Characterization of Si Detectors through TCT at Delhi University

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Abstract : Transient Current Technique (TCT) is one of the important methods to characterize Silicon (Si) detectors and is based on the time evolution of the charge carriers generated when a laser light is shone on it. For red laser, charge is injected only to a small distance from the surface of the detector. For such a system, one of the charge carriers is collected faster than the readout time of the electronics and therefore, the effective signal at the electrodes is decided by the charge carriers that traverse throughout the active volume of the detector, giving insight to the electric field profile, drift velocity, effective doping density, etc. of the detector. Delhi University is actively involved in the Si detector R&D and has recently installed a TCT setup consisting of a red laser system, a metal box, a SMU (Source Measuring Unit), a bias tee, and an amplifier. Measurements on a few Si pad detectors have been performed using the developed system, and the results have been found in good agreement with the CERN setup.

INTRODUCTION

• Silicon Sensors are PN junctions operated in reverse bias.
Process: Particle hits sensor → Creation of e-h pairs → Signal at electrodes.

• LHC Phase II Upgrade in year 2022: Integrated luminosity = 3000 fb^{-1}, Luminosity = 10^{35} $cm^{-2}s^{-1}$
Delhi University is contributing in Phase 2 Outer Tracker Upgrade!

• Radiation damage effect on CMS Si Tracker: Breakdown voltage decreases, Depletion voltage increases, charge collection efficiency (CCE) decreases.

TRANSIENT CURRENT TECHNIQUE

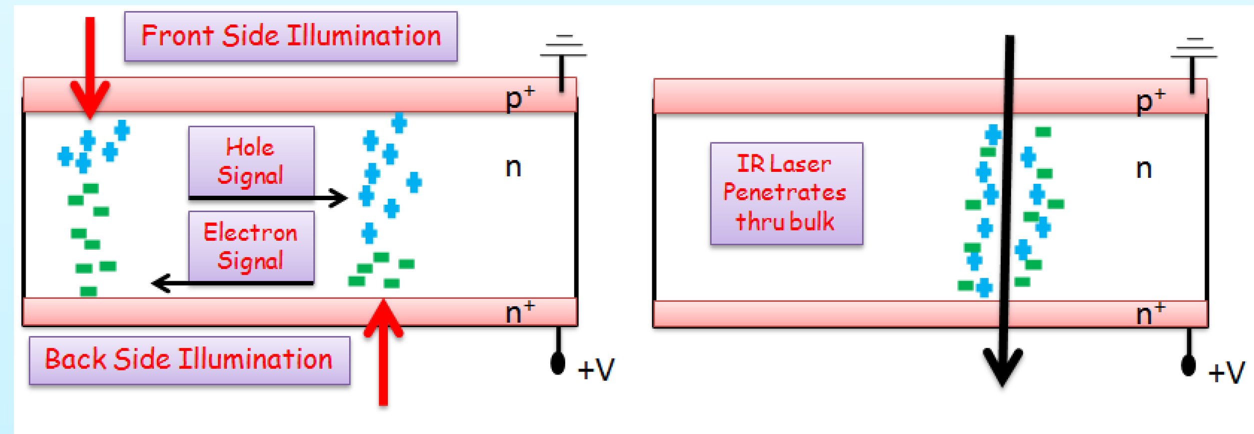
• Requirements for a new Si Sensors: Radiation hard, Higher breakdown voltage, Lower depletion voltage, Higher CCE.

• Transient Current Technique is a dynamic characterization technique.
TCT is the study of time evolution of charge carriers generated when a laser light is shone on Device Under Test (DUT).

• Ramo's Theorem: Charge induced (Δq) on the electrodes by the charge carriers generated (q) is the ratio of the displacement (Δx) of those charge carriers with the total depth (d) of the detector.

$$\Delta q = (\Delta x/d) \cdot q$$

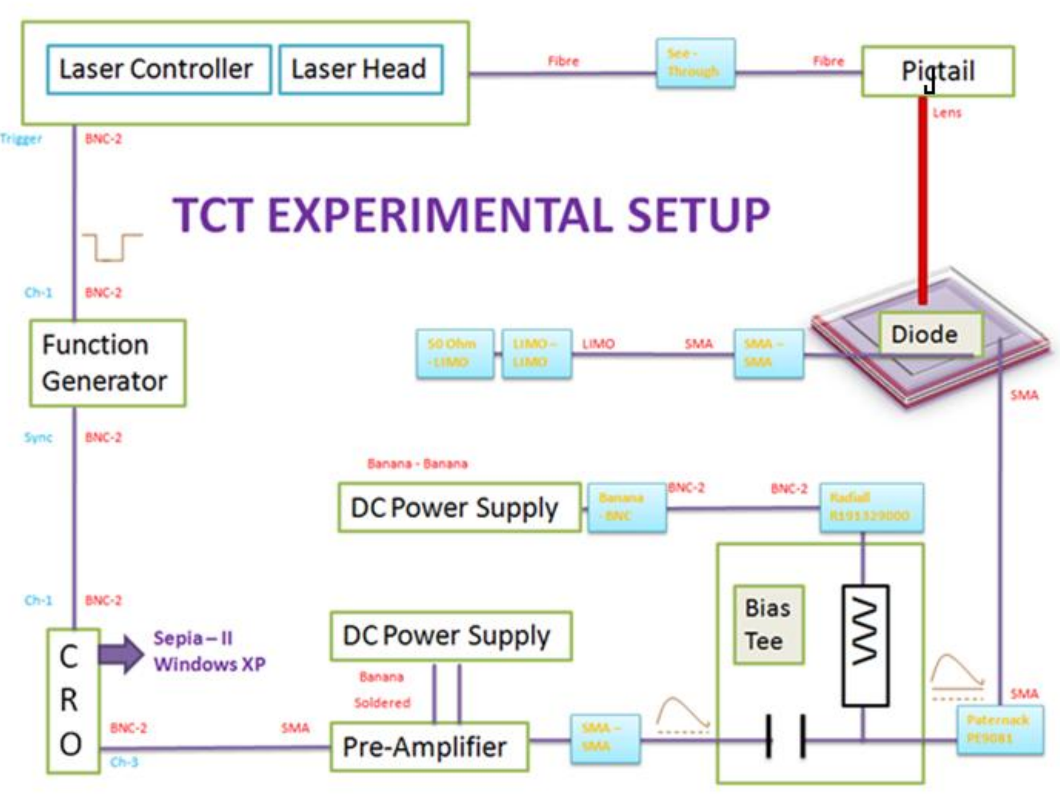
TYPES OF TCT TECHNIQUES



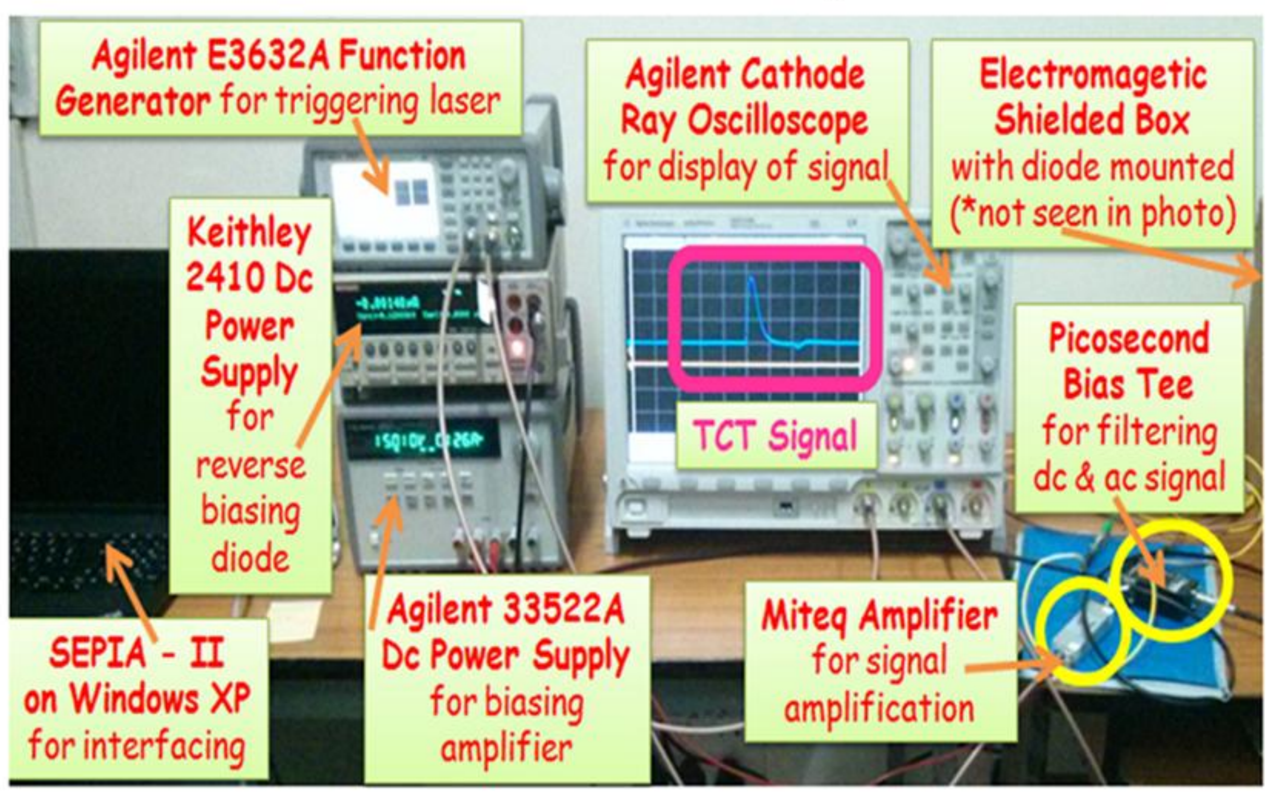
• Red Laser TCT
- Creates electron–holes (e-h) on the surface.
- Output signal from charge carrier that travels in the active bulk.
- To find drift velocity, trapping time, CCE.

• Infrared Laser TCT
- Moderate e-h created in bulk.
- Output signal from both charge carriers.
- To measure CCE.

DU Circuit Diagram



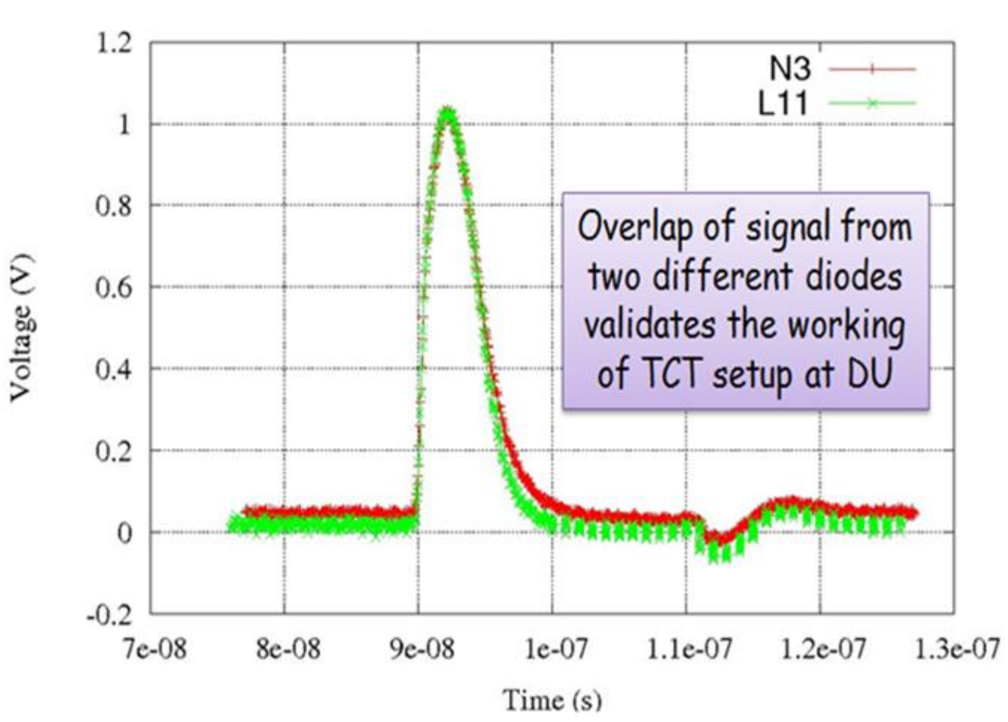
DU TCT Setup



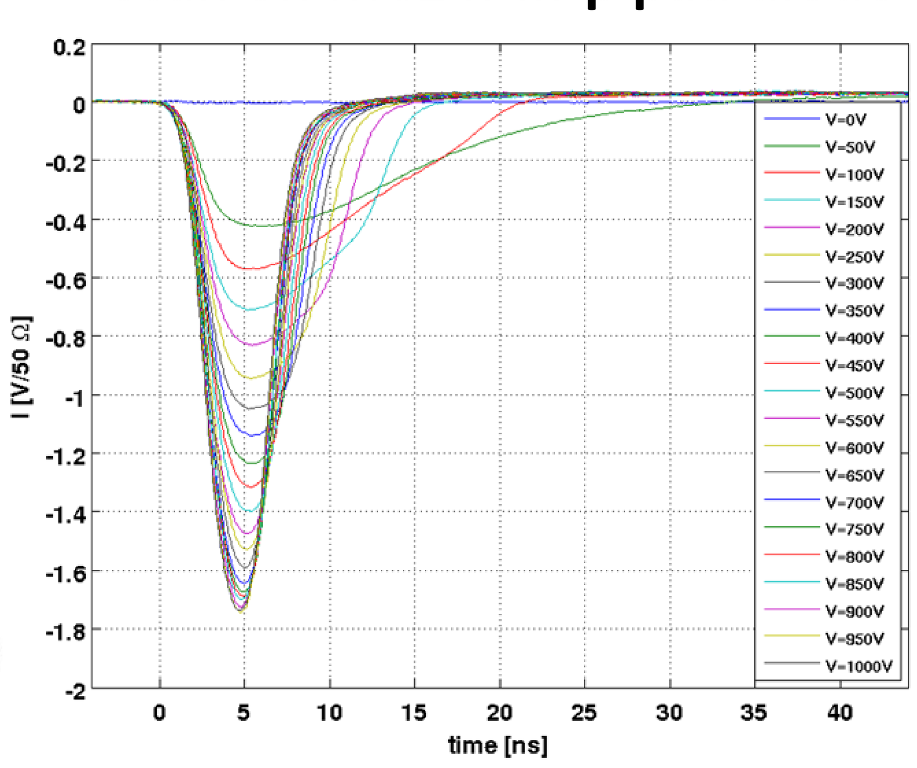
EXPERIMENTAL SPECIFICATIONS

• Function Generator: Frequency = 200.0Hz, Amplitude = 1.0V, Offset = -500.0mV
• Laser wavelength 660nm
• Keithley 2410: Bias = 0 to ±1000V
• Agilent DC Supply: Bias = 0 to +15.0V
• Cathode Ray Oscilloscope: Bandwidth = 1.0GHz, Sampling rate = 4.0GSa/s
• Bias Tee: Resistance = 3.127kΩ, Capacitance = 2.2nF
• Amplifier: Gain = 58.0dB

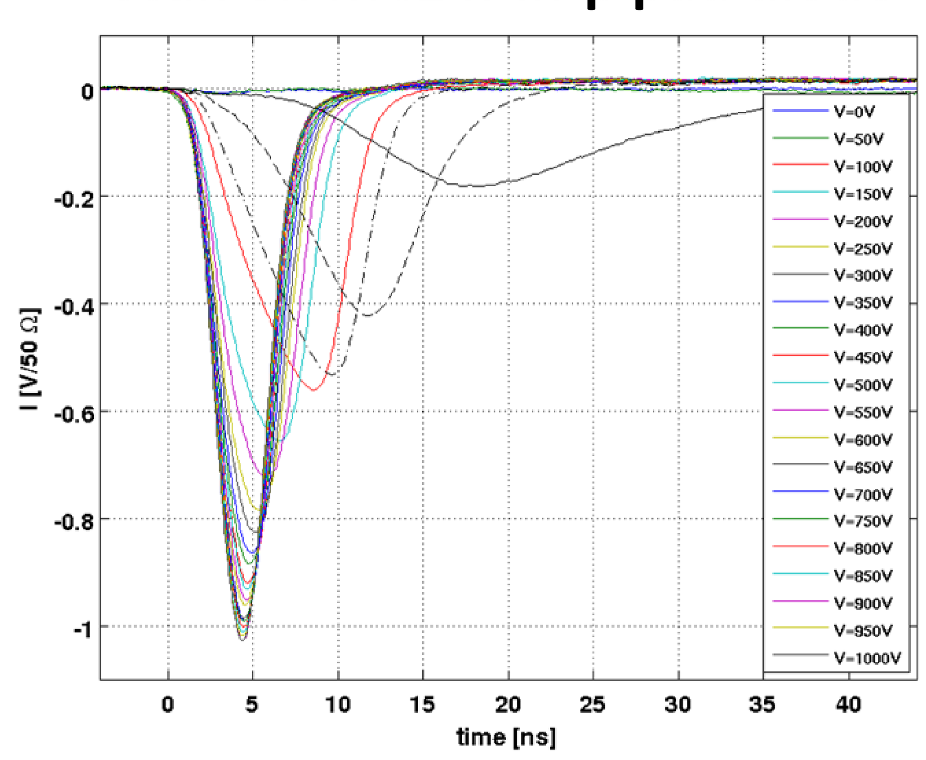
Frontside TCT Signal of 2 p-in-n FZ pad diodes @ 200V



Frontside TCT Signal voltage scan on MCZ n-in-p pad diode



Backside TCT Signal voltage scan on MCZ n-in-p pad diode



OBSERVATIONS

• Overlap of TCT signal from 2 same type, i.e. p-in-n FZ pad diodes, validates the TCT setup at DU.
• Rise in signal is due to movement of the charge carriers.
• A bend in the rising edge of the signal is seen when the first carrier is collected at the electrode.
• Decrease in the signal is voltage dependent, & depends on the drift of the carriers.

Summary :

• TCT setup using red laser (660 nm) is installed & commissioned at Delhi University.
• Measurements on diodes are in good agreement with each other, validating the TCT setup installed at DU.
• To complement the measurements, MixedMode TCT simulations using Silvaco TCAD tool are being done.
• Infrared Laser (1060 nm) TCT capability will be added to the existing setup for calculating CCE.

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