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Scanning SQUID Microscopy for Sensing Vector Magnetic Field

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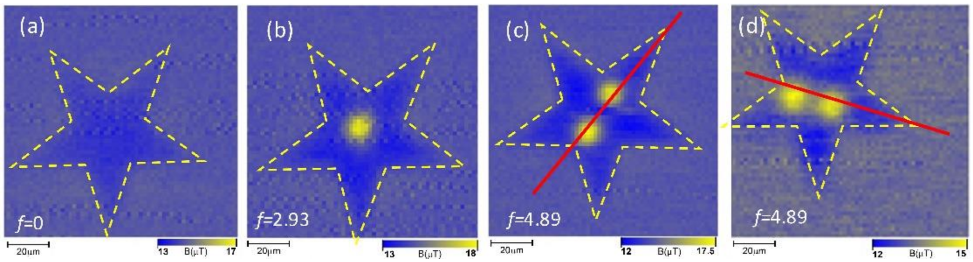
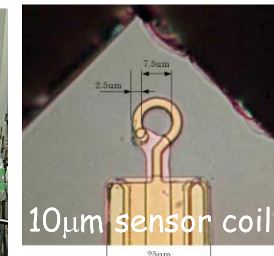
7. Summary

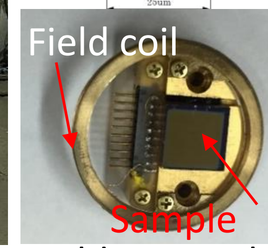
Aim of present study

❖ SQUID microscope: Various applications such as nanoscience, nano-engineering, nano-biology, spintronics, vortex physics, *etc.*



[1] T. D. Vu *et al.*, Physica C(2016), doi:10.1016/j.physc.2016.07.020





Holder sample

- **How to improve sensitivity and spatial resolution**

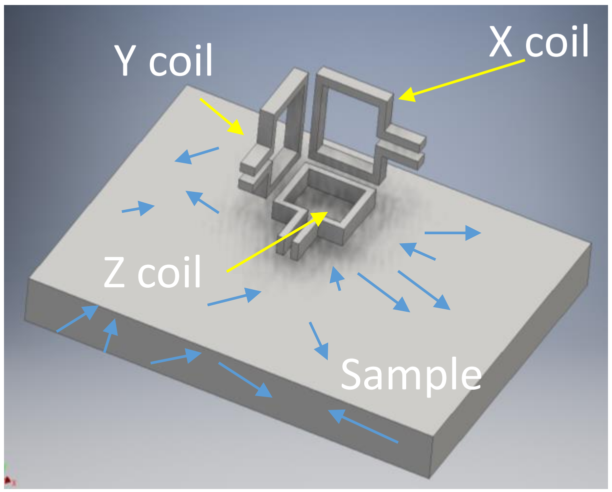
  - Sensitivity is essentially governed by an inductance of a pick up coil
  - Spatial resolution is limited by inner diameter of a pick up coil

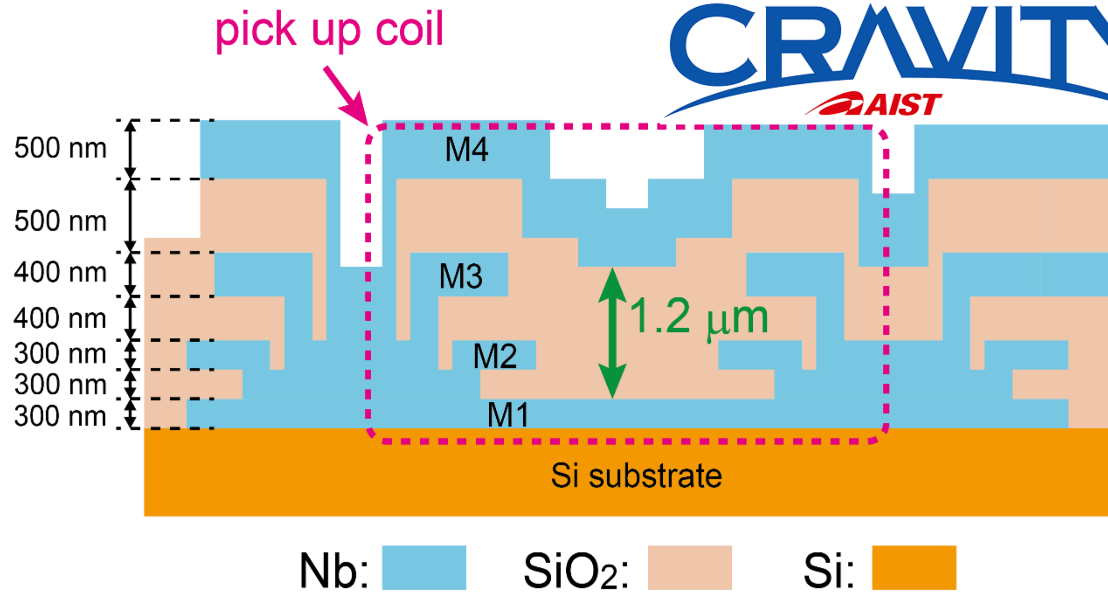
➢ **Novel vector pick-up system**

Our action
- Multiply winding coil with small area
- Image processing

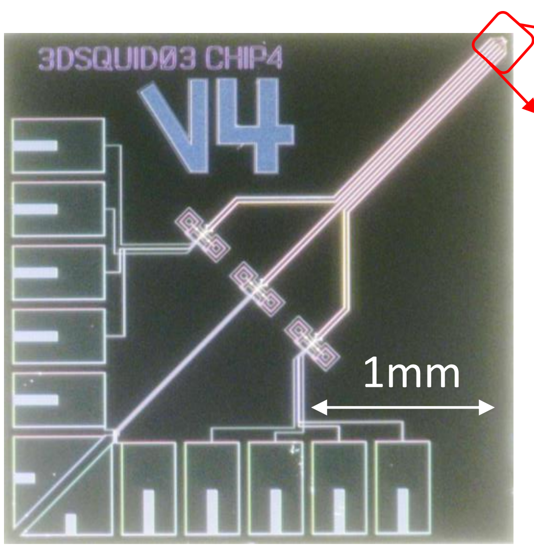
Our action
- 3D *XYZ* pick-up coils fabricated on one chip

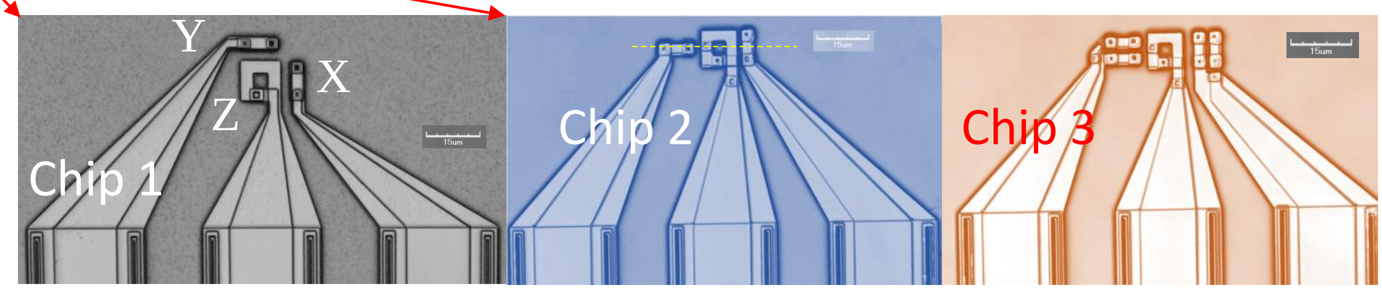
Sensor design for vector scanning SQUID microscope





Cross sectional view of a designed pick up coil of *X* and *Y* direction



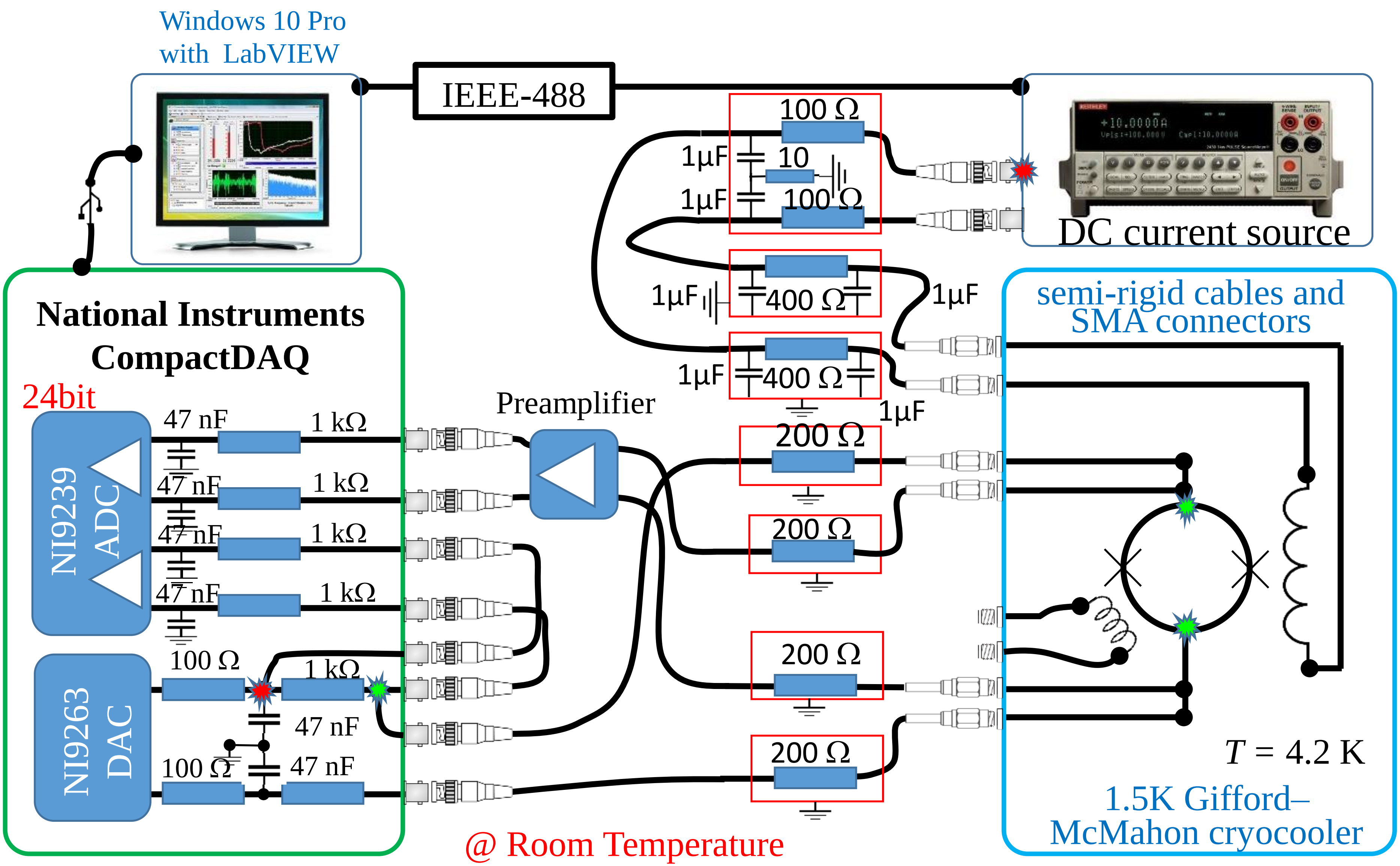


X,Y&Z coils are orthogonal to each others

X,Y&Z coils are single turn in winding and their centers are located along a single line.

X,Y&Z coils are two turns and their centers are located along a single line.

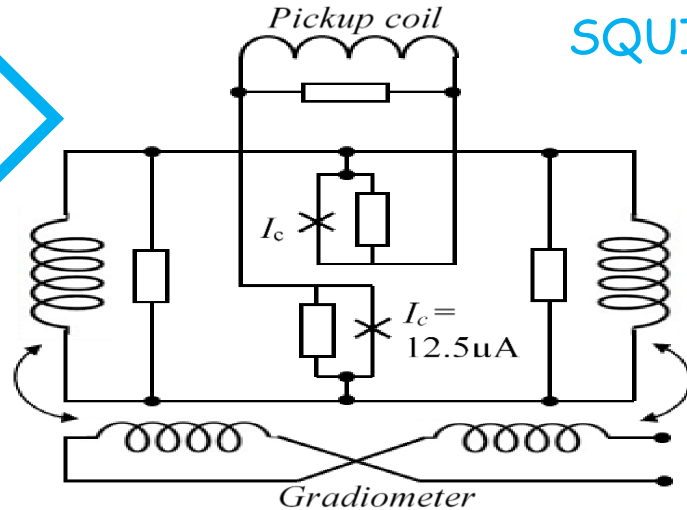
Lab-made system to measure the characteristics of SQUID sensors



Characteristics of vector SQUID sensors

Construction of the IV curve tracer by using a 1.5K GM cryocooler

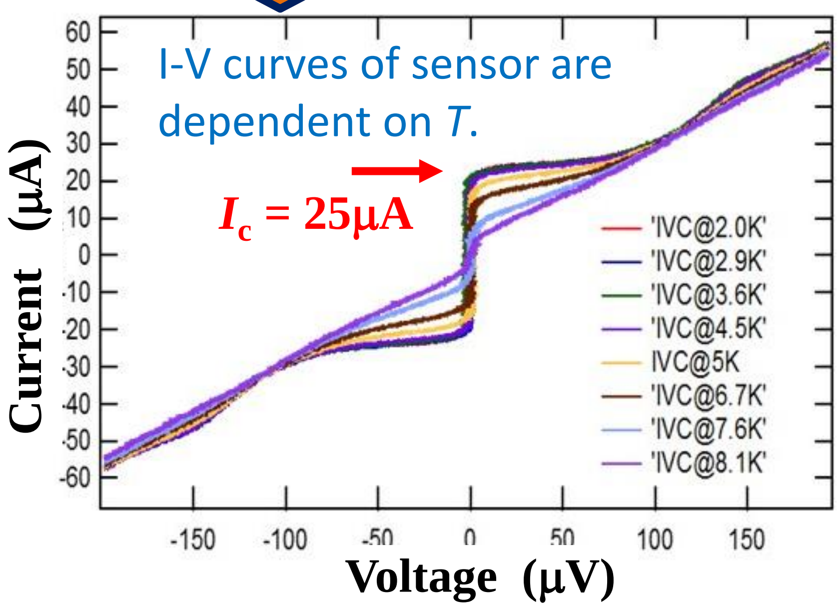
Equivalent circuit of our SQUID sensor

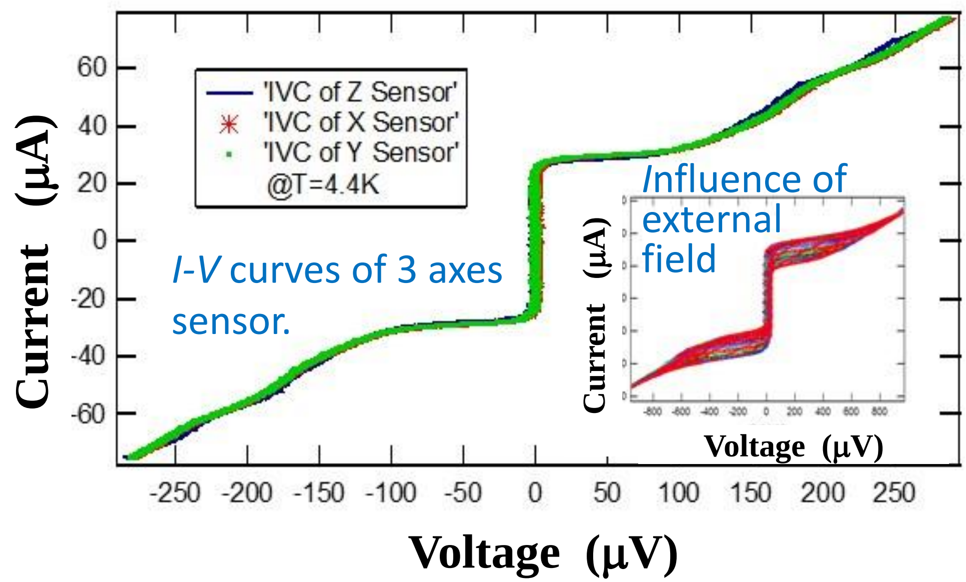


SQUID consists of two JJ.

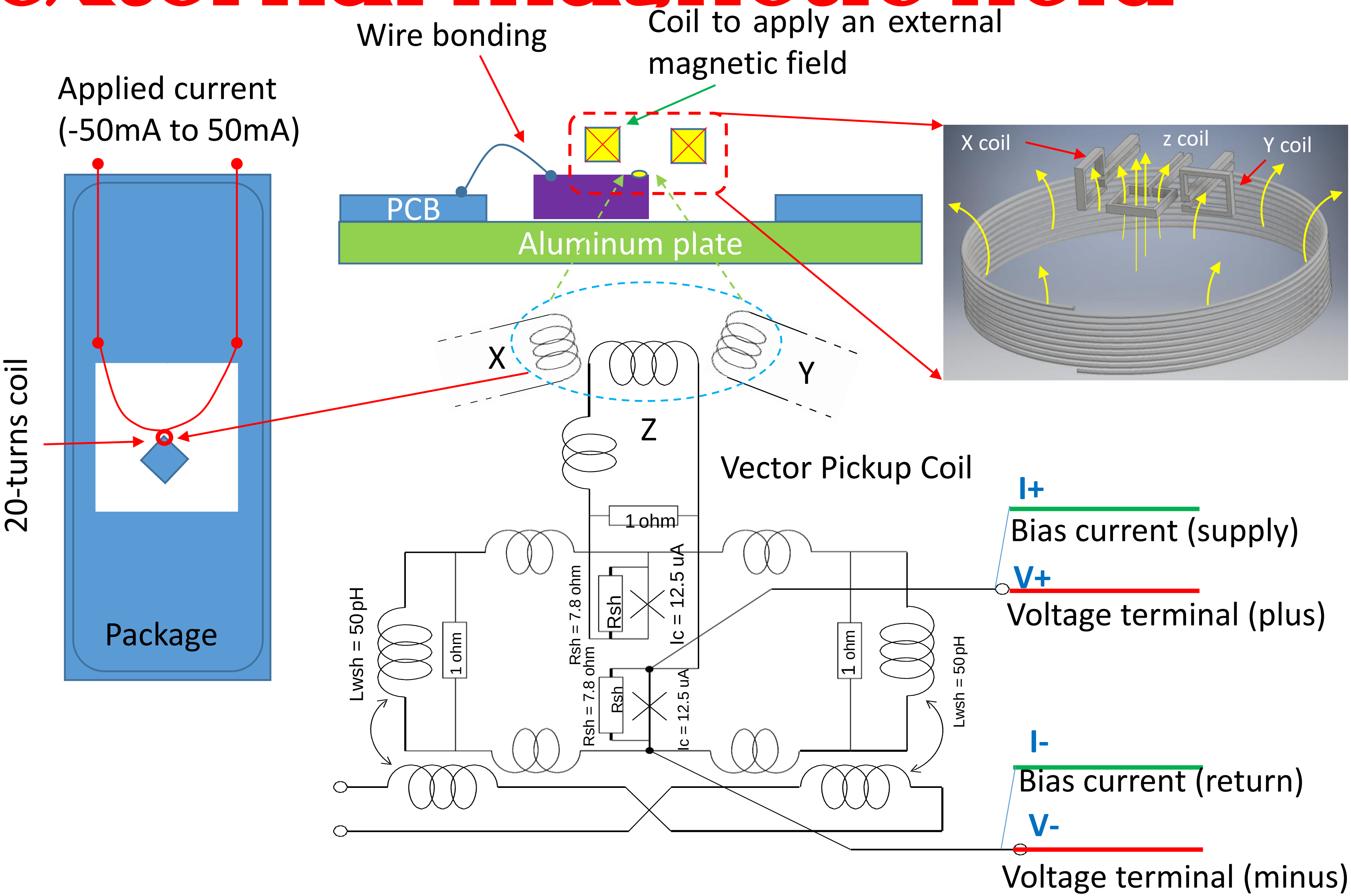
Each SQUID in a vector sensor has a similar characteristic in the IV curve

I_c of a SQUID sensor is 25 μA at 4.2 K, as designed in CAD

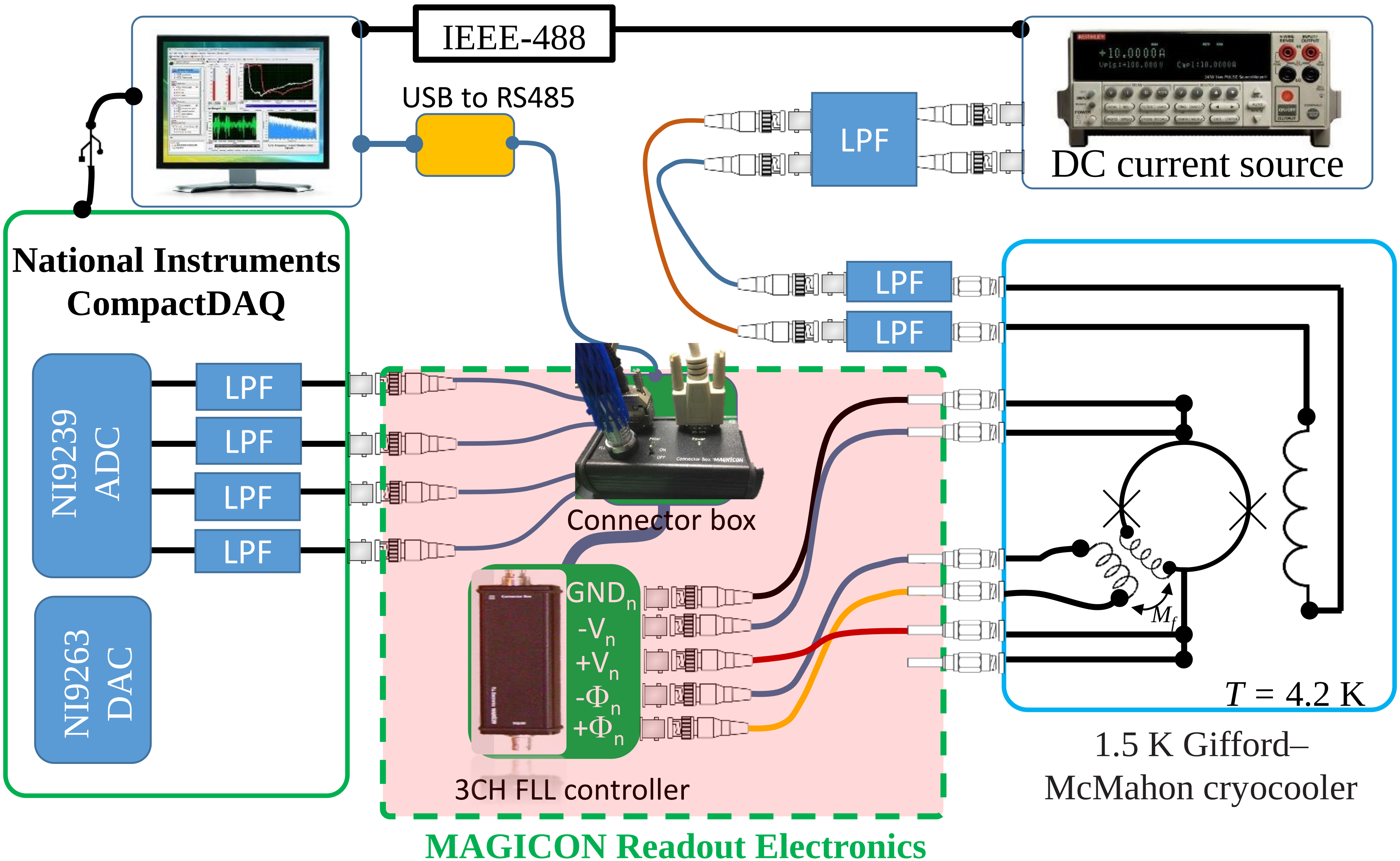




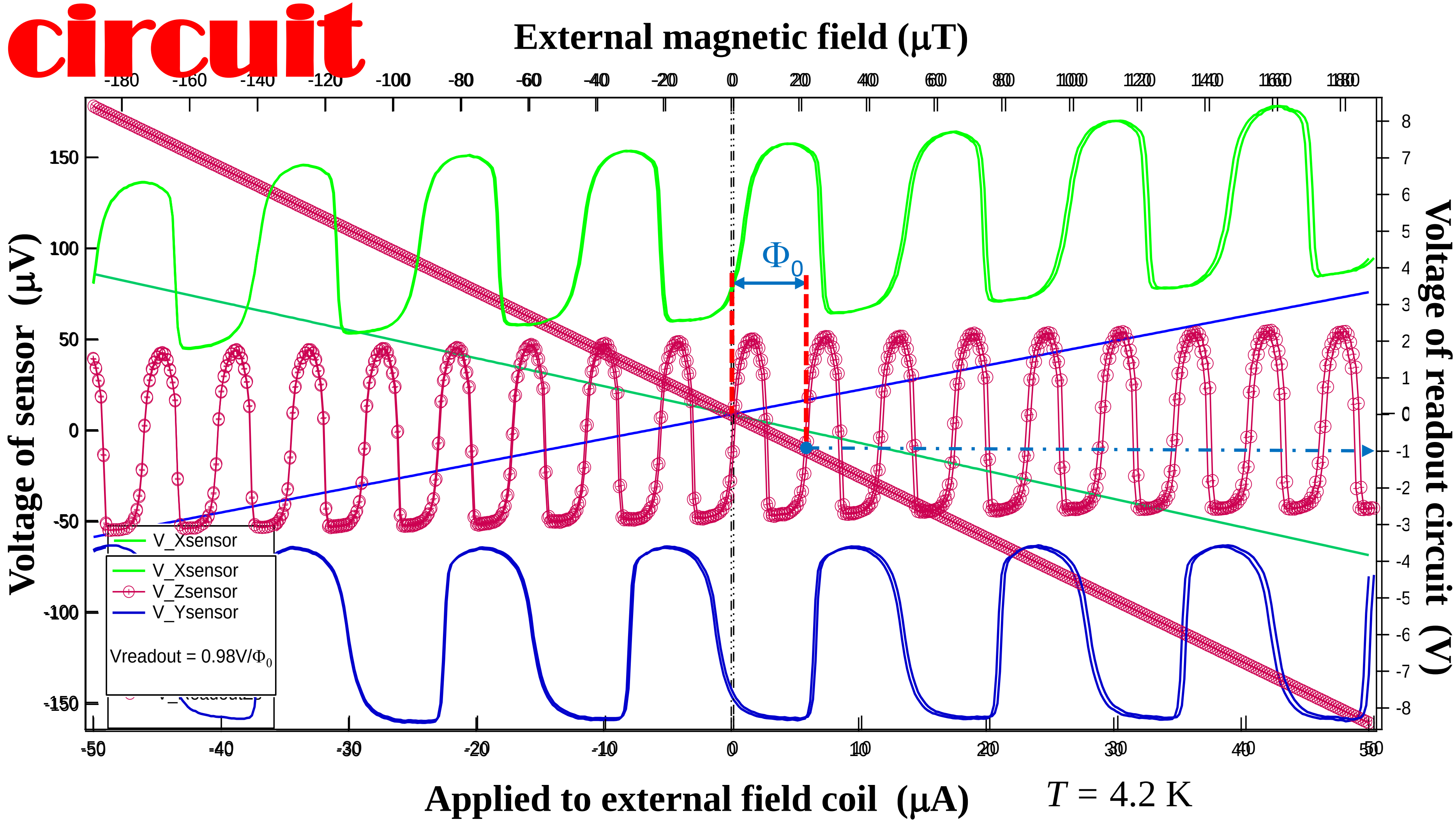
How to apply an external magnetic field



Installation of MAGNICON electronics system

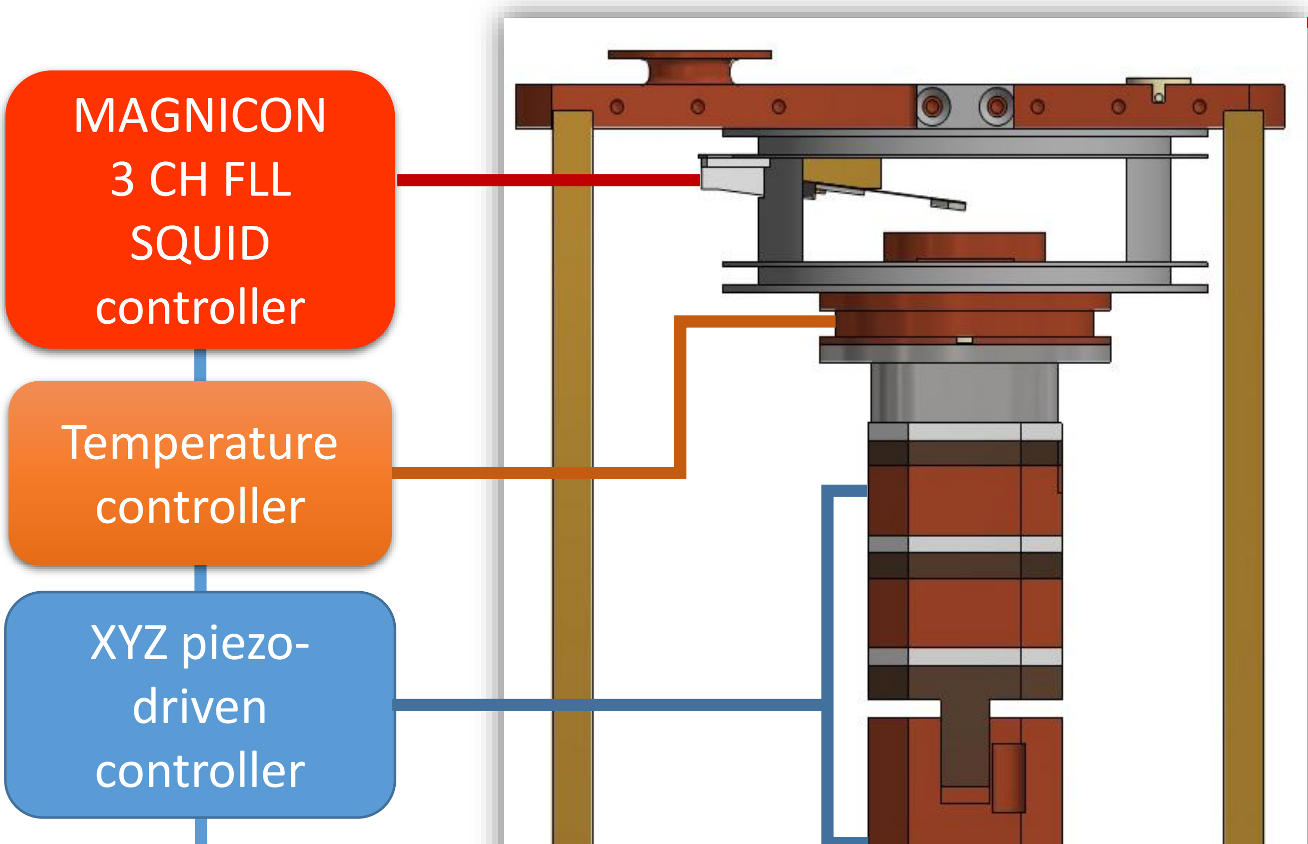


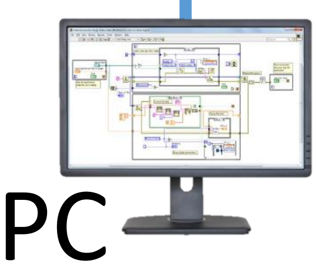
characteristics and the voltage of readout circuit

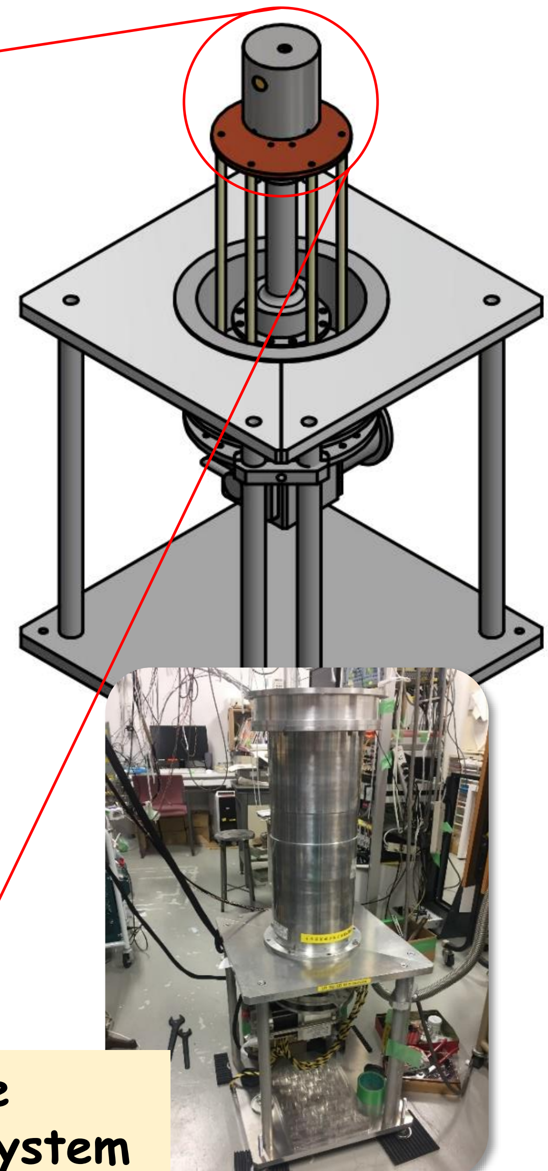


We confirmed a good linearity.

Our Scanning SQUID System



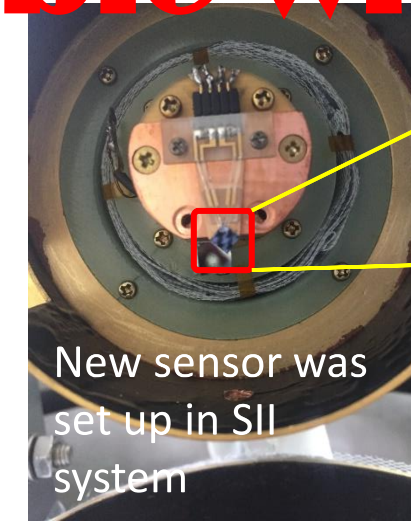


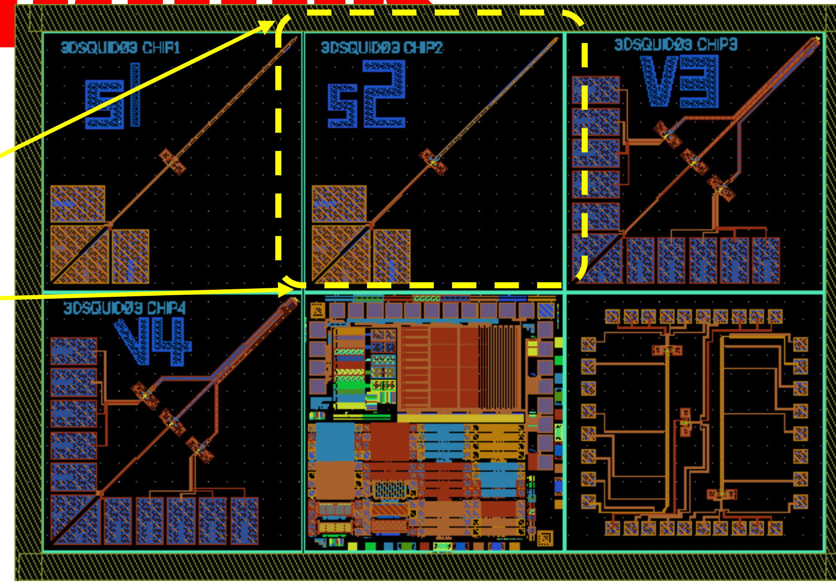


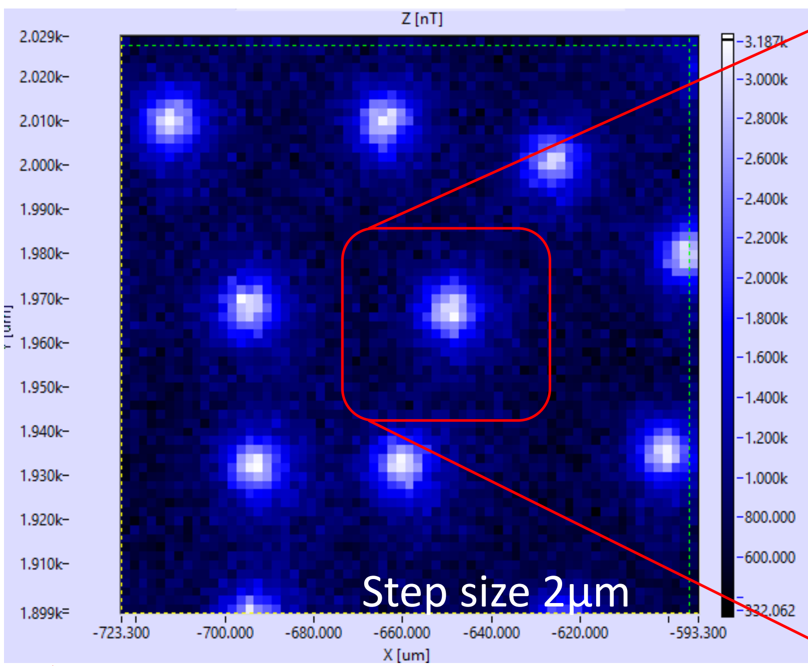
A vector SQUID microscope on the refrigerator platform & anti-vibration system

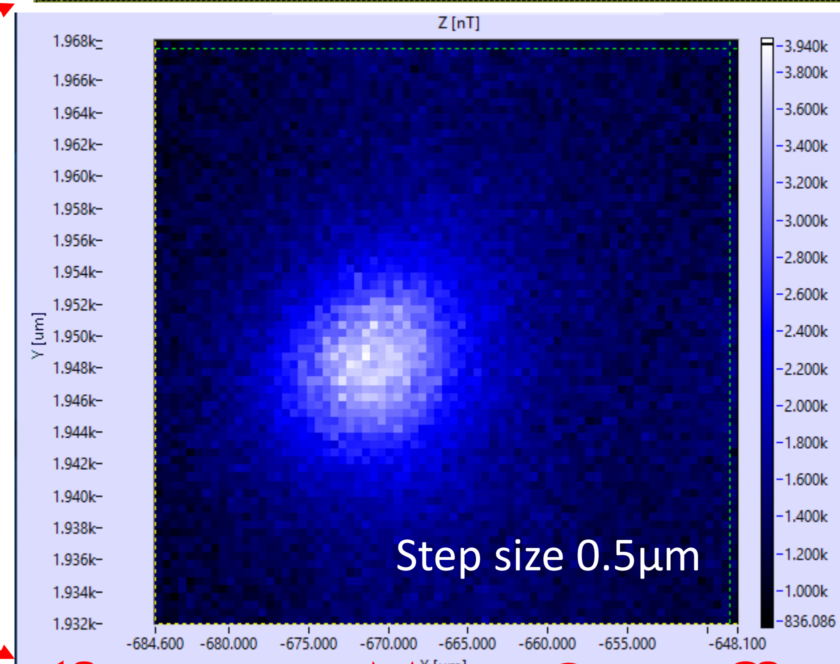
Non-vector sensor with double windings

SSM vortex Images obtained by using our own sensor



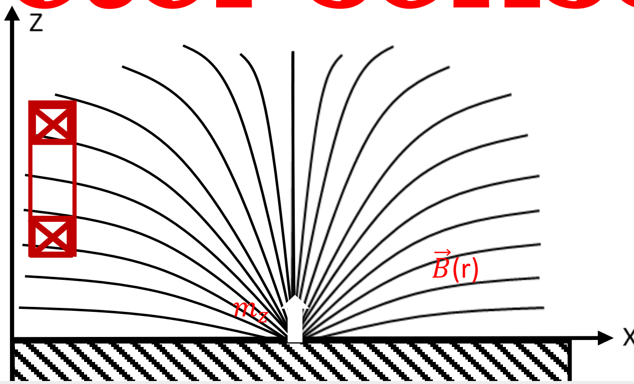






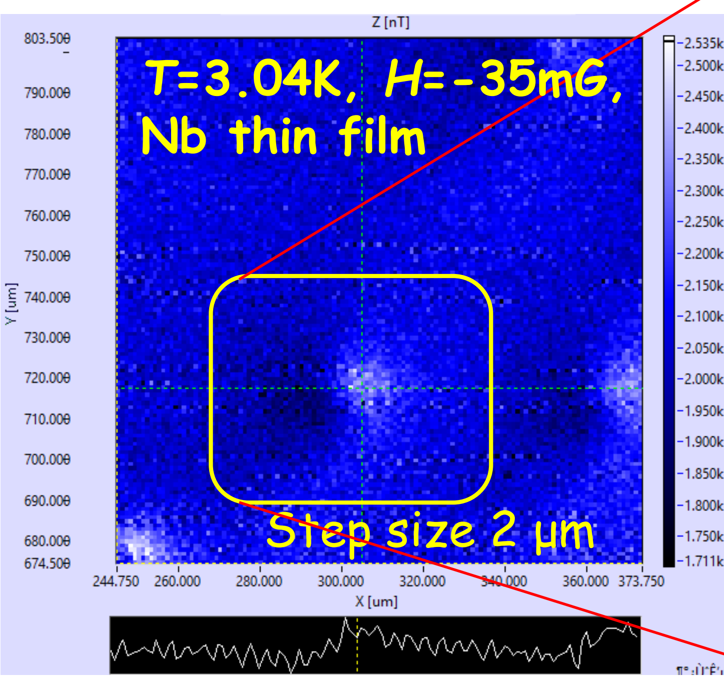
We observed clear vortices on $Mo_{80}Ge_{20}$ film

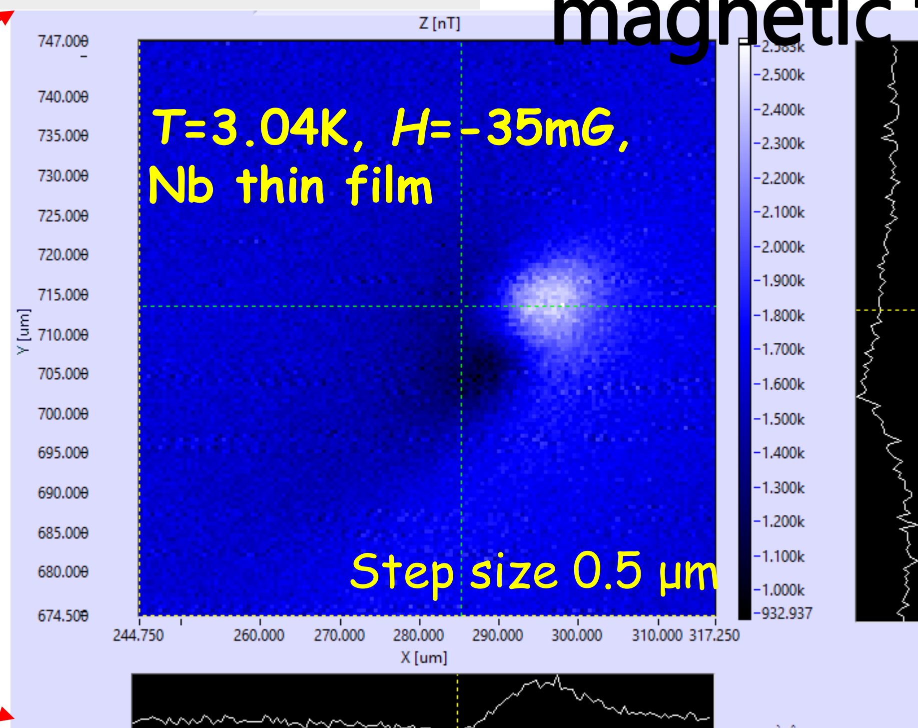
Image by using X coil of vector sensor



X coil and Y coil of sensor has no essential difference from X coil.

X coil gives a polarized field image by sensing the broadened magnetic flux.





Summary

1. Characteristics of 3D SQUID sensors have been investigated systematically by using a lab-made *I-V* curve tracer.
2. Fundamental characteristics of our SQUID sensors showed a good performance, which is suitable for our SQUID microscope.
3. Voltage outputs from a commercial readout circuit were in good agreement with the profiles of the V-Φ characteristics.
4. We succeeded in observing vortices by using a doubly winding pickup Z coil as well as an X coil on the conventional platform.
5. We are going to construct a vector SQUID microscope on the refrigerator-based platform in near future.

Thank you for your attention