Radiation-Induced Optical Fibre Loss in the FarIR

EXTENDED ABSTRACT

As discussed in [IJ , the predominant opinion was that the radiation-induced loss of optical fibres at 1550 nm wavelength is distinctly lower than at about 1300 nm, as it is Imown from the "initial" attenuation (of unirradiated fibres). The reason is that the majority of the published measurements were irradiations of relatively short duration, and that most of the residual tests with longer irradiation times (>> 10000 s) were often perfomed at only one of these two wavelengths.

Some few experimentalists, however, reported very early on higher loss increase at 1550 nm during irradiations of longer duration [2-4]. Kyoto et al. [3] show spectral measurements between about 800 and 1800 run where the loss decreased with increasing wavelength only up to a minimum around 1 100 nm (undoped single mode fibre = SMF) or 1200 nm (Ge-doped SMF), respectively, and then began to increase again. They explained this behaviour by the existence of three short-lived defects with absorption maximum in the UV (causing "dose rate dependent loss") and one long-lived defect with maximum attenuation in the far IR (causing "dose dependent loss"). With increasing inadiation time the radiation-induced loss at longer wavelengths will thus continue to increase. whereas the loss at shorter wavelengths should show some saturation.

In [l] we demonstrated that the ratio of the radiation-induced loss at 1300 and 1550 nm increases within an irradiation time of about 10 s to a maximum value of about 2 (Ge-doped SMF) or about 2.7 (undoped SMF). respectively. After about 100 s (Ge-doped fibre) or about 1000 s (undoped fibre) the ratio begins to decrease and reaches a value of I after about IO^S s (about one day). with a tendency to fall further.

For the present paper we irradiatd a Ge-doped SMF nearly two years (680 d) with ^{60}Co gammas of low dose rate up to a total dose of only 450 Gy (= 45 krad). During the first IO^S s the loss increase was measured continuously and very accurate at 1 550 nm with an optical power meter. The next 15 months (453 d) the loss increase was only measured from time to time, with decreasing frequency. at 1550 as well as at 1300 nm, with an OTDR. The difference of the radiation-induced loss between 1550 and 1310 nm increased constantly. After 454 days we mesured 1.13 dB/km at 1310 nm and 1.52 dB/km at 1550 nm (ratio of 0.74).

With Ge-doped graded index (Gl) fibres of 50 and 62.5 gm core diameter we measured the loss increase at 830 and 13 10 nm with two different dose rates (1.54 and 0.048 Gy/s). The loss ratio decreased for both dose rates from values around 10 after 10 s down to nearly 2 after about 12 days (see Fig. l). If åis tendency would hold, one should expect that after about one year ffe loss increase at 830 nm could be lower than at 1310 nm.

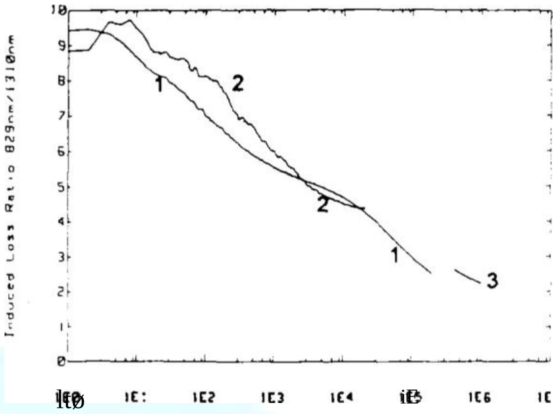


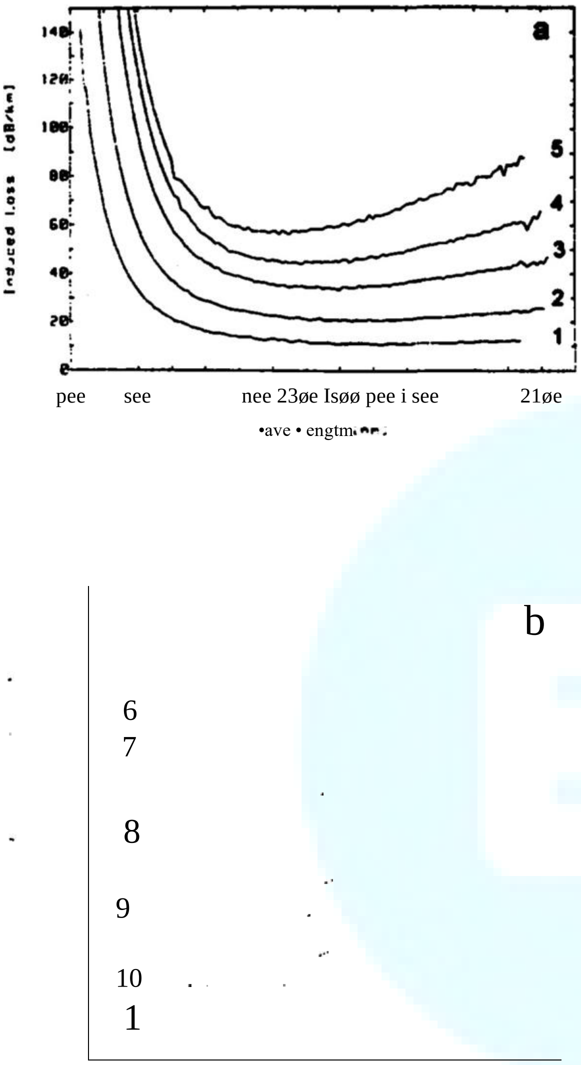
Fig. 1: Ratio of radiation-induced losses at 829 and 13 10 nm as a function of irradiation time. Fibre: POF 62.5/125 GI Fibre CP02057H (Ge-doped graded index fibre). Light power: 10 PW. Room temperature. l: Dose rate b = 1.54 Gy/s•. 2. 3: 0.048 Gy/s.

Since the decrease of the loss ratio with irradiation time seems to be independent of dose rate (as it was also observed for the loss ratio at 13 10 and 1550 nm [l l). one should consider these results for all radiation environments. Thev are. however. onlv valid at room temperature. In [I] it was shown that the situation at distinctly lower (-50 °c) or higher (+80 °c) temperatures is completely different.

In order to observe the temporal change of the wavelength dependence of the radiation-induced loss we also made spectral measurements between about 450 and 2500 nm with all investigated fibres. Especially we hoped to confirm the hypothesis of Kyoto et al. (Refs. [3, 4]). to extend the measurement of their "dose dependent loss in the far IR" by several 100 nm into the "very far" IR and, to find out whether this peak at > 2400 nm has noticeable influence down to the nearer IR (800 - 1300 nm) and is also responsible for the decrease of the loss ratio at 830 and 1310 nm.

Figs. 2a,b show loss increase during irradiation (2a) and loss annealing (2b) for a 62.5/125 pm GI fibre made by POF (Plasma Optical Fibre, NL). It can be seen that with increasing irradiation time (and dose) the loss increase rate around 2000 nm is higher than at shorter wavelengths. As a consequence the loss minimum shifts from around 1600 nm after 1000 s/214 Gy (curve of fig. 2a) to about 1250 nm afier 103220 s/22.l kGy (curve 5).

Loss Ctneaiing (Fig. 2b) is by eviding be **induced** loss **measured at** caufri åe end of frradinion by the loss meöured åe ad of (curve S of fig. 2a). Annealing seems to become slower wiå inaeasing wavelength. This would explain a s&mger increa.* of loss at 1550nm than 1310nm, as well as smnger increase **at** 1310 nm than at 830 nm during longer **irradiation** periods. Since annealing is existent even above 2000 am, the loss incre.ase also in fre far IR should depend on dose Ü1d should show sÜration, but after longer irradiation times/higher dose values.



Figs. 2a.b: Increase of loss during irradiation (a) and loss annealing after the end of irradiation (b). Fibre: POF 62.5/125 GI Fibre CP02057H. Dose rate: 0.21 Gy/s. Room temperature.

Fig. 2a. curve l: irradiation time 1000 s. 2: 3000 s. **3**: **1000**4: 30145 s. 5: 103220 s.

Fig. 2b. curve 6: time after irradiation 1010 s. 7: 3010 s, 8: 10150 s. 9: 31800 s, 10: 68100 s.

Our investigations show that choice of the optimum wavelength for fibre optic data transfer and sensor systems that are intended for very long service times in a radiation environment should not be based on the results of short tests. arapa **and often still** more reliable sy—s Qzating at about 830 nm or 1310 nm, r.ectively, mi#t not be inferior to åe altanüive solutions wiå a wavelengtl of 1310 or 1550 nm,**respectively.**

REFERENCES

[1] H. Haschel, O. Köhn, H.U. Schmidt, "uiüioninduced loss of fibres 1300 run and 1550 nm wavelengå", SPIE Vol. 2811: Photonics for Spee Environmene IV, **Radiation** Effects: Optical Fibas, pp. 68-76, 19%.

[21 EJ. Friebele, C.G. Askins, and M.E. Gingerich, *Effece of low dose mte irradiation on doped silica core optical fibers", Appl. opt, vol. 23, No. 23, pp. 42024208, 1984.

[3]M. Kyoto, Y. Chigusa, M. Ohe, M. Watanabe, T. Matsubara, T. **Yamamoto,** and S. Okamoto, "Gamma-Ray Irradiation Effect on Loss Increase of Single Mode Optical Fibers, (I), Loss Increase Behavior and Kinetic Study", Joumal of Nucl. Sci. and Techn., Vol. 26, No. 5, pp. 507-515, May 1989.

[41 M. Kyoto, Y. Chigusa, M. Ohe, H. Go, M. Watanabe, T. Matsubara, T. Yamamoto, and S. Okamoto, "GammaRay Radiation Hardened Properties of Pure Silica Core Single-Mode Fiber and Data Link System in Radioactive Environments", Joumal of Lightwave Technology, Vol. 10, No. 3, pp. 289-294, March 1992.