



Understanding Quantum Technologies 2025

I am happy and relieved to release **Understanding Quantum technologies 2025**. It is the 8th edition of this book and the fifth in English. For the first time, I reduced its size, from 1,554 to 1,522 pages, while increasing its content size. I'll explain why and how later. It is always organized in five parts for e-readers but the most commonly used version is the single free-to-download PDF file containing all parts.

This post describes the book organization, how to download it, including the short format version of 36 pages, its new content and its uniqueness. It explains how it was created and updated including my migration to LaTeX and adds some fun facts. At last, I acknowledge the folks who helped me improve it. I really encourage you to be outspoken with me and help me improve the book content. I correct mistakes as readers help me discover them!

In a nutshell for those who are impatient:

- Like the new iPhone, it's the **greatest version ever** of this book! All its content was updated and extended, whether on the science, technology, vendor and ecosystems dimensions.
- It adopts a **new format and presentation** thanks to a (tedious) migration from Word to LaTeX in the editing of the book. It's not just a matter of switching tool, but also, adopting a writing style and presentation that are more commonplace in scientific publications. It's got the largest bibliography ever for a book on quantum science and technologies, with about 9,175 entries. I will publish soon a paper describing the technical details of this migration and how I manage such a large document.
- It provides **multiple angles** to look at quantum science and technologies. It fits the needs of quantum physicists, quantum software developers, and various "decision" makers (in some parts). It is both about the science and the engineering of quantum technologies. It explains things you won't find (easily) elsewhere like how cryogenics and other enabling technologies work, how to analyze quantum computing case studies across multiple vertical markets, the energetics of quantum computers, what materials are used, quantum geopolitics and the entrepreneurial scene, and so on.
- It is **free like beer**, and you are not the product. It promotes the dissemination of science and knowledge to the many folks who want to learn this broad field. It creates vocations and passion. It drives curiosity.
- I **update it every** year, until I stop. Like veggies and fish in your nearby market, it is a fresh product. It is important as the quantum science and technology space is changing rapidly. The book plays a key role in science intermediation, and also creates bridges between the classical and quantum computing worlds.

Now, let's look at the details...

Book organization

Like in last year's 2024 edition, this 2025 revision is structured as follows:

Part 1 **“Prologue”** (360 pages) starts with the history of quantum physics highlighting the key contributors of this field and quantum physics 101 (quantization, superposition, entanglement and the likes). It then digs into quantum computing with starting with describing how gate-based quantum computing operates (linear algebra, qubits, gates, measurement), and then quantum computing engineering which includes quantum computer systems architecture, quantum error handling, quantum memory, quantum energetics, a new scientific part on a rarely discussed topic, the Lieb-Robinson limit, how to deal with uncertainty and economics.

Part 2 **“Computing hardware”** (452 pages) contains a description of all qubit types with their science, engineering and vendors offerings and roadmap, then quantum enabling technologies, and at last unconventional computing, which may compete with both classical computing and quantum computing. It is probably the most detailed place describing what industry vendors are doing.

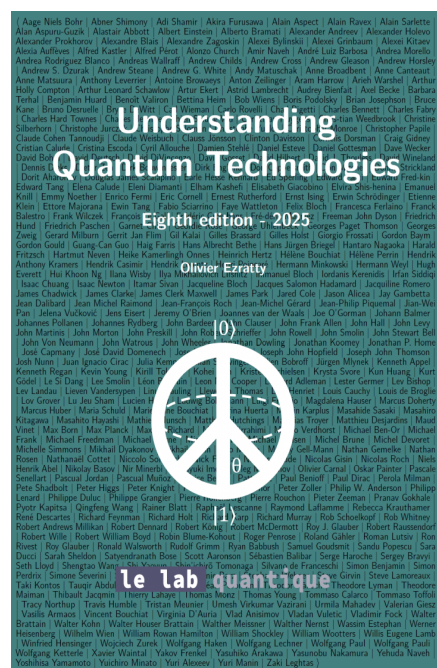
Part 3 **“Computing software”** (346 pages) covers quantum algorithms, software tools, use cases and case studies across about 20 different markets (chemical engineering, life sciences, transportation, financial services, etc.).

Part 4 **“Communications and sensing”** (176 pages) contains the parts related to quantum communications, quantum cryptography, quantum post-quantum cryptography and quantum sensing.

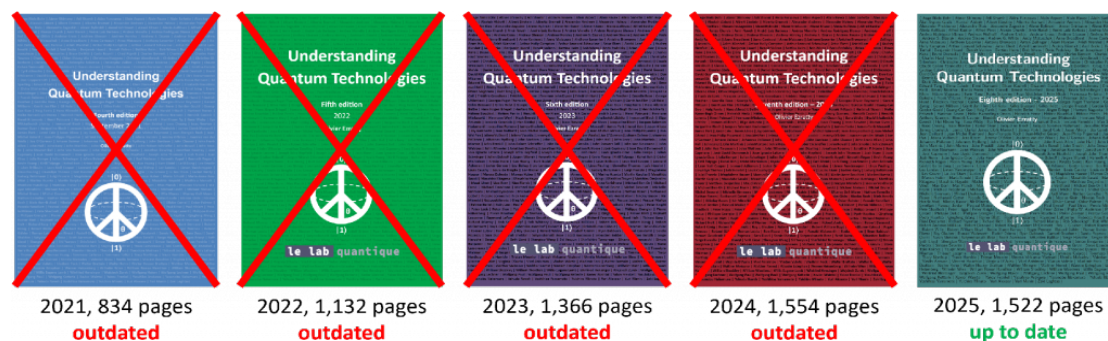
Part 5 **“Ecosystem”** (208 pages) describes quantum ecosystems throughout the world from the entrepreneurial to the country scene, corporate adoption, quantum technologies and society, and quantum fake sciences, plus a glossary, and index. I even added a timeline of key technology and ecosystem advances year by year since 2018, the year I started to publish this book.

Getting the book

This book is directly downloadable as a PDF file with no required personal data, with an optional lighter version for a readers like Amazon Kindle split in 5 files. A paperback printed version will also be available in November 2025.



I continue to use a color code to help you remember which edition we are talking about. The previous editions were in red (2024), purple (2023), green (2022) and blue (2021) and are all outdated.



Here are the various PDF versions available for download. You'll be better off downloading the relevant files just before your start reading it since I continuously update the document until January 2026.

This book current version is **8.3**, updated on **February 12th, 2026** (the updates log is at the end of the single book file or at the end of part 5). Version 8.1 is also **published on arXiv** and is **available on Amazon** for printed versions.

Downloads are available with either a single PDF file containing the full book with images in full resolution (1,522 pages, 530Mb) or split in five parts smaller than 32 MB with images in low resolution, all in A4 or LETTER format (at the exception of part 2 which is 43 MB large).

The page numbers of A4 and Letter format files are consistent from part to part, but not from single part 2-to-5 and the single file versions. For example, page N in Letter Part 3 matches page N in the A4 Part 3. But the page numbers are not the same between the full book PDF version and the five parts versions.

A4 format full book

Part 1: prologue

Part 2: computing hardware

Part 3: computing software

Part 4: communications and sensing

Part 5: ecosystem

USA/CANADA LETTER PAPER SIZE

Letter format full book

Part 1: prologue

Part 2: computing hardware

Part 3: computing software

Part 4: communications and sensing

Part 5: ecosystem

I also updated the short version of the book which is only 36 pages long (images in best resolution, 8 Mb). It is

an illustrated compilation of the “key takeaways” from the end of each book’s parts.

Book short version A4

Book short version Letter

New features

Like all previous editions, this 8th edition is an update. Most of the book content has been corrected and updated. Here are its key evolutions and new features given the entire updates log is at the end of the book:

History: added JJ Thomson, Klaus von Klitzing and Ronald Hanson in the hall of fame. Updated content related to Planck constants. Explained why 2025 was the 100th anniversary of quantum mechanics. Added more practical content on LaTeX and on paper mills in “research for dummies”.

Quantum 101: inventory of quantum numbers used in elementary particles, explained the difference between an electromagnetic wave, and a wave like in the Schrödinger wave equation. Added more content on entanglement, loophole free experiments, GHZ, W states and Dicke states, energy-time and time-bin entanglement, quantum steering, Bell tests on high-energy physics particles. Added a small subsection on the role of symmetries in quantum physics. Explained the difference between a wave and a field. Added Constructor Theory, Local Friendliness no-go theorem, the BHSI, RQD, Algorithmic Idealism and Topos Quantum Theory interpretations, and retrodiction in quantum foundations. More on realism.

Gate based: added matchgates and fermionic SWAP gate in gate types. More details on exotic quantum computing paradigms.

Quantum engineering: differentiating errors, noise and decoherence. Explaining how a magic state is consumed to implement a T gate on a target qubit. Added explanations on error syndrome decoding on entanglement purification. Added some background on the parallel between classical memory hierarchy and quantum memory. Reorganized the part on quantum energetics. Best practices in quantum computing energetic estimations. Added data on supercomputers energy consumption. Added a new subsection on the Lieb-Robinson bounds.

Restructured and improved the part on quantum uncertainty (optimism vs pessimism).

Added a Sankey chart with deployed QPUs worldwide per vendor country origin and destination.

Quantum hardware: lots of updates on D-Wave. Updates and cleanup of China’s superconducting qubit efforts. Added a description of the Niemeyer–Dolan bridge used in manufacturing Josephson junctions. Significant updates on IBM and Google. Added Anyon Technologies, QuamCore and Qaraka Quantum in superconducting qubit vendors. Significant update in IonQ’s and Quantinuum. Added Logiqal in the cold atom vendors. Two tables summarizing the key technology differences between trapped-ions QPU vendors.

Quantum enabling technologies: many new vendors added. Added a chapter on PDK in manufacturing.

Unconventional computing: added Linque and Q.ANT in photonic computing vendors and Snowcap Compute in superconducting computing vendors.

Quantum algorithms: frame explaining how you create or use algorithms. Added quantum state transfer in basic quantum algorithms. Added a description of Hamiltonian encoding. Added the QITE and Decoded Quantum Interferometry algorithms. Added Digitized Counter-Diabatic Quantum Optimization in NISQ algorithms. Added LIN and PQP in the complexity classes. Updates and corrections about the QFT and its speedup. Defined the orthogonality catastrophe with QPE. More stuff on quantum machine learning and AI challenges. Added definitions for Krylov and Komolgorov complexities.

Software tools: added QLOPS in benchmark types. Added Phase2, Q-Gear, QEA and Qimax in quantum emulators. Added China's cloud offering from China Telecom and China Mobile in the quantum cloud section.

Applications: added semantic definitions of case studies, use cases, proof of concepts and benchmark studies. Added a cheat sheet to avoid being cheated by case studies and use cases. Added a part on civil engineering case studies. Added protein dynamics computation in life science. Added many software, tools and service vendors.

Quantum communications and cryptography: added many vendors. Scientific updates everywhere.

Quantum sensing: a frame explaining how we measure the electric and magnetic fields of photons. Added a subsection on dark matter quantum sensors. Added many vendors.

World: updates many charts on startup numbers and funding. Added one chart on the best funded startups across the top 6 countries (USA, Canada, UK, France, Finland, Israel). Many updates on most countries. Added Slovakia and Malaysia in countries overview.

Corporate adoption: added some stuff and a book reading frame.

Quantum fake sciences: added a couple of new fake quantum science scams, like in the production of free energy.

Resources: added a table summarizing the key quantum computing advances per year since 2018. In the 8.1 Arxiv edition, I added a 7-pages part describing the "making of" of this LaTeX edition.

Glossary: added AOD, Approximate Amplitude Encoding, Artificial atoms, ASIC, AWG, Bloch state, cryo-CMOS, Dicke state, Heisenberg cut, HEMT, Intersubjectivity, Loophole, PDK, phase classification, phase space, SFQ, Shortcuts to Adiabaticity, SLM, Squeezing, Superradiance, Superselection and Zoo.

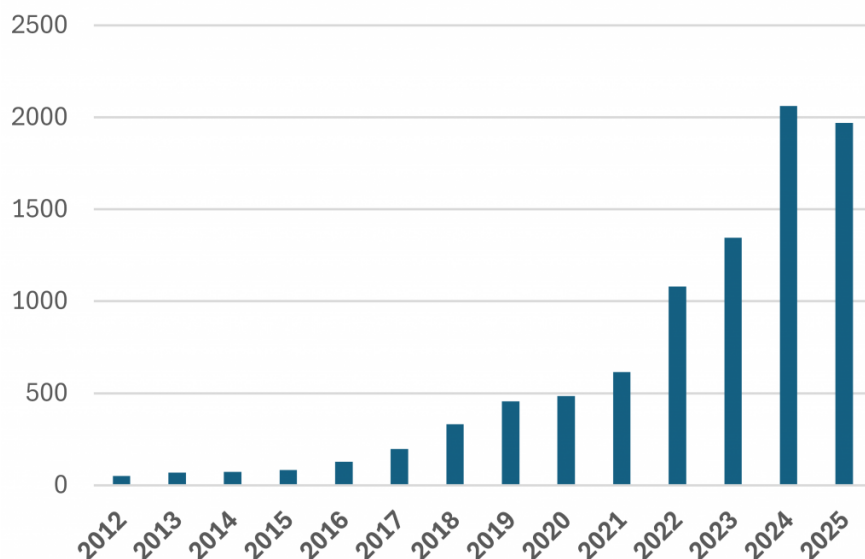
Removed the index. It reached the limits of my LaTeX configuration when I tried to create it for the whole book. I'll find out later whether there is a solution.

Facts and figures

Here are some statistics on the book content:

- >1,250 **annotated figures** and custom schematics.
- >9,450 **bibliographical references** including about 2,000 published in 2025, and the year has not ended yet!

Bibliographical references by year of publication



- A **500 terms** glossary.
- Each part ends with a summary of about **7 key takeaways**.
- It took me **5 months** to produce this update, from May to September 2025, including two months to migrate from Word to LaTeX while updating the content in parallel (yes, that's possible...).

Audience

This ebook target audience is broad but rather technical. Some parts are accessible to non-scientific readers, particularly the geopolitics and societal parts at its end. Other parts require some scientific background at the licence or master level. Reading the many referenced scientific papers requires at least a master level, if not a PhD level in the related domains.

The first target audience are computer science and information technology specialists, and software developers who want to understand the whereabouts of quantum computing hardware, software and use cases. It is also made for students and professionals who are attracted by quantum technologies and would like to develop some skills in this emerging domain. Many quantum startups ask their new hires to learn their field with this book!

It is also interesting for most quantum scientists, engineers and entrepreneurs since most of them are specialized in a narrow field while this book provides an up-to-date 360° view on all quantum technologies. Covering all of this is nearly a full-time-job and most quantum physics or technology specialist don't have the time to follow the related continuous scientific news cycle.

I recommend to use tools like Google Notebook LM to interrogate the book as I explained in this **post in 2024** for the 7th edition of the book.

Business model

It has not changed since the last edition. I favor distribution over revenue. I am an advocate of open science. I benefited from it when looking for scientific data when learning quantum science and technologies. Otherwise, I sell my time in a traditional and non-scaleable way with speaking, teaching, training and various consulting missions. I even do some research in quantum foundations, and as part of my work as a cofounder of the Quantum Energy initiative. Another way to describe my business model is I give away the long version and sell

the short one. Since with businesses, time is money and students have time but no money, all things go round. This is particularly true with quantum technologies which “*nobody understands*”.

But the real business model is “emotional”. Having a worldwide impact on students and other people who want to learn anything about quantum science, technology and its ecosystem, is the best reward for a content producer! Thus the importance of getting some feedback, particularly to improve the book on an ongoing basis.

Reviewers

This book and its previous editions benefited from the help of several scientists and entrepreneurs who proofread the document, mostly on specific parts. As the book size grows, it is a huge challenge to get some time from scientists to review such a book. They are short on time!

Specific help for crafting this 8th edition came from **Lucas Leclerc** (Lieb-Robinson), **Stefan Bogdanovic** (case studies evaluation), **Raphael Lescanne** (cat-qubits), **Olivier Hess** (Eviden), **Tom Darras**, **Mathys Rennela** and **Kenzo Bounegta** (Welinq), **Pierre Desjardins**, **Lydia Baril** and **Evan Tanner** (C12), **Jonatan Wicht** (satellite optics), **Alexandre May** (single microwave photon detectors), **Jean-Philippe Nominé** (various parts), **Elisabeth Eude** (economics), and **Fanny Bouton** (cloud).

And a special thank to **Vincent Pinte-Deregnacourt** who pushed me hard to migrate to LaTeX and helped me along the way, **Michel Kurek** who carefully reviewed several times the whole book as with many previous editions and even developed some Python script to detect dead links in my bibliography, and **Christophe Jurczak** (Quantonation) for his updated foreword. This book is also supported by **le Lab Quantique** (not financially, but for its visibility).

I also have to acknowledge the contribution of **Google Gemini**, **OpenAI ChatGPT** and **Microsoft Copilot** (derived from the latter). They helped me migrate from Word to LaTeX, fix many LaTeX coding issues, and on the content.

I appreciate any feedback, corrections, updates and suggestions, particularly if you are one of the 870+ vendors mentioned, and even anecdotes or stories on how you use this book. I update the book content whenever required until the end of the year.

Best,

Olivier Ezratty

September-November 2025

Cet article a été publié le 29 septembre 2025 et édité en PDF le 13 février 2026.
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