1 - 06 Radiation Damage Tests of Semi-Conductors

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In the high intensity proton accelerators, solid state amplifiers using high power Metal-Oxide-Semiconductor Field Effect Transistors, MOSFETs, were not used often because of the radiation effects. In 2012, CERN starts the R&D to use a wideband accelerating cavity system to replace the existing RF accelerating system in the PS booster [1]. And the system includes many high power solid state amplifiers to drive the cavities. By the long-term collaboration efforts, it was found that a compensation scheme to adjust the bias current of MOSFET will extend its life time. Amplifiers were tested with the gamma rays at QST-Takasaki and with the mixed radiation fields in the CHARM, Cern High energy AcceleRator Mixed field/facility. Comparing the results from both facilities, it is also possible to evaluate the Single Event Effect, SEE, and neutron effects.

In 2017, we irradiated two sets of 100 W solid state amplifiers with different dose rates at the QST-Takasaki. All amplifiers use VRF151G MOSFET of Microsemi Co. with radiation compensation circuit and RF auto-level control loop to keep 100 W output constant. The devices were protected with thermal switches and fuses to avoid over heat. These amplifiers were located at the positions of the dose rates of 15 Gy/h and 2 Gy/h. Figure 1 shows an amplifier irradiated with the dose rate of 15 Gy/h. The MOSFET has high Drain-Source break-down voltage of 180 V and it will be used for the CERN PS booster RF based on the measurements at the J-PARC MR [2] and other places.

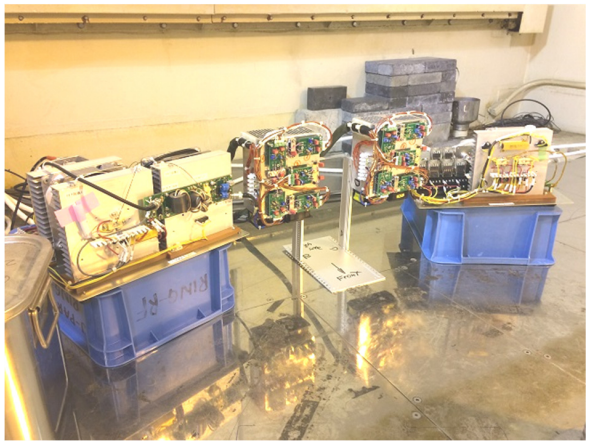

Fig. 1. The setup of irradiation test of solid state amplifier (left) at the QST. Middle and right show the setup to test MOSFETs without RF power.

In total, 2.39 kGy and 319 Gy were irradiated. The dose was measured using Alanine dosimeters, Amino-gray. The gain variation was measured between 0.5 MHz and 5 MHz. Both amplifiers show an excellent stability of less than 1 dB variation. These amplifiers were shipped to CERN for the test at the irradiation facility, CHARM after replacing MOSFETs. At the CHARM, 5.25×10^{16} protons on target were used. Total Ionizing Dose, TID, of 1.9 kGy, 1-MeV neutron equivalent fluence (cm^{-2}) of 1.09×10^{13} and High Energy Hadron-equivalent fluence (cm^{-2}) of 7.7×10^{12} were irradiated. Gain variations for both tests are shown in Fig. 2. In both cases, the gain variations are less than 1 dB and the compensation scheme worked well [3]. The result suggests the major effect below 2 kGy irradiation on the amplifier using VRF151G is TID.

The radiation results in 2017 show that the solid state amplifier can be used at the PS booster for many years if the MOSFET is properly adjusted according to the TID. The test will be continued at both QST and CHARM.

In parallel, radiation damage test on Access Points [4] and calibration test of OSL dosimeter [5] were performed.

The work is supported by Facility-service system of QST.

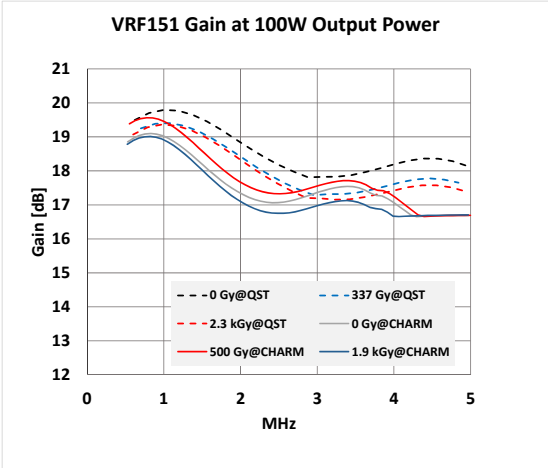

Fig. 2. Gain variations of the amplifiers using MOSFET, VRF151G. Both results at QST-Takasaki and at CHARM are consistent.

References

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