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Comparative study of the influence of the oxide thickness on the internal amplification

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Overview

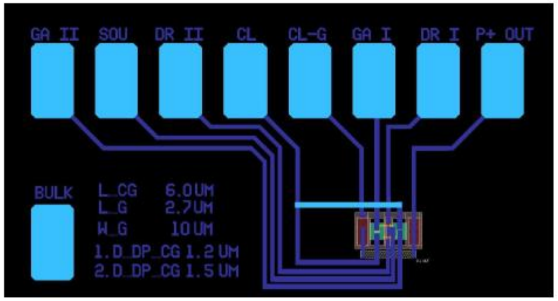
- Scope of investigation
- Setup
- Expectations from basic transistor theory
- Scaling

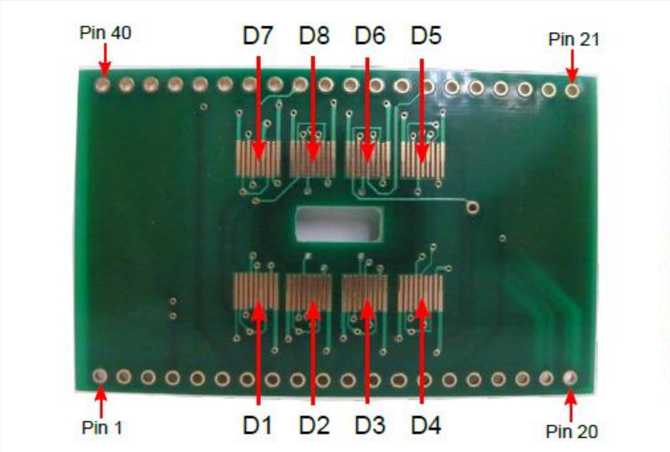
Scope

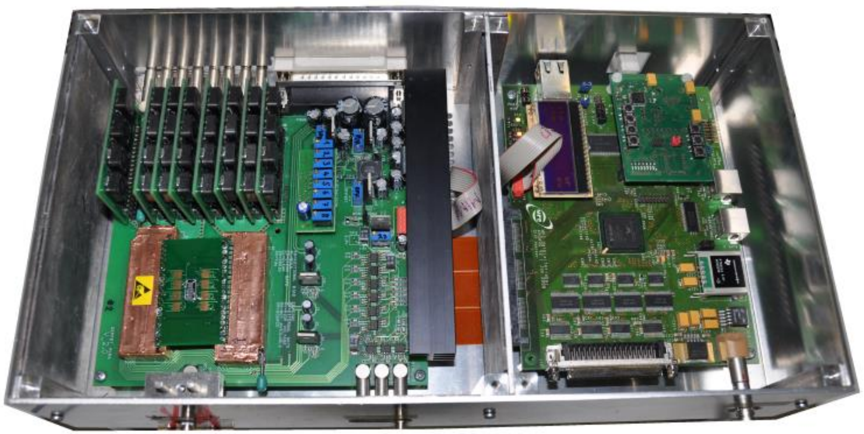
- Oxide thickness is crucial for radiation hardness of DEPFET
- Baseline for PXD9 ~105nm vs. ~210nm for previous productions
- Back on the envelope calculation points to a 40% reduced gq
- Impact on gq is crucial for performance of PXD

Minimatrix setup

- Minimatrix setup designed to readout up to 8 rows in parallel
  → 8 “Single Pixel Setups” in parallel
- Precision low noise setup







gure 4.2 : Plan view of the mini-matrix box with the main board located on the left sid

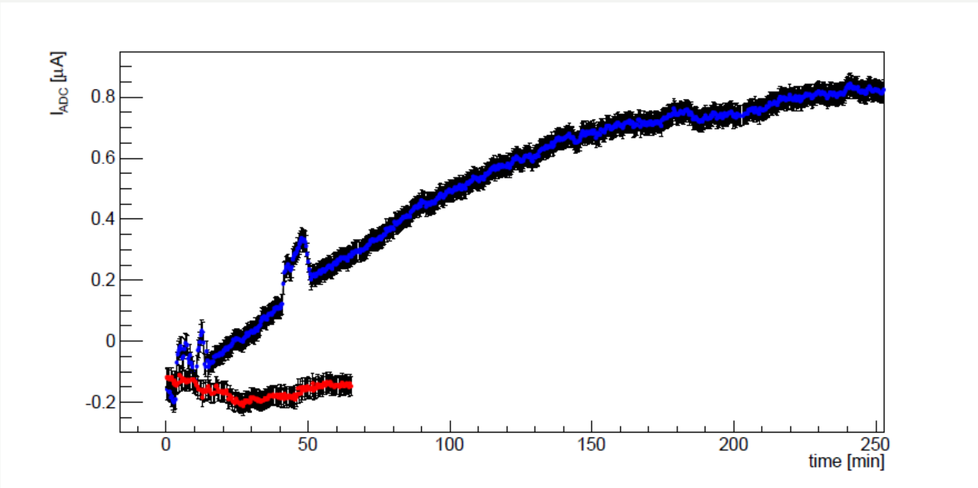
Issues

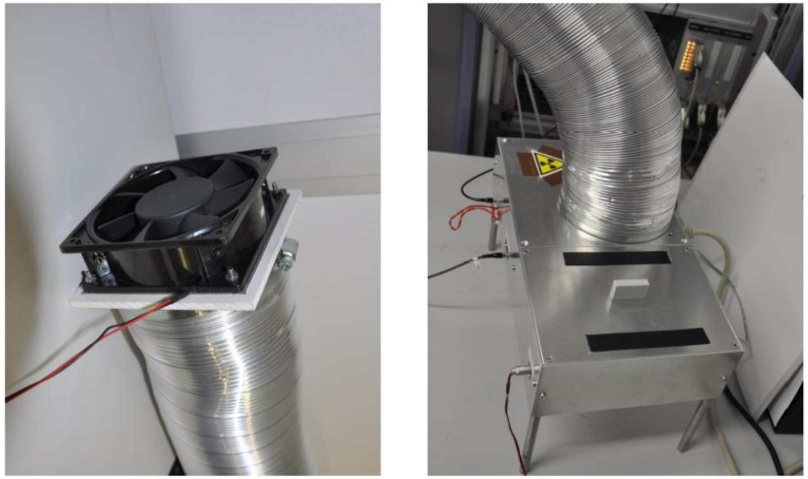
- Issues when operating the Mini Matrix Setup with Single Pixel structures
  - Characteristics Ids(Ugs) of transistors of a matrix is rather homogeneous
  - → With Single Pixels characteristics can significantly vary from pixel to pixel
  - → Adjustment of baseline can be done only manually for each row
  - → Power dissipation of amplifier which are not adjusted to 0V is getting an issue

- Adapted sequences to operate the DUT in Single Pixel mode
- Added software functionality to adapt baseline automatically via “Subtraction Voltage”

→ With this changes automatic scans of a DUT’s containing serval geometries

Issues – Cooling





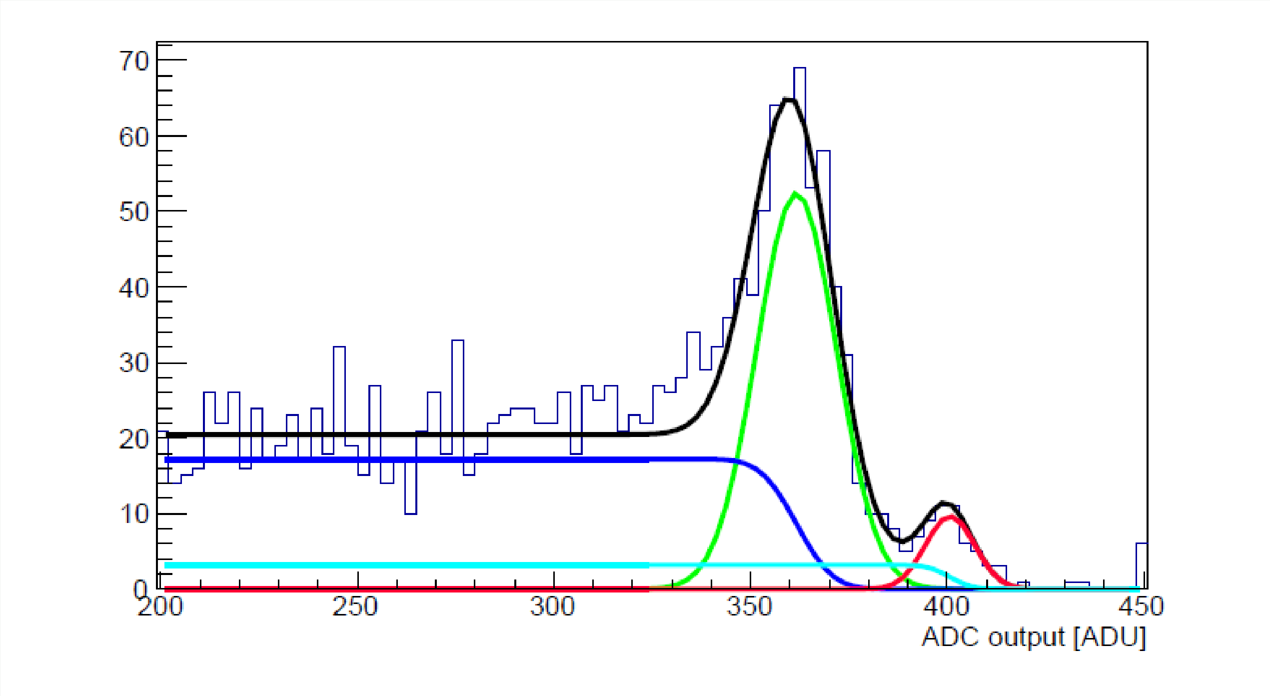
(a) Tube with fan.

(b) Tube with mini-matrix box.

Figure 4.3.: Improved cooling system.

- Setup shows significantly shifts while warming up
  - Input bias current drift of input stage
  - Drift of gain
- Even after CDS spectra show significant spread
- Permanent cooling improves situation significantly

Typical output



- Good spectra despite back side illumination – front side was covered with potting
- Evaluation was done using a combined signal (Ka,Kb) and background model

DEPFET

- Simple scaling rules can be derived from text book transistor theory:

$$I_{ds} = \frac{1}{2}\frac{W}{L}\mu_h C_{\grave{o}x}\left(f\frac{Q_{sig}}{C_{ox}} + U_{gs} - U_{thr}\right)^2 \longrightarrow$$

$$g_m = \sqrt{2\mu_h C_{\grave{o}x}\frac{W}{L}I_{ds}}$$

$$g_q = \sqrt{2\mu_h f^2 \frac{1}{L^3 W C_{\grave{o}x}} I_{ds}}$$

- Influence of the internal gate is modeled by an equivalent gate voltage of the charge in the internal gate

- Does explain gq dependencies qualitatively

Scaling

$$g_m = \sqrt{2\mu_h C_{\grave{o}x} \frac{W}{L} I_{ds}}$$

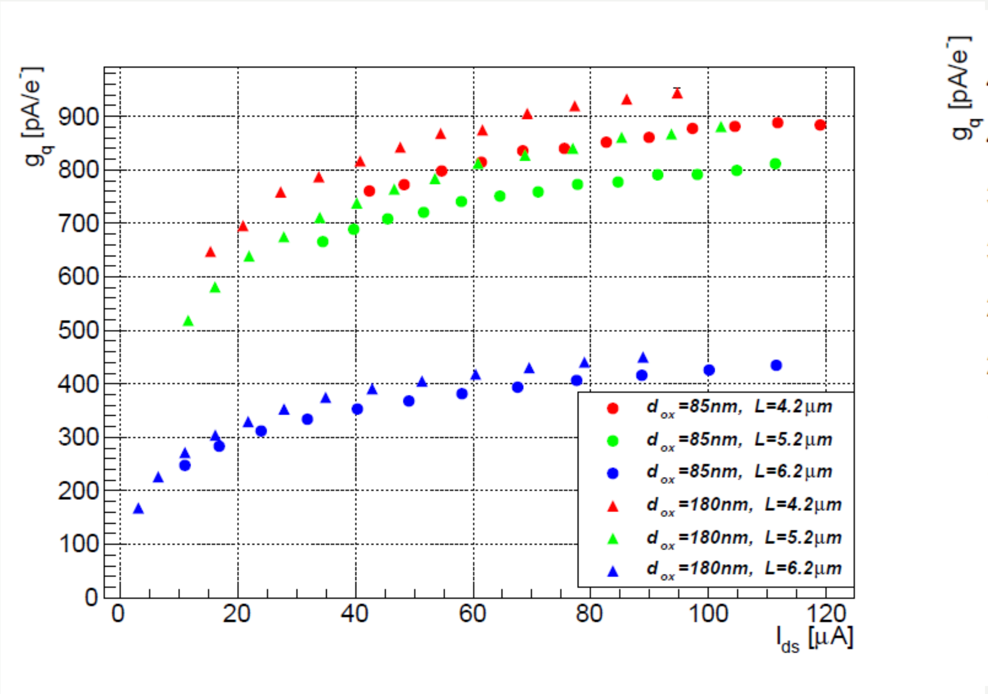
$$g_q = \sqrt{2\mu_h f^2 \frac{1}{L^3 W C_{\grave{o}x}} I_{ds}}$$

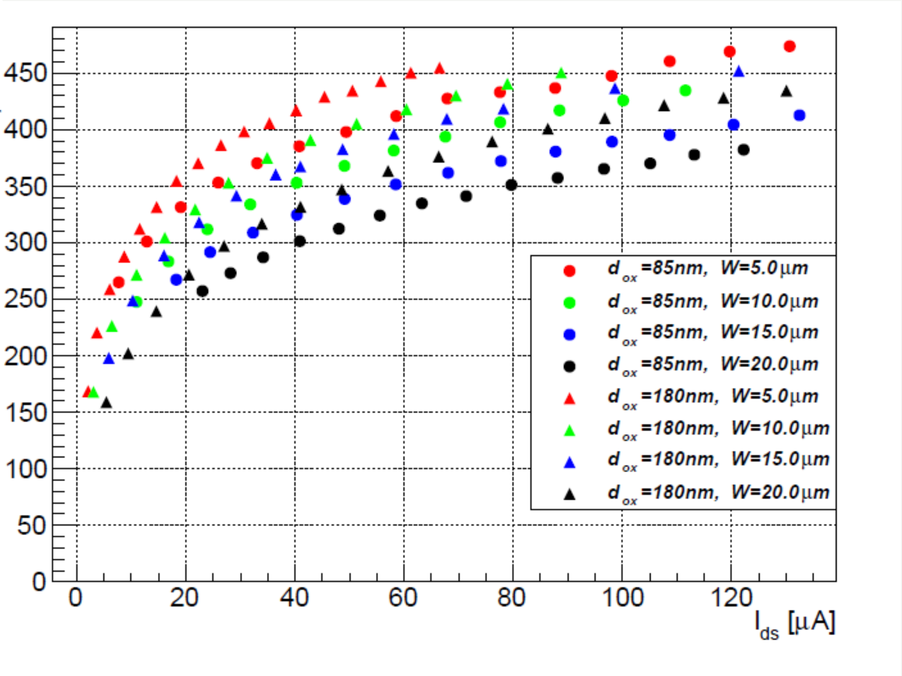
$$\frac{g_{q,1}}{g_{q,2}} = \sqrt{\frac{C_{to\grave{t},2}}{C_{to\grave{t},1}}} = \sqrt{\frac{\epsilon_{ni} d_{ox,1} + \epsilon_{ox} d_{ni}}{\epsilon_{ni} d_{ox,2} + \epsilon_{ox} d_{ni}}} \,,$$

$$\frac{g_{q,1}}{g_{q,2}} := \frac{g_q(d_{ox} = 180\,nm,\ d_{ni} = 30\,nm)}{g_q(d_{ox} = 85\,nm,\ d_{ni} = 30\,nm)} = 1.39$$

- Thick oxide is expected to show a significantly decreased gq

Gq Results

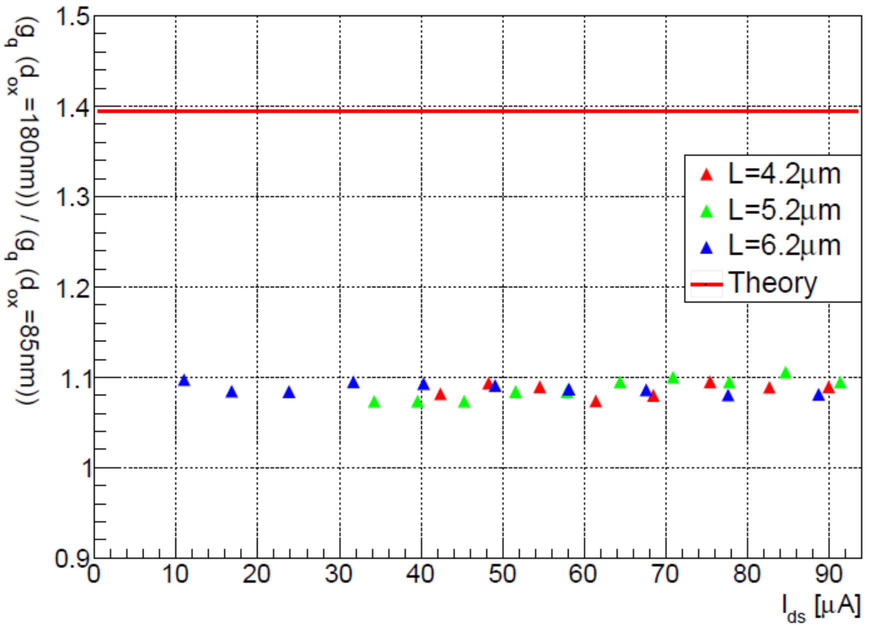


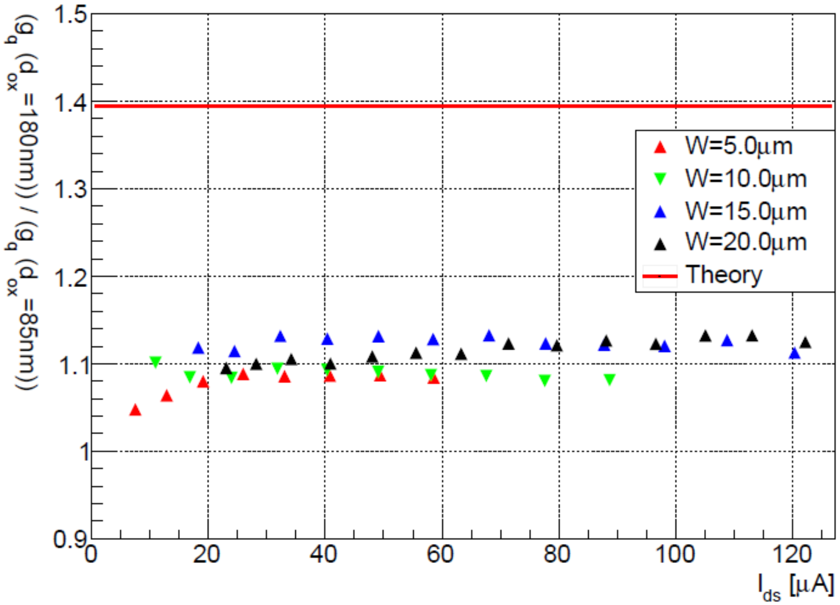


- Behavior with respect to Ids, L, W as expected
- 40% drop hardly visible

Gq - Scaling

$$\frac{g_{q,1}}{g_{q,2}} = \sqrt{\frac{C_{t\grave{o}t,2}}{C_{t\grave{o}t,1}}} = \sqrt{\frac{\epsilon_{ni} d_{ox,1} + \epsilon_{ox} d_{ni}}{\epsilon_{ni} d_{ox,2} + \epsilon_{ox} d_{ni}}} \; ,$$





- All structures show a clear scaling independent of geometry and current
- Measurement indicates an drop in gq of 10%

Summary

- Mini Matrix Setup has been adapted to conduct single pixel measurements automatically

- A uniform drop of 10% of the gq has been found for the thin oxide independent of current and geometry