Monday Morning, November 4, 2024

Quantum Science and Technology Mini-Symposium
Room 123 - Session QS1+VT-MoM

Vacuum Systems for Quantum Applications

Moderators: Freek Molkenboer, TNO Science and Industry, the Netherlands, **Russell Gleason**, Infleqtion, **Corey Rae McRae**, National Institute of Standard and Technology, **David Pappas**, Rigetti Computing

8:15am **QS1+VT-MoM-1 High-Precision, Four-Way Comparison of Three Cold Atom Vacuum Standards and an Orifice Flow Standard*, Stephen Eckel*,** *D. Barker, J. Fedchak, J. Scherschligt,* National Institute of Standards and Technology (NIST)

The cold atom vacuum standard (CAVS) is the first primary standard and sensor for vacuum in the ultra-high vacuum regime and below. By measuring the loss rate of ultra-cold atoms from a conservative magnetic trap, the CAVS infers the pressure of the surrounding vacuum from first principles calculations of the scattering cross section. Various CAVSs have been constructed or are under construction, with different sensor atoms, sizes, and technical capabilities. In 2023, we reported the first comparison of two CAVSs – a laboratory-sized version based on ^{87}Rb and a portable version based on ^{7}Li – to a traditional vacuum metrology apparatus, an orifice flow standard. This initial experiment showed agreement between all three at roughly the 2 % uncertainty level. Here, we report a comparison between three different CAVSs – a laboratory-sized version that can use either ^{7}Li or ^{87}Rb and a portable version that uses ^{7}Li – and our orifice flow standard. We anticipate our new comparison will have total uncertainties < 1 %. In combination with other studies, our results represent a stringent test of quantum mechanical scattering theory.

8:30am **QS1+VT-MoM-2 Vacuum Based Quantum Technology with Aluminum Alloys for Space Applications*, Klaus Bergner*,** *F. Löwinger, C. Gruber, L. Gerlach, S. Hüttl, L. Axtmann, A. Trützschler, J. Hertel,* VACOM, Germany*; J. Schneider, L. Kanzenbach, T. Schmidt, S. Wieland, D. Richter,* Fraunhofer Institute for Machine Tools and Forming Technology IWU, Germany*; J. Grosse, M. Warner, M. Elsen,* ZARM Center of Applied Space Technology and Microgravity, Germany

The advancement of quantum technologies has opened new horizons for space applications with capabilities in communication and metrology. This talk explores the potential of vacuum-based quantum technology utilizing aluminum as a pivotal material to enabling access to a wide range of robust and miniaturized turn-key solutions. Vacuum systems used in these quantum physics package solutions often require low form factors, low weight as well as robust and economic design combined with a low magnetic susceptibility and low outgassing rates. But current first demonstrators mainly rely on expensive, bulky, fragile, and unique solutions.

To overcome these limitations, these systems demand the miniaturization as well as increased reliability of used vacuum systems. Optimization and up-scaling of manufacturing processes is key to distinguish competitive technologies for use in commercial applications. One key factor of this approach could be the use of aluminum alloys as base material of vacuum systems. An advantage of aluminum is simpler processing during manufacturing and the associated simpler miniaturization approach. However, the use of aluminum-based ultra-high vacuum (UHV) systems for space applications has not been qualified, nor have the effects of static and dynamic mechanical loads and temperature fluctuations been researched. Due to the complexity of this qualification work, in this joint paper we present the effects of mechanical and thermal influences on the critical system components - the releasable ConFlat (CF) sealing technologies.

The mechanical load of aluminum UHV CF sealing was characterized within a cooperation between Center of Applied Space Technology and Microgravity in Bremen and VACOM. The talk shows results of leakage rate due to static loads. In addition, a disadvantage of aluminum is the temperature limitation of only 120 °C. Within the cooperation between Fraunhofer Institute IWU in Chemnitz and VACOM it was possible to raise this limit up to 200 °C with our newly developed aluminum UHV CF sealing technology. Both results demonstrate the high temperature and mechanical stability of aluminum related CF sealing technology. In summary, this talk is intended to understand the demands of quantum space technology for vacuum systems and allows to develop a proper design of space suitable commercially viable solutions.

8:45am **QS1+VT-MoM-3 Compact UHV Technology for Quantum*, Alex Kato*,** IonQ **INVITED**

UHV systems for quantum technology (E.g. sensors, computing) can be made smaller by moving away from conventional vacuum parts. I will review several ways in which size, weight, and power can be significantly reduced without sacrificing on desired system performance. This requires moving away from conventional vacuum components, such as off the shelf conflat flanges and windows, feedthroughs, and gauges.

9:15am **QS1+VT-MoM-5 Quantum-Based Sensors and Standards with the NIST on a Chip Program*, Jay Hendricks*,** NIST*; B. Goldstein,* NIST-Gaithersburg

The NIST on a Chip program (NOAC) is briefly introduced as a forward-looking vision of the future of measurement science.The world-wide redefinition of units that occurred on May 20th, 2019, has opened new ways to think about metrology under a “zero-chain-traceability” paradigm.Next generation quantum-based sensors and standards, based on physical constants of nature, are briefly introduced, for pressure, vacuum, mass and more.The re-definition of the SI units enables new ways to realize the units for the kelvin, mass, and therefore the pascal. A new way to realize the pascal is exciting for vacuum technology (VT), will lead to other exciting applications. These quantum-based systems; however exciting, do raise new challenges and several important questions: Can these new realizations enable the size and scale of the sensor to be miniaturized to the point where it can be imbedded into everyday products?What will be the role of metrology institutes in this new ecosystem of measurement?Where will these new quantum-based systems go and what will they do? This talk will begin to explore these important questions.

9:30am **QS1+VT-MoM-6 3D Printed Ion Traps for Quantum Computation*, Kristin Beck*,** Lawrence Livermore National Laboratory **INVITED**

Trapped atomic ions are one of the leading qubit candidates for quantum computing. The fidelity of quantum gates and the noise performance of a quantum processor built on this platform depends on the degree of isolation between the classical environment and the ions. One leading noise source is electric field noise. Additive manufacturing has introduced the possibility of generating accurate, replicable and scalable ion traps with geometries that promise to reduce sensitivity to this noise source. In this talk, I will describe miniaturized RF Paul traps that we have fabricated at LLNL using high-resolution 3D printing approach based on two-photon polymerization and share the results of initial tests.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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