Characterisation of the transient response of diamond and SiC detectors with short intense electron pulses

Thanks to the large band gap and high binding energy of diamond crystals, synthetic diamond sensors are widely used as solid-state particle detectors, beam loss monitors and dosimeters in high-radiation environments. Diamond detectors are been often employed by the experiments and the accelerator components at high-luminosity proton-proton and electron-positron colliders, but also at Synchrotrons and FELs facilities.
In order to use them as radiation and beam-loss monitors, beta and X radiations have been employed for a static calibration, spanning a dose-rate range from nrad/s to rad/s. Specific additional tests are however needed in order to assess the transient response to fast and intense radiation bursts, which may lead to non-linear effects in the collection of ionisation charges. For this reason, we designed, instrumented and installed an experimental setup that uses a collimated, sub-picosecond, 1 GeV electron beam, with a bunch charge of tens of pC, provided by the electron linac of FERMI in Trieste, Italy.
Two diamond detectors are mounted on a mechanical support located in a vacuum chamber on the beam line. A remotely controlled stepper-motor can move the support vertically, positioning in turn one of the mounted detectors on the beam axis, and performing position scans across detectors.
We performed a systematic characterisation of transient diamond sensors response as a function of the bunch charge in the range of few to 100 pC, and of the bunch size from several tens of microns to millimeters.
The high charge carrier density generated by ionisation in the diamond bulk caused a transient modification of the sensor electrical properties, such as resistance and capacitance, which in turn affected the signal shape.
We successfully interpreted the experimental results with a model based on a two-step numerical approach. We simulated first the effects on the signal of both the charge carrier density evolution in the diamond bulk, and then the consequent changes in the circuit parameters.
Validation of this approach is conducted by comparing the simulation with measurements of the TCT (Transient Current Technique) signals generated by α particles.
These results give confidence in the extrapolation of the non-linear response of diamond sensors to intense radiation peaks.
Recently the experimental setup has been improved adding a fluorescent screen on the detector support, in order to have a better control of the beam position and collimation. A silicon carbide detector, with a similar geometry of our diamond detectors, has been installed in addition to the installed detectors, with the aim of comparing the transient response for the two different detectors.