Magnetic Influence on Cryogenic InP HEMT DC Characteristics

Isabel Harrysson Rodrigues*[1], Arsalan Pourkabirian[2], Giuseppe Moschetti[2], Joel Schleeh[2], Per-Åke Nilsson[1], Jan Grahn[1]

[1]*GigaHertz Centre, Department of Microtechnology and Nanoscience – MC2, Chalmers University of Technology, SE-41296 Gothenburg, Sweden*
[2]*Low Noise Factory AB, Nellickevägen 22, Gothenburg, SE-41663, Sweden*

InP HEMTs is the device of choice in many ultra-low-noise and high-speed applications due to its high electron mobility in the 2DEG. InP HEMT based low noise amplifiers (LNAs) are also frequently used in cryogenic applications where the noise added by the amplifier to the system noise temperature has to be extremely low. However, there are some cryogenic applications where the low noise amplifiers are exposed to high magnetic fields, such as MRI scanners [1]. It is therefore of high interest to study how the performance of these transistors is affected by a magnetic field.

In a previous study, cryogenic AlGaAs/GaAs HEMT LNAs operating below 1 GHz in high static magnetic fields was reported [2]. It was found that the noise temperature of the LNA increased with magnetic field. It was proposed that the Lorentz force, caused by the applied magnetic field, affected the electron channel transport in the device.

In the scientific literature, there is an apparent lack of device data for cryogenic InP HEMTs exposed to magnetic field. In this work, we present cryogenic DC measurements for a 1x100 µm InP HEMT under the influence of static magnetic fields. A cross-section of the 100 nm gate-length device is shown in Fig. 1. The InP HEMT fabrication has been described in [3]. The measurements were conducted in a physical property measurement system (PPMS), see Fig. 2, in which the device under test was electrically connected through wire bonding. The device was mounted in a cold stage and cooled down to 2 K in vacuum. A static magnetic field ranging up to 2 T was then applied. We performed the electrical measurements in different orientation of the HEMT with respect to the applied magnetic field.

It was found that the influence on the cryogenic HEMT DC current-voltage, when increasing the in plane (parallel) magnetic field from 0 to 2 T, was negligible; see Fig. 3(a). In contrast, when the transistor channel was oriented 90 degree out of plane (perpendicular) to the magnetic field, the DC behavior of the HEMT was strongly affected. The output drain current as a function of drain voltage was significantly reduced; see Fig. 3(b). As a result, the device transconductance g_m was heavily decreased with magnetic field; see Fig. 4(a).

In Fig. 4(b), the on-resistance R_{on} as a function of gate voltage for the InP HEMT kept at 2 K and aligned out of plane, is shown for various applied magnetic fields. The value for the R_{on} at the highest gate voltage of 0.4 Vis illustrated as a function of magnetic field; see Fig. 5. We see a clear difference when the HEMT is placed perpendicular to the field, compared to when aligned parallel. The results point to the importance of aligning the InP HEMT in plane in a cryogenic LNA exposed to magnetic fields.

Acknowledgement: This work was performed in GigaHertz Centre in a joint research project between Chalmers University of Technology, Low Noise Factory AB, Wasa Millimeter Wave AB, Omnisys Instruments AB and RISE Research Institutes of Sweden. We are grateful to David Niepce for valuable assistance using the PPMS set-up.

References:

[1] Robert H. Coverly, *IEEE Microwave Magazine*, vol. 5(2), 769-772 (2015).
[2] Edward Daw & Richard F. Bradley. *Journal of Applied Physics*, vol. 82(4), 1925 (1997)
[3] Joel.Schleeh et al, *IEEE Electron Device Letters,* vol. 33(5), 664-666 (2012)

*Corresponding author: isabelr@chalmers.se, Phone: +46317726310

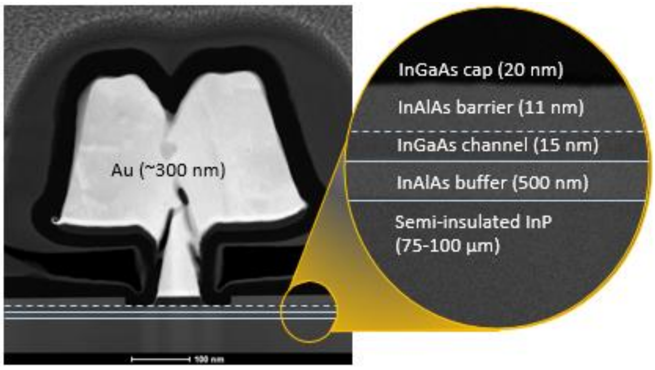

Fig. 1. SEM cross section of the InP HEMT, with the heterostructure including cap layer, barrier, channel, buffer layer and semi-insulating InP bulk, zoomed in to the right.

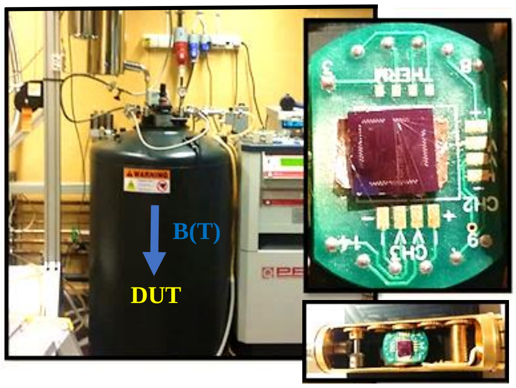

Fig. 2. Photo of the PPMS set up and the device under test. The HEMT was held in vacuum, cooled down to 2 K and exposed to magnetic field up to 2 T aligned according to blue arrow.

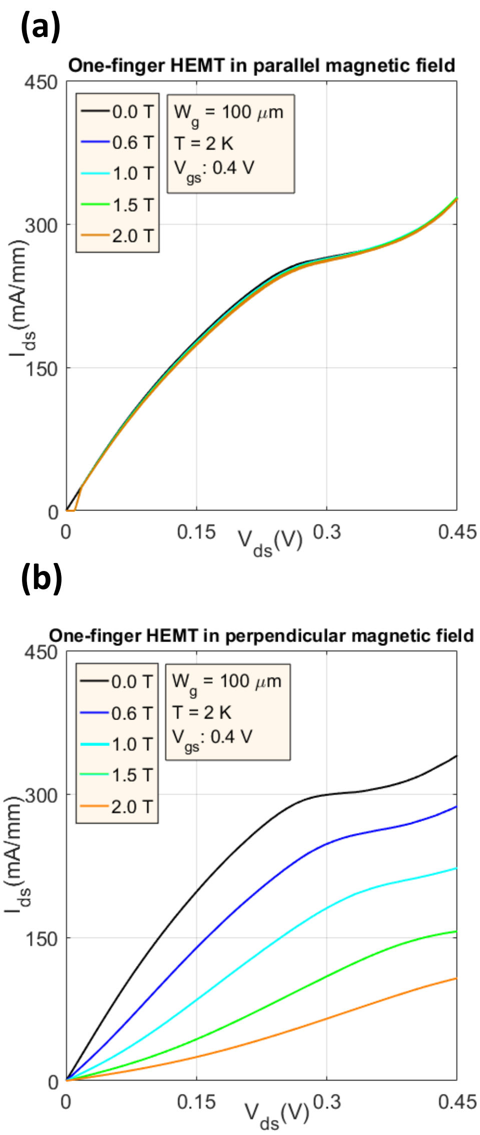

Fig. 3. Drain current versus drain voltage at 2 K for various external applied magnetic fields, ranging from 0 to 2 T. (a) Magnetic field aligned in plane with the device. (b) Magnetic field aligned out of plane with the device.

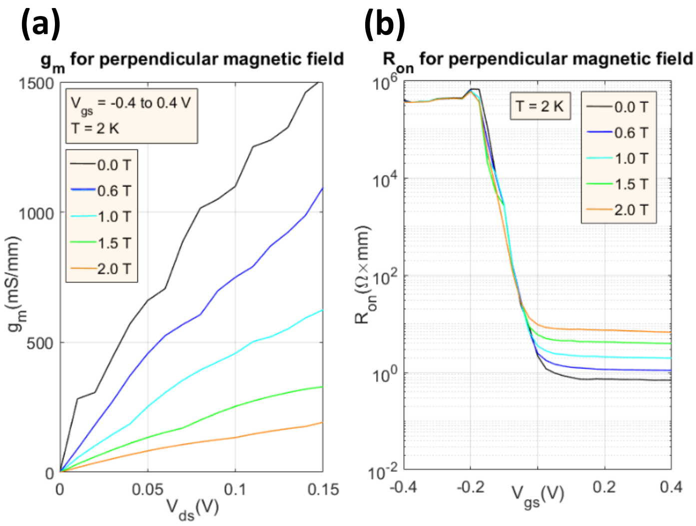

Fig. 4. (a) g_m as a function of drain voltage for various magnetic fields. The oscillations are caused by a non-stable 50 Ohm impedance at the input and output. (b) R_{on} as a function of gate voltage for various magnetic fields.

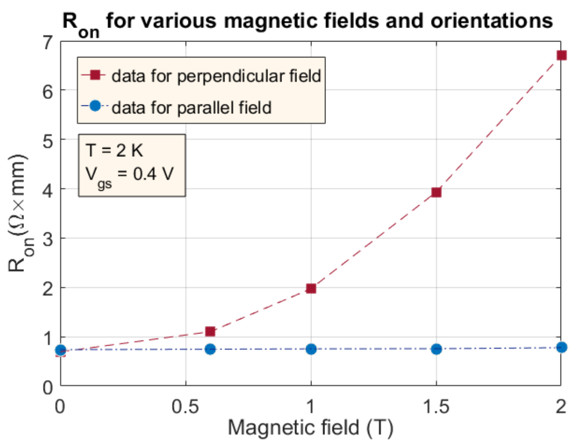

Fig. 5. Relation between R_{on} and the applied magnetic field B(T).