3. Fig.4 shows that the RIA of the SMF is inversely proportional to the dose-rate, which is so-called ELDRS.

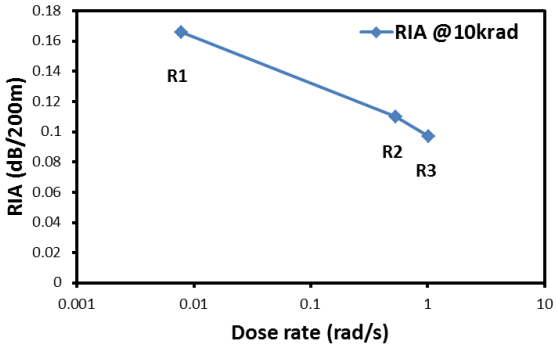

Fig.4. The effects of ELDRS for SMFs

IV. CONCLUSION

In this test, the SMFs were irradiated by Co^{60} radiation source. By measuring the 1550-nm RIA of the SMFs at dose-rates of 0.0078 rad/s, 0.53 rad/s and 1.01 rad/s, the ELDRS effect of the SMF was observed. When the total dosage was 10 Krad, the RIA at a low dose-rate of 0.0078 rad/s would be 1.6 times higher than the RIA at the high dose-rate of 1.01 rad/s. For the 200-meter SMF, the RIA at the dose-rate of 0.0078 rad/s was 0.166 dB, and the RIA at the dose-rate of 1.01 rad/s was 0.097 dB. Our results showed that the RIA of the SMF is inversely proportional to the dose-rate.

By employing the switching dose-rate method proposed in Reference 5, we rebuilt the RIA curve of three coils at the dose-rate of 0.0078 rad/s to estimate the overall low dose-rate RIA curve of the SMF. When comparing the traditional low dose-rate irradiation, our accelerated radiation test showed the test time was reduced by 40%.

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