SWTEST

PROBE TODAY, FOR TOMORROW

Quantum Computing Sets New Demand for Wafer Probing

AFORE

AN AEM COMPANY

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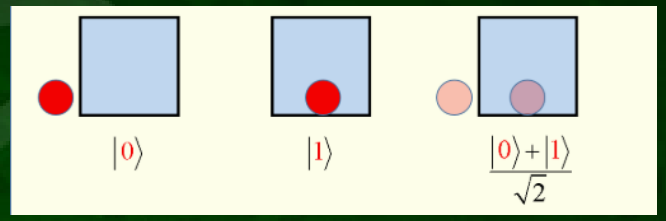
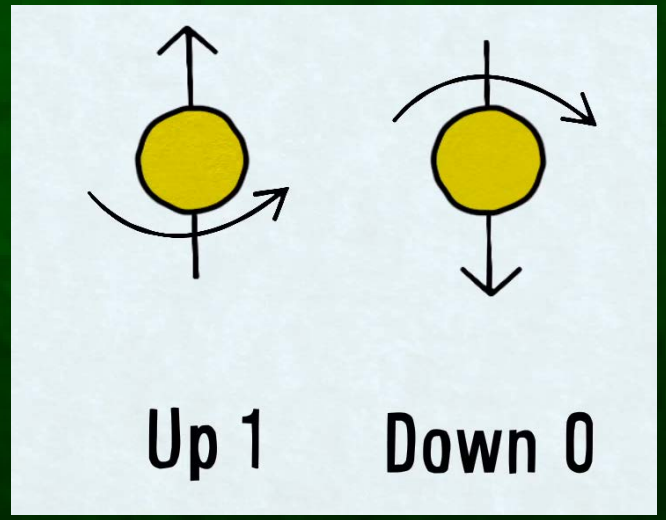
June 2-5, 2019

Table of Contents

1. Introduction – Quantum Computing

- In 1981 Paul Benioff theorized the concept of quantum computing using Max Planck‘s idea that energy exists in individual units.
- Quantum computing make use of quantum phenomena, such as quantum bits, superposition and entanglement to perform data operations.
- In a quantum superposition state, all four of the possible states for “0” and “1”can co-exist in time and space simultaneously.
- Any two-level quantum-mechanical system can be used as a qubit. In reality, qubits would be stored in atoms, ions, electrons or photons.
- E.g. in quantum spin technology, When the electron spins up, the data signifies the binary value 1 and vice versa.
- Any noise or unintended observation of them can cause data loss. This fragility requires them to operate at extremely cold temperatures.





1. Introduction – Intel Quantum Computing

- In September 2015 announced 10 year collaborative relationship with the Delft University of Technology and TNO, to accelerate advancements in quantum computing
- October 2017, announced the delivery of a 17-qubit superconducting test chip for quantum computing. Needed operation temperature was ca. 20 mK.
- March 2018, showcase in APS March Meeting about 300 mm Process Line for Qubit Fabrication
- March 2019, presentation in APS meeting about 300mm process line for spin qubit devices. Transistors and quantum dot devices are then co-fabricated on the same wafer and allow calibration to Intel's internal transistor processes. Electrical characterization and feedback is accomplished through wafer scale testing at both room temperature and 1.6K prior to milli-kelvin testing.

Source: https://newsroom.intel.com

1. Introduction – Afore

- Established 1995 for mechanical engineering R&D company.
- Located in Lieto, Finland
- Afore provides special probe stations with real physical stimulus.
  - Rotating wafer prober for motion sensor testing.
  - Chamber type wafer prober for environmental sensor testing and high vacuum testing applications.
- Part of AEM since January 2018.

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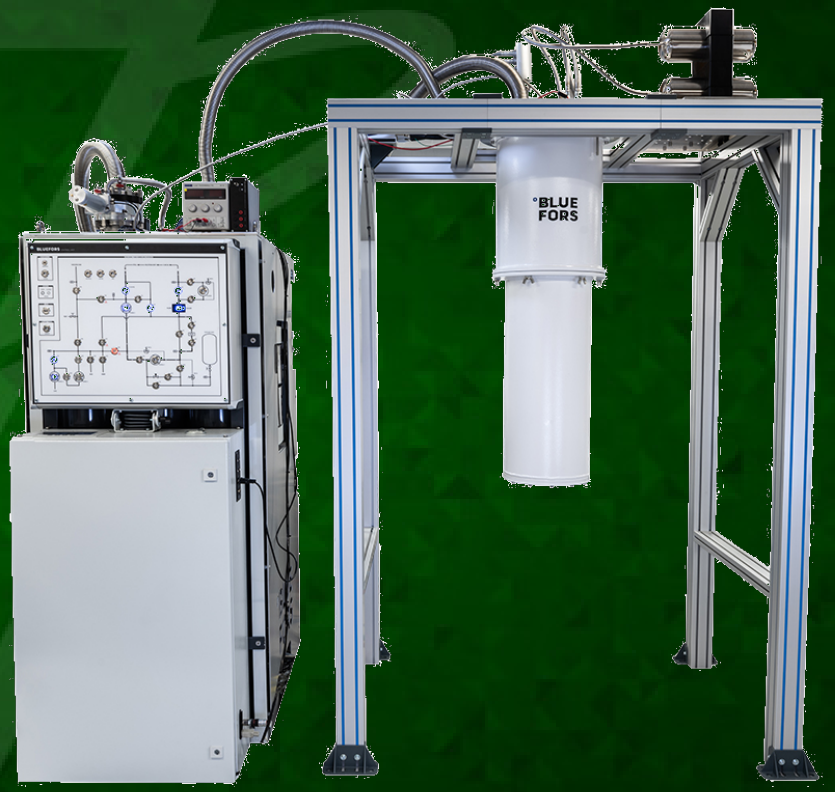
1. Introduction – Bluefors

- Bluefors Cryogenics specializes in ultra-low temperature dilution refrigerator system
- Technology was developed at the world famous Low Temperature Laboratory (LTL) at Helsinki University of Technology (now Aalto University).
- In 2007 the first dry-DR was taken into use by the NANO-group of the LTL, shortly after Bluefors Cryogenics was established as a company.
- With over 400 systems installed worldwide, the leading supplier of cryogen-free dilution refrigerator systems.



Source: https://bluefors.com/

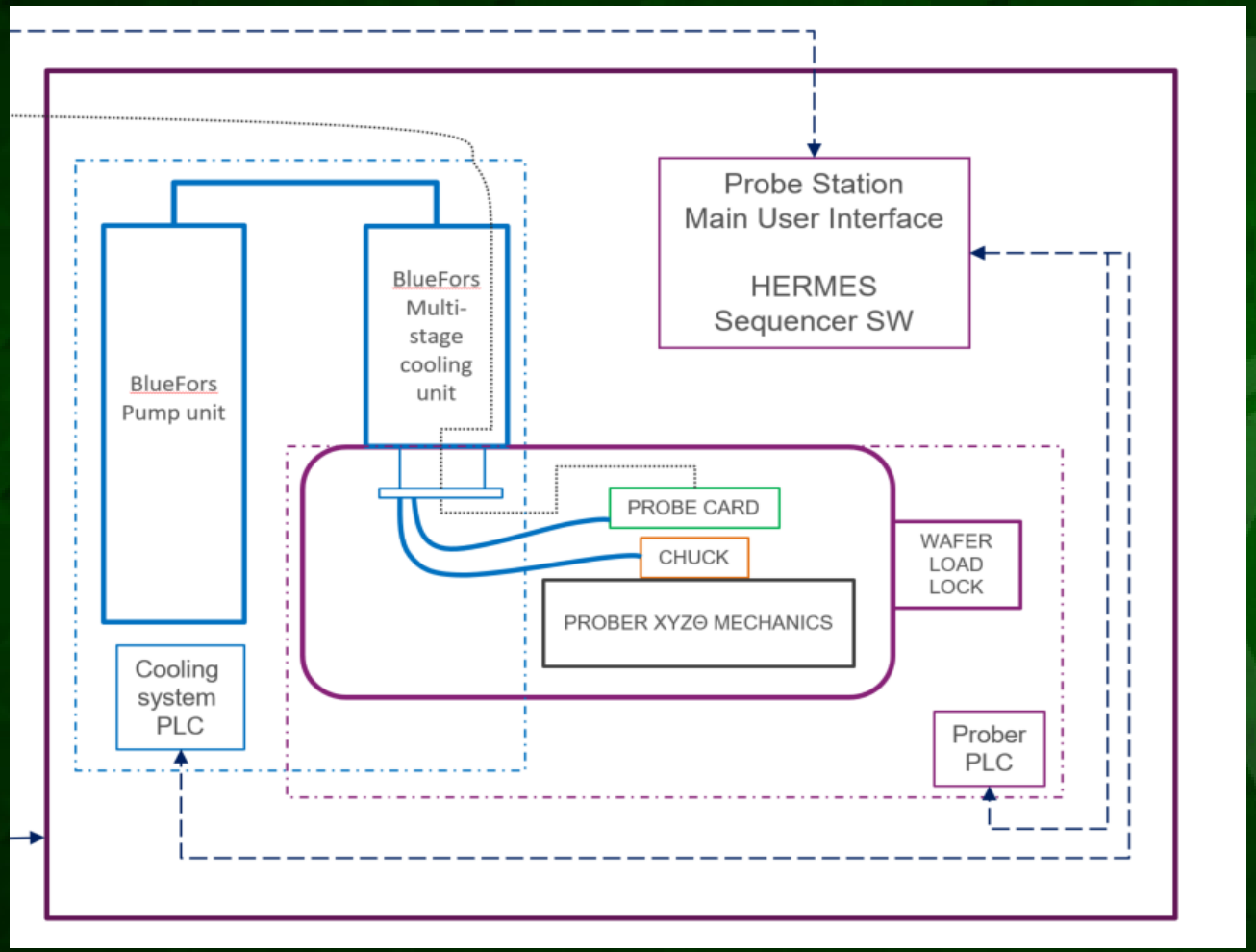
BLUEFORS

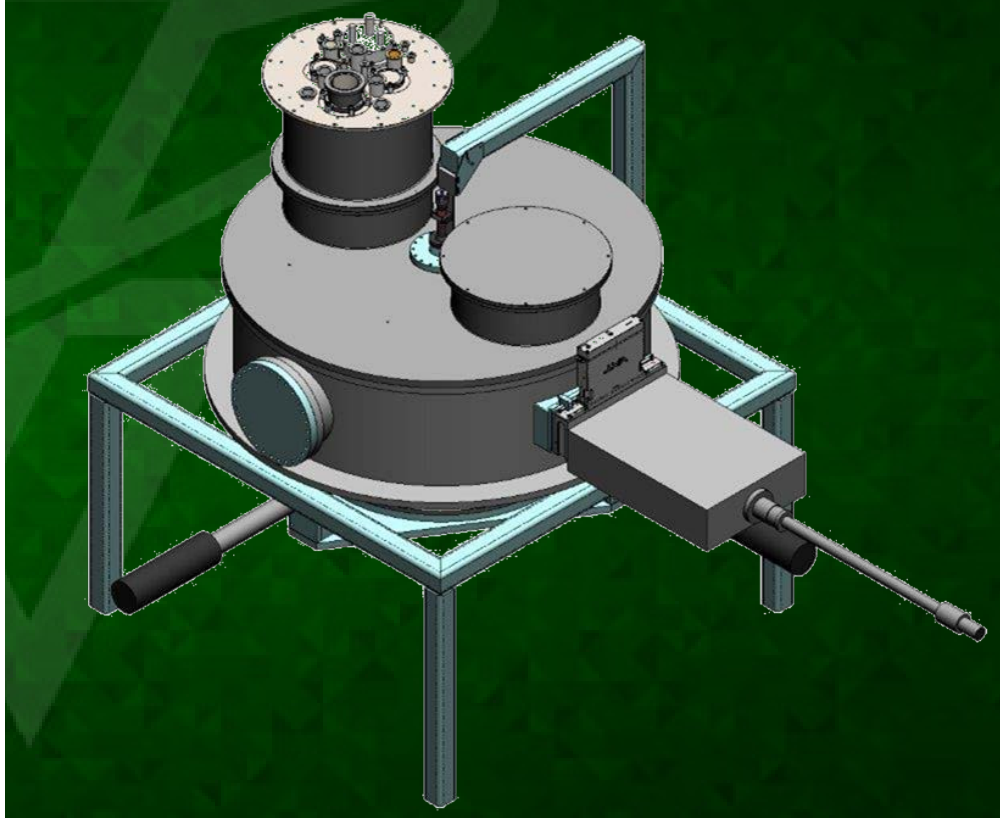
2. Cryogenic Wafer Prober – Specification and Technical Demands

- 300 mm wafers
- Reliable contacting in 50µm pads.
- No. of signal lines 72, min. 1 GHz.
- Closed loop cooling system to keep operating costs in reasonable level.
- Wafer and probe card temperature below 4K.
- Wafer load without need of heating up the system.

- Prober, cooler and radiation shields in high vacuum.
- All heat sources outside vacuum chamber.
- Heat load because of radiation must be minimized.
- Heat load because of conduction must be minimized.
- Mechanical cooler instead of liquid helium.
- Optical alignment of the wafer is needed.
- Wafer load through load lock.

2. Cryogenic Wafer Prober





2. Cryogenic Wafer Prober – Radiation shields

- Cryostat has 3 cooling stages, same stages must be applied to prober.
- Absorbed heat must be transferred to cooler.
- Chuck has to move, so must shields.
- Shields must be thermally linked to related cooler stages in order to get rid of absorbed heat.
- Thermal behavior of materials must be taken into account.

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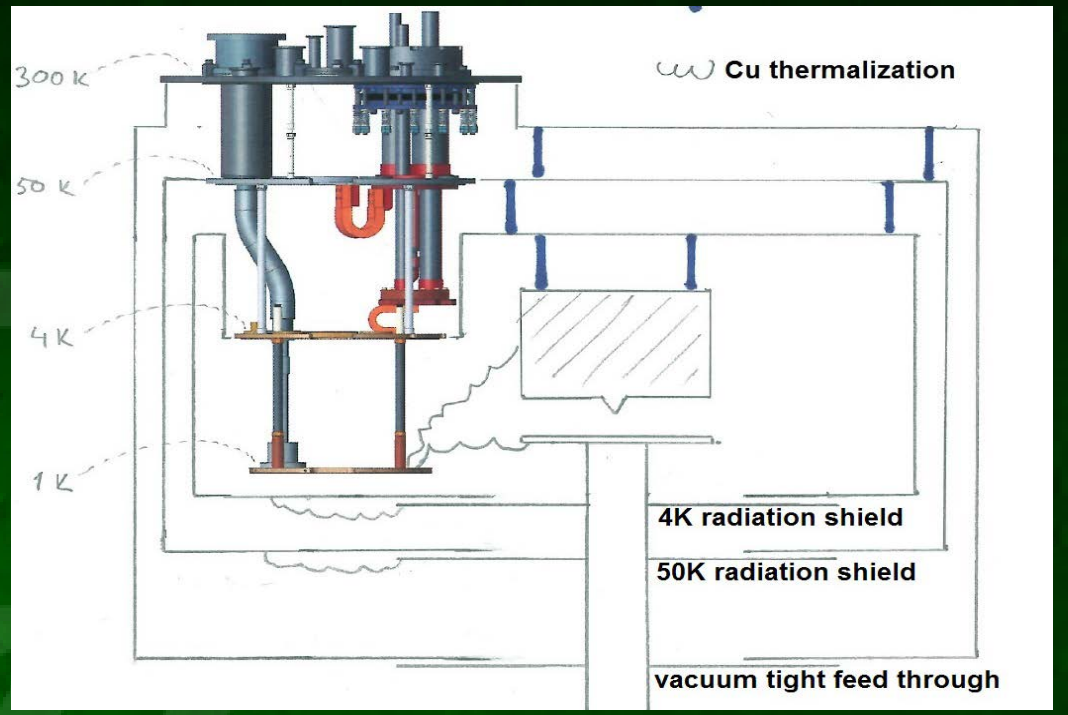
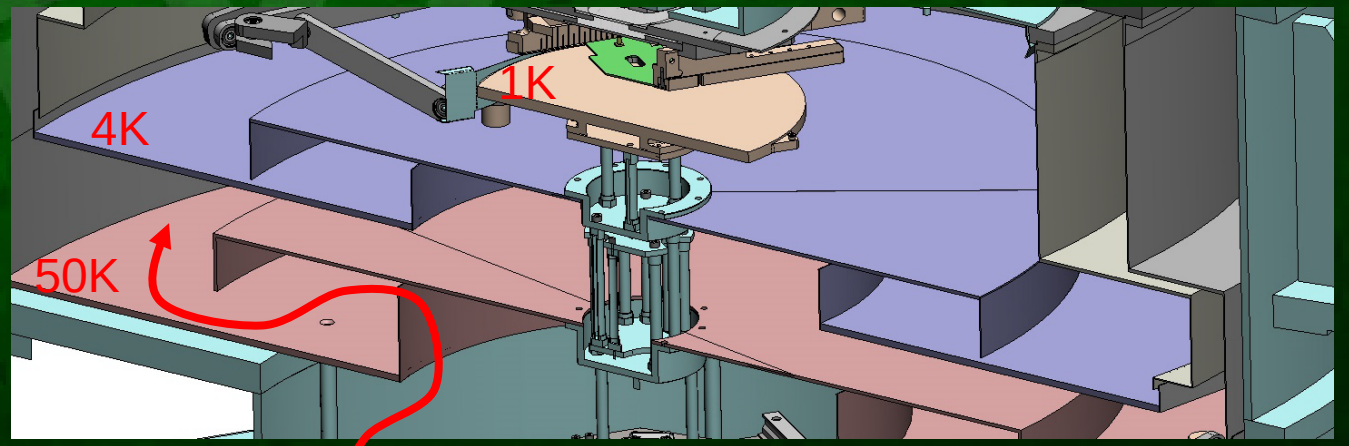
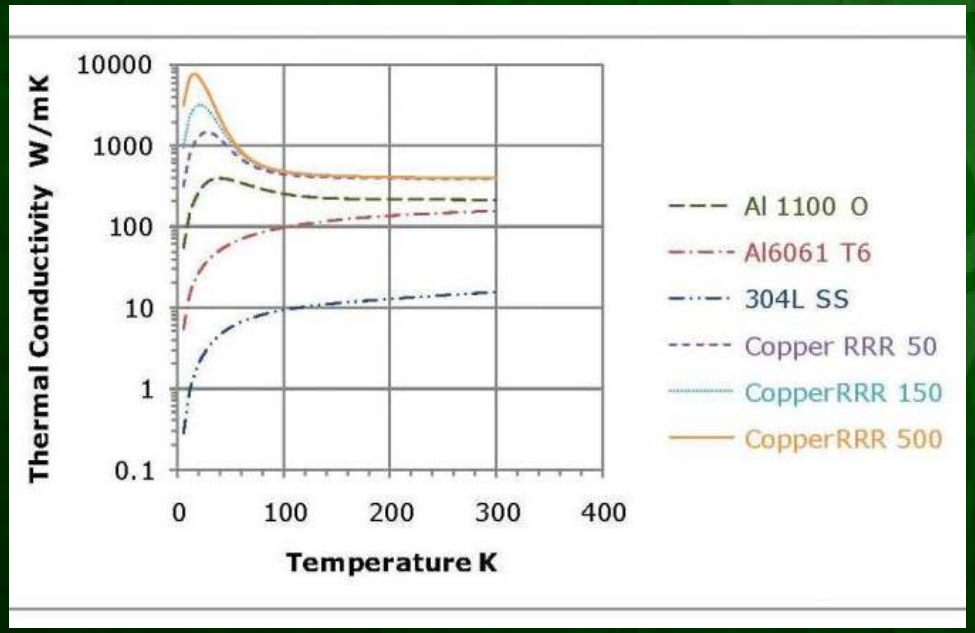




2. Cryogenic Wafer Prober – isolation between stages



https://www.mtm-inc.com/ac-20110627-heat-shields-materials-and-cost-considerations.html

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2. Cryogenic Wafer Prober – optical alignment of the wafer and probe card

- No heat generators allowed in system → no probe alignment camera from bottom.
- Long distances because of the radiation shields.
- Optical path, path for heat radiation.
- Pin/pad height measurement accuracy?
  - Currently ~ XY=10µm, Z=20µm → further development needed

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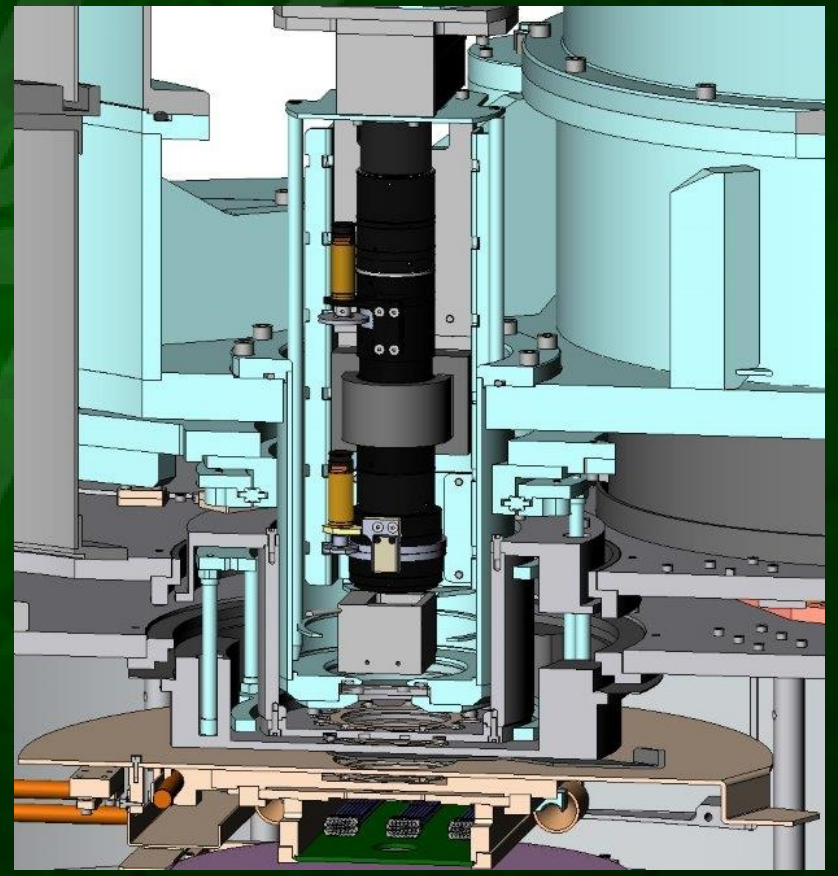
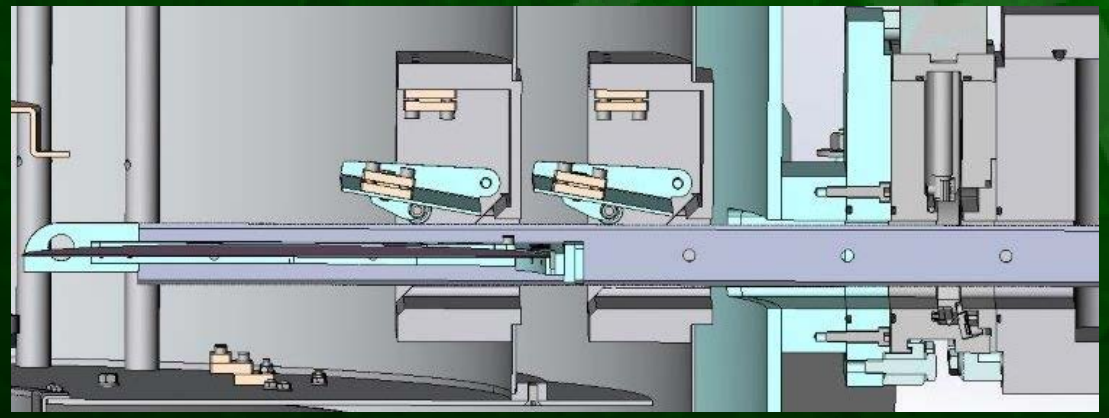
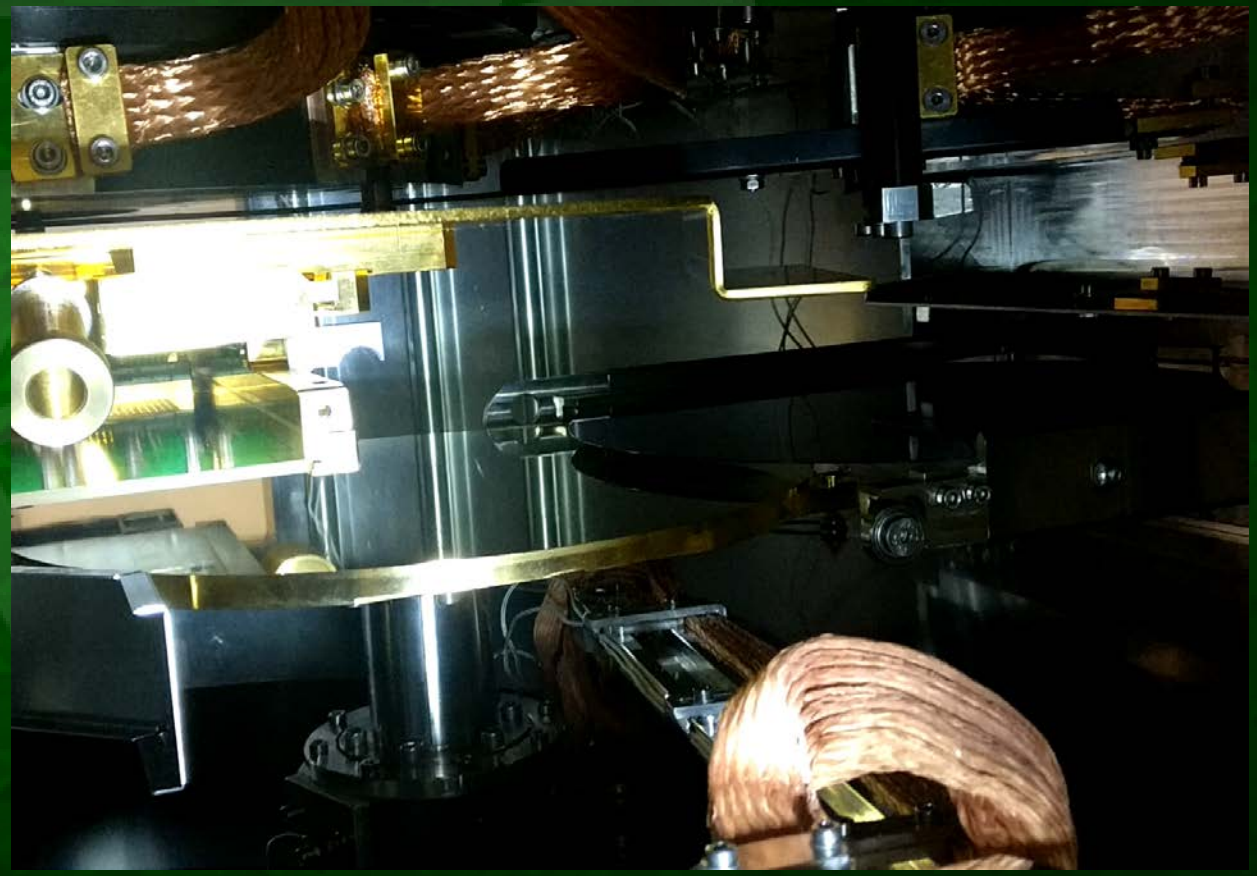


2. Cryogenic Wafer Prober – wafer loading

- Wafer must be loaded to chuck:
  - without compromising the vacuum
  - without generating excessive heat load.
- Wafer must be pre-cooled before loading on chuck.
- Thermal connection from chuck to wafer must be ensured.





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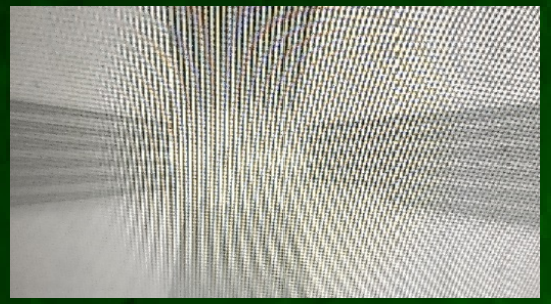
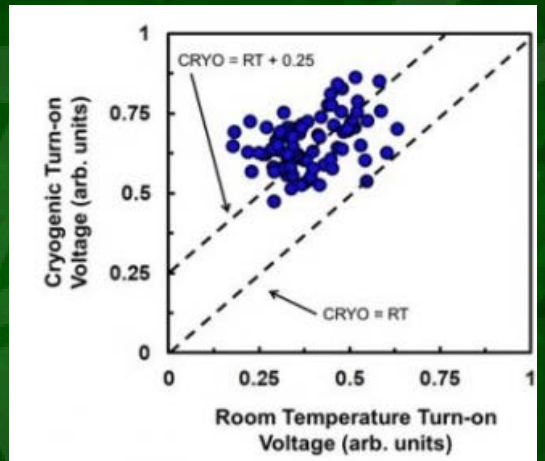
2. Cryogenic Wafer Prober – Results

December 2018, chuck ~20K

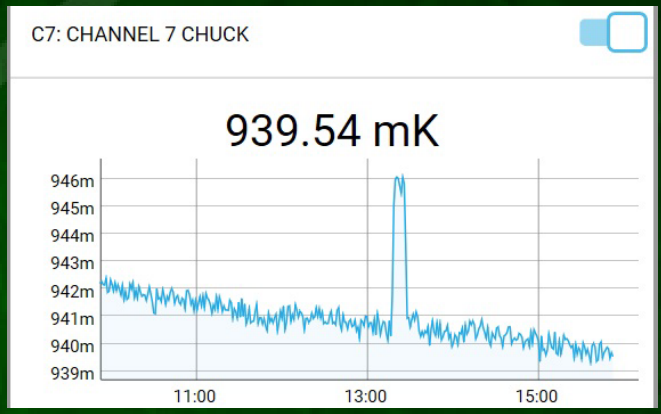


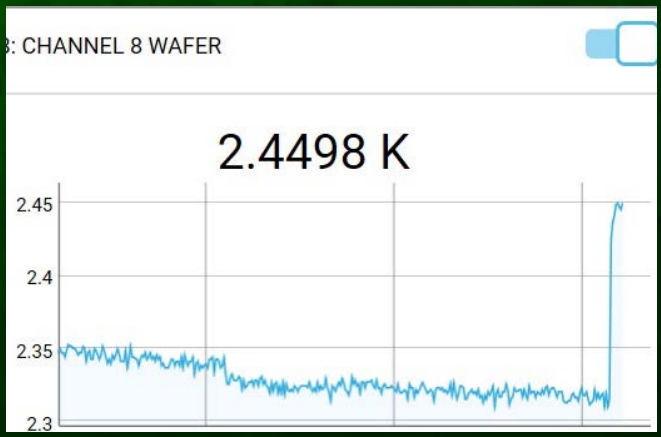
February 2019, chuck temperature 5.5K



Initial data characterizing multiple Intel qubit devices from the Cryogenic Wafer Prober illustrate the increased voltage required for qubit gate "turn-on" at cryogenic temperatures when compared with room temperatures across a 300mm wafer. (Credit: Intel Corporation)

April 2019, chuck below 1K





3. Summary

- All known quantum computing technologies need near absolute zero temperatures to minimize noise in the system
- Sub 4K wafer prober is needed to screen the quantum chip wafers and to bring quantum computing development closer to actual applications.
- Several new mechanical constructions were developed on Cryo-Prober project, patents are pending.
- Bluefors and Afore were able to realize first 300 mm sub 4K wafer prober in the world.

4. Next steps

- Further development of probe cards:
  - Materials
  - RF-demands
  - higher parallelism
  - Alignment for vertical contacts
- Magnetic shielding
- Support for photon based chips
- Investigation of new applications

5. References

- **Intel newsroom:** https://newsroom.intel.com/news/intel-drives-development-quantum-cryoprober-bluefors-afore-accelerate-quantum-computing/#gs.1fgqlp
- **Mayer tool & mfg:** https://www.mtm-inc.com/ac-20110627-heat-shields-materials-and-cost-considerations.html
- **Bluefors product catalog:** https://bluefors.com/products/ld-dilution-refrigerator/

6. Thank you / Q&A

Thank You,

questions, opinions, solutions for addressed problems, now or later….

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