"Noise Model of cryogenic High Electron Mobility Transistor, Low threshold and high discrimination Ge cryogenic detector for Coherent Elastic Neutrino Nucleus Scattering and low mass Dark Matter"

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ALGaAs/GaAs hetero-junction, Energy band diagram.

The investigated HEMTs are based on an ALGaAs/GaAs hetero-structure grown by MBE (Molecular Beam Epitaxy). It consists of a GaAs buffer layer, a 20 nm ALGaAs spacer layer (thicker than for commercial HEMT), a Si δ-doping layer, a 15 nm undoped ALGaAs barrier layer, and a 6 nm undoped GaAs cap layer.

HEMT developed at CNRS/C2N

- Si δ doped layer
- GaAs buffer layer
- ALGaAs spacer layer
- Si δ doped layer
- ALGaAs barrier layer
- GaAs cap layer

I_d-V_{ds} characteristics of a 100 pF C_{gs} HEMT @ 4.2K

- High transconductance can be obtained with typical power dissipation < 100 μW
- Characteristics unchanged at T < 4K and noise improves a bit
- HEMT can be placed close to the detector : low cabling capacitance

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Detector + HEMT Noise Model

- Additional noise sources easily calculated considering:
  - Bias and feedback noises
  - Bias, detector, parasitic (incl. cabling), feedback and gate-source HEMT impedances
  - Feedback noise can be cancelled with an active reset
  - Bias noise can be limited to thermal noise ofRibias
  - Thermal noise of heat sensor (Ge-NTD) should be added for heat resolution
  - Knowing the heat and ionization signals FIDs, rms baseline resolution are given by:

Cold Amplifier schemes investigated

- Full HEMT-based cryogenic amplifier
  - Tested on a 240 g, 130 pF CDMS-II Ge cryogenic detector @40 mK
  - 91 eVee ionization baseline measured with 100pF HEMT (100 eVee expected by our Model)

Low Capacitance Ge Detector

- Electrostatic Simulation ongoing on the electrodes geometry :
  - Keep the efficient FID (Full Interdigitized Detector) geometry used by EDELWEISS to reject surface event

CONCLUSION

- 10 eV Heat and 20 eVee Ionisation baseline resolution (rms) feasible according to our model on ~ 35 g / 20 pF Ge cryogenic detector
- Allows for low threshold nuclear recoils sensitivity and high background rejection for Sub-GeV WIMPs and MeV neutrinos.
- Low Capacitance Cabling to be designed (kapton, vacuum coaxial cables).
- 1 kg of detector will be produced for the RICOCHET experiment (CENNS) and EDELWEISS-SubGeV (Low Mass Dark Matter)