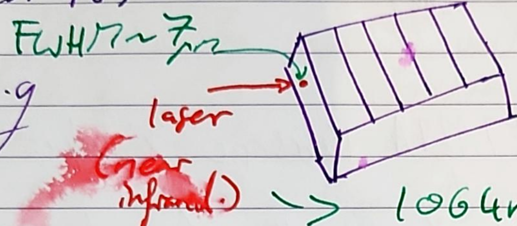
Edge-TCT measurements.

- Edge - Transient Current Technique.
- Sensor irradiated by near infrared laser (focussed)
  ↳ Parallel to sensor surface and normal to silicon (strips).

e.g



(Can be used for pixel detectors too).

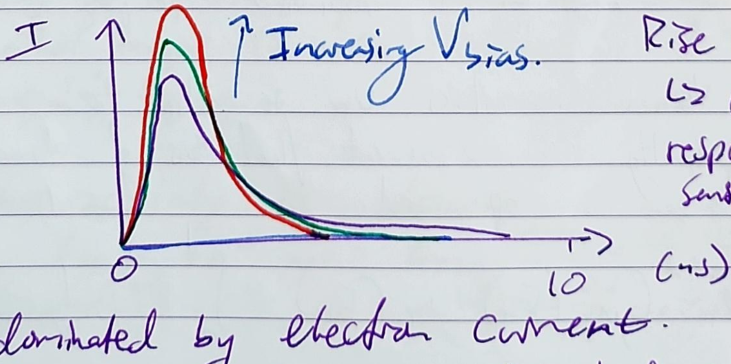
→ 1064nm → 1mm absorbtion length in Si at 300K.
→ 50ps duration.

Current recorded as a function of the distance of the laser beam to the readout plane.
Initially induced current pulse $\propto E v_e/v_h$ → electric field can be determined.

- One strip connected via current amplifier to a 1.5 GHz scope. (amplifier 10 kHz - 1 GHz)
- Remaining strips connected to a fixed potential via 50 Ω resistors.
- Average of 400 transients recorded.
- Carefully polished edge for laser injection.

Example.

(I(t) plot).



Rise time
↳ electronics response of sensor + readout.

Peak → dominated by electron current.
Tail → holes (field decreases towards back of sensor).

edge TCT setup.

-> Jonathan's Thesis

↳ reproduce his results in LGADs.

-> Beam spot too large?

-> weighting field.

Malta 2.

- 180 nm process.
- 100-300 μm process.
- ~ 1 μW/pixel power dissipation.
- $36.4 \times 36.4 \, \mu m^2$ pixel pitch.
- low front capacitance < 5 fF
- 512x224 pixels.
- Operating thresholds ~ $100 e^-$.
- Characterised in MALTA telescope -> before & after neutron & x-ray irradiation.
- New carrier board design allows for edge measurements.
- Polish edge as such there is uniform surface.

- Spot size & focus position.
- $f(x, A, \mu, \sigma) = A\left(\mathrm{erf}\left(\frac{x-\mu}{\sigma}\right) + 1\right)$

Fitting parameter.

$$\mathrm{erf}\left(\frac{x-\mu}{\sigma}\right) = \frac{2}{\sqrt{\pi}} \int_0^{\frac{x-\mu}{\sigma}} e^{-t^2} \, dt$$

width parameter.

$$\omega(z) = \omega_0 \sqrt{1 + \left(\frac{z - z_0}{z_R}\right)^2}$$

Rayleigh length

↳ $z_R = \frac{\pi \omega_0^2}{\lambda} = \frac{1}{2} k \omega_0^2$

↳ distance for double the cross section of the beam.

What is a weighting field? chapter in Speiter.

$$I(t) = Q \cdot \underline{v}(\underline{r}(t)) \cdot \underline{E_w}(\underline{r}(t))$$

$$\chi^2 = \frac{1}{\sigma_{vel}^2} \sum_{k=1}^{n_k} \left(1 - \frac{vel_k}{v_{scale} \cdot v_k}\right)^2 + w_{pen} \sum_{j=2}^{n_E - 1} \left(\frac{0.5(E_{i-1} + E_{i+1}) - E_i}{E_i}\right)^2$$

assumed

Vscale normalises v_k to vel_k. $\sigma^2 \sim 2\%$. w_{pen} is a penalty term -> prevents fluctuations of adjacent E_i values. w_{pen} is optimised.

E-field. bias voltage.

$$v_k = (\mu_h(E_k) + \mu_e(E_k)) \quad \int_0^d E(y) \, dy = V.$$

Weighting potential, Φ => Coupling of a charge at a position to electrode k.

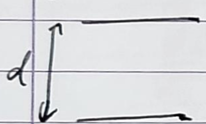
If a charge moves along a path s from 1->2, induced charge is: $\Delta Q_k = q(V_{q_1}(2) - V_{q_1}(1)) \equiv q(\Phi_k(2) - \Phi_k(1))$

Instantaneous current expressed in terms of the weighting field

$$i_k = -q \underbrace{\mathbf{v}}_{\text{velocity}} \cdot \mathbf{E}_Q \leftarrow \text{weighting field.}$$

- E_Q determined by applying unit potential to the measurement electrode & zero to the others.
- Electric field & the weighting field are distinct.
- ↳ E-field determines the charge trajectory & velocity.
  ↳ Weighting field depends only on geometry & determines how charge motion couples to a specific electrode.

<u>e.g. Parallel plate geometry.</u>



Very large overbias, can be approximated by a uniform field. V_b voltage across electrode spacing d. => $E = \frac{V_b}{d}$, determines the motion of a charge carrier in the detector. $\underline{v} = \mu E = \mu \frac{V_b}{d}$

Weighting field determined by appling unit potential to collection electrode & grounding the other. $E_Q = 1/d$

$\therefore$ induced current $i = qvE_Q = q\mu \frac{V_b}{d} \cdot \frac{1}{d} = q\mu V_b/d^2$

In this geometry, $\underline{E}$ & $\underline{E_Q}$ are uniform across the detector.

$\therefore$ i is constant as a charge flows towards the collector.

For a charge that traverses the entire thickness: $t_c = \frac{d}{v} = \frac{d^2}{\mu V_b}$ ← collection time.

& $Q = i t_c = q\mu \frac{V_b}{d^2} \frac{d^2}{\mu V_b} = q$.

For a distance x into the detector, if a e-h pair is created. $t_{ce} = \frac{x}{v_e} = \frac{xd}{\mu_e V_b}$ $t_{ch} = \frac{d-x}{v_h} = \frac{(d-x)d}{\mu_h V_b}$

$\therefore$ $Q_e = e\mu_e \frac{V_b}{d^2} \frac{xd}{\mu_e V_b} = e\frac{x}{d}$, $Q_h = e\mu_h \frac{V_b}{d^2} \frac{(d-x)d}{\mu_h V_b} = e(1 - \frac{x}{d})$