My first peer-reviewed paper on quantum computing

Since 2018, I have been exploring quantum technologies and quantum computing as a newbie. It started with a conference (with Fanny Bouton), then 18 posts on this blog, then a book in French, which turned into a **1132 pages book in English**. Plus **two series of podcasts** again with Fanny Bouton, teaching on quantum technologies and computing in various places and cofounding the **Quantum Energy Initiative** with Alexia Auffèves, Robert Whitney and Janine Splettstoesser. What a journey!

I also started to publish preprints on arXiv, like **Mitigating the quantum hype** (January 2022, 26 pages) and **Is there a Moore's law for quantum computing?** (March 2023). Plus an upcoming one titled "Where are we heading with NISQ?" (I'm still looking for reviewers for this rather long 47 pages piece).

Last but not the least, I was asked during summer 2022 by Thomas Ayral (Atos/Eviden) and Thomas Duguet (CEA) to contribute to a special edition of the **European Physical Journal A** with a perspective paper on superconducting qubits. After a long ride, "Perspective on superconducting qubit quantum computing" was recently published and you can access the **PDF file online**.

It is part of the "**Quantum Computing in Low-Energy Nuclear Theory**" section, coordinated by Thomas Ayral, Thomas Duguet, Denis Lacroix and Vittorio Somà.

It happens to be a premiere as I am concerned since this is the first of my papers being published in a peer-reviewed journal. This was quite an experience for me, like the one any young PhD candidate is going through when publishing his/her first papers. But with a key difference: I didn't do some actual research and didn't have a PhD thesis supervisor. I also had to learn using LaTeX for the first time and going through the submission, reviewing, updating and final editing process for the paper.

I will share more details on this experience in the next version of my book Understanding Quantum Technologies, to be published before the end of 2023.

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Review

Perspective on superconducting qubit quantum computing

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Abstract This perspective describes the history, scientific and technology developments of superconducting qubit-based quantum computers, which are currently dominant, particularly with industry vendors. Adopting an engineering viewpoint, it showcases the great diversity of technology options, explains how superconducting qubit chipsets are manufactured, describes some challenges with how qubits are driven by classical electronics, how to improve their fidelities and how their energetic footprint can be optimized. We also briefly describe the current status of so-called NISQ (noisy intermediate scale quantum) computers and the resource estimations to run their potential use cases, particularly for running quantum many-body physics simulations.

1 Introduction

Superconducting qubits are currently the leading technology in the quantum computing commercial space, being exploited or chosen by IBM, Google, Rigetti, Amazon, Alibaba, Baidu as well as many startups such as IQM (Finland), OQC (UK), Anyon Systems (Canada), Alice&Bob (France), Nord Quantique (Canada) and others. It is the currently best scalable architecture in the gate-based model, with a record of 433 qubits with IBM and 121 qubits in China as of January 2023 [1, 2], although, so far, the quality of these qubits is still insufficient for these being useful on a practical basis.

The Josephson junction used in these qubits is a thin nanometric insulating barrier between two superconducting metals, creating a tunnel junction. It creates a quantum electrical component with a single degree of freedom, the superconducting phase difference between its electrodes, conjugated to the number of Cooper pairs passed through the junction. The supercurrent through the junction (direct current Josephson effect) is driven by the phase difference. From the electrical point of view, a Josephson junction behaves as a non dissipative and non-linear inductance whose value depends on the phase, and thus on the current. Superconducting qubits have the particularity of being the only mainstream ones that are macroscopic, in the sense that they are not linked to the control of a single particles such as individual atoms, electrons or photons, as in most other qubit technologies.

At superconducting temperature well below the superconductivity critical temperature, Josephson junctions embedded in an electrical circuit behave as an artificial atom, with gate and/or flux controlled quantum levels and about 10^{11} electrons (100 billion) of electron Cooper pairs.

They form an artificial atom with precisely controllable energy levels according to their parameters comprising a Josephson barrier, some capacitances and inductances connected in series and/or in parallel and some readout circuits using a nearby resonator. This artificial atom property was first demonstrated in 1985 [3].

Superconducting qubits use non dissipative elements: capacitors, inductors and the Josephson junction which act as a nonlinear non-dissipative inductor. Capacitors store energy in the electric field while inductors store energy in the magnetic field. But at any non-zero frequency, superconductors still dissipate some power, through two channels: the transport by the Cooper pairs and by normal charge carriers (quasi-particles), that is proportional to the quasi-particle density, which diminishes exponentially at low temperatures.

In this paper that is based on the open sourced book "Understanding Quantum Technologies 2022", we assume the reader is already familiar with what is a gate-based quantum computer, how qubits operate from a mathematical standpoint and have some knowledge of quantum physics and classical electronics engineering [4].

Olivier Ezratty is a cofounder of the Quantum Energy Initiative.

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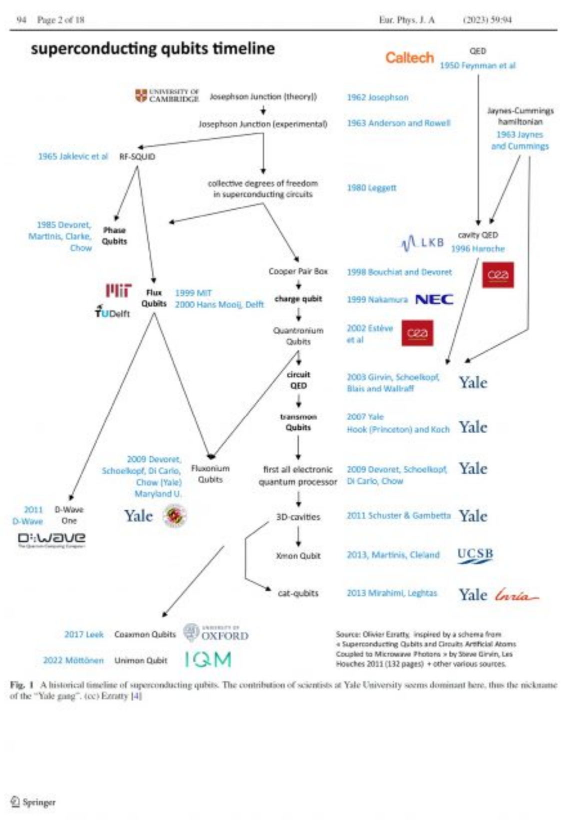

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Fig. 1 A historical timeline of superconducting qubits. The contribution of scientists at Yale University seems dominant here, thus the nickname of the "Yale gang". (cc) Ezratty [4]

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I wouldn't have done all of that without the help and kindness from the many quantum physicists and other specialists I have met these last 5 years. You know who you are! Thank you all!

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