DiNAQC
Digital Neutral Atom Quantum Computer

On the DLR QCI premises in Ulm, planqc is building a prototype of a digital quantum computer based on neutral strontium atoms. The DiNAQC project will be the quantum computer with the largest number of qubits within the DLR QCI.

- 100 physical qubits
- 2 logical qubits
- Demonstrator for future error-correction capabilities of planqc machines
- Project duration: September 2023 – March 2027 (42 months)

Project Aims

In the DiNAQC demonstrator, individual ultracold strontium atoms in optical traps are used as qubits. Each atom represents a qubit, which is controlled by additional laser beams. Entanglement between two qubits is generated by fast laser pulses that couple the qubits to highly excited Rydberg states. Neutral-atom quantum computers are particularly scalable because the atoms can be arranged in any two-dimensional configuration, and because each atom — and therefore each qubit — is identical to every other atom. The atoms do not require cryogenic cooling, as they can be cooled to microkelvin temperatures using lasers alone.

Challenges

Digital quantum computing with neutral atoms has only become conceivable in recent years, thanks to the development of increasingly powerful and high-quality laser technologies. The unique feature of DiNAQC is that planqc, as the first spin-off from Munich Quantum Valley, has chosen the bosonic isotope of the alkaline earth atom strontium as its quantum information carrier. This choice is expected to yield outstanding gate fidelities and coherence properties. Our approach enables rapid scaling to hundreds and, in the longer term, thousands of qubits.

Key Features

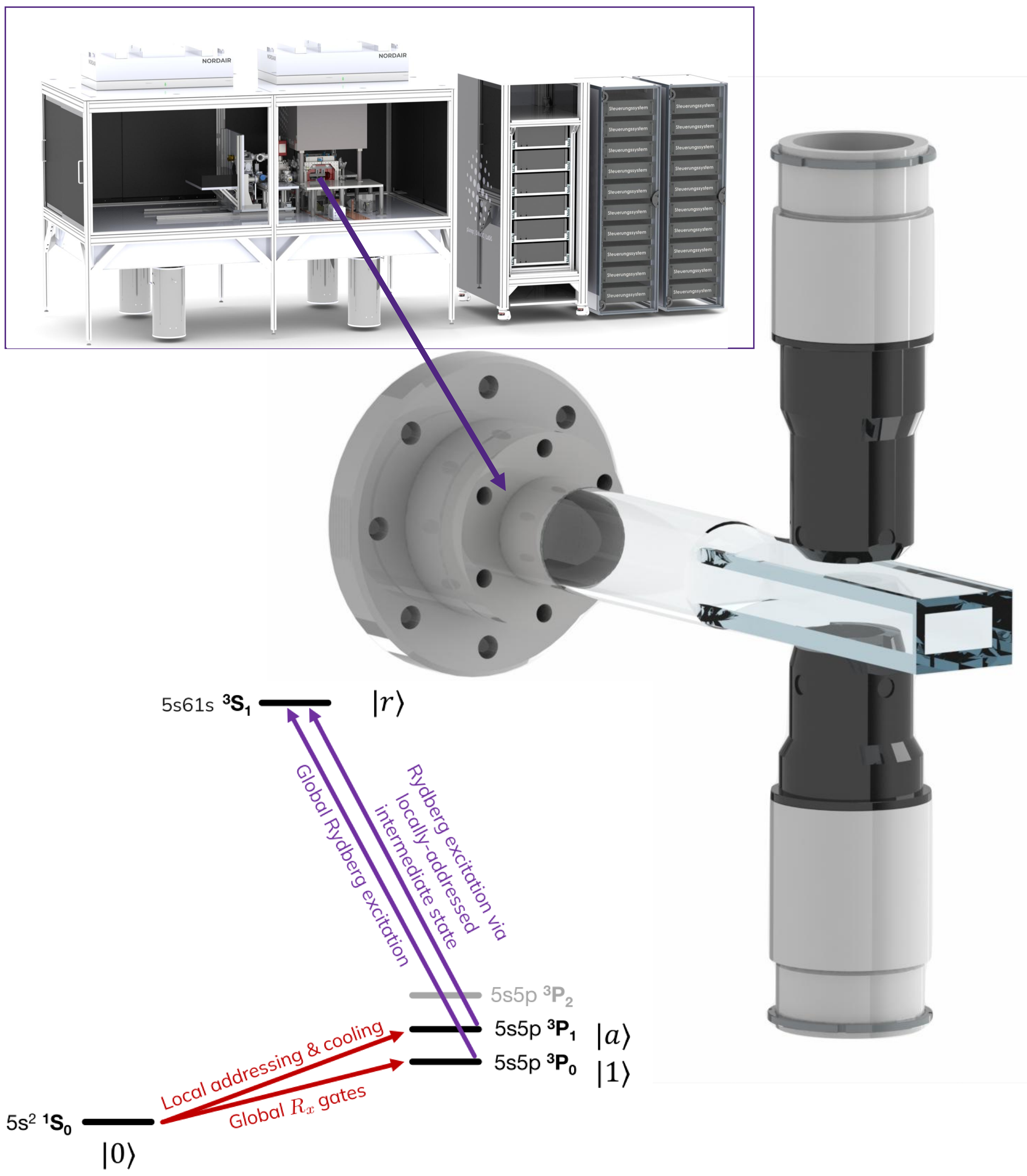
The DiNAQC project will have the following key features at the end its duration:

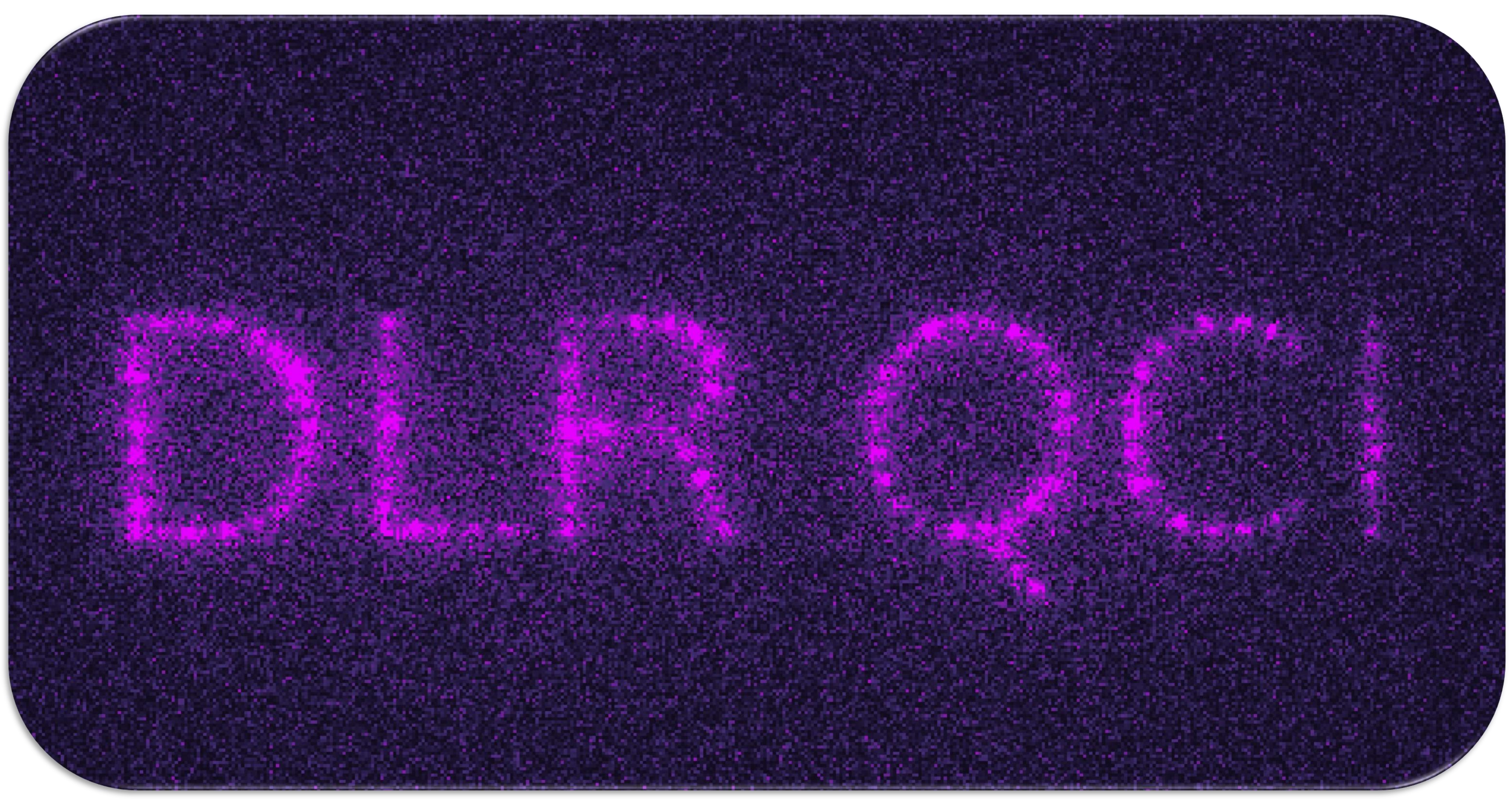
- 100 identical atomic qubits.
- Reconfigurable qubit register with nearest-neighbour interactions.
- Optically encoded qubits with long coherence times.
- Global single-qubit R_x rotations using the clock transition of ^{88}Sr under magic trapping conditions.
- Global UV-light Rydberg excitation for fast two-qubit gates at MHz rates.
- Target fidelities of 99.9% for single-qubit gates and 99.5% for two-qubit gates.
- Local addressing for fast single-qubit $R_z$rotations.
- Locally-addressed two-photon Rydberg gates via local addressing to an intermediate state.

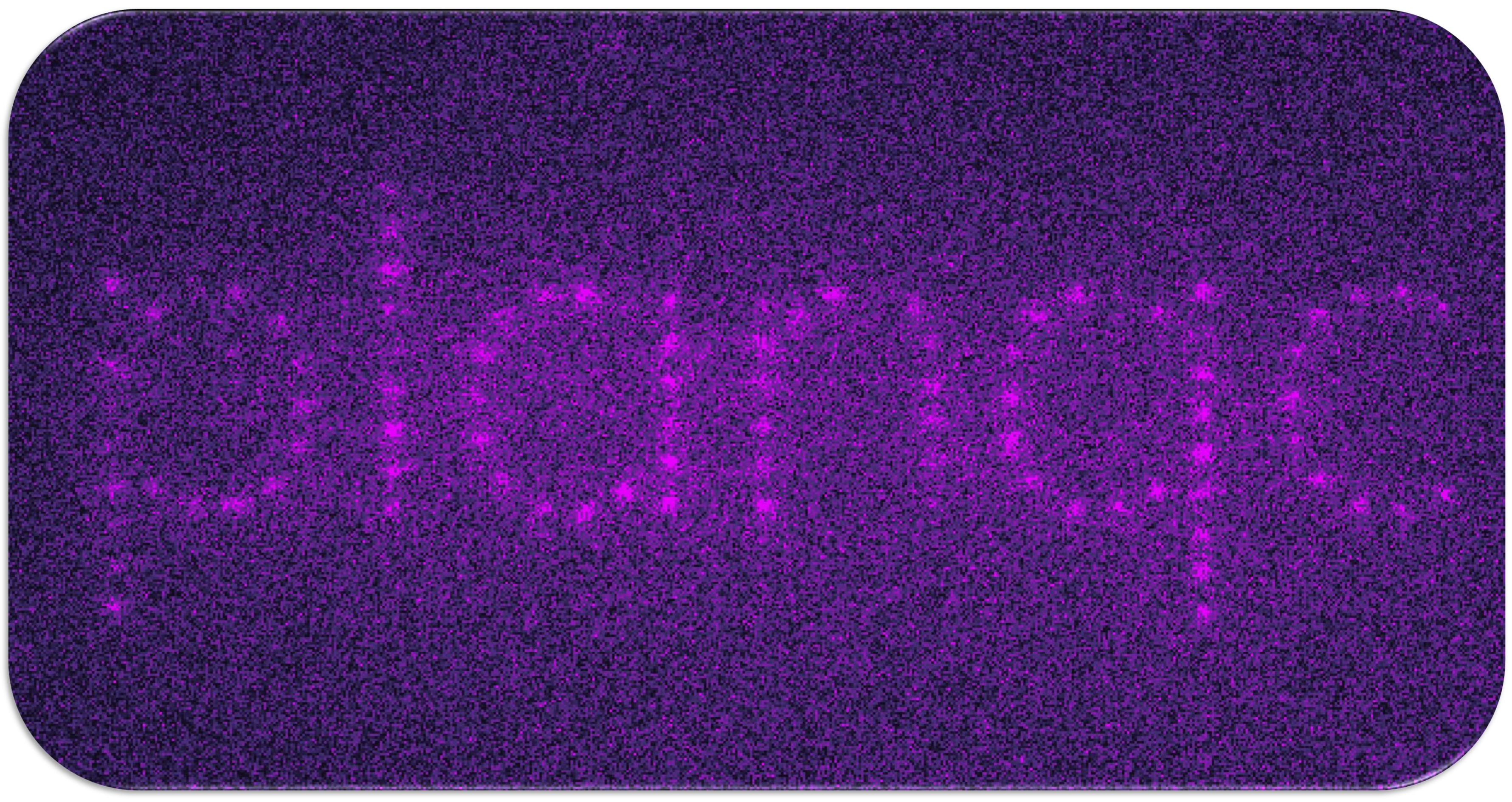
Outlook

The DiNAQC quantum computer is future-proof and extensible:

- The number of qubits could be increased to one thousand.
- Continuous atom reloading could be implemented to increase the repetition rate of the machine [1].
- Coherent atom transport between gate operations could be added to enable the implementation of more complex logical qubit operations [2].
- The project is compatible with an alternative qubit encoding architecture using fine-structure states [3].
- Support for analog quantum computation with Rydberg atoms can be added.







The two images above show fluorescence from optically trapped strontium atoms. Each atom can be used as a qubit, and all atoms are identical by nature. Hundreds of atoms can already be trapped in this way, and their positions in space are freely reconfigurable. This demonstrates some of the key strengths of neutral-atom quantum computing technology.

More information about the project on our website

References:
[1] **Gyger, F., Ammenwerth, M., Tao, R., Timme, H., Snigirev, S., Bloch, I., & Zeiher, J.** *Continuous operation of large-scale atom arrays in optical lattices* **Phys. Rev. Research, 6**(3), 033104 (2024).
[2] **Bluvstein, D., Evered, S.J., Geim, A.A. et al.** *Logical quantum processor based on reconfigurable atom arrays.* **Nature 626**, 58–65 (2024).
[3] Tao, R., Lib, O., Gyger, F., Timme, H., Ammenwerth, M., Bloch, I. & Zeiher, J. *Universal gates for a metastable qubit in strontium-88.* **arXiv:2506.10714** (2025).

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Project Partners
MenloSystems
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