

SYNTHEOS BRIEFING • OCTOBER 2026

Quantum technology in 2026: the plumbing is the payload

A Syntheos briefing. We followed five threads of citations out of quantum research, reading the papers at every step, to see what the field actually sends into the world.

−30%

change in the community that builds qubit readout amplifiers, 2021 to 2024, while qubit control electronics grew 50%

0.33×

how much European researchers cite Chinese quantum-sensing work, relative to its weight

0.9%

of China's leading quantum authors who went on to publish without Chinese co-authors

Here's a game we like to play with the map. Pick a community of scientists and ask a simple question. Who reads their work, and what do they do with it? Then ask the same question of those readers, and keep going until somebody builds something you could hold in your hand.

We played it five times, starting inside quantum technology, and we read the titles and abstracts on both sides of every step. The threads ended in an optical link for AI data centers, a receiver on a weather satellite, the cryptography meant to outlast quantum computers, a high-voltage power cable and a drone that navigates without GPS.

In almost every case, what traveled down the thread was the plumbing. The quantum effects mostly stayed home. What left the field were the tools people built to make quantum devices work, ways to grow a crystal, cool an amplifier, glue one chip onto another or count the errors in a code. That turns out to matter a great deal for who benefits and for where the next bottleneck sits.

BOTTOM LINE

Quantum technology's real exports today are engineering. Integration methods paid for by European quantum programs now feed AI interconnects that China and the US industrialize. Amplifiers built for qubits are the same devices used in satellites, and Chinese space-electronics groups are qualifying them. Two threads that look like quantum turn out to be ordinary materials and mechanics, which means controls drawn around the word quantum catch the wrong things.

The walls between the US and China are going up in people faster than in papers. Western researchers read Chinese quantum-sensing work at a third of its weight, China's strongest quantum areas are its least international, and almost nobody moves between the two systems anymore.

PUBLIC VERSION

Everything in this briefing comes from the open literature, and we publish it so the argument can be checked. The judgment we build on top of it is the part a client pays for. The four questions at the end are the ones we answer in that work.

THREAD 1

From a single photon to an AI data center

COMMUNITY 1

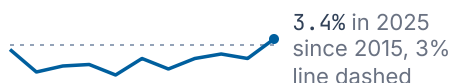
Single photons from quantum dots

Papers, 2024
362

Since 2021
+8%

Lead
Europe 58%

how to lift a tiny light source off one wafer and print it onto silicon



24 of 148 institutions write half the papers that draw on this link. Largest: University College London, 5%.

Transfer-printed single-photon sources coupled to wire waveguides (2018), read by Present and future of micro-transfer printing for heterogeneous photonic integrated circuits (2024).

COMMUNITY 2

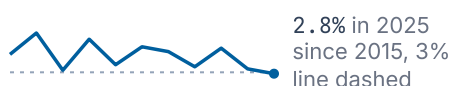
Quantum-dot lasers on silicon

Papers, 2024
263

Since 2021
+1%

Lead
Europe 30%

the roadmap for putting the laser right next to the switch



32 of 171 institutions write half the papers that draw on this link. Largest: Ghent University, 3%.

Perspective on the future of silicon photonics and electronics (2021), read by Co-packaged optics (CPO): status, challenges, and solutions (2023).

COMMUNITY 3

Co-packaged optics

Papers, 2024
231

Since 2021
+62%

Lead
China 23%, US 21%

To get one perfect photon at a time, quantum-optics groups learned to grow tiny islands of indium arsenide, quantum dots, so precisely that every photon comes out identical. Then they had a practical problem. The dots live on one kind of chip and the circuits that route photons live on silicon. So they invented ways to lift a single emitter off one wafer and print it onto another.

The laser community noticed. Papers on lasers grown on silicon now cite quantum photonics directly for those printing tricks ("Hybrid integrated quantum photonic circuits" and "Transfer-printed single-photon sources coupled to wire waveguides" are favorites), and that link crossed our 3% threshold in 2025.

Those lasers are what the people building co-packaged optics want, because an AI switch moving 51.2 terabits a second needs its light sources millimeters from the chip. Corning, GlobalFoundries, Broadcom and Intel all publish at that end, and it grew 62% in three years.

Here's the funny thing about who pays. The upstream work is 58% European and its biggest funders are Germany's DFG and the European Commission. At the far end Europe writes 23% of the papers, while China and the US together write 44%. Among the busiest bridges is a Russian microlaser group at HSE St Petersburg and the Ioffe Institute, alongside UCL and Institut Polytechnique de Paris.

So what. European quantum programs should count integration and packaging know-how as an output worth exploiting at home. Export controls on quantum hardware do nothing to stop this flow, because it moves through the open literature.

From a qubit's amplifier to a weather satellite

COMMUNITY 1

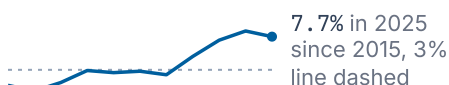
Cryogenic control electronics for qubits

Papers, 2024
200

Since 2021
+50%

Lead
Europe 33%

the physics of transistors at 4 kelvin, and a brutal power budget



7 of 29 institutions write half the papers that draw on this link. Largest: Chalmers, 17%.

Cryo-CMOS Circuits and Systems for Quantum Computing Applications (2017), read by Design of ultra-low noise amplifier for quantum applications (QLNA) (2024).

COMMUNITY 2

Cryogenic low-noise amplifiers

Papers, 2024
44

Since 2021
-30%

Lead
Europe 46%

device recipes for quiet transistors at cryogenic temperatures



9 of 30 institutions write half the papers that draw on this link. Largest: BIT Mesra and Zhengzhou University, 7% each.

InP HEMTs for Sub-mW Cryogenic Low-Noise Amplifiers (2020), read by Influence of BCB Protection on Irradiation Response of InP-Based HEMTs: A Comparative Study (2023).

COMMUNITY 3

InP transistor engineering and space qualification

Papers, 2024
27

Since 2021
-33%

Lead
China 33%

A qubit whispers. To hear it you need an amplifier that adds almost no noise of its own, and that means cooling it to a few degrees above absolute zero, where every milliwatt of heat is precious. The qubit-electronics community, centered in Grenoble and working with TSMC, IBM, STMicroelectronics and Google, has grown 50% in three years. It hands its device physics to a small group that builds indium phosphide amplifiers, led by Chalmers and Fraunhofer IAF.

That small group builds the same amplifier for everyone who needs to hear a faint signal. Its papers cover qubit readout, the planned upgrade to the Event Horizon Telescope, deep-space receivers and the Arctic Weather Satellite. Then a third community, a third of it Chinese and including the China Academy of Space Technology, picks up the same transistor designs, including work on qualifying them for satellites with radiation tests. One of its most-cited papers cites the qubit-amplifier work on its way to satellite communications.

Now look at the numbers in the middle. The pull from quantum is new. The amplifier builders took 2% of their outside citations from qubit electronics in 2021 and 8.5% in 2024. Demand is climbing, and the community that supplies the amplifiers shrank 30% in three years. Its industry share is about 1%, and seven institutions, led by Chalmers, write half of the amplifier papers that draw on qubit electronics.

So what. Anyone planning a quantum computer with thousands of qubits should worry about readout amplifiers as much as qubits. Any control on qubit-readout amplifiers is also a control on satellite and radio-astronomy receivers, and the reverse.

From an error-correcting code to the post-quantum migration

COMMUNITY 1

Quantum error correction

Papers, 2024
548

Since 2021
+78%

Lead
Europe 32%, US 30%

one trick, turning a classical code into a quantum one



21 of 170 institutions write half the papers that draw on this link. Largest: Hefei University of Technology, 10%.

Good quantum error-correcting codes exist (1996), read by [Relative Hulls and Quantum Codes](#) (2024).

COMMUNITY 2

Classical coding theory

Papers, 2024
406

Since 2021
-13%

Lead
China 38%

tools for telling when two codes are secretly the same



26 of 132 institutions write half the papers that draw on this link. Largest: Nankai University, 5%.

[Computing automorphism groups of error-correcting codes](#) (1982), read by [Take Your MEDS: Digital Signatures from Matrix Code Equivalence](#) (2023).

COMMUNITY 3

Code-based cryptography

Papers, 2024
137

Since 2021
-3%

Lead
Europe 40%

scheme specifications and hardness results, read less every year

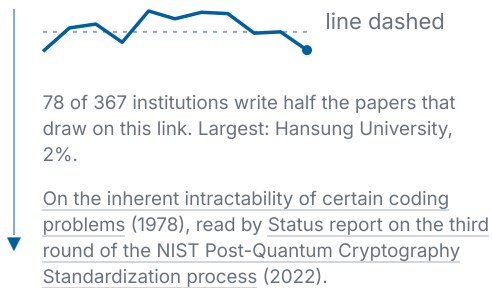


We hoped for a lovely irony here, that the math protecting quantum computers from their own errors flows into the cryptography built to protect us from quantum computers. The papers say it's subtler. Quantum error correction and code-based cryptography are cousins. Both grew from the same parent, classical coding theory, and very little of the quantum work passes through to the cryptographers. Of 105 recent papers in code-based cryptography that cite coding theory, one cites a paper that itself draws on quantum error correction.

The quantum-to-coding link is old and steady, 10 to 16% of coding theory's outside citations every year since 2015, and mostly about one trick, turning a classical code into a quantum one. What the two families share is one object, the hull of a code, the part of a code that overlaps with its own mirror image. On the quantum side, the hull tells you how much entanglement a certain kind of quantum code needs. On the crypto side, a 1997 paper on the hull is the tool people use to attack signature schemes built on code equivalence. The parent community is 38% Chinese, China's national science foundation is thanked on about a quarter of its papers, and it has published 142 papers on hulls.

Meanwhile the parent is shrinking while both children boom. Quantum error correction grew 78% and post-quantum cryptography grew 121%. And the post-quantum community reads the code-based work less every year, 4.4% of its outside citations in 2022 and 1.6% in 2025.

So what. NIST picked HQC, a code-based scheme, as its backup in 2025. Organizations counting on that backup should know its cryptanalysis rests on about 140 papers a year, with Europe the largest contributor, and should fund or follow that small community.



COMMUNITY 4

Lattice-based post-quantum cryptography

Papers, 2024	Since 2021	Lead
773	+121%	Europe 28%

Two threads that turned out to be decoys

COMMUNITY 1

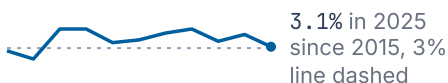
Quantum emitters in boron nitride

Papers, 2024
460

Since 2021
+3%

Lead
China 25%

*recipes for peeling boron nitride into flakes
(0.3% of the citations concern emitters)*



64 of 576 institutions write half the papers that draw on this link. Largest: Sichuan University, 4%.

Boron nitride colloidal solutions, ultralight aerogels and freestanding membranes through one-step exfoliation and functionalization (2015), read by Hexagonal boron nitride nanosheets: Preparation, heat transport property and application as thermally conductive fillers (2023).

COMMUNITY 2

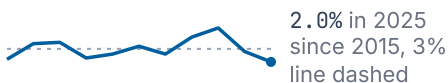
Boron nitride heat-spreading fillers

Papers, 2024
984

Since 2021
+32%

Lead
China 66%

*rules for adding heat-conducting fillers
without losing insulation*



21 of 204 institutions write half the papers that draw on this link. Largest: Xi'an Jiaotong University, 10%.

Enhancing dielectric strength of thermally conductive epoxy composites by preventing interfacial charge accumulation using micron-sized diamond (2021), read by Space Charge Behavior in Epoxy-Based Dielectrics: Progress and Perspective (2022).

COMMUNITY 3

Insulation for high-voltage DC cables

Papers, 2024
497

Since 2021
+10%

Lead
China 54%

Two of our threads looked like quantum technology flowing into things that matter. When we read the papers, the quantum part was missing. Boron nitride hosts some of the best single-photon emitters known, and the heat-management community cites that research community 2,337 times. Only 7 of those citations concern emitters. What they want are recipes for peeling boron nitride into flakes, which make fillers that carry heat away while still insulating. China's State Grid and China Southern Power Grid then use those rules in high-voltage cable insulation.

The second decoy runs from optomechanics, the study of light pushing tiny drums, to the gyroscopes in drones. Every step clears our threshold, and none of the downstream abstracts mention anything quantum. What travels is classical mechanics from before 2018, ways to make two vibrating modes trade energy. It does end somewhere important. China writes 51% of the research on vibrating micro-gyroscopes and 52% of the work fusing arrays of cheap gyroscopes into one good one. The top institution in gyroscopes is China's National University of Defense Technology. In the array papers, 20 abstracts mention drones and 14 mention flying without satellite navigation.

So what. Research-security screening should look at what a paper does, because a material or a community label can mislead in both directions. A filter that flags boron nitride as quantum would flag 601 heat-management papers, and a filter that looks for quantum would miss the gyroscope arrays entirely.

What the big players publish

Then we read what the biggest players actually publish. Reputations and paper trails don't always agree.

Chinese Academy of Sciences

Its largest quantum bloc is optical clocks and long-distance time transfer, 15% of its quantum papers, including time sent through open air over 113 km at 10^{-19} instability. China out-publishes the US three to one in optical clocks.

SHARE OF ITS 1,057 PAPERS IN THE FIELD

Optical clocks	15%
Majorana devices	8%
Boron nitride materials	6%
Quantum algorithms	5%
Everything else	67%

USTC

Communication first, with record-distance quantum key distribution and the Micius satellite. Its second bloc is diamond sensors used on tumor tissue and single molecules, ahead of its computing work.

SHARE OF ITS 1,053 PAPERS IN THE FIELD

Quantum key distribution	18%
Diamond and SiC spins	9%
Quantum algorithms	8%
Quantum memories	5%
Everything else	61%

IBM

Reads like a theory and software house. Nearly half its quantum papers are about error mitigation and new error-correcting codes.

SHARE OF ITS 188 PAPERS IN THE FIELD

Algorithms and error mitigation	46%
qLDPC and surface-code QEC	14%
Superconducting qubits	13%
Cryogenic control electronics	6%
Everything else	21%

Google

A tight program aimed at one goal, surface-code error correction below threshold, plus careful papers testing claims of quantum advantage in chemistry.

SHARE OF ITS 142 PAPERS IN THE FIELD

Algorithms and simulation	34%
Superconducting qubits	18%
Surface-code QEC	16%
Quantum learning theory	7%
Everything else	25%

Microsoft

A fifth of its quantum papers are on Majorana devices and another fifth on error-correction theory, and a striking share argues against near-term advantage. Its real peer on Majoranas is Beijing, where Chinese institutions out-publish US ones, 409 papers to 379.

SHARE OF ITS 89 PAPERS IN THE FIELD

Algorithms and compilers	30%
Majorana devices	21%
Fault-tolerant QEC	20%
Quantum learning theory	9%
Everything else	19%

NTT

The outlier. It bets on optical computing with squeezed light at gigahertz rates and on Ising machines, with an almost entirely Japanese partner network.

SHARE OF ITS 114 PAPERS IN THE FIELD

Squeezed-light computing	25%
Error mitigation and algorithms	19%
Ising machines	17%
Quantum key distribution	6%
Everything else	33%

China publishes about a fifth as much as the US on fault-tolerance theory while building real logical-qubit hardware. It reads those ideas in the open literature.

RESEARCH SECURITY

The walls are going up in people

We traced every citation between quantum papers published from 2022 to 2024. Everyone favors their own. Europe and the US read each other at 0.78 to 0.88 times their weight. Both read Chinese work at about 0.4 times its weight, and in quantum sensing, where Chinese institutions wrote 24% of the cited work, European papers cite it at 0.33. Lower quality doesn't explain it, because Chinese quantum papers draw 0.87 times the field's average citations.

Co-authorship tells a quieter story. US-China quantum papers grew 18% from 2022 to 2024 while US-China co-authorship across science fell, and the surviving ties sit in basic physics and Majorana materials. China's strongest areas, communication and timing, are its least international, with Western partners on 13% to 22% of papers.

People have nearly stopped moving. Of 1,529 authors who published only with Chinese colleagues at China's four leading quantum institutions in 2022 and 2023, 13 went on to publish without any Chinese co-author. Going the other way, from the leading US institutions, it was 4 of 953.

HOW MUCH US AND EUROPEAN RESEARCHERS CITE CHINESE QUANTUM WORK, RELATIVE TO ITS WEIGHT

■ US ■ Europe

Sensing and metrology



Communication



Computing



All quantum



1.0 means cited in proportion to China's share of the recent papers being cited. Citations between quantum papers published 2022 to 2024. The dashed line marks parity.

Second-order effects

01 China's quantum effort partly looks like a navigation program

Put the optical clocks next to the gyroscope arrays. Precise time and precise inertial sensing are the two halves of navigating without satellites, and China leads the open research on both by wide margins.

03 Export controls drawn around the word quantum catch the wrong things

They would sweep in boron-nitride fillers and miss the integration methods flowing into AI optics, which travel through the open literature.

05 The post-quantum backup rests on a small bench

The cryptanalysis behind code-based schemes like HQC is about 140 papers a year, while the coding theory it depends on shrinks.

02 Readout amplifiers are the quiet bottleneck

Quantum computers need more of them every year, and the community that designs them shrank 30% with about 1% industry participation.

04 Europe pays upstream and others build downstream

Europe writes 31% of quantum research and gets about 5% of private quantum funding. The photonics thread shows the same pattern in miniature.

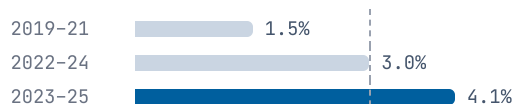
06 Decoupling is furthest along in people

Fewer than 1% of China's leading quantum authors crossed into Western-only publishing, and the reverse flow is smaller still.

The next threads

Then we ran the game forward. We looked for links out of quantum research that are still weak but growing fastest, read the papers on both sides, and threw out the ones that only share a word or a material. Two survived.

The qubit amplifier may jump to ordinary silicon



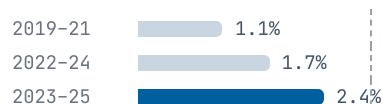
Share of outside citations drawn from the giving side. Dashed line at 3%, our bar for a strong link.

Remember the amplifier community that's shrinking. Something is quietly working around it. Qubit electronics is now a fast-rising source of ideas for a group that designs silicon-germanium transistors, the kind commercial foundries already make for radios. Its pull on that group grew from 1.5% of outside citations in 2019 to 2021 to 4.1% in 2023 to 2025.

What crosses are 4-kelvin device models and measurement methods, used to redesign those transistors for liquid-helium temperatures. The US writes 30% of the papers and China 25%, and STMicroelectronics, GlobalFoundries and Infineon publish in the community. Some of the Chinese papers test the transistors under radiation at cryogenic temperature, which is what you'd do for a space receiver.

So what. If qubit readout moves onto commercial silicon-germanium, the bottleneck in thread 2 eases and the parts get much harder to control, because the same foundries make chips for phones and base stations. Watch which foundries publish cryogenic models of their processes.

Quantum acoustics is feeding radio filters



Share of outside citations drawn from the giving side. Dashed line at 3%, our bar for a strong link.

Some optomechanics groups build tiny circuits for sound, phononic chips designed to hand a vibration to a qubit. A community that designs the acoustic filters in 5G and satellite radios, the parts that keep one channel from bleeding into the next, has started reading them. The pull rose from 1.1% of its outside citations in 2019 to 2021 to 2.4% in 2023 to 2025, and to 4.3% in 2025 alone.

Only 7 of the 62 filter papers that draw on this work use any quantum vocabulary. They want the design tricks. China writes 45% of those papers and the US 33%, and Qorvo, Murata and China Electronics Technology Group publish in the community.

So what. High-frequency filters are a part where China still leans heavily on American and Japanese suppliers. Open quantum-acoustics research now feeds the effort to close that gap, and no quantum export rule touches it.

WITHHELD

What the full version answers

01 The gating step in each thread

Which single step decides whether each chain keeps moving, and what would have to change for it to stop being the bottleneck.

These four are judgments rather than findings, so they are not on this page. Each one goes to a client with the evidence underneath it, and with what we could not establish stated as plainly as what we could.

02 What a control would have to name

Which specific capabilities a control aimed at this field would have to cover to bite, and which of the categories in use today miss the work that is actually moving.

03 Everyone carrying each link

The full roster of organizations that carry each link, by name, share and funder, rather than the counts and the single largest that appear here.

04 Early-warning indicators

The specific numbers we would recompute each quarter to tell whether each prediction is turning, and the thresholds that would count as a turn.

ON THE RECORD

What we expect by October 2027

A forecast you can't check isn't worth much. Here's what we expect, and in October 2027 we'll rerun the numbers on the new map and publish the score.

01 The amplifier community won't turn around.

True if its 2026 papers stay at 44 or fewer and its industry share stays under 2%.

Now: 44 papers in 2024 and 32 in 2025, industry share 1.4%.

02 The photonics shortcut stays switched on.

True if silicon lasers draw at least 3% of their outside citations from quantum-dot photonics in 2026.

Now: 3.4% in 2025.

03 Western readers won't warm to Chinese quantum sensing.

True if US and European citation of it stays at 0.40 of its weight or below for 2023 to 2025.

Now: 0.35 and 0.33 for 2022 to 2024.

04 Quantum acoustics becomes a full thread into radio filters.

True if the link passes 3% for 2024 to 2026.

Now: 2.4% for 2023 to 2025.

05 Post-quantum work keeps outgrowing its code-based bench.

True if in 2026, post-quantum cryptography publishes at least 8.5 times as many papers as code-based cryptography.

Now: 7.9 times in 2025, up from 2.5 times in 2021.

HOW WE DID THIS

Threads follow links where the receiving community draws at least 3% of its citations to other communities from the giving one, from 2022 to 2024 on the 2026 Syntheos Map of Science, except the newest photonics link, which crossed in 2025. At each link we read the most-cited papers on the giving side that the receiving side uses, and a sample of the receiving papers, from their titles and abstracts. The pair of papers shown on each link is a citation we checked in the data, not an illustration. Country shares split each paper evenly across its authors' countries, and bridge counts split each receiving paper evenly across its institutions. Institution profiles count papers in the 73 quantum communities and read each institution's most-cited and most recent work. Mobility counts authors with at least two papers in each period. Data from OpenAlex.

SOURCES

1. [Google Quantum AI, Quantum error correction below the surface code threshold, Nature, 2024](#)
2. [NIST, NIST selects HQC as fifth algorithm for post-quantum encryption, March 2025](#)
3. [European Commission, Quantum Europe Strategy, July 2025](#)
4. [The ngEHT radio telescope project, URSI GASS 2023](#)

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