Master thesis Project

Investigation of sub-Kelvin behaviour of advanced SiGe heterojunction bipolar transistors for quantum bits experiments

For decades, 3 technologies of transistors have co-existed. The most ubiquitous device, silicon field-effect transistors (MOSFETs), are by far leading in volume but remain slower and more noisy than competing technologies. At the other extreme, high mobility transistors (HEMTs) can reach very high speeds and ultra low noise. However, they are based on 'exotic' materials such as GaAs or InP, and suffer from much lower production volumes, higher cost and lower yield. Silicon Germanium (SiGe) Heterojunction Bipolar Transistors (HBTs) bridge this gap since they achieve the best performances of Si-based technologies, being fully CMOS compatible, in the so-called Bipolar-CMOS (BiCMOS) technologies. They are now enabling low-noise and high-speed applications, with high-volume production [1].

The breakthrough came when a graded content of Ge was introduced in the epitaxial growth of the HBT base. By doing so, a true bandgap engineering is achieved and allows to optimize the transistor characteristics far beyond the limits of pure materials like Si [2].

Our laboratory in PHELIQS at CEA-Grenoble studies spin quantum bits made with Si MOSFETs from CEA-Leti or homemade Ge heterostructures [3,4]. Even though it is not always widely known, all such qubits experiments include a HEMT or a SiGe HBT in the first front-end cryogenic low noise amplifier (LNA) of the readout chain [5]. Recently we have designed and fabricated our own LNAs, using a commercially available BiCMOS technology, which exhibits low performances than more recent technologies.

In this internship we will investigate advanced BiCMOS devices from the B55 technology of STMicroelectronics [6], for applications in quantum bits experiments. We will measure their characteristics down to 3.2K or 0.45K in homemade pulse-tube based cryostats.

This work will be carried in close collaboration with STMicroelectronics which not only provides advanced BiCMOS chips but also shares its deep knowledge of SiGe HBT devices, including previous cryogenic characterizations at high frequency and above 4K.

[1] P. Chevalier and A. Pallotta, IEEE Microwave Magazine, 25, 10, 2024.
[2] Cressler J.D. & Niu G., *Silicon-germanium heterojunction bipolar transistors*, Artech House 2002.
[3] Piot N. *et al.*, Nature Nanotechnology 17, 2022. https://doi.org/10.1038/s41565-022-01196-z
[4] Kiyooka E. *et al.*, in preparation
[5] Bardin J.C., IEEE Solid-State Circuits Magazine, spring 2021. https://doi.org/0.1109/MSSC.2021.3072803
[6] P. Chevalier et al., IEEE IEDM Tech. Digest, 2014 https://doi.org/,doi: 10.1109/IEDM.2014.7046978.

Insert : BiCMOS chip packaged to enable characterization and making a functional amplifier for quantum bits experiments. Measurements with a vector network analyzer will be performed in a cryostat (blue cubes).

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To apply for this position, send your application (including CV) by e-mail to: xavier.jehl@cea.fr

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