Quantum Science and Technology Mini-Symposium
Room B110-112 - Session QS+VT-WeM

Vacuum Technology for Quantum Applications

Moderators: Ekta Bhatia, NY CREATES, **Freek Molkenboer**, TNO Science and Industry, the Netherlands

9:20am **QS+VT-WeM-5 Stand-Alone Vacuum Cells for Compact Ultracold Quantum Technologies***, **Oliver Burrow**, A. Arnold, P. Griffin, E. Riis,* University of Strathclyde, UK **INVITED**

Compact vacuum systems are key enabling components for cold atom technologies, facilitating extremely accurate sensing applications. There has been important progress toward a truly portable compact vacuum system; however, size, weight, and power consumption can be prohibitively large, optical access may be limited, and active pumping is often required. We have been developing centilitre-scale vacuum chambers with He-impermeable viewports and an integrated diffractive optic, enabling robust laser cooling with light from a single polarization-maintaining fibre. With these devices, a cold atom demonstrator based on the vacuum cell delivers 107 laser-cooled 87Rb atoms per second, using minimal electrical power.

Pressure measurements in these compact systems are made from cold-atom loading curves, and pressure evolution have been studied in a ceramic based vacuum chamber. With continuous Rb gas emission, active pumping yields a 10−7 mbar equilibrium pressure, and passive pumping stabilizes to 3×10−6 mbar with a 17 day time constant. With no Rb dispensing and only passive pumping, a ceramic based vacuum chamber has currently kept a similar pressure for more than 500 days. The passive-pumping vacuum lifetime is several years, which is estimated from short-term He throughput with many foreseeable improvements.

Progress is also reported, including new cell materials, mobile cold-atom demonstration and adaptation of the fabrication technique into a cold-atom gravimeter vacuum system. This technology enables wide-ranging mobilization of ultracold quantum metrology.

Oliver S. Burrow, Paul F. Osborn, Edward Boughton, Francesco Mirando, David P. Burt, Paul F. Griffin, Aidan S. Arnold, Erling Riis; Stand-alone vacuum cell for compact ultracold quantum technologies. Appl. Phys. Lett. 20 September 2021; 119 (12): 124002. https://doi.org/10.1063/5.0061010

11:00am **QS+VT-WeM-10 Hybrid Quantum-HPC Computing Clouds in Europe***, **Richard Versluis**,* TNO Science and Industry, the Netherlands **INVITED**

Quantum computing technology holds great promises for the long future but requires large investments in the near future as an enabler. Not only in terms of money and human resources such as talent, but also in infrastructure. This ranges from clean room infrastructure for QPU development, such as dedicated processing lines for quantum chip development to dedicated software and testing equipment for the screening and validation of quantum chips, to full stack system prototypes to demonstrate and validate crucial interfaces, but also to enable early adaptors to start implementing and exploring the potential of these new compute paradigms. Since a couple of years, some full stack demonstrators have been built, some in-house in a lab environment and some in an environment that is already a bit more market-orientated, such as a private cloud or a public cloud. Notably, some US companies like IBM, Google, Rigetti, IonQ and the Canadian company Dwave have set standards for online access to quantum computers. In Europe, the first publicly available cloud service for quantum computing, giving access to European quantum computers was Quantum Inspire, implemented by QuTech in The Netherlands. Since its launch in 2020, more online quantum computers have been launched in Europe, such as Quandela cloud.

With the necessity to get the most out of these early systems, hosting QPU's with still noisy and small numbers of qubits, a connection to HPC systems is crucial. It is anticipated that early advantage will be reached by combing classical and quantum algorithms, where the QPU could outperform an HC on some specific tasks, such as efficiency of the calculation in terms of wall clock time or energy used, the accuracy of the calculation, or simply by providing a different method of calculation that could not be done with a classical system. Integration of these, relatively immature systems, in an HPC workflow requires quite some effort. First of all, the language used to program quantum computers cannot be compared to high level classical programming languages like Python, C++, Rust etc. Secondly the integration of (runtime) compilers in the workflow is non-trivial. Hybrid classicll-quantum algorithms, therefore require systems that can handle multiple languages, compiler services. Thirdly, the workflow management is not-standard: where the integration of classical accelerators like GPU's is based on standard-predefined interfaces such as scrum, these workflow interfaces for QPUs have not been defined yet.

In this talk I will highlight the goals and some first results of European activities on the integration of HPC and Quantum Computers in European projects such as the EuroHPC projects, OpenSuperQ plus and Quantum Large Scale Integration.

11:40am **QS+VT-WeM-12 Design Considerations of an XHV System for an Ion Trap Quantum Computer***, **Paul Smith**, N. Burch, A. Chew, P. Jones, P. Lamb, E. Lucchetta, S. Lodge, P. Milner,* Edwards Ltd, UK*; D. Clement, T. Sinha,* Gamma Vacuum*; A. Abolghasemi, L. Earl, J. Randall,* Universal Quantum, UK

The design and configuration of an XHV system for an ion trap quantum computer is presented. A target operating pressure of 10^{-12} mbar has been identified to increase ion lifetime. Contributions to the residual gas load from leaks, permeation and outgassing will be evaluated as will the pumping strategies employed for each. The relative pumping performance of two combined NEG-IGP pumps will be reported. Other factors will be discussed including conductance optimization, limitations on component bakeout and NEG activation temperatures, vibrations, and shielding of magnetic fields and radiant heat loads.

12:00pm **QS+VT-WeM-13 Chances and Challenges: Aluminum Vacuum Components for Quantum Technology***, **Stefan Kiesel**, A. Trützschler, J. Hertel, K. Bergner,* VACOM Vakuum Komponenten & Messtechnik GmbH, Germany

Quantum technology currently experiences a huge push towards commercialization, since it promises a variety of attractive applications, including quantum sensors, quantum computers, and quantum clocks. Many of these systems require a vacuum to isolate quantum objects or devices from the surrounding environment and to create stable conditions. In addition, signal paths into the vacuum are necessary to manipulate quantum objects, facilitated by hermetically sealed electrical and optical feedthroughs. The most advanced modern systems are built up from large and expensive laboratory equipment. However, the needs of commercially usable applications drive the development of quantum systems towards transportable, durable, and standardized solutions. To meet these challenging demands, better materials, novel manufacturing technologies and innovative designs are issues of today’s development projects. As an example, aluminum Con-Flat (CF) components offer the possibility of providing customized solutions with high geometrical accuracy, reduced weight, low outgassing rates as well as vanishing magnetic permeability. As a manufacturer of vacuum components, VACOM is actively collaborating in several publicly funded projects to promote the development of quantum technology. In this talk we show goals and results of these projects regarding the development of vacuum systems and vacuum components for quantum technology.

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