Quantum Learning Machine

Atos

Get Ready for the Quantum Revolution

To tackle increasingly demanding industry challenges, we need to find alternatives to existing computing solutions. In this context, Quantum Computing is one of the most promising technologies.

Leveraging quantum properties

The first quantum revolution has took place at a microscopic level and brought some major innovations of the 20th century such as the transistor, the laser, superconducting devices and optical fibers. Many experts are convinced that the second quantum revolution, which will see quantum information emerging, is already upon us. A binary digit is always in one of two definite states (0 or 1) however quantum computing uses qubits which can be in a superposition of states (1 and 0 superposed), enabling massively parallel computation. This multiplies capacity, so that quantum computers with a modest number of qubits, as little as 60, could solve problems that today's most powerful supercomputers cannot address with years of computing time! Advances in quantum science are extensive and demonstrate the reality of the tremendous opportunities to accelerate calculations, which together allow quantum superposition and quantum entanglement.

Atos Quantum R&D Program

Atos Quantum' is the first quantum computing industry program in Europe. This global program aims to develop quantum computing solutions but also to learn how to enhance cyber security products to anticipate quantum advantage and its impact on cryptography.

Atos' ambition is to be a quantum player in three domains: quantum programming and simulation platforms and, later, next-generation quantum-powered supercomputers, as well as quantum-safe cybersecurity. It is piloted by a Scientific Council with world-renowned members. The 'Atos Quantum' Scientific Council is enriched with the immense knowledge and visionary power of its members, all highly renowned researchers. The Council is chaired by the Chairman and CEO of Atos and is made up of universally recognized quantum physicists and mathematicians.

The first products of the Atos Quantum Program have been the Atos Quantum Learning Machine - Atos' world-class quantum simulation appliance - and the Atos Quantum consulting practice.

Go beyond HPC

Quantum Computing is a new computing paradigm that will solve critical problems in all industries more efficiently than current high performance computing (HPC) systems.

Manufacturing

- Autonomus vehicle
- Logiastic
- Supply chain
- Software validation
- Batteries
- Polymer

Public Sector & Defence

- Neural networks
- Process optimization
- Cryptanalysis
- Material science
- Nanotechnologies

Financial Services & Insurance

- Fraud detection
- Trading strategies
- Market simulation
- Portfolio optimization
- Risk assessment
- Cryptocurrency

Telecom, Media & Technology

- Personalized content
- 5G antenna location
- Chip layout optimization
- Post-quantum cryptography

Resources & Services

- Smart grids
- Flight scheduling
- Oil well optimization
- Yeild management
- Cybersecurity
- Carbon dioxide capture

Healthcare & Life Sciences

- Genomics
- Virtual Screening
- Protein folding
- Drug discovery
- Personalized medicine

Atos QLM benefits

- Bootstrap in Quantum Computing
- Ease end-user quantum programming language, a set of provided Quantum Libraries and a Jupyter
- Notebook environment

- Program and execute hybrid quantum-classical algorithms
- Integrate with existing frameworks to leverage algorithms developed via other frameworks

- Support real noise simulation models on different hardware
- Simulate different technologies through its hardware agnostic environment with unprecedented performances.
- Explore both digital and analog quantum computing technological approaches

Develop quantum applications today

The Atos Quantum Learning Machine (Atos QLM) is a complete on-premise environment designed for quantum software developers. It is dedicated to the development of quantum software, training and experimentation.

Programming **Optimization** **Simulation**

The Atos Quantum Learning Machine provides 3 environments

It embeds a programming platform and a high-performance quantum simulator. Its capabilities and performances are unmatched on the market. The Atos Quantum Learning Machine allows researchers, engineers and students to develop and experiment with quantum software. Powered by a powerful dedicated hardware infrastructure, the Atos QLM will emulate execution as a genuine quantum computer would.

Software developed on the Atos QLM can run on simulated, as well as on future quantum accelerators, without changing a line. The Atos Quantum Learning Machine computes the exact execution of a quantum program, with double digit precision. It simulates the laws of physics, which are at the very heart of quantum computing.

This is very different from existing quantum processors, which suffer from quantum noise, quantum decoherence, and manufacturing biases, as well as performance bottlenecks. Simulation on the Atos Quantum Learning Machine enables developers to focus on their applications and algorithms, without having to wait for quantum machines to be available.

The Atos Quantum Learning Machine is a complete appliance

Thanks to the bespoke software and hardware developed by Atos, the Atos QLM has superior simulation capabilities, much more than any other affordable appliance. In its maximum configuration, it can simulate up to 41 Qbits, which was until now, only possible on large supercomputers, despite the fact that the Atos QLM has the physical dimensions of a simple business server.

The appliance is composed, non-exhaustively of:

- A specific hardware infrastructure, with large in-memory capacity and – available soon – a dedicated hardware accelerator
- An extensible quantum circuit model (data representation model)
- A universal quantum assembly programming language (AQASM, Atos Quantum Assembly Language)

- A high-level quantum hybrid language, built on top of the popular Python language
- A set of mathematic libraries and algorithms – ready to use

Thanks to Atos' large in-memory infrastructure, it is simple and seamless to upgrade the simulation capabilities from 30 to 41 qubits. Grow as your business needs it while leveraging existing investments.

The Atos Quantum Assembler (AQASM)

The Atos Quantum Assembler is an important component of the Atos QLM appliance. AQASM is designed in the Atos R&D labs. AQASM is Atos' implementation of the universal quantum software development language: QASM. Programs using AQASM can be used on the quantum simulator today, as well as on the physical quantum computers of tomorrow. AQASM is configurable; it has the ability to program new quantum gates or to mix existing gates. AQASM offers high-level wrappers for developers and accepts quantum programs from other frameworks thanks to a versatile software development kit.
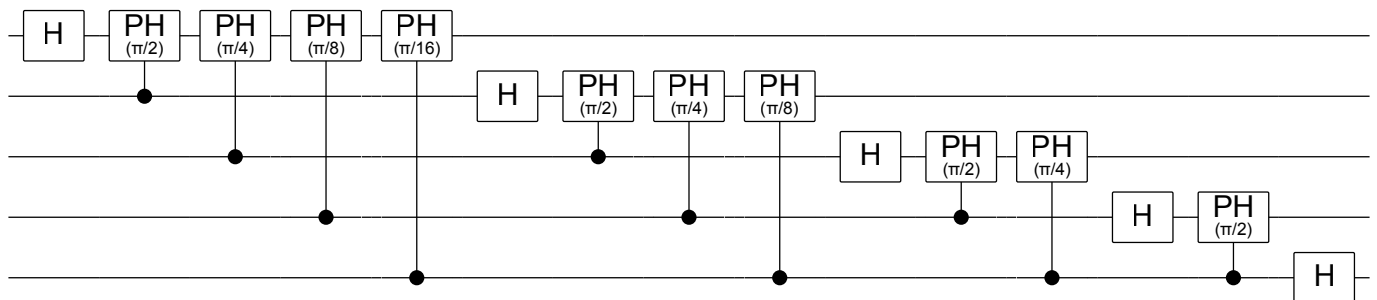
Atos Quantum Learning Machine functional scope

Programming

AQASM
Assembly language to build quantum circuits

pyAQASM
Python extension to AQASM

CIRC
Binary format of quantum circuits

QLIB
Quantum arithmetic libraries

Quantum algorithms
Variational Algorithms,, such as QAOA and VQE

QPU

QPU
Quantum processing unit emulation

Optimization

Gate set rewriter
Abstract gates

Plugins
Expressive and concise programming

Circuit optimizers
Generic circuit optimizer
Topology constraint solver

Simulation

Simulators
Different simulation modules for Circuit models
Simulated Quantum Annealing

Physics
Physical noise models
Gateset tomography

Quantum Noise Simulation

The simulation of physics includes different models for quantum noise. Should the underlying technology be trapped ions, superconducting circuits or semiconducting silicon, the noise models can be chosen and used to be as close as possible to reality.
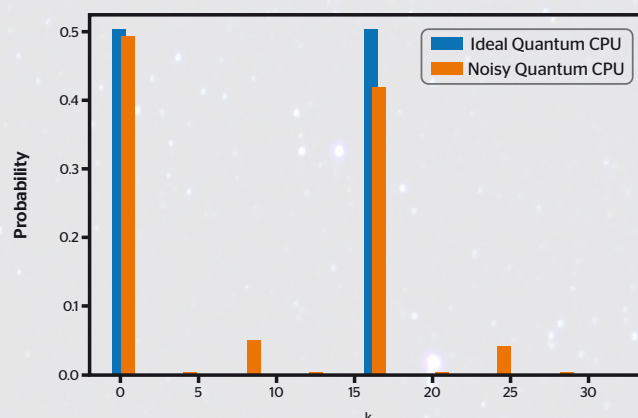
A broad range of services based on the Atos QLM

1	Quantum Computing Basis	Beginner ½ day	A comprehensive approach to quantum computing
2	Atos QLM Fast Start	Intermediate 2 days	Quick knowledge ramp-up on the Atos QLM appliance
3	Decoding of quantum algorithm	Advanced 2 days	Principles and building steps of a specific quantum algorithm
4	Proof of Concept	Business + experts 5 days → 8 months	Study the feasibility of quantum implementation relative to the customer's use cases

Join the Quantum revolution with Atos experts

Atos provides a broad range of services based on the Atos QLM. Our mission, with our Quantum experts, is to accompany you in every aspects.

From the discovery of the Atos QLM appliance, to the development and simulation of your first Quantum codes, our experts' outstanding teaching skills and the QLM intuitive programming environment gives you the knowledges to join the Quantum revolution

Atos QLM E – accelerating research in the NISQ era

NISQ – Noisy Intermediate-Scale Quantum – devices will be the first quantum accelerators to be commercialized in the next few years. Herein lies a double challenge for the industry: developing NISQ algorithms is as important as building the machines, since both are required to identify concrete applications. Atos QLM E has been optimized to drastically reduce the compilation time of hybrid quantum-classical algorithms simulations, leading to quicker advancement in application research.

Get your quantum simulations results up to 12x faster	Optimized for variational algorithms best suited for the NISQ era (up to 30 qubits)	Upgrade your QLM to a QLM E very easily to benefit from these enhanced features

Accelerate research on variational algorithms using Atos QLM E

Quantum Approximate Optimization Algorithm

Variational Quantum Eigensolver

Variational Quantum Factoring

Variational Quantum Classifier

…among other application fields!

Explore both analog and digital quantum simulation paths to solve optimization use cases using the Atos QLM

NP-hard optimization problems have critical applications in all industries, such as portfolio management, logistics, antenna location, chip design or clinical trial database search. Classical tools like solvers and heuristics provide either exact solutions for a small number of variables or approximate ones for larger problems, but their use is problem-dependent, and they do not all have provable behaviors.

In this field, quantum computing holds major promises:

- Address larger problems
- Improve accuracy level
- Reduce time to solution
- And thus, reduce energy consumption

Using the Atos QLM, you can explore now two quantum-related technological paths to solve such problems in the future:

Key benefits of using both approaches in the Atos QLM

- Better understand the specificities of digital and analog quantum computing
- Compare the benefits and constraints of two quantum computing technological paths applied to combinatorial optimization problems
- Prepare code to then run on NISQ accelerators or Quantum Annealing machines using the same programming environment

Describe your use case as a high-level NP-hard problem

- Max cut
- Graph partitioning
- Graph colouring
- K-Clique
- Vertex Cover
- Number Partitioning
- Binary Integer Linear Programming

Encode it in a mathematical formulation

- QUBO (Quadratic Unconstrained Binary Oprimization) formulation
- Ising model

Simulate it

- Digital Quantum Computing: Variational Algorithms such as QAOA (Quantum Approximate Optimization Algorithm)
- Analog Quantum Computing: SQA (Simulated Quantum Annealing) or SBA (Simulated Bifurcation Algorithm)

myQLM

Explore the capabilities of quantum programming on your laptop using the world's most powerful quantum simulator's programming framework.

Start building quantum programs on your laptop with myQLM

myQLM is a python package that is provided with open source interoperability connectors with frameworks such as Qiskit, Cirq, ProjectQ or Forest™.It was designed to democratize quantum computing by allowing researchers, students and developers to create and simulate quantum circuits on their laptops.

It is fully compatible with the Atos Quantum Learning Machine: users will be able to launch their myQLM programs on their organization's Atos QLM to benefit from larger simulation capabilities and advanced features like quantum circuit optimizers and noisy simulators.

Expand your quantum programming community with myQLM

- myQLM is the best framework to help students, scientists and developers get acquainted with quantum computing and quantum programming.
- It's a tool to brainstorm, test and share ideas without being bothered by quantum noise.
- Users will have access to a broad user community as Atos also provides open source translators from myQLM to other main quantum programming environments.
- Everyone's myQLM ideas can be shared via a community GitHub repository.
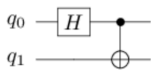- All research done using myQLM will remain the property of the entity who produced it.

Join the myQLM community

To download myQLM and stay informed on the latest developments of our community, please visit: www.atos.net/myqlm
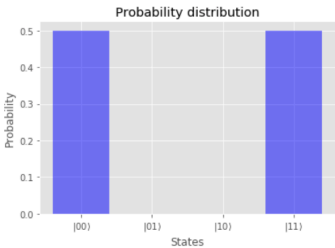
Start building quantum programs on your laptop with myQLM

```
from qat.lang.AQASM import Program, H,
CNOT
#Create a program
qprog = Program()
#Number of qubits
nbqubits = 2
#Allocate some qubits
qubits = qprog.qalloc(nbqubits)
#Apply some quantum gates
qprog.apply(H, qubits[0])
qprog.apply(CNOT, qubits[0], qubits[1])
#Export this program into a quantum circuit
circuit = qprog.to_circ()
#And display it!
%qatdisplay circuit
```

1
Write

2
Visualize

3
Simulate

Inspired by the Atos Quantum Learning Machine

Programming

| AQASM |
| Assembly language to build quantum circuits |

| INTEROP |
| Connectors' source codes: build your own! |

Open Source

| CIRC |
| Binary format of quantum circuits |

| QLIB |
| Quantum arithmetic libraries |

| pyAQASM |
| Python extension to AQASM |

| Quantum algorithms |
| Variational Algorithms, such as QAOA and VQE |

Optimization

| SIMULATOR pyLinalg |
| Source code of this simulator: build your own! |

Open Source

Discover Atos' broad quantum simulation ecosystem

Features	myQLM freeware	Atos QLM appliance	Atos QLM E appliance
Programming			
pyAQASM/AQASM/CIRC formats	✓	✓	✓
Custom gates	✓	✓	✓
QLIB libraries	✓	✓	✓
Interoperability kit – open source translators	✓	✓	✓
Pre-/Post-Processing			
Custom plugins	✓	✓	✓
Gate set rewriter	✗	✓	✓
Topology constraints solver	✗	✓	✓
Circuit Optimizer	✗	✓	✓
Digital QC Simulation			
Simulation capabilities	Up to 20 qubits	Up to 41 qubits	Up to 41 qubits
Simulation performances	★	★★★	★★★★
PyLinalg – open source noiseless simulator	✓	✗	✗
Advanced noiseless simulators • Linalg • Feynman • Stabilizers (stabs) • Matrix Product State (mps) • Binary Decision Diagram (bdd)	✗	✓	✓
Noisy simulators • Deterministic • Stochastic	✗	✓	✓
Acceleration up to 12x – best suited for variational algorithms	✗	✗	✓
QLM for Combinatorial Optimization			
• Simulated Quantum Annealing • [SOON] Simulated Bifurcation Algorithm	✗	✓	• (default) up to 500 variables • (optional) up to 2,000 variables • (optional) up to 5,000 variables
• [SOON] Acceleration for Simulated Bifurcation Algorithm	✗	✗	✓
Services			
Training	Self training	Instructor-led training	Instructor-led training
Support	Community	Subscription	Subscription
Consulting	On demand	On demand	On demand

About Atos

Atos is a global leader in digital transformation with 110,000 employees in 73 countries and annual revenue of € 12 billion. European number one in Cloud, Cybersecurity and High-Performance Computing, the Group provides end-to-end Orchestrated Hybrid Cloud, Big Data, Business Applications and Digital Workplace solutions. The Group is the Worldwide Information Technology Partner for the Olympic & Paralympic Games and operates under the brands Atos, Atos|Syntel, and Unify. Atos is a SE (Societas Europaea), listed on the CAC40 Paris stock index.

The purpose of Atos is to help design the future of the information space. Its expertise and services support the development of knowledge, education and research in a multicultural approach and contribute to the development of scientific and technological excellence. Across the world, the Group enables its customers and employees, and members of societies at large to live, work and develop sustainably, in a safe and secure information space.

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Let's start a discussion together