Updates on High Bandwidth Readout at SCIPP

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DRD3 WG6 SiC LGAD Meeting
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Two types of readout we're considering

Optimized for fast timing

- ➔ Typically $\tau_{\text{amp}} \approx \tau_{\text{rise}}$
- ➔ 0.5 – 1.5 GHz
- ➔ "SCIPP" board for Si LGADs; where to go from here?
- ➔ Not part of this talk (discussion afterwards?)

Optimized for feature extraction

- ➔ The faster the better
- ➔ Focus of this talk (updates from the past month)

High Bandwidth Inspiration: Compact Readout

Two institutions working independently on this: SCIPP and OAW

Similarities

- Compact geometry
- RF amplifier IC rather than discretes

Differences

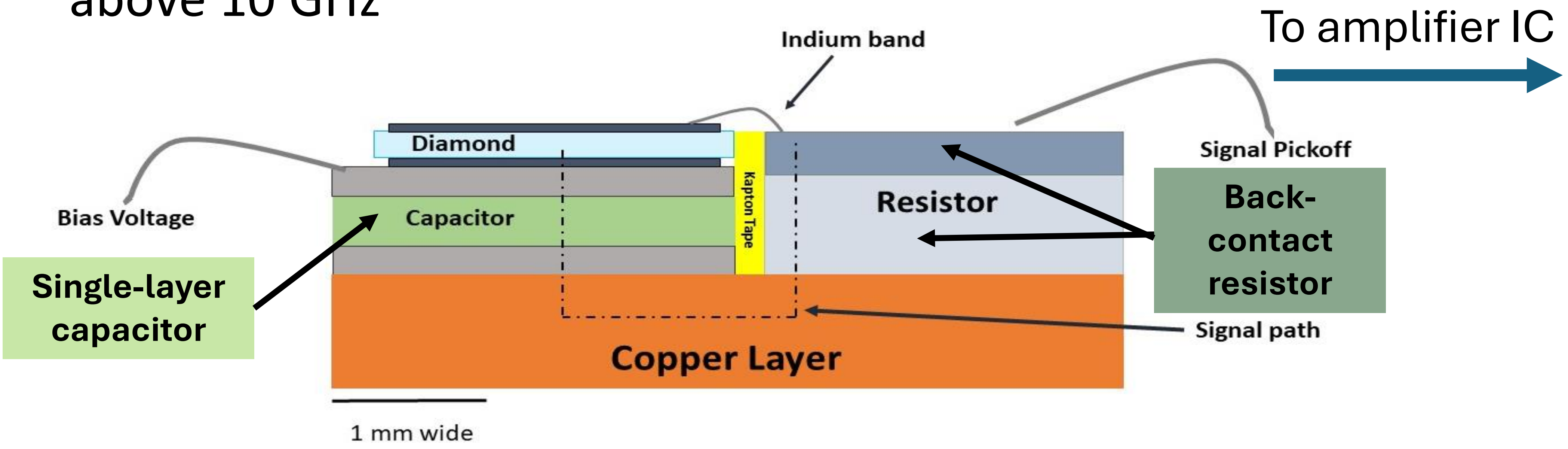
- OAW: Signal return path through amplifier
- SCIPP: Signal return path local to sensor
- Which is best? Let’s find out!

Collaboration

- Working together has great advantages. SCIPP has already benefited significantly from the wisdom of this group (see below)

SCIPP Compact Signal Path Approach

- Make use of RF industry components to develop mm-scale signal path
- Limit inductance, capacitance to push LC resonance above 10 GHz

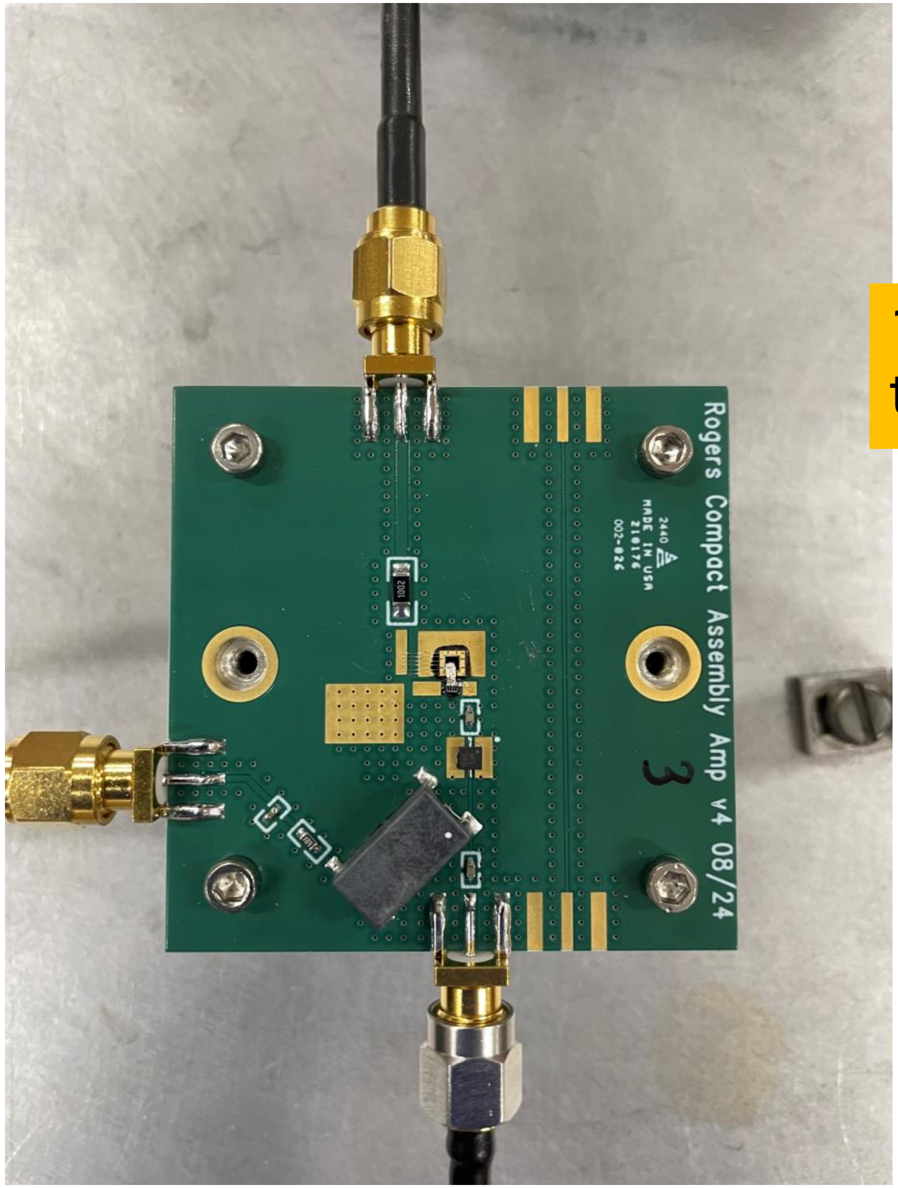


To amplifier IC

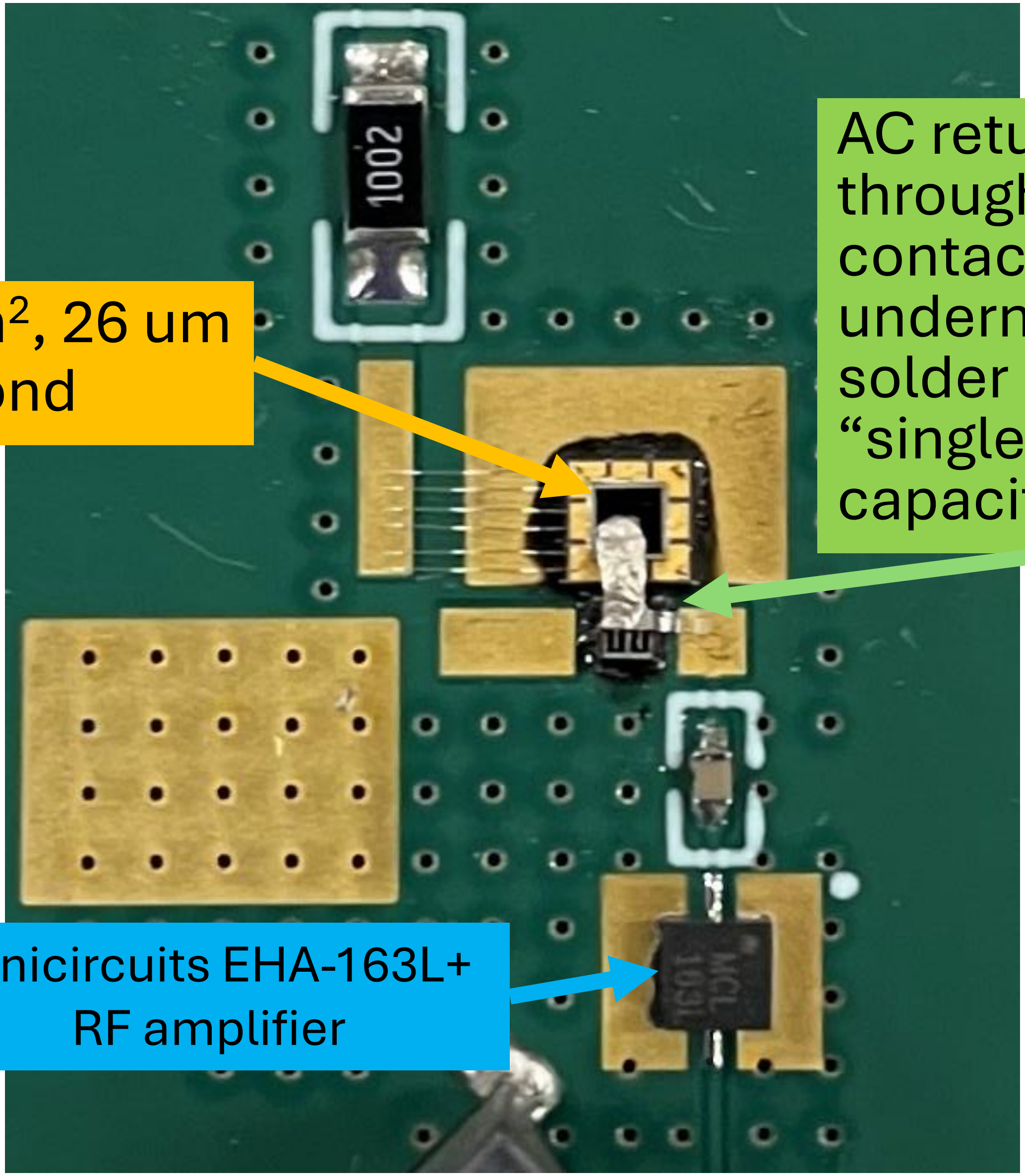
Single-layer capacitor

Back-contact resistor

Integrate with localized readout to eliminate signal transport degradation



1.5x1.5 mm^2, 26 um thick diamond



AC return through “back contact resistor, underneath solder mask to “single-layer capacitor” array

Minicircuits EHA-163L+ RF amplifier

Diamond capacitance, per mm^2, 30 um thick: 1.7 pF (so this sensor is 4.4 pF)

From last month’s presentation:

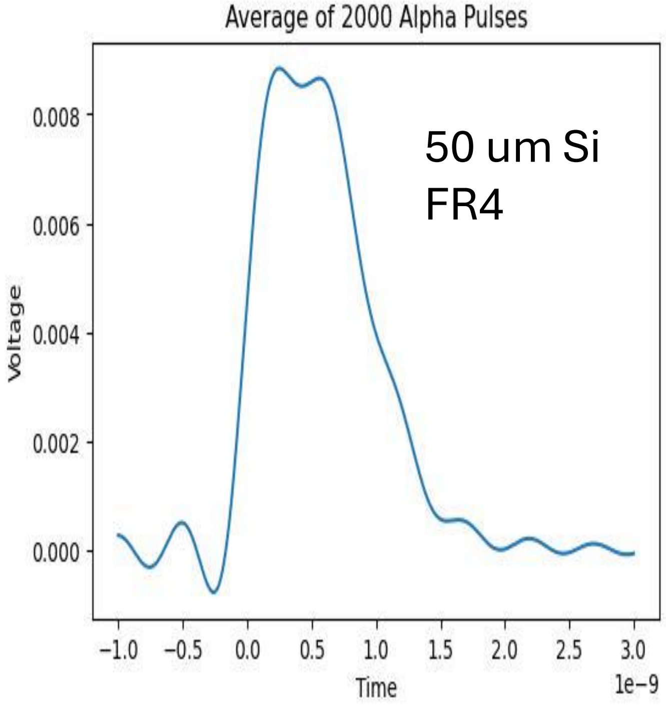
At that point we had studied

- Board with (slow) FR4 dielectric
- Board with (fast) Rogers 4350b dielectric

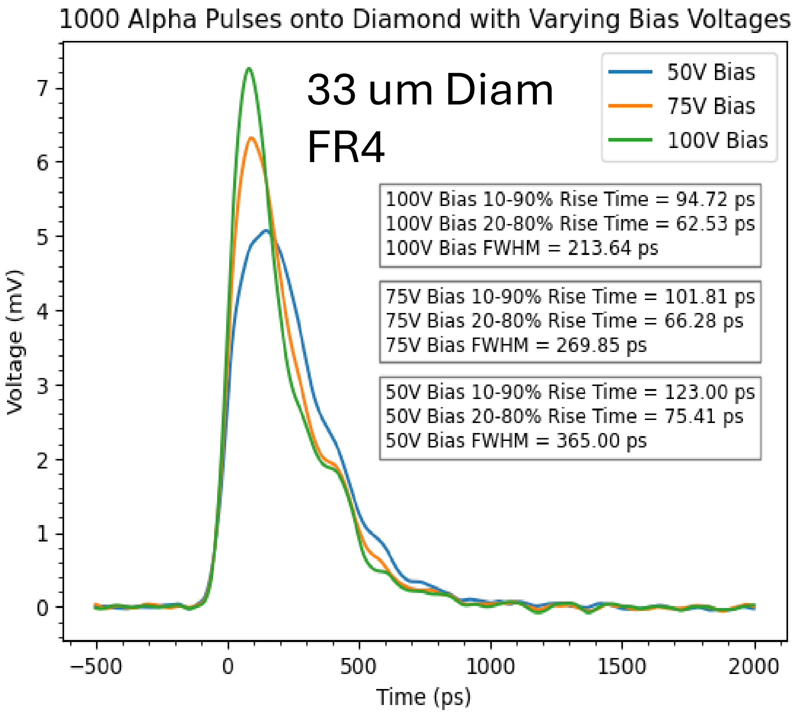
And on these, we had excited (with an alpha source ~ 5 MeV)

- Silicon PiN on FR4
- 33 um, 2x2 mm^2 diamond on FR4
- 26 um, 1.5x1.5 mm^2 diamond on Rogers 4350b

From last month’s presentation


Average of 2000 Alpha Pulses

50 um Si
FR4

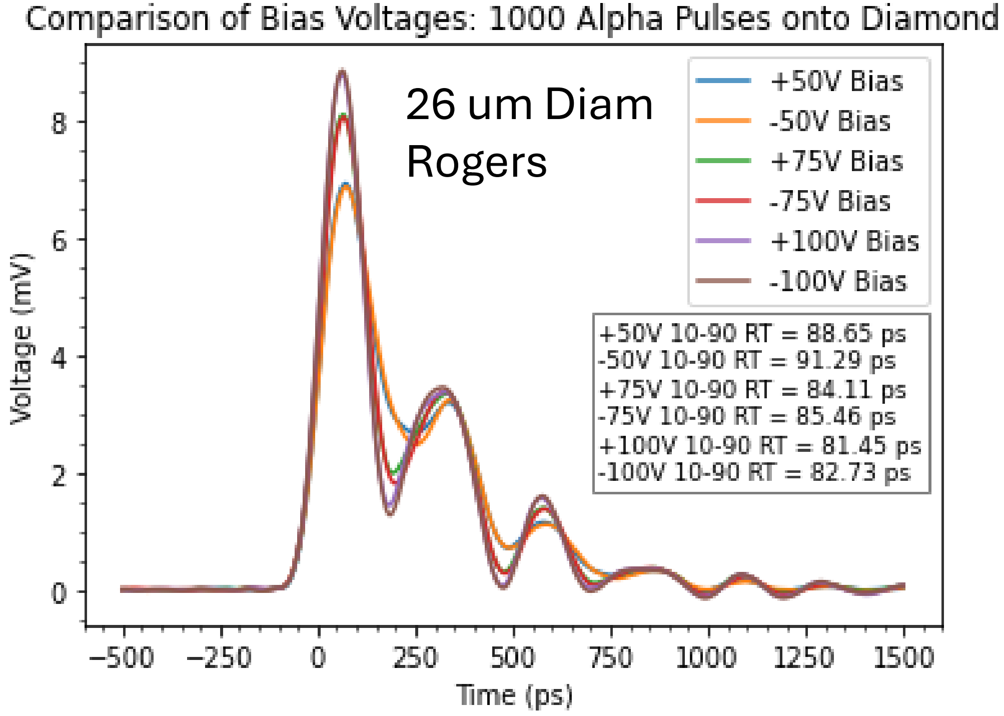

1000 Alpha Pulses onto Diamond with Varying Bias Voltages

33 um Diam
FR4

100V Bias 10-90% Rise Time = 94.72 ps
100V Bias 20-80% Rise Time = 62.53 ps
100V Bias FWHM = 213.64 ps

75V Bias 10-90% Rise Time = 101.81 ps
75V Bias 20-80% Rise Time = 66.28 ps
75V Bias FWHM = 269.85 ps

50V Bias 10-90% Rise Time = 123.00 ps
50V Bias 20-80% Rise Time = 75.41 ps
50V Bias FWHM = 365.00 ps

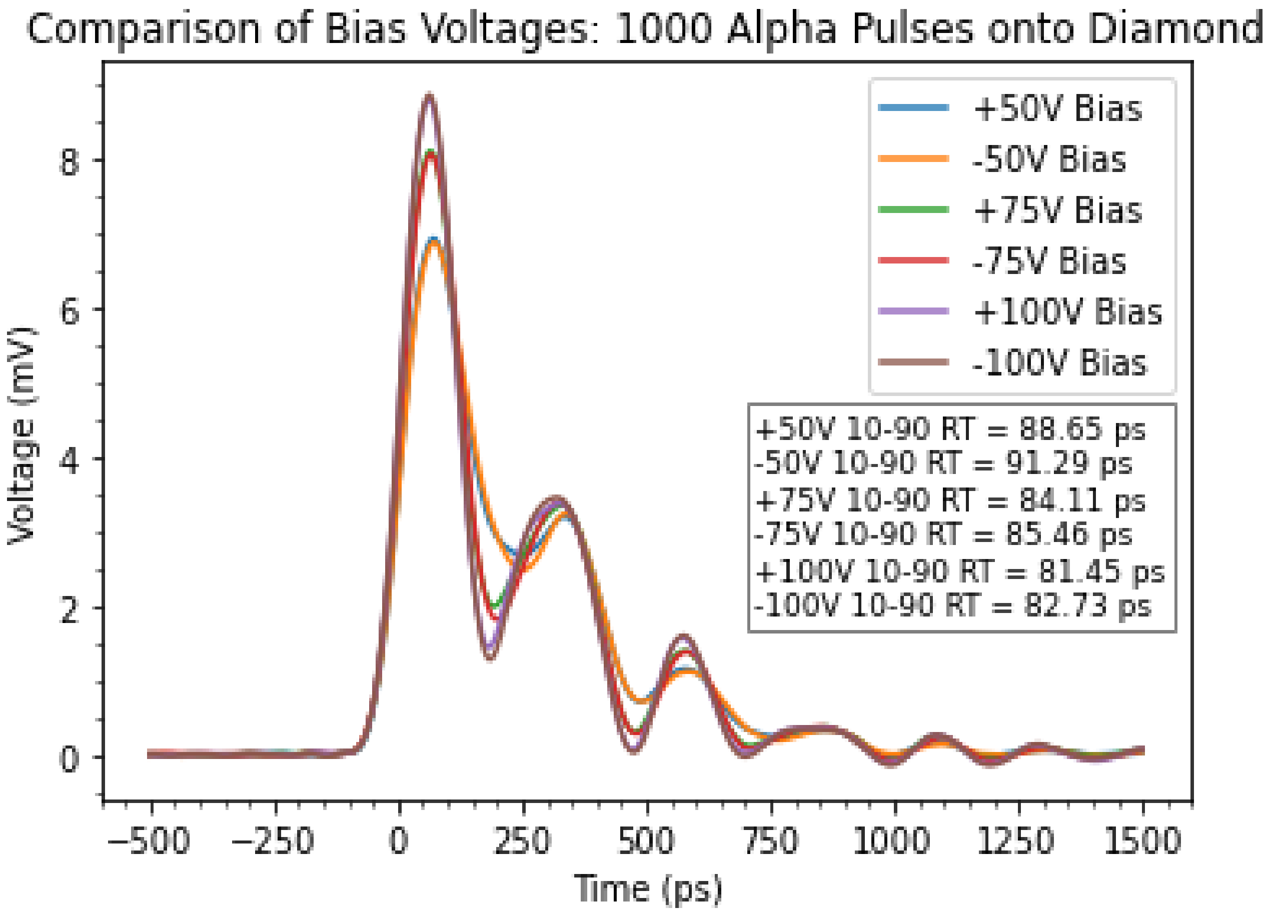

Comparison of Bias Voltages: 1000 Alpha Pulses onto Diamond

26 um Diam
Rogers

+50V 10-90 RT = 88.65 ps
-50V 10-90 RT = 91.29 ps
+75V 10-90 RT = 84.11 ps
-75V 10-90 RT = 85.46 ps
+100V 10-90 RT = 81.45 ps
-100V 10-90 RT = 82.73 ps

- Rogers assembly fast, but develops ringing
- Taking into account 13 GHz scope BW, τ_{rise} = 81 ps is ~ 4.8 GHz
- Si PiN pulse features (~500 ps collection time) appear visible
- Systematic difference for +/- voltage (Rogers assembly) suggests possible sensitivity to hole vs. electron drift in diamond
- Studies underway in ANSYS HFSS to identify source of limitations

N.B.: For feature extraction, “Instrument response function (IRF)”, which is just the FWHM, may be more appropriate figure of merit than rise time



- 82 ps rise time ➔ 4-5 GHz

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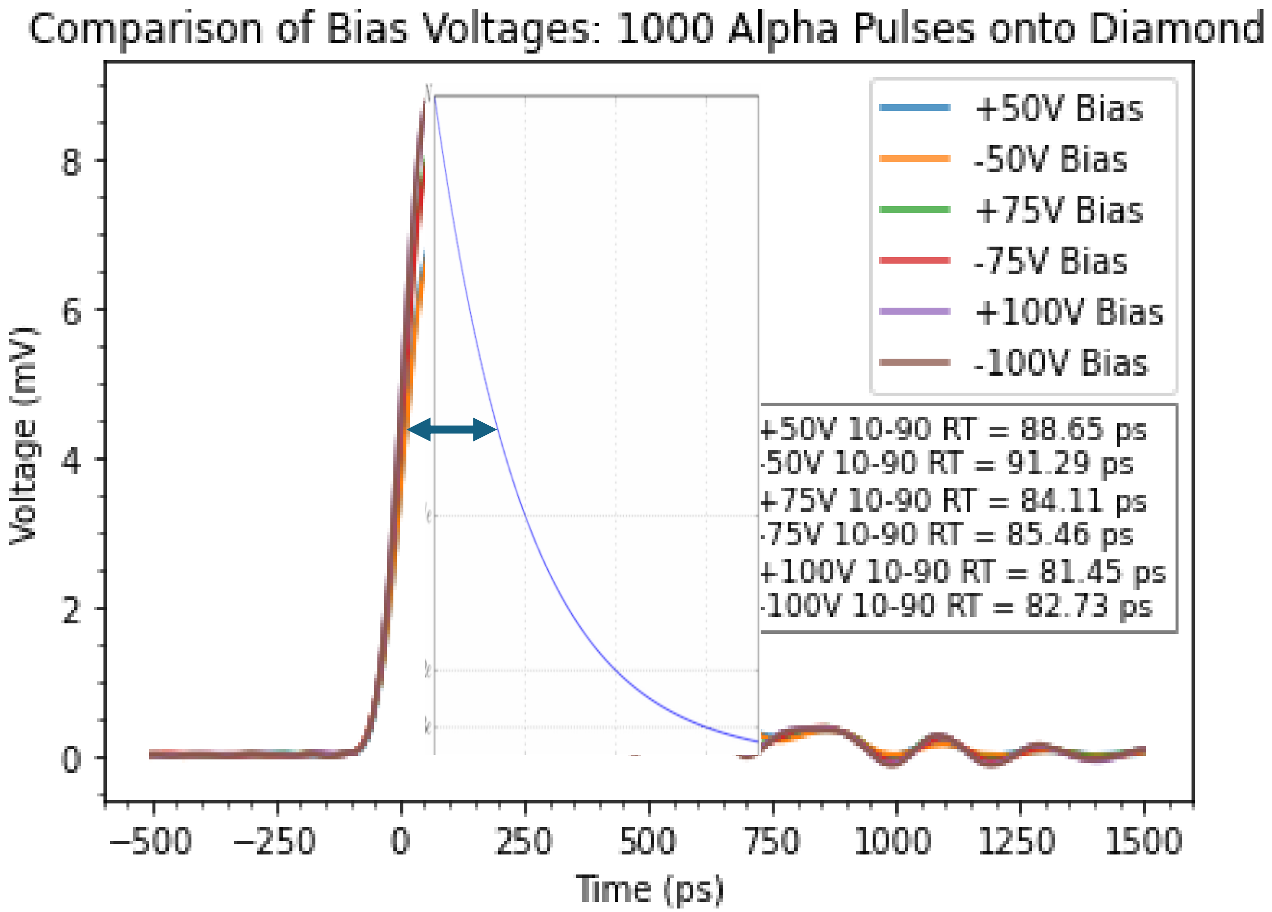
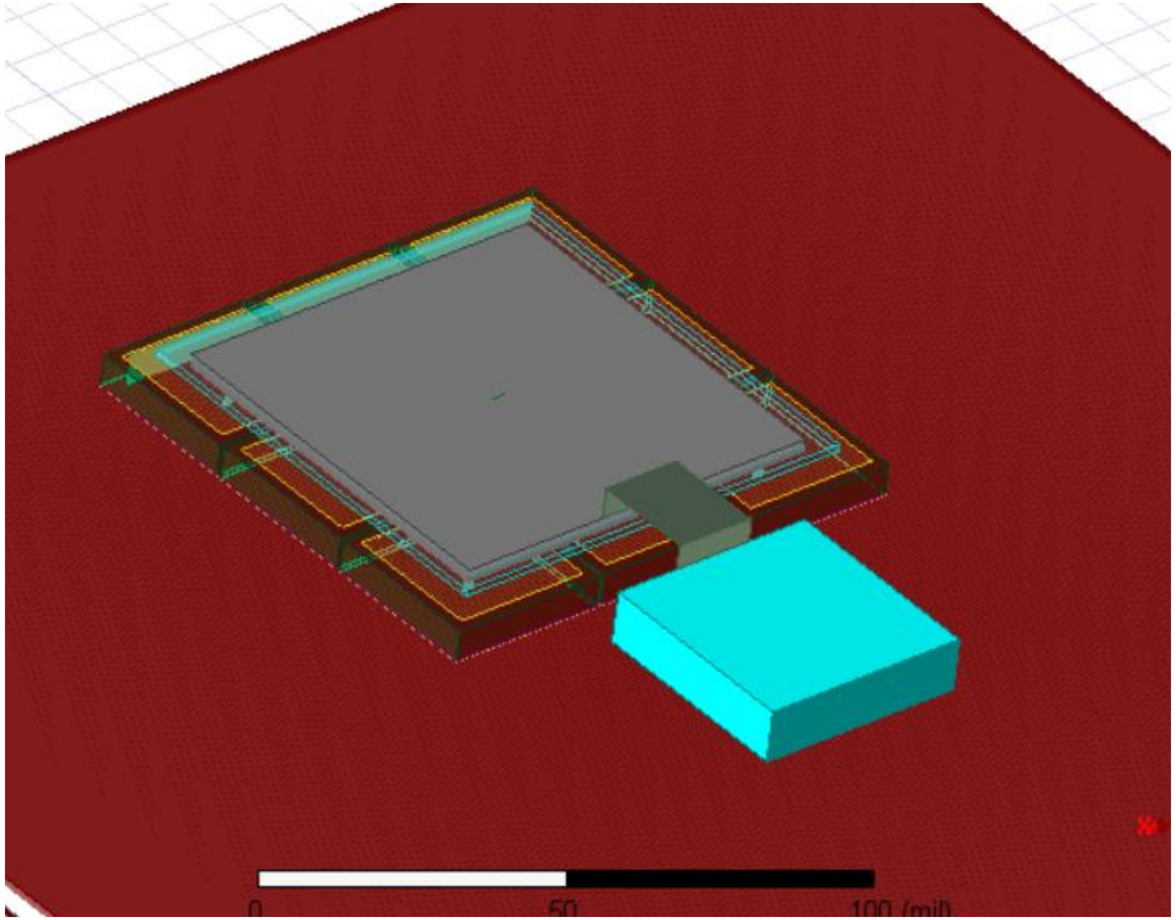
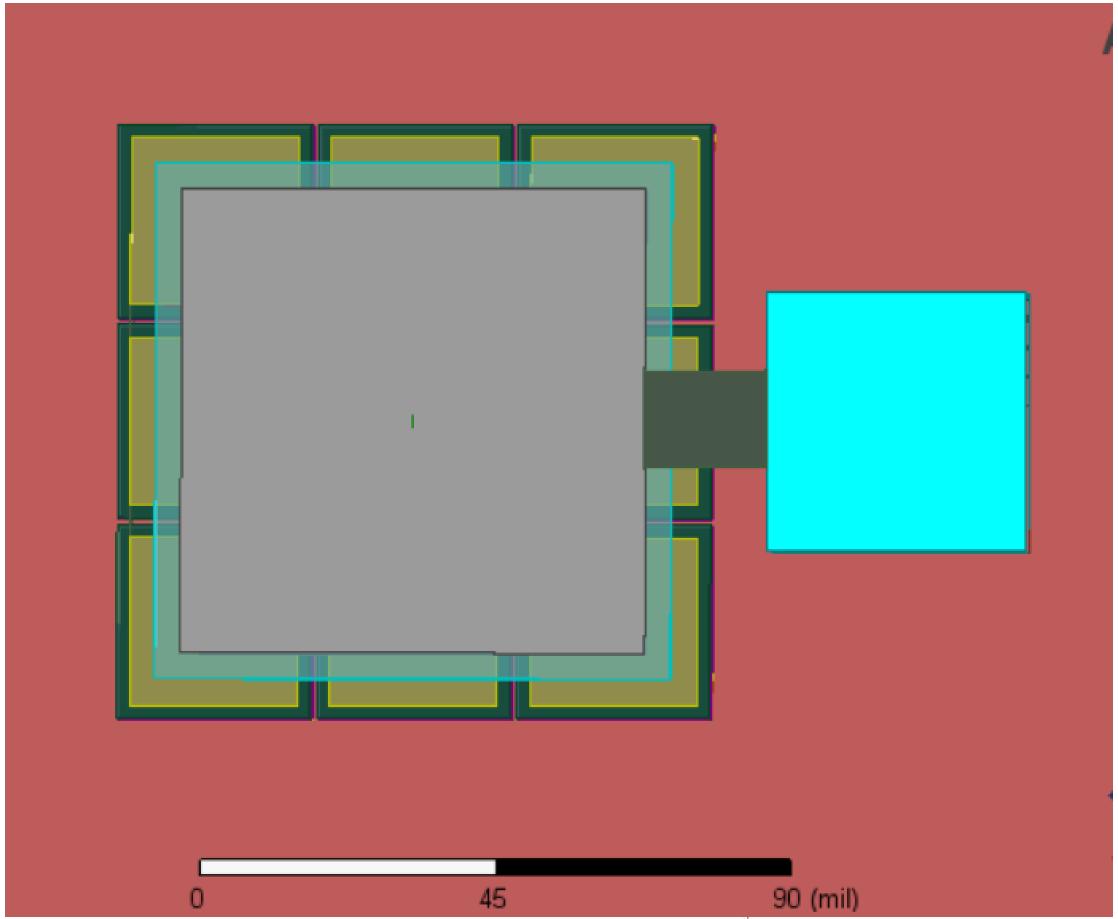


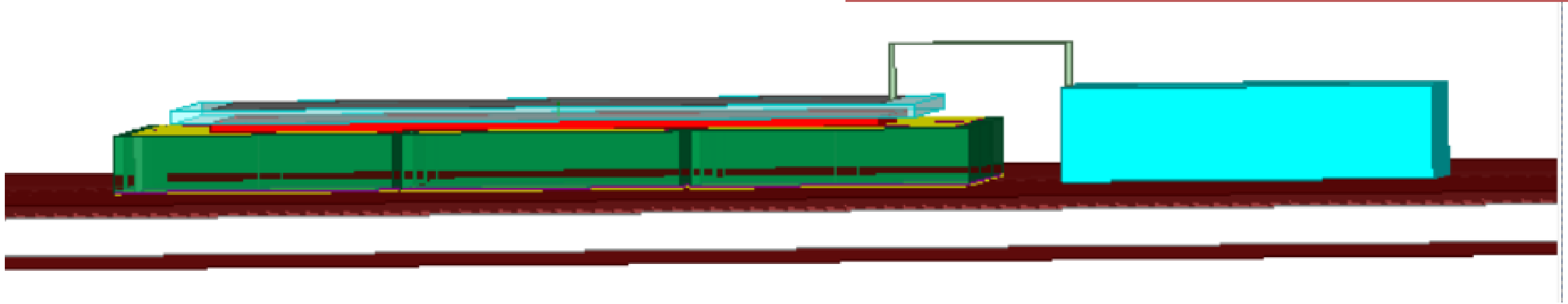
- 82 ps rise time ➔ 4-5 GHz
- 200 ps FWHM ➔ 2-3 GHz

Exponential tail (and ringing) degrading IRF

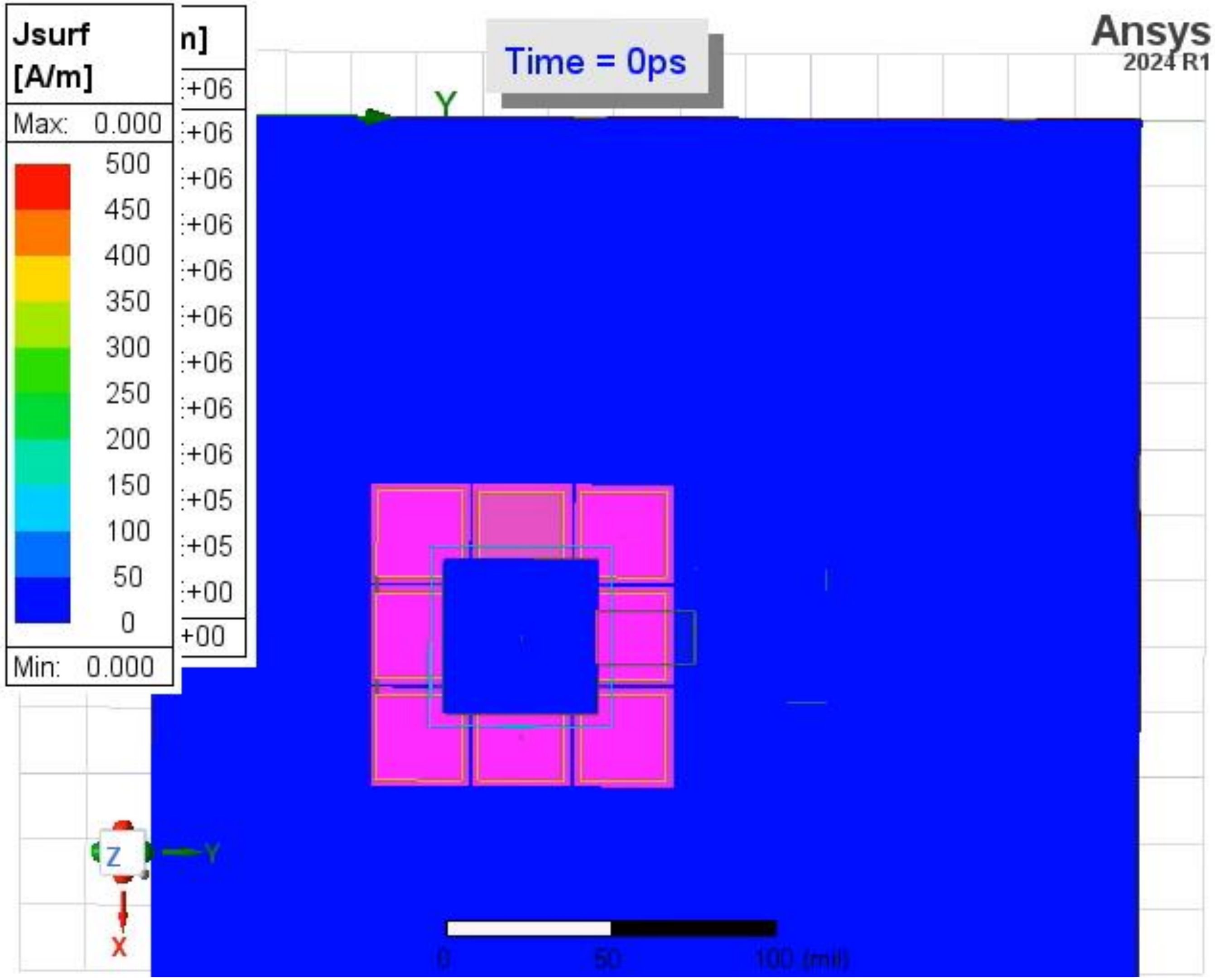
Ansys HFSS Simulations: Can we understand the response?







The sort of thing one can explore with HFSS...



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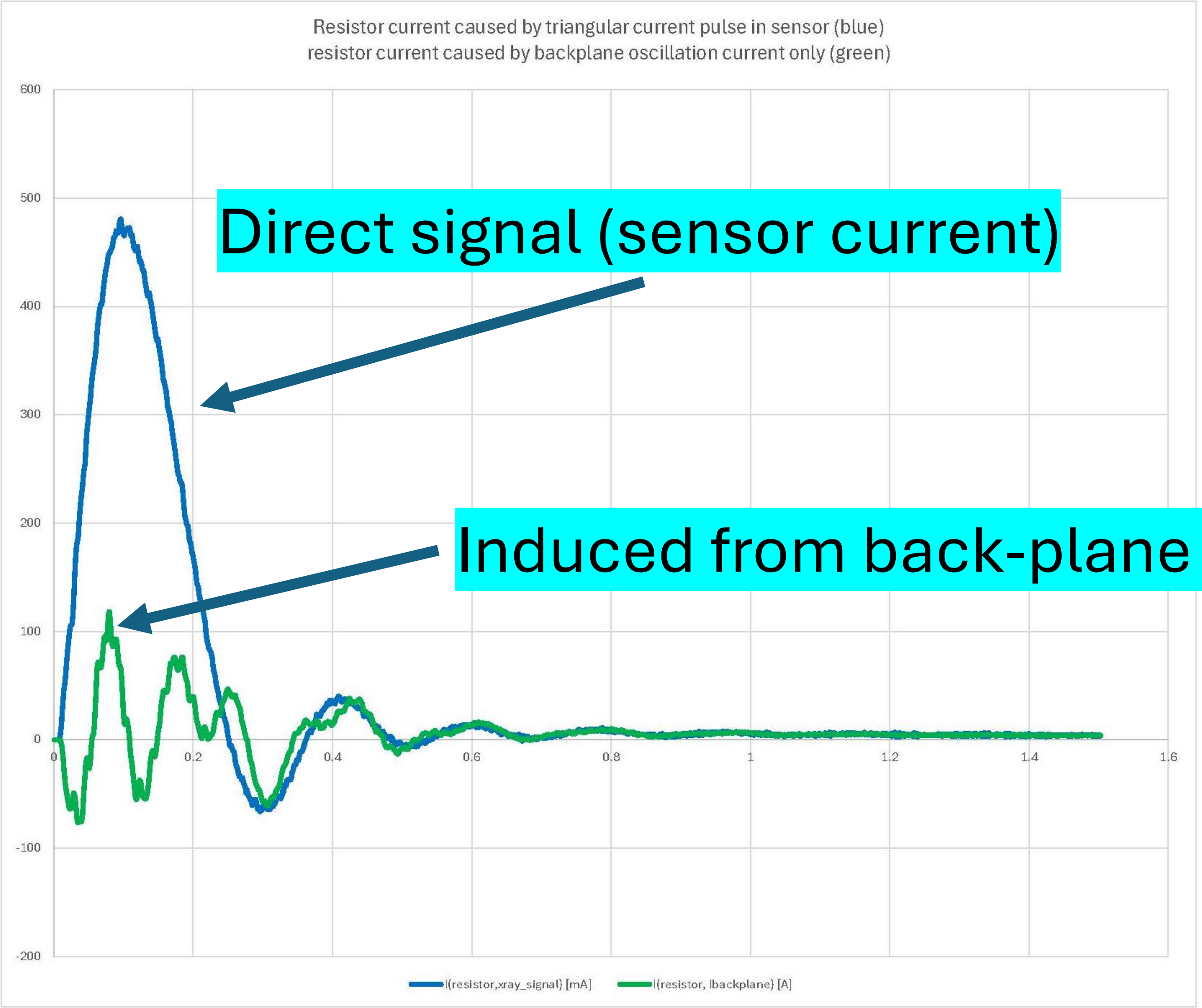


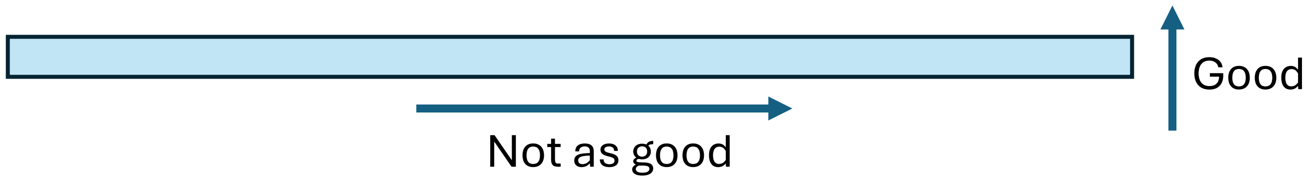
Direct signal (sensor current)

a.u.

Induced from back-plane oscillation

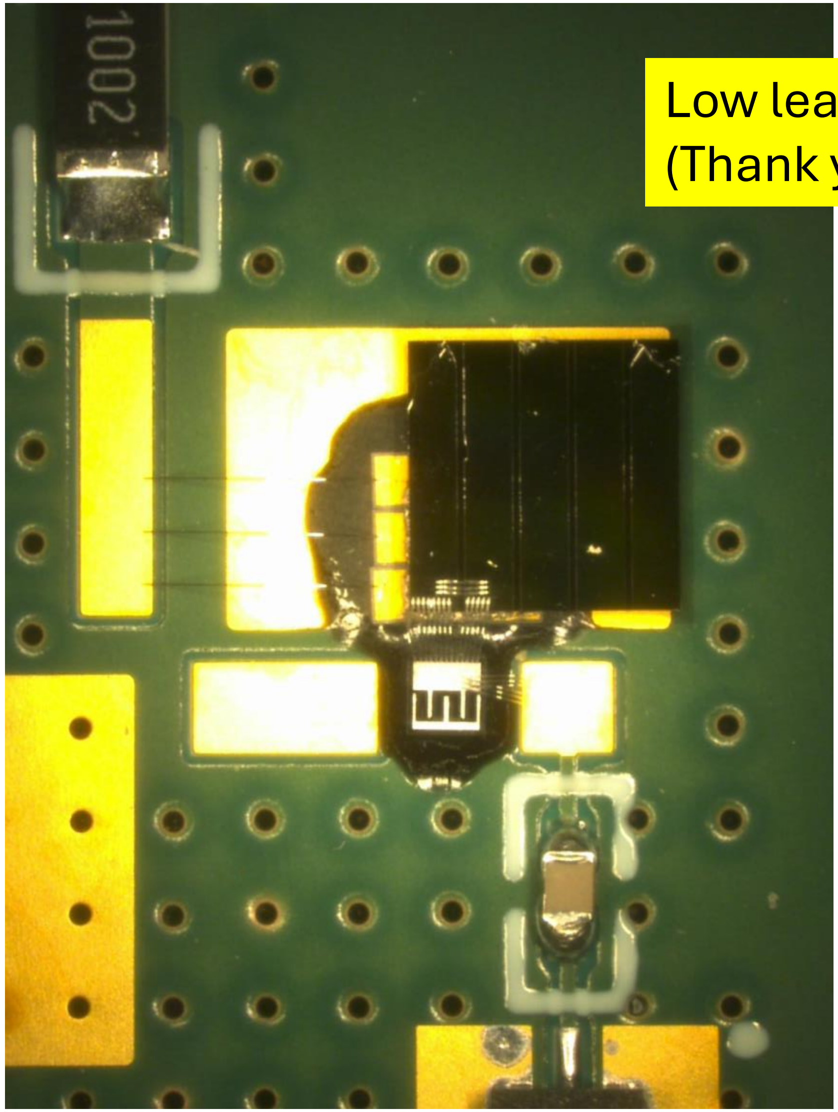
Compact signal-path assembly

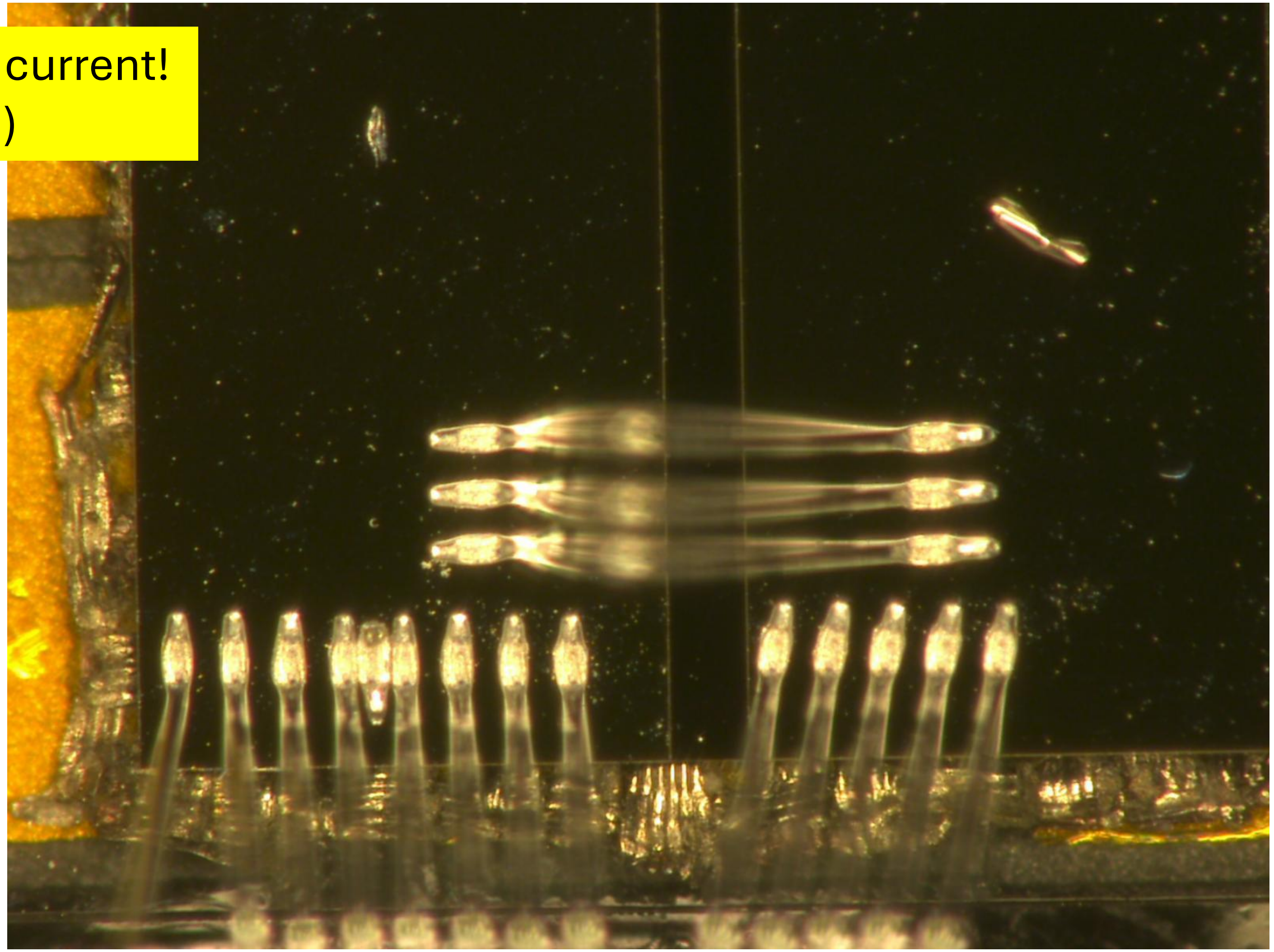
- Were having trouble with leakage when biased (~mA)
- This group suggested conducting tape
  - Conductivity much better "through" than "along" the tape



  - May suppress backplane oscillation?
- HFSS simulation also suggested multiple bind wires about as good as conducting band

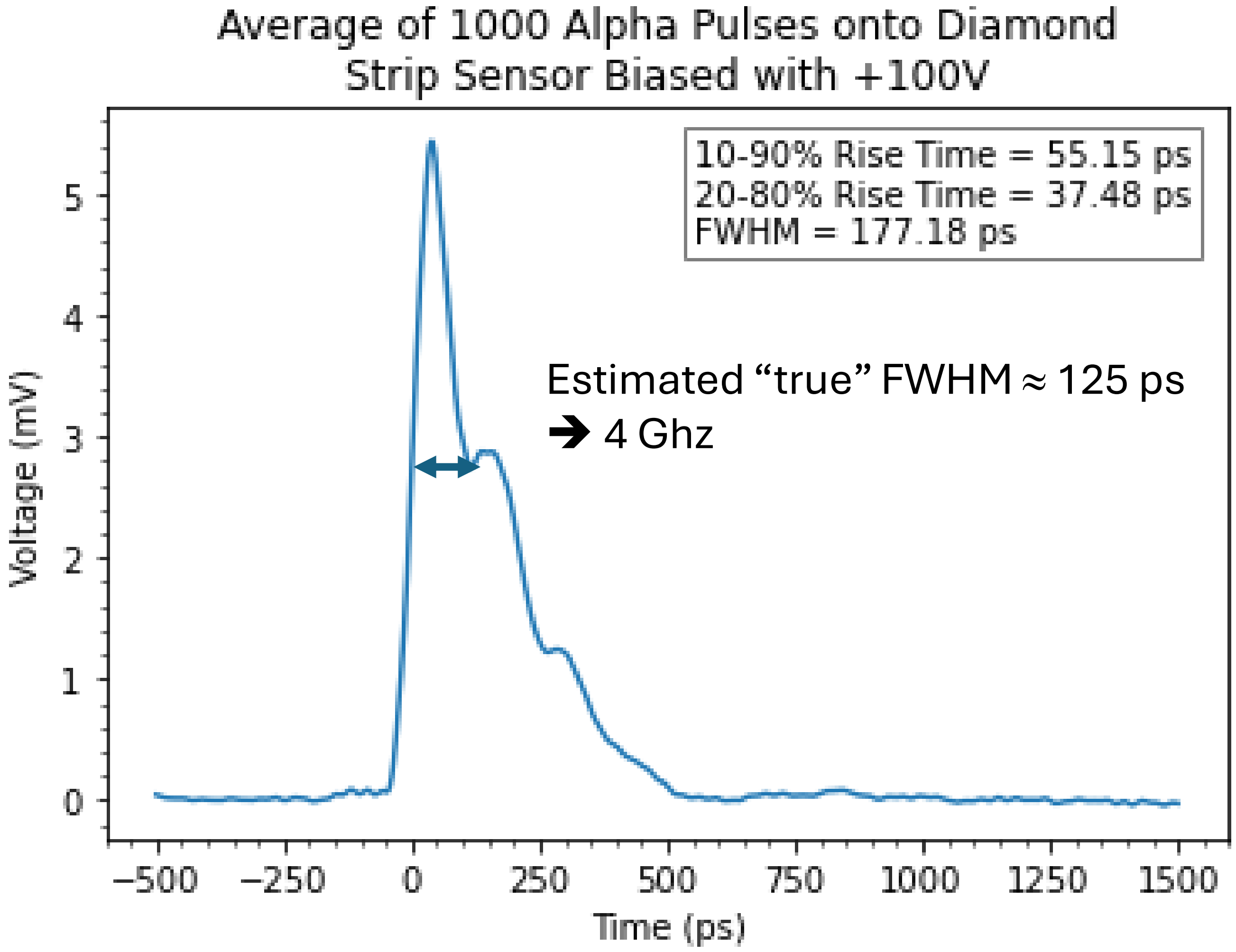
- Decided to test new assembly method on defective strip sensor (isotope production project)
- Illuminated with α’s just for fun





Low leakage current!
(Thank you…)

Response of assembly test structure



Estimated “true” FWHM ≈ 125 ps
➔ 4 Ghz

Encouraging result (could it be the tape?)

4 GHz (IRF) to 7 GHz (rise time)

Is this reproducible?

Thoughts on next steps for multi-GHz readout

- Source improvement between pad and strip sensor assemblies?
- IRF being limited by exponential-like tail – what is source of that?
    - Detector capacitance? HFSS says maybe not…
    - Continue to explore in lab and in simulation
- Will work for a bit more to try to achieve reproducible system with <100ps IRF
- Provide system for characterization studies
- Discussing very thin (10 um) diamond sensor with small (100-um scale) pad (Los Alamos National Lab collaborator)
    - 50 ps collection time
    - < 1 pF capacitance
- Further develop UCSC “alpha station” (collimation, degradation) for independent characterization studies

BACKUP

Fast Timing Readout Scaling Laws (?)

Readout designed to optimize

$$\sigma_t = \frac{\sigma_V}{{dV}/{dt}}$$

	Si	**SiC**
e/h energy	3.6 eV	7.8 eV
density	2.3 g/cm^3	3.2 g/cm^3
V_{drift} (saturated)	100 um/ns	200 um/ns

- Per um of bulk, SiC pair creation rate is roughly $(3.2/7.8)\ /\ (2.3/3.6) = 64\%$ of Si
- But SiC is twice as fast
- So dV/dt would be ~25% larger?
- SCIPP board OK for SiC LGAD?
- Gain = 1 signal would be difficult though

Feature Extraction Readout (multi GHz)

A fast readout system may be able to

- Extract features in pulse
- Be sensitive to v_{drift} and τ_{impact} as a function of local field

Best geared towards large depositions due to readout noise (alpha particle)

Under study at SCIPP

“Chain only as strong as weakest link” (charge collection, signal path, signal transport, readout…)