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Thermal Annealing in Silicon Photonics Ring Modulators

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Silicon Photonics is a promising technology for future HEP experiments and upgrades. Such experiments and upgrades will require high levels of radiation tolerance and Silicon Photonics Modulators have already been shown to be very radiation tolerant when exposed to high levels of TID under certain conditions. We demonstrate for the first time that changing the temperature of Ring Modulators during or after the irradiation can improve their performance.

Summary (500 words)

The increase in both the radiation levels and the required readout data rate are the main challenges of the High Luminosity upgrade of LHC at CERN. Optical data links placed at the front-end of the innermost detectors will need to withstand a Total Ionizing Dose (TID) over 10 MGy and a 1 MeV-equivalent neutron fluence of 1.6 ·10ˆ16 n/cm2. Since the current technologies deployed in the detectors cannot endure those levels of radiation, new technologies will need to replace them. Silicon Photonics (SiPh) is a technology that promises to cope with these requirements. One more advantage of SiPh is its compatibility with CMOS technology and the possibility of tight integration between electronics and photonics circuits. Therefore, there are opportunities to build low-mass radiation-hard components for the new generation detectors at CERN.

A new version of Silicon Photonics Integrated Circuit (PICv2) was designed at CERN and manufactured by imec [1] as a part of a multi-project wafer (MPW) using the iSiPP50G platform. For a better understanding of the radiation hardness of SiPh, the PIC contains different structures: Mach-Zehnder Modulators (MZMs); Ring Modulators (RMs); Ge photodiodes; and Si waveguides of different lengths. The previous version of the PIC, fabricated in the iSiPP25G platform, has shown MZMs to be radiation tolerant up to a few hundred kGy of TID [2]. PICv2 produced using the newer process has already been shown to improve on the earlier result with devices being able to withstand as much as 11 MGy (SiO2) [3].

Ring Modulators on PICv2 are based on a pn-junction phase shifter, on top of which a Tungsten micro-heater is integrated. The role of the micro-heater is to locally change the temperature of the ring phase shifter, which results in fine-tuning the resonance wavelength of the RM.

Ring Modulators have been shown to be very radiation tolerant, but the level of tolerance is dependent on the operating temperature. In this work, we present how the temperature influences the annealing process and how with the right choice of temperature we can maximize the radiation tolerance of the devices. The boards with PICv2 were irradiated with an X-ray source with peak energy at 10 keV at different dose rates. Even though the dose rates used in the tests are much higher than the actual dose rate that will be during the High Luminosity, comparing the results from the tests gives a good understanding of the processes that will be happening in the SiPh modulators in LHC.

References:

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[3] M. Lalović et al., “Ionizing Radiation Effects in Silicon Photonics Modulators,” in IEEE Transactions on Nuclear Science, doi: 10.1109/TNS.2022.3148579.

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