

# Q-BEAST Preliminary Meeting

## LRZ

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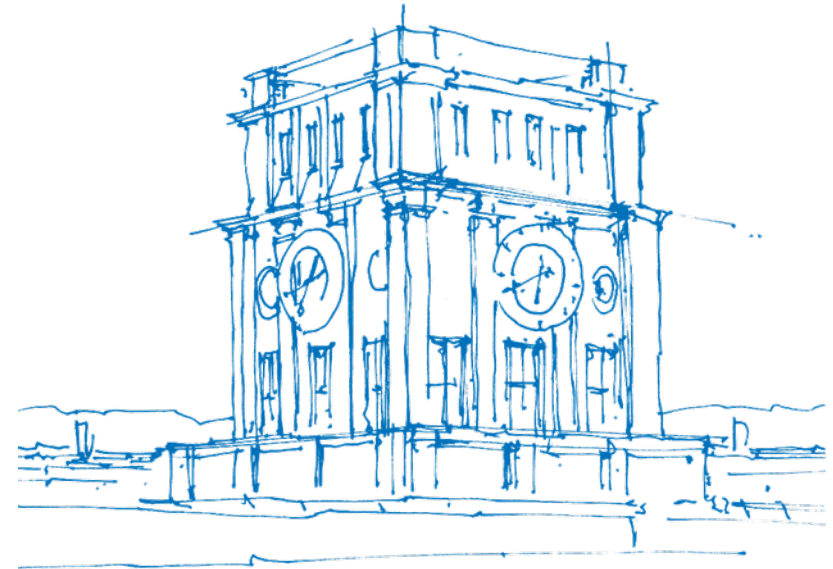
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*TUM Uhrenturm*

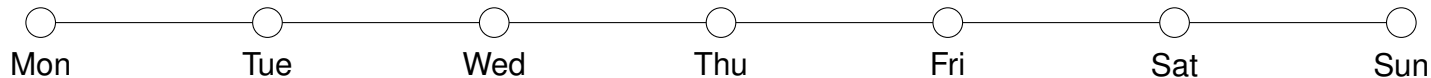


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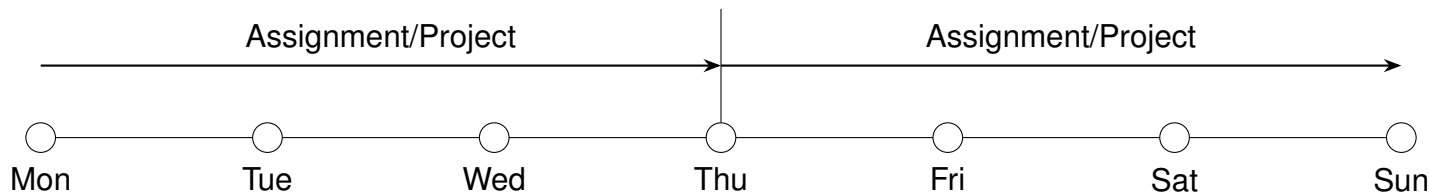


## Lab Meetup

16:00-18:00

- + Theory/Vendor Presentation
- + Previous Assignment Presentation || Tutorial/Exercise Discussion
- + Next Assignment Introduction

# Weekly Schedule

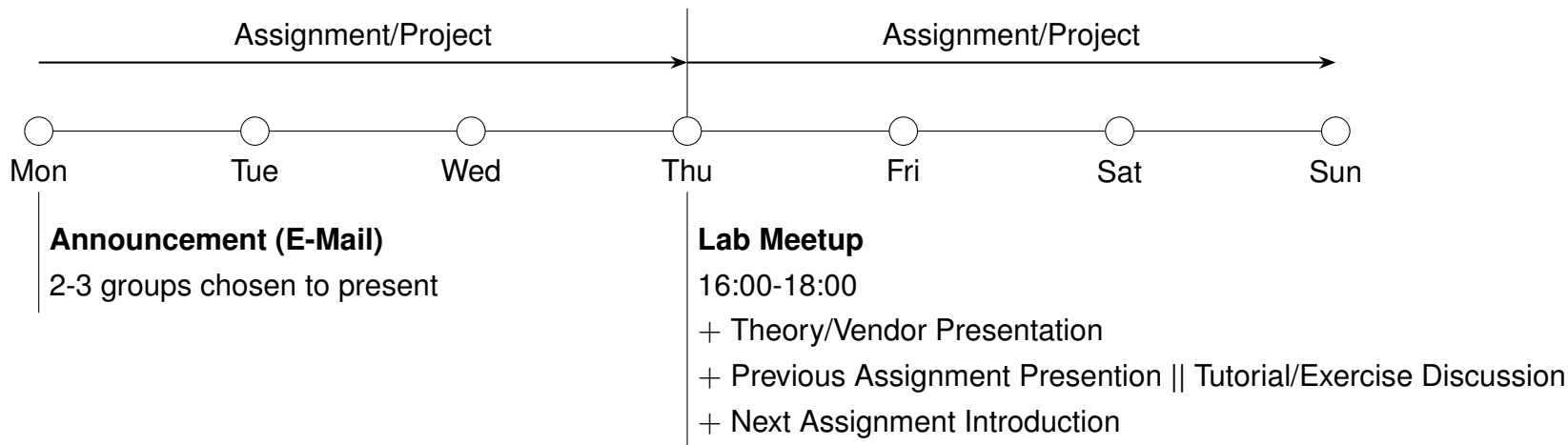


## Lab Meetup

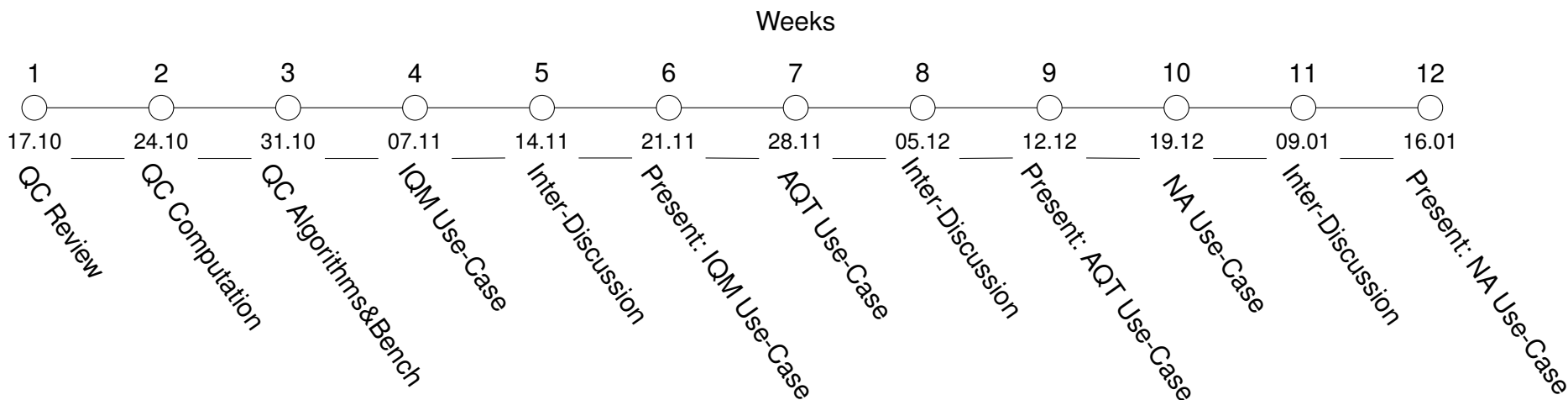
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# Weekly Schedule



# Tentative Semester Overview

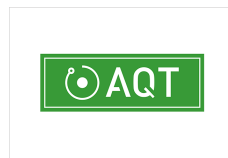


## Organization

- Note: This is preliminary plan and is subject to improvements
- 6 Assignments (1-2 weeks/each)
- 1-2 Projects (2-3 weeks/each)
- Student groups of 3 (Bachelor) or 2 (Master)

## Vendor Talks

IQM



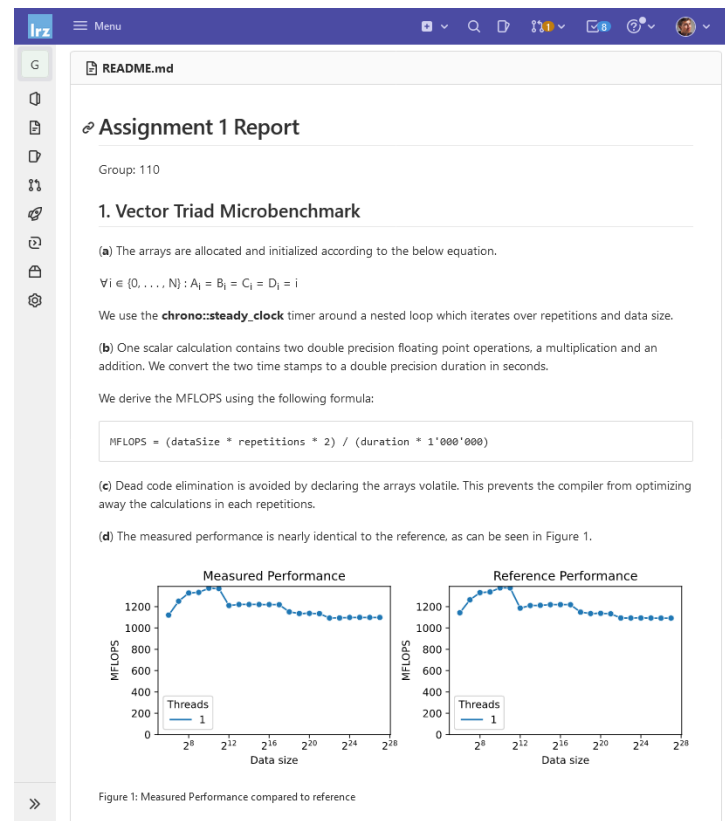
# Deliverables/Grading

## Git Repository

- **Assignment/Project Report** in Markdown
- Your Code

## Presentation

- No slides. Go through the report
- Talk about what you learned from the assignment & experimental results
- Q&A



The screenshot shows a GitHub repository interface. The main content is a README.md file titled "Assignment 1 Report" for Group 110. It describes a "1. Vector Triad Microbenchmark".

(a) The arrays are allocated and initialized according to the below equation.

$$\forall i \in \{0, \dots, N\} : A_i = B_i = C_i = D_i = i$$

We use the `chrono::steady_clock` timer around a nested loop which iterates over repetitions and data size.

(b) One scalar calculation contains two double precision floating point operations, a multiplication and an addition. We convert the two time stamps to a double precision duration in seconds.

We derive the MFLOPS using the following formula:

$$\text{MFLOPS} = (\text{dataSize} * \text{repetitions} * 2) / (\text{duration} * 1'000'000)$$

(c) Dead code elimination is avoided by declaring the arrays volatile. This prevents the compiler from optimizing away the calculations in each repetitions.

(d) The measured performance is nearly identical to the reference, as can be seen in Figure 1.

Figure 1 consists of two side-by-side line graphs. Both graphs plot MFLOPS (Y-axis, 0 to 1200) against Data size (X-axis, logarithmic scale from  $2^8$  to  $2^{28}$ ). The left graph is titled "Measured Performance" and the right graph is titled "Reference Performance". Both graphs show a single data series for "Threads: 1", which peaks at approximately 1200 MFLOPS for data sizes between  $2^{10}$  and  $2^{14}$  and then slightly declines to around 1000 MFLOPS for larger data sizes.

Figure 1: Measured Performance compared to reference

# Next Steps

## Register on Matching System

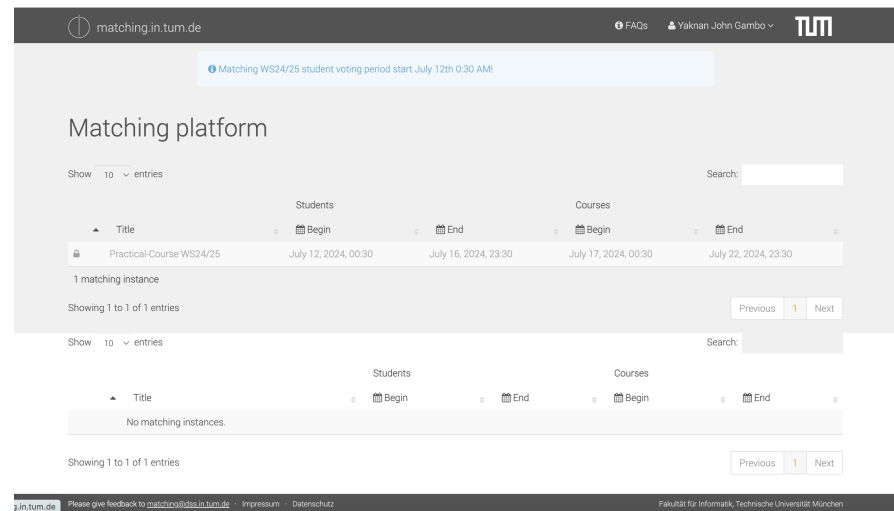
- We will prioritize you if you attended today
- Open until 12.07.2024
- Wait for announcement of matching results (25.07.2024)

## Group Preferences

- Only after matching has ended
- Send us by e-mail (yaknan.gambo@tum.de)
- No preferences submitted → we will match you

## Attend Course Kickoff

- At university if everything goes according to plan
- We hope to see you there :)



The screenshot shows the 'matching.in.tum.de' website. At the top, there's a navigation bar with 'FAQs', 'Yaknan John Gambo', and the TUM logo. A blue banner below the header states: 'Matching WS24/25 student voting period start July 12th 0:30 AM!'. The main heading is 'Matching platform'. Below it, there's a search bar and a table with columns for 'Title', 'Students', and 'Courses'. The table shows one entry: 'Practical-Course WS24/25' with 'Begin' and 'End' times for both students and courses. Below the table, it says '1 matching instance' and 'Showing 1 to 1 of 1 entries'. There are 'Previous', '1', and 'Next' buttons. The bottom of the page has a footer with 'g.in.tum.de', a feedback link, 'Impressum', 'Datenschutz', and 'Fakultät für Informatik, Technische Universität München'.





## Up Next: Introduction to Q-BEAST



# Q-BEAST: Experimental Evaluation and Characterization of Quantum Computing Systems

# Collaboration Among 3 Institutions



## **LMU** (Chair Prof. Kranzlmüller)

- Korbinian Staudacher
- Michelle To
- Florian Krötz

## **TUM** (Chair Prof. Schulz & Chair Prof. Mendl)

- Yaknan Gambo
- Burak Mete

## **LRZ**

- Minh Chung
- Amir Raoofy
- Xialong Deng

# Quantum Systems at LRZ



## Superconducting Technology

### System 1: 5 qubits (R&D system)

- + Vendor: IQM
- + Accessible: 2023

### System 2: 20 qubits (R&D system)

- + Vendor: IQM
- + Accessible: H1-2024 to select research partners

### System 3: 20 qubits

- + Vendor: IQM
- + Accessible: Late H1-2024 to Bavarian, German, and European users in the pilot phase initially, with wider access in 2024

**More info at** <https://www.quantum.lrz.de/>



src: <https://www.quantum.lrz.de/bits-of-qubits/detail/in-the-future-we-will-use-different-computing-methods-side-by-side>

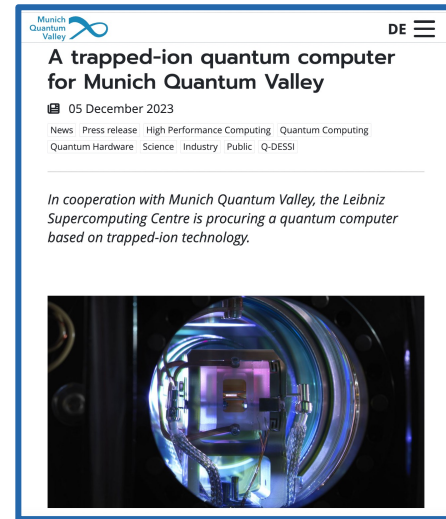


src: <https://www.quantum.lrz.de/bits-of-qubits/detail/germany-launches-its-first-hybrid-quantum-computer-at-leibniz-supercomputing-centre>

## Ion-trapped Technology

**System 1:** 20 qubits  
+ Target system for software development initially with Munich Quantum Valley  
+ Accessible: TBA

More info at <https://www.quantum.lrz.de/>



# Quantum Systems at LRZ



## Neutral Atom Technology

# Focus: Experimental Evaluation



We want you to learn and get experience in performance evaluation

- Between quantum simulators and realistic quantum machines
- On different quantum technologies

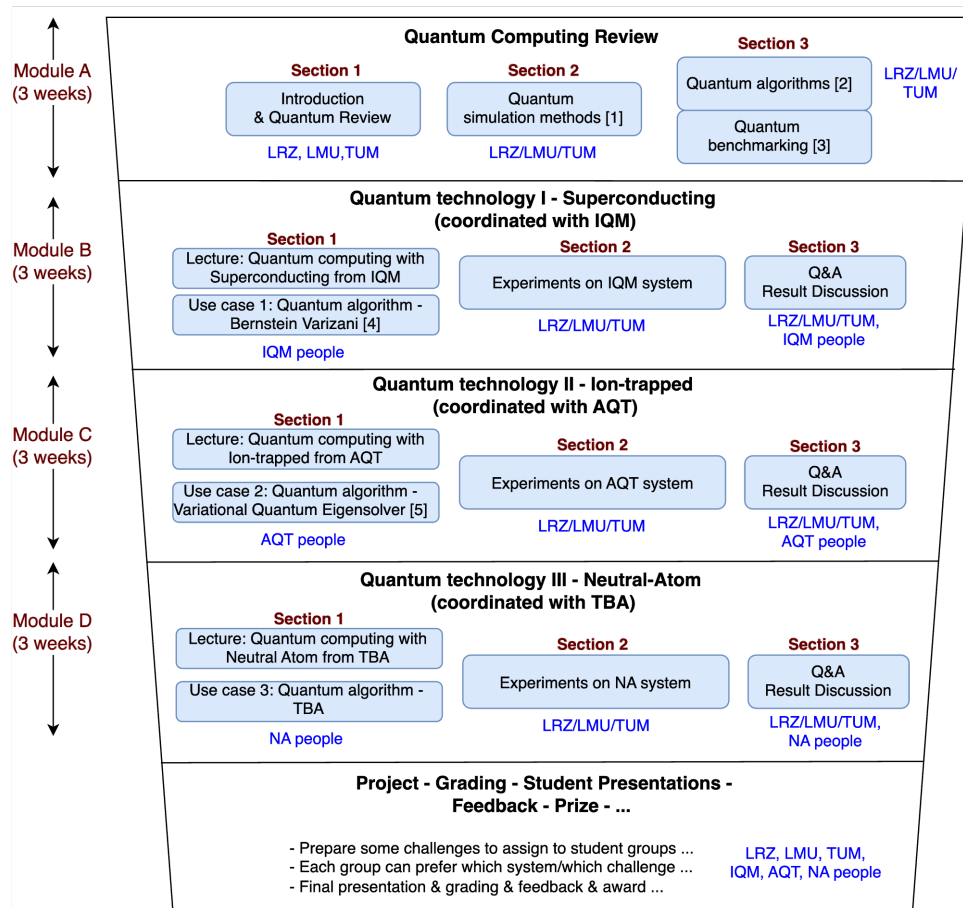
Part 1: get started with small given codes with

- Quizzes/tutorials during weekly meetings
- Assignment with experiments across systems
- Q&A → Discussion → QC experiments in practice

Part 2: working with the use cases from the vendors

Part 3: working with a realistic use-case or application

# Focus: Experimental Evaluation



[1] Kieran Young, Marcus Scese, Ali Ebneenasir. Simulating Quantum Computations on Classical Machines: A Survey, 2023, <https://arxiv.org/abs/2311.16505>.

[2] Montanaro, A. Quantum algorithms: an overview. npj Quantum Inf 2, 15023 (2016), <https://doi.org/10.1038/npjqi.2015.23>.

[3] Thomas Lubinski, Joshua J. Goings, Karl Mayer, others. Quantum Algorithm Exploration using Application-Oriented Performance Benchmarks, 2024, <https://arxiv.org/abs/2402.08985>.

[4] <https://www.iqmacademy.com/curriculum/algorithms04.html>

[5] <https://www.aqt.eu/molecule-simulation-on-a-quantum-computer/>



# Target Architectures for the Lab



- Classical computing nodes (BEAST system)
  - For running quantum simulators
  - For performance characterization
  
- Quantum computing systems
  - Superconducting (from IQM)
  - Ion-trapped (from AQT)
  - Neutral atom (from ...)

# Organization



- Work in student groups (expected to split up the work equally)
- Weekly meeting (Thursday, 16:00 – 18:00)
- Assignments
- Final project

# Prerequisites



- Basic knowledge of Quantum Computing
- Familiar with computer architecture & HPC
- Interested in QC & HPC
- Knowledge of Python, C++, Linux

# Leibniz-Rechenzentrum der Bayerischen Akademie der Wissenschaften

## Technical specification

PROCESSOR: 5 qubits	GUARANTEED	TYPICAL
Single-qubit gate fidelity	$\geq 99.7\%$	$\geq 99.9\%$
Two-qubit gate (CZ) fidelity	$\geq 96\%$	$\geq 98\%$
Single-qubit gate duration	$\leq 60\text{ns}$	$\leq 40\text{ ns}$
Two-qubit gate (CZ) duration	$\leq 100\text{ ns}$	$\leq 60\text{ ns}$
Readout fidelity *	$\geq 92\%$	$\geq 95\%$
Quantum volume*	$\geq 8$	$\geq 8$
Q-score*	$\geq 4$	$\geq 5$

\*with TWPA option ordered

<https://www.meetiqm.com/products/iqm-spark>



src: <https://www.quantum.lrz.de/bits-of-qubits/detail/in-the-future-we-will-use-different-computing-methods-side-by-side>

## What are the latest performance benchmarks of IQM hardware?

With our latest benchmarks measured on the 20-qubit quantum computer, we have demonstrated a median two-qubit (CZ) gate fidelity of 99.51% across 30 qubit pairs, with maximum fidelity over a single pair reaching as high as 99.8%.

Among the system-level benchmarks IQM obtained:

- Quantum Volume (QV) of  $2^5=32$
- Circuit Layer Operations Per Second (CLOPS) of 2600.
- 20-qubit GHZ state with fidelity greater than 0.5.
- Q-score of 11

<https://www.meetiqm.com/products/iqm-radiance>



src: <https://www.quantum.lrz.de/bits-of-qubits/detail/germany-launches-its-first-hybrid-quantum-computer-at-leibniz-supercomputing-centre>