

TEMPERATURE DEPENDENCE OF UFSD RESPONSE

MEASUREMENTS AND COMPARISON WITH SIMULATION

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29th RD50 Workshop — CERN - November 22, 2016



TEMPERATURE
DEPENDENCE OF
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INTRODUCTION
LGAD

GAIN VS T
GAIN IN WF2

SETUP

PRODUCTIONS

MEASUREMENTS
ON FBK LGAD

IV vs T
GAIN vs T
 σ_i vs T

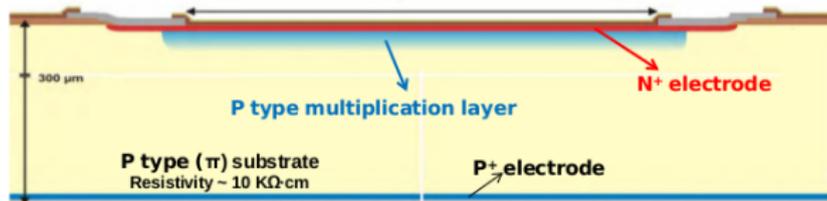
SIMULATION ON
FBK LGAD

GAIN vs V
GAIN vs T

SIMULATION ON
CNM LGAD

CONCLUSIONS

LGAD AS CANDIDATE FOR UFSD



Multiplication layer: creates a locally high electric field ($E \gtrsim 300kV/cm$) so that the drifting electrons will induce a controlled avalanche.

External bias voltage: high enough ($E_{bias} > 30kV/cm$) to saturate the charge drifting velocities \rightarrow fast charge collection \rightarrow steep signal.

$$N(x) = N_0 \cdot e^{\alpha x} = N_0 \cdot G \quad (2)$$

$G = e^{\alpha x}$ is the gain as function of α , impact ionisation rate

GAIN IMPLEMENTATION IN WEIGHTFIELD2¹

ELECTRIC FIELD AND TEMPERATURE DEPENDENT MODELS

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Chynoweth law for the impact ionisation rate:

$$\alpha_{e,h}(E) = \gamma \alpha_{e,h,\infty} \exp\left(-\frac{\gamma \beta_{e,h}}{|E|}\right) \quad (3)$$

Electric field dependence: **2** doping profiles implemented:

Gain

No gain implant

No gain implant

Shallow doping: linear from the electrode

Deep doping: a square starting 0.6 micron deep)

Force Gain

15

Gain recess (um):

0

A shallow doping profile best describes the CNM production, deep doping profile for FBK sensors.

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¹open source available at <http://personalpages.to.infn.it/~cartigli/Weightfield2/Main.html>

GAIN IMPLEMENTATION IN WEIGHTFIELD2

ELECTRIC FIELD AND TEMPERATURE DEPENDENCE IN THE IMPACT IONISATION RATE

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Temperature dependence: 4 models implemented:

Two based on the Chynoweth law (eq. 3):

van Overstraeten Model

Massey Model

$$\gamma(T) = \frac{\tanh\left(\frac{\hbar\omega}{2kT_0}\right)}{\tanh\left(\frac{\hbar\omega}{2kT}\right)} \quad (4)$$

$$\gamma = 1$$

$$\beta_{e,h}(T) = A_{e,h} + B_{e,h} \cdot T \quad (5)$$

Two proposed their own law for $\alpha_{e,h}$:

Bologna Model

Okuto Model

parameters with linear,
quadratic or exponential
temperature dependence

impact ionisation rate directly
shows the temperature
dependence

All but the Massey model are also implemented in Synopsys

Sentaurus

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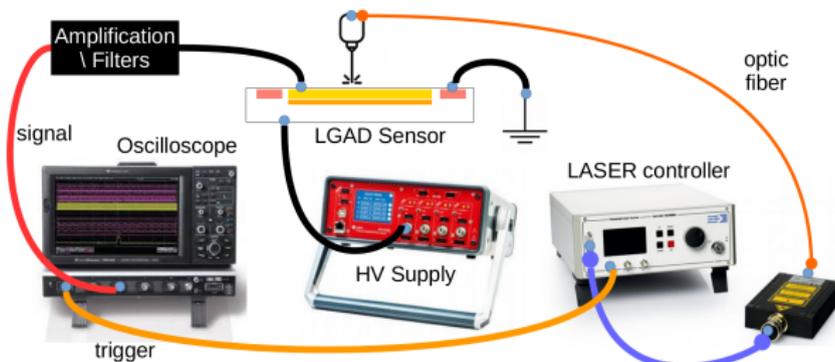
SETUP DESCRIPTION

INSTRUMENTATION

Climatic chamber with automatic data acquisition

(LabVIEW based).

1064ns non collimated picosecond laser (intensity set to replicate 1 MIP)



See Marco Ferrero's talk for more details about the boards and the instruments.

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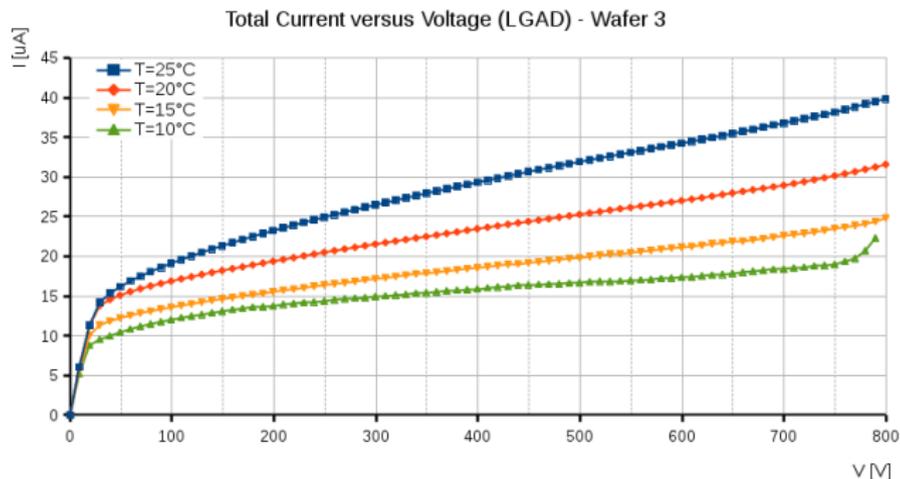
CONCLUSIONS

TOTAL CURRENT VERSUS TEMPERATURE

300 μm FBK – MODERATE GAIN (WAFER 3)

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Decrease of total current for low temperatures as immediate and predictable effect.

→ IV curve for $T = 10^{\circ}\text{C}$ shows an early breakdown

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GAIN VERSUS TEMPERATURE

300 μm FBK – MODERATE GAIN (WAFER 3) AND HIGH GAIN (WAFER 10)

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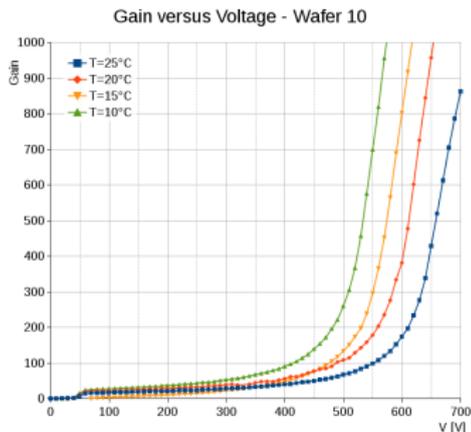
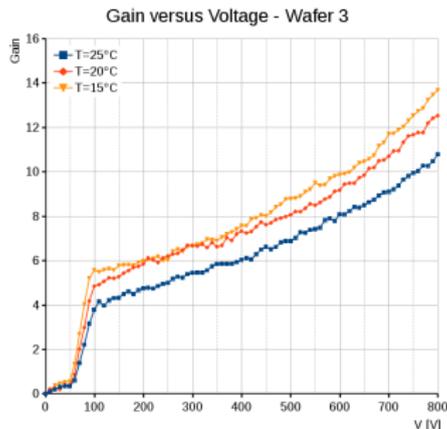
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Increase of gain for lower temperature \rightarrow high gain sensors see a bigger increase.

\rightarrow Decrease of Breakdown bias voltage values.

TIME RESOLUTION VERSUS TEMPERATURE

300 μ m FBK – MODERATE GAIN (WAFER 3)

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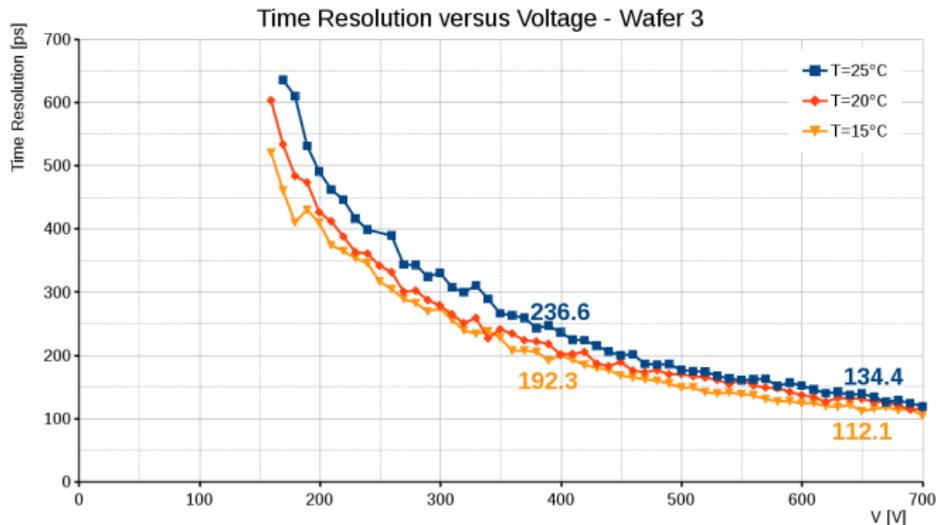
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Increase in gain causes sensibly improved timing performance for low temperatures.

(Time resolution defined in Slide 9)

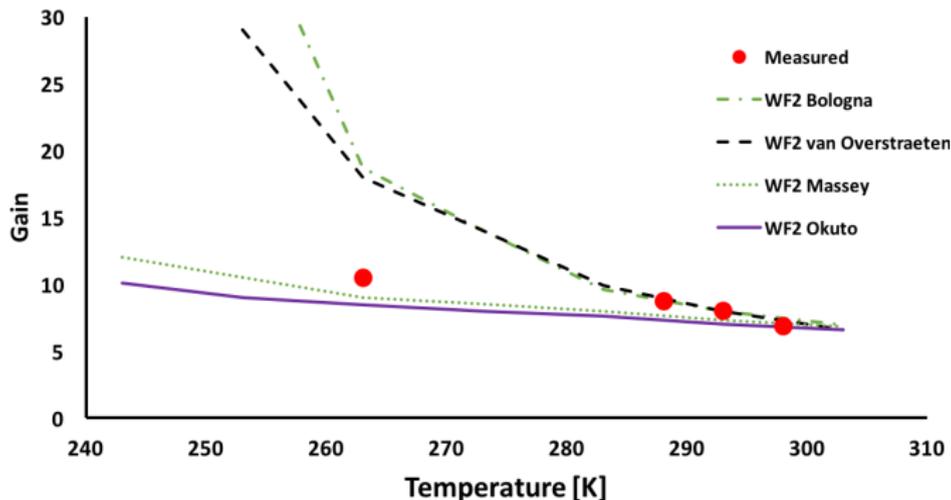
SIMULATION OF GAIN VS TEMPERATURE

300 μ m FBK – MODERATE GAIN (WAFER 3)

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Gain dependance as a function of Temperature
FBK, 300-micron thick sensor , Vbias = 500 V



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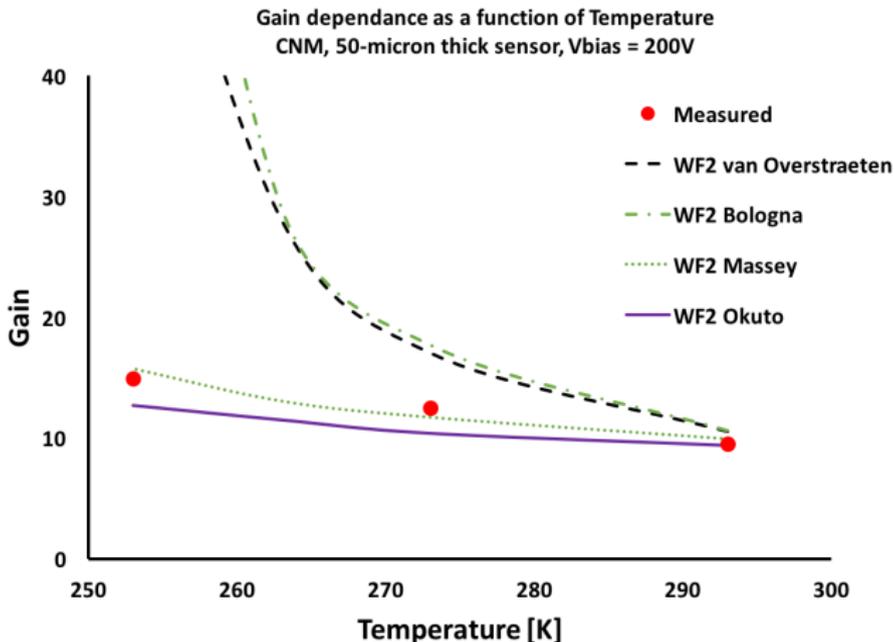
Very different predictions and measurements taken in Turin and Ljubljana → Further experimental study is necessary

SIMULATION OF GAIN VS TEMPERATURE

50 μm CNM – MEASUREMENTS TAKEN AT UCSC

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Measurements show a 50% increase in gain from RT to -20°C , in agreement with the *Massey* and *Okuto* model.

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ACKNOWLEDGMENTS

We kindly acknowledge the following funding agencies:

- ▶ INFN – Gruppo V
- ▶ Horizon 2020 Grant URC 669529
- ▶ Ministero degli Affari Esteri, Italy, MAE
- ▶ U.S. Department of Energy grant number DE-SC0010107
- ▶ The RD50 collaboration

FAST ANALYZER

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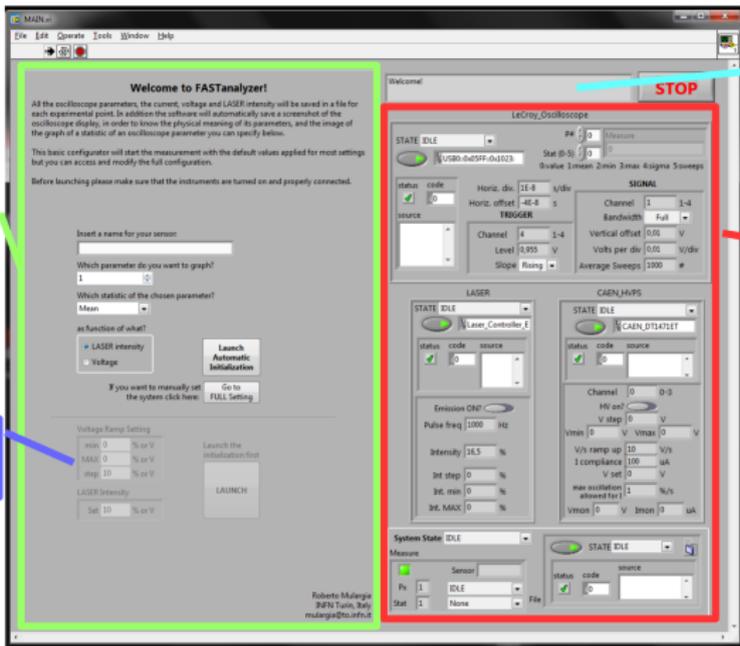
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Configuration
Wizard

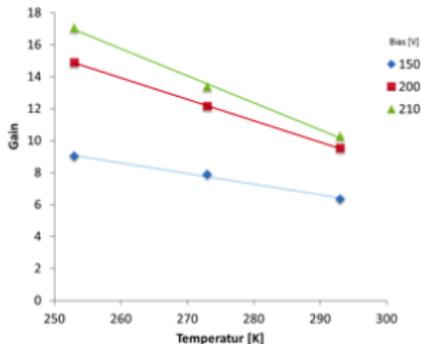
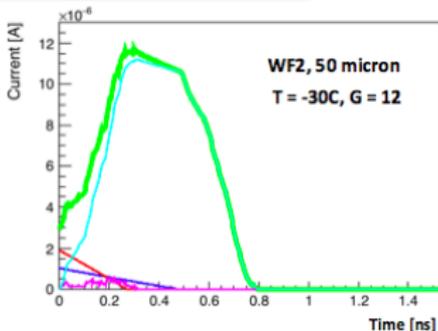
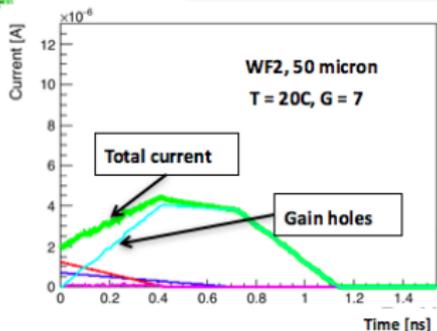
Automatically
Adapting
interface



System
messages

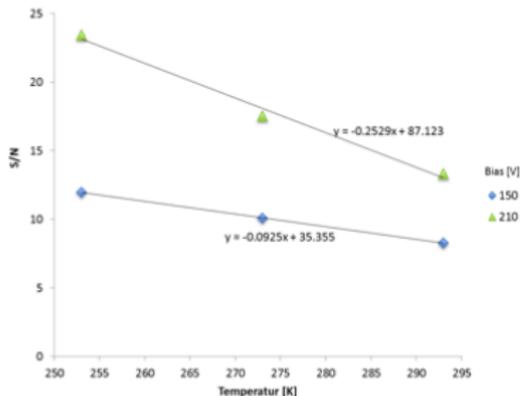
System
Display
(indicator)

Effect of Temperature on Gain



RT \rightarrow -20C : 50% more gain (measured)
RT \rightarrow -30C : 70% more gain (WF2)

Signal/Noise: 50um 9088 W3 HG21 (Pad 1.2)



Noise is constant independent of temperature or voltage at 1.6 mV for C = 10pF (2mm pad) [same as for C=3.3 (1mm pad)]

Lowering the temperature from RT to -20C:
 Signal/Noise improves by
 45% (150V)
 76% (210V)

Hartmut F.-W. Sadrozinski "Temperature Effect on Gain", RD50 Nov. 2015

