ARTIQ Day

28th April 2021 (CEST)

Schedule and abstracts

9:00-9:05:	**Markus Hennrich** **Introduction to technical coffee series**
9:05-9:35:	**Robert Jördens** **ARTIQ Overview and Introduction**
9:35-10:05:	**David Nadlinger** **Five years of ARTIQ in Oxford**
10:05-10:35:	**Tanja Mehlstäubler** **SiPyCo module to integrate external components into ARTIQ**
10:35-11:00:	Break/discussions
11:00-11:30:	**Sébastien Bourdeauducq** **NAC3: a new compiler for ARTIQ**
11:30-12:30:	Session for discussions
12:30-14:00:	Lunch
14:00-14:30:	**Nils Huntemann** **Opticlock ARTIQ for a robust optical clock**
14:30-15:00:	**Norman Krackow** **ARTIQ integration on the gateware level**
15:00-15:30:	**Martin Steinel** **ARTIQ for $^{171}Yb^{+}$ & $^{88}Sr^{+}$ optical atomic clocks**
15:30-16:00:	Break/discussions
16:00-16:30:	**Philip Kent** **A Framework for Writing and Executing Scans**
16:30- 17:30:	Session for discussions

ABSTRACTS

1. Robert Jördens
QUARTIQ and M-labs
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ARTIQ Overview and Introduction

In this talk I will shortly review the history of ARTIQ and Sinara and how the community evolved into the vibrant world-wide collaboration that it is today. The talk will introduce the fundamental concepts of ARTIQ including working with the timeline and managing real time input/output (RTIO) events. It will provide an overview of the ARTIQ building blocks, their interaction, and a few simple use-cases and programming patterns that may be useful in practice. Finally it will attempt to explain some mechanisms of interactively developing open source software and hardware within the community and describe ongoing and future developments.

2. David Nadlinger
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Five years of ARTIQ in Oxford

ARTIQ is the real-time control system of choice in the Oxford Ion Trap Quantum Computing group, where it powers six different experiments (and counting); one of the largest deployments to date. This talk is a brief technical account on the systems in our group, comprising over a dozen crates of Sinara open-source hardware, and making heavy use of DRTIO real-time optical fibre links. A key advantage of ARTIQ lies in its extensibility. To this end, I discuss some of our custom FPGA components, e.g., for low-latency decision making, and summarise our current approach to balancing low-friction exploratory work with code reuse, traceability of results, and debuggable automation through the open-source ndscan framework. I describe some of our internal support infrastructure, for instance regarding firmware and software deployment, before closing with a brief look at some of the remaining technical and non-technical challenges.

3. Jonas Keller, Jan Kiethe, Henning Fürst, Daqing Wang, Kilian Singer, and **Tanja Mehlstäubler**
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SiPyCo module to integrate external components into ARTIQ

We introduce two use cases of M-Labs' SiPyCo module by which we integrate external components into our ARTIQ setup.
The first is a set of Python programs for network-based communication with HighFinesse wavemeters and laser locking. We use it to control and monitor wavemeters and laser locking parameters from various computers across the campus simultaneously, which facilitates sharing those resources between labs and remote operation. An event-driven design minimizes latency and supports locking bandwidths of tens of Hz, limited by the hardware update rate. Besides control via standalone GUIs, the use of SiPyCo for all communication makes ARTIQ integration straightforward.
Second, we present the communication between a C++ control software named MasterControlProgram (MCP), developed by K. Singer, and ARTIQ. MCP benefits from the multi-threading ability and speed advantages of C++, and comes with a run-time adaptable and flexible GUI. Recently, MCP has been enhanced with an internal Python interpreter which has access to the user-defined C++ objects and functions. Inside this interpreter we run an RPC target to provide SiPyCo access to those C++ resources. In combination with SiPyCo clients, this allows two-way interoperability between ARTIQ and MCP.

4. Sébastien Bourdeauducq
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NAC3: a new compiler for ARTIQ

The ARTIQ-Python language and its compiler were developed around six years ago. Since then, ARTIQ hardware technology and user experiments have evolved and exposed ARTIQ-Python limitations. Third-party compiler libraries and the Python language itself have also evolved, providing new avenues of improvement for ARTIQ-Python.
The NAC3 project aims at redesigning ARTIQ-Python and its implementation in order to take advantage of the new Python type annotations, and of new Rust libraries for developing compilers and interfacing with Python. The goal is to make the compilation process more transparent and predictable for the user, and to drastically improve compilation speeds

5. Nils Huntemann
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Opticlock ARTIQ for a robust optical clock

The most accurate and stable clocks are based on optical reference transitions of single ions confined in radio-frequency traps or neutral atoms trapped in optical lattices. Today's prototypes in leading metrology laboratories reach fractional accuracies of 10^{-18} and below. Their unprecedented precision opens up numerous commercial applications. Up to now, however, such optical clocks must be operated by scientists in highly specialized laboratories under well-defined conditions restricting the use to applications in basic research. Within one of three pilot projects for quantum technology supported by the German Federal Ministry of Education and Research, the opticlock consortium [www.opticlock.de] has developed a robust and easy-to-operate optical clock, which can be reliably operated outside a specialized laboratory. The clock is based on the $^2S_{1/2}$-$^2D_{3/2}$ transition of a single $^{171}Yb^+$ ion at 436 nm wavelength (688 THz) that has been selected as one of the secondary representations of the second. The talk will give an overview of the fully functional clock demonstrator, particularly the functionality implemented with ARTIQ to perform clock spectroscopy and implement automatic optimization routines.

6. Norman Krackow
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ARTIQ integration on the gateware level

The talk will present the experience and process of integrating a new signal processing scheme into ARTIQ at the gateware and driver level. The scheme uses the Phaser Sinara hardware module and the "Fastlink" digital interface to the Kasli central controller. The RTIO system on the Kasli SoC is used to stage and transfer data from the ARTIQ kernel CPU. An ARTIQ driver abstracts the hardware access into a convenient programming interface. The components involved will be presented and the development workflow will be explained.

7. Martin Steinel
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ARTIQ for $^{171}Yb^+$ & $^{88}Sr^+$ optical atomic clocks

We employ ARTIQ to control four setups of optical atomic clocks with different ion trap designs. The clocks reference the electric quadrupole transitions of $^{171}Yb^+$ and $^{88}Sr^+$ and the electric octupole transition of $^{171}Yb^+$ for which a fractional frequency uncertainty of a few 10^{-18} has been evaluated. While the oldest trap design is predominantly used to provide frequency information to contribute to the international atomic timescale and frequency comparisons to other atomic clocks for tests of fundamental principles, we presently focus on an improvement of stability and accuracy of the new clock setups. For all experiments we use a variety of Sinara hardware. It provides radiofrequency signals for the ion trap drive and acousto-optical modulators, digital I/O for mechanical shutters, RF-switches and fluorescence counting of the trapped ions, analog signals to control magnetic fields, power stabilization, and the confinement in a segmented linear ion trap, enabling ion transport between different segments. We also make use of analog samplers for monitoring purposes. Besides the data from the Sinara hardware, ARTIQ also processes data from devices such as frequency counters through InfluxDB directly. Communication between ARTIQ and commercial devices like cameras and some homebuilt hardware is integrated using Python libraries. Exemplarily, we will discuss our implementation of automated ablation loading of ions. This way, ARTIQ provides an interface between various components and the trapped ions to enable clock spectroscopy.

8. Philip Kent, Kyle McKay
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A Framework for Writing and Executing Scans

At NIST we have developed a framework for performing scans over experimental parameters. The framework handles many of the tasks common to scan experiments such as looping over experimental parameters, sending collected data to the host, analysis of data, real-time display of plots, and fitting of the data. This reduces the amount of code needed to implement an individual scan. The framework also provides a number of useful features for ion trap experiments such as automatic centering of scan ranges around a previously fitted value, the ability for a scan to yield to a higher priority experiment and subsequently resume the scan, and the ability to reload a lost ion and resume a scan in which an ion was lost mid-scan. In my talk I will cover the basics of writing scans using this framework and cover some of its more useful features.