Two Photon Absorption Transient Current Technique for electric field mapping in solid state particle detectors

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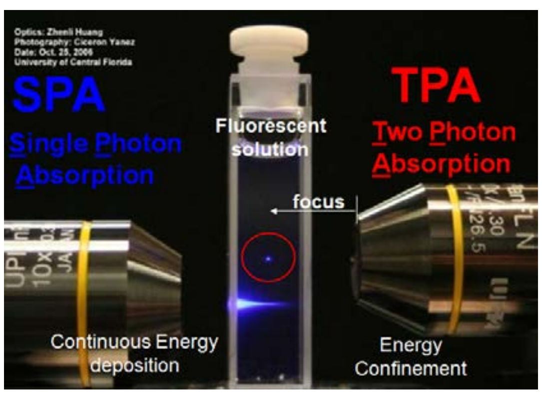
Introduction

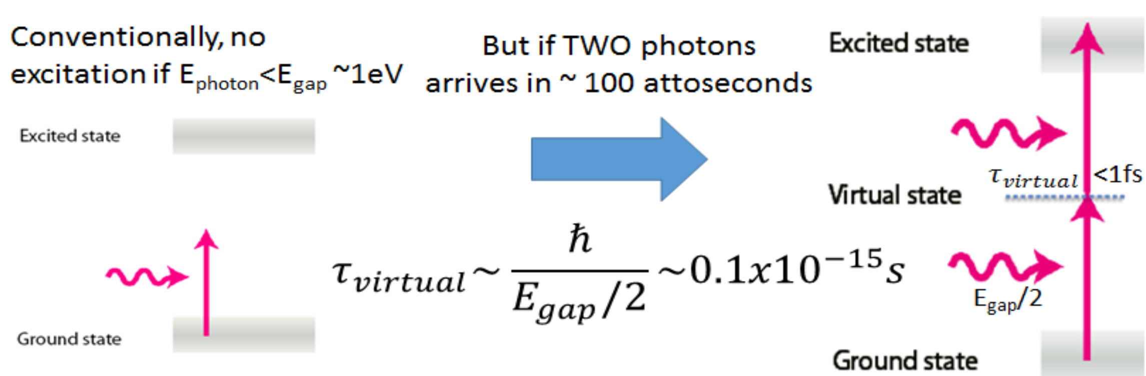
We evaluate solid state particle detectors by localized volume generation (voxels) of electron-holes pairs with femtosecond infrared lasers. The localized charges allow calculation of the built-in electric field applying the Ramo theorem directly. Classical Transient Current Technique (TCT) uses ps-long pulsed visible lasers (short penetration, reduced spot area) or very near infrared ps-pulsed lasers (up to 1064 nm, full detector penetration, no spatial resolution along the beam) . Ultrashort Pulsed Lasers, with a photon energy shorter than the detector bandgap, can excite carriers by Two Photon Absorption (opposed to linear phovoltaic effect) giving both localized eh pairs generation and full device length penetration. TPA Transient Current Technique (TPA-TCT) can be applied both to irradiated and non-irradiated semiconductor detectors.

The Concept

Two Photon Absorption in semiconductors operates at photon energies below the bandgap. Conventional photoelectric effect is strongly suppressed so the device is basically transparent. Only in the focal volume the light intensity is strong enough to generate current carriers by means of electron virtual state assisted absorption. We use femtosecond pulsed lasers because, for the same average power, the two photon absorption probability increases with shorter light pulses. Transient Current laser excitation in the TPA regime opens the possibility to generate charge voxels at any depth in the device. Collected charge correlated with focus position resolves position and size of charge collection junctions. Analyzing the current transients we can estimate the built in detector electric field limits and its modification due to radiation damage.



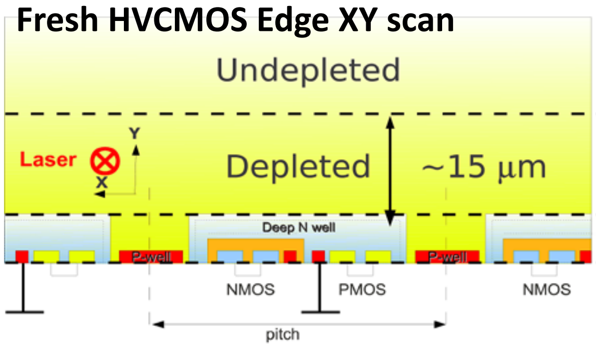
Visual Example of TPA in fluorescent liquids

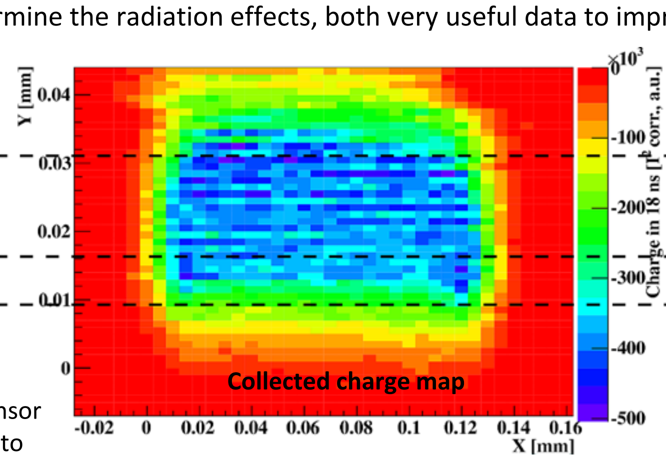


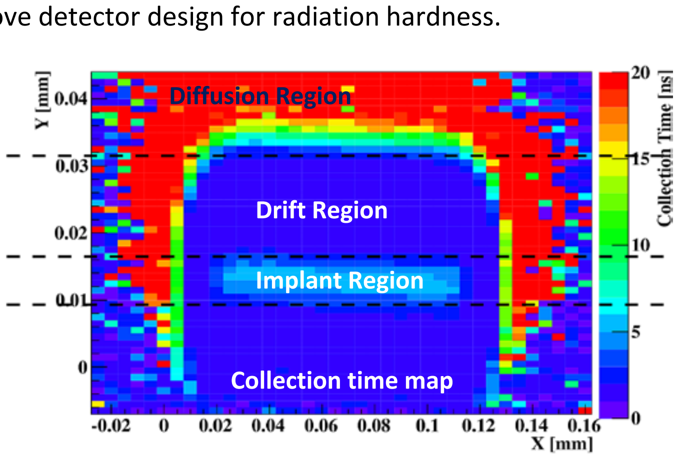
Potential Impact

Transient Current TPA shows in real time the detector signal response at different voxels. With that information we can determine the geometry of the electric field in the detector. For a fresh (non-irradiated) detector, is a test method to know if the (by doping) electric field design is correct. For irradiated detectors, TPA-TCT enables a higher resolution on the electric field measurement, compared with other classical TCT. Drawing the electric field geometry, we can evaluate the detector design efficiency and also determine the radiation effects, both very useful data to improve detector design for radiation hardness.

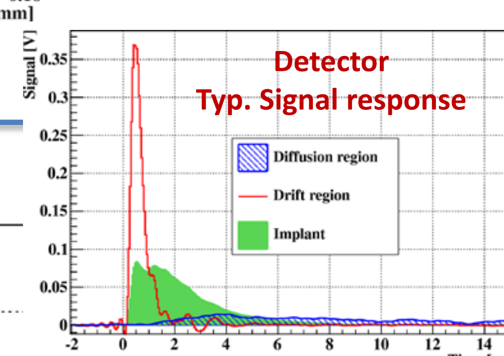
Fresh HVCMOS Edge XY scan



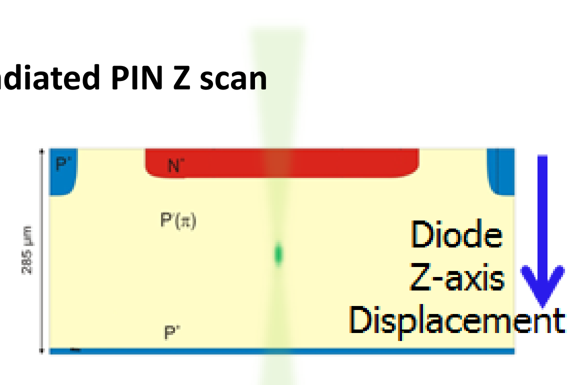


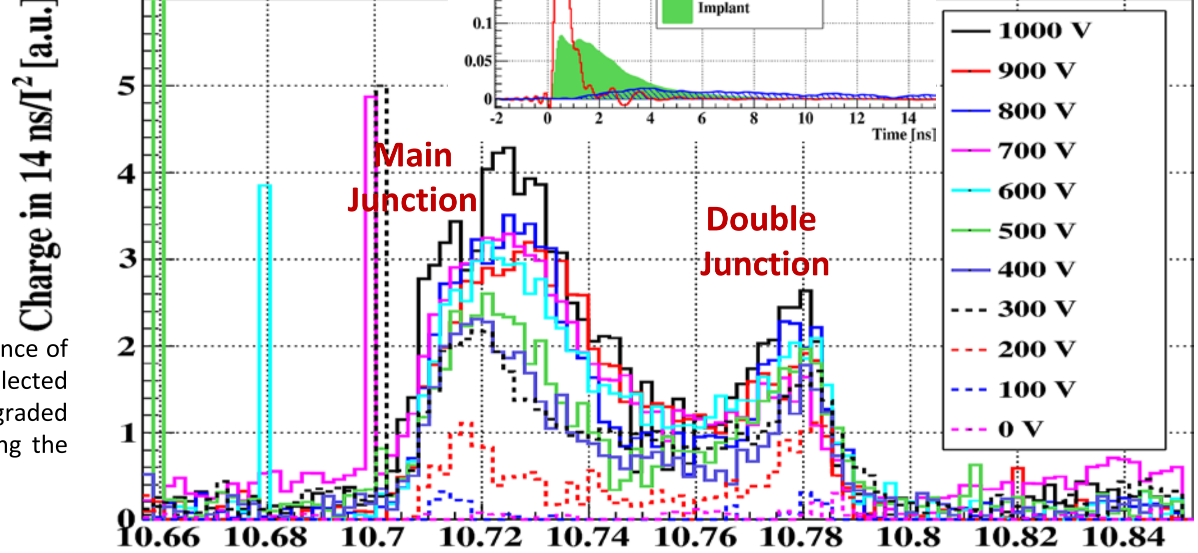


Laser at 1300 nm, 240 fs, pJ pulse energy, XY scan of sensor edge (Δx=5 μm, Δy=1 μm).Voxel pair generation allows to pinpoint the built in electric field by means of collected charge and collection time maps



Irradiated PIN Z scan





Right: We make a TPA Z-scan on an irradiated PiN detector (fluence of 10^{16} n_{eq}/cm^{2}), for different voltage bias. The plot shows the collected charge in 14 ns of detector signal. The main electric field is degraded and a parasitic electric field appears at the device end, showing the well known double junction effect for heavy detector damage.