



wrap-up

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< auteur | ... >

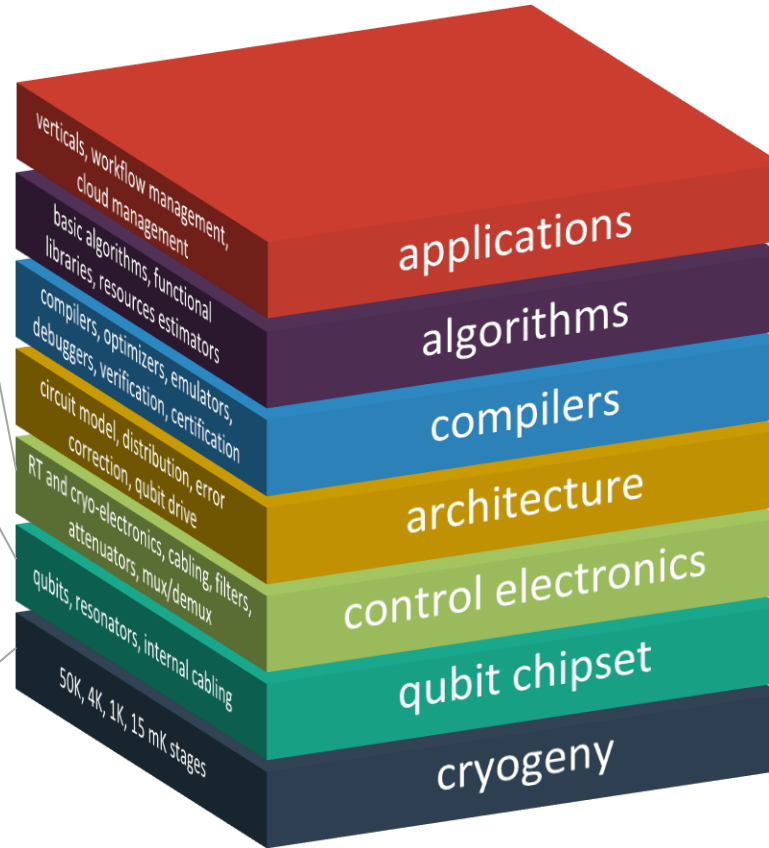
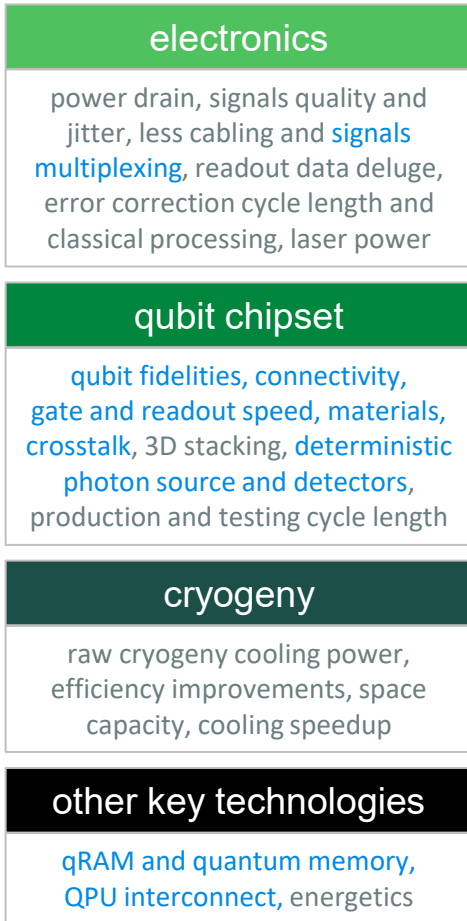
Palaiseau, 21 mars 2024

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Rose Dieng-Kunz

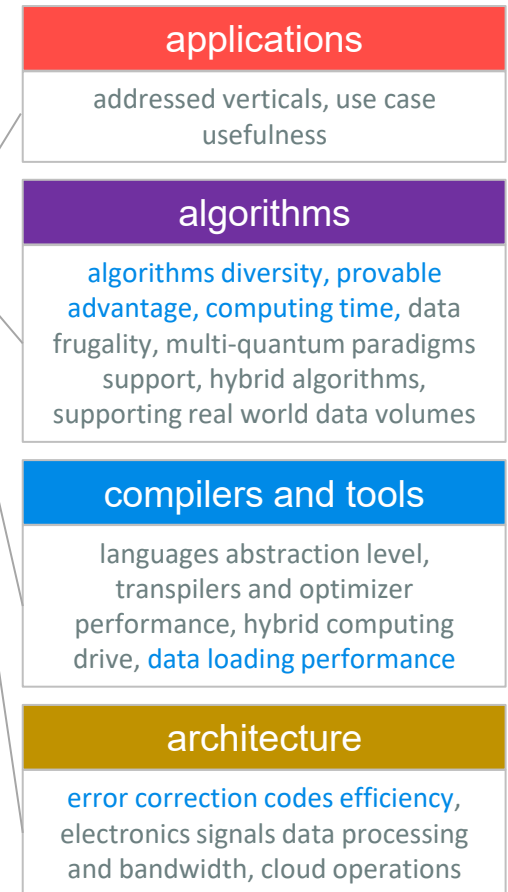


hardware stacks



blue =scientific challenge (« hard tech »)
 black: technology challenge (« deep tech »)

software stacks



photonics

laser sources



photon sources and detectors



other



NV centers



cold atoms



error correction



control electronics



cabling and connectors



cryogeny





Delft Circuits
Hardware for quantum engineers.



Leiden Cryogenics
Leader in Low Temperature Techniques



QuSoft
Research Center for Quantum Software



THE FASTEST WAY TO A QUANTUM FUTURE



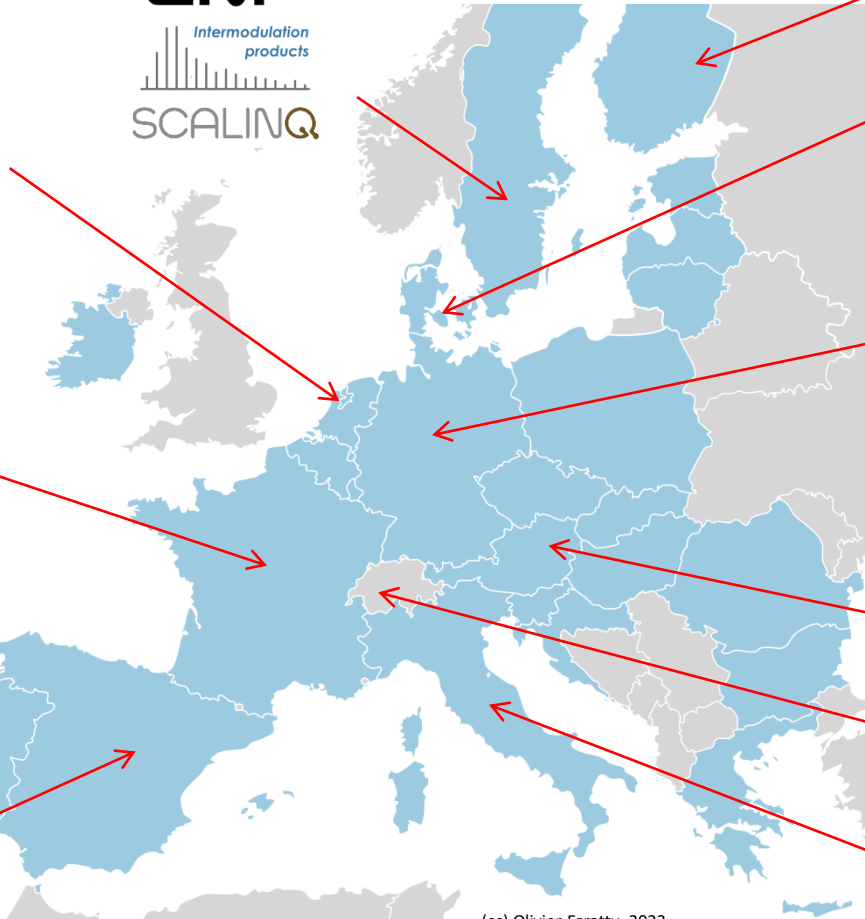
SINGLE QUANTUM
Excellence in photon detection



SILENT WAVES



SILENTSYS
ULTRAVIOL HOSE SYSTEMS



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industry vendors ecosystem

computing



software



cybersecurity



sensing



cryogeny



electronics



photonics



manufacturing



materials



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fabs



research fabs



pre-industry
research fabs



foundry vendors



in-house
vendor fabs

mostly small fabs, superconducting electronics and III/V

with 300 mm wafers capabilities in many cases

(cc) Oliver Ezratty, 2022-2023

alkali metals: used in trapped ions qubits, mostly strontium and calcium

transition metals: titanium and niobium, used in superconducting cables, niobium used in superconducting qubits

iron, cobalt, nickel, chrome: used in cryostats

group IIB metals: sometimes used in trapped ions qubits, zinc, cadmium, mercury

carbon: used in nanotubes for silicium qubits

nitrogen: used in some cryostats, mostly for quantum sensing

helium: used in cryostats at lower than 10K, and helium 3 to reach <3K temperature

silicon: used in wafers for electron spins qubits and photonics, Si₂₈ for silicium qubits wafers.

germanium: used in some CMOS components and some electron spins qubits.

« III-V » elements: used for photonic semiconductors (arsenic, gallium, indium)

rare earths: ytterbium, europium, praseodyme and erbium used in trapped ions qubits, optical memories and some lasers.

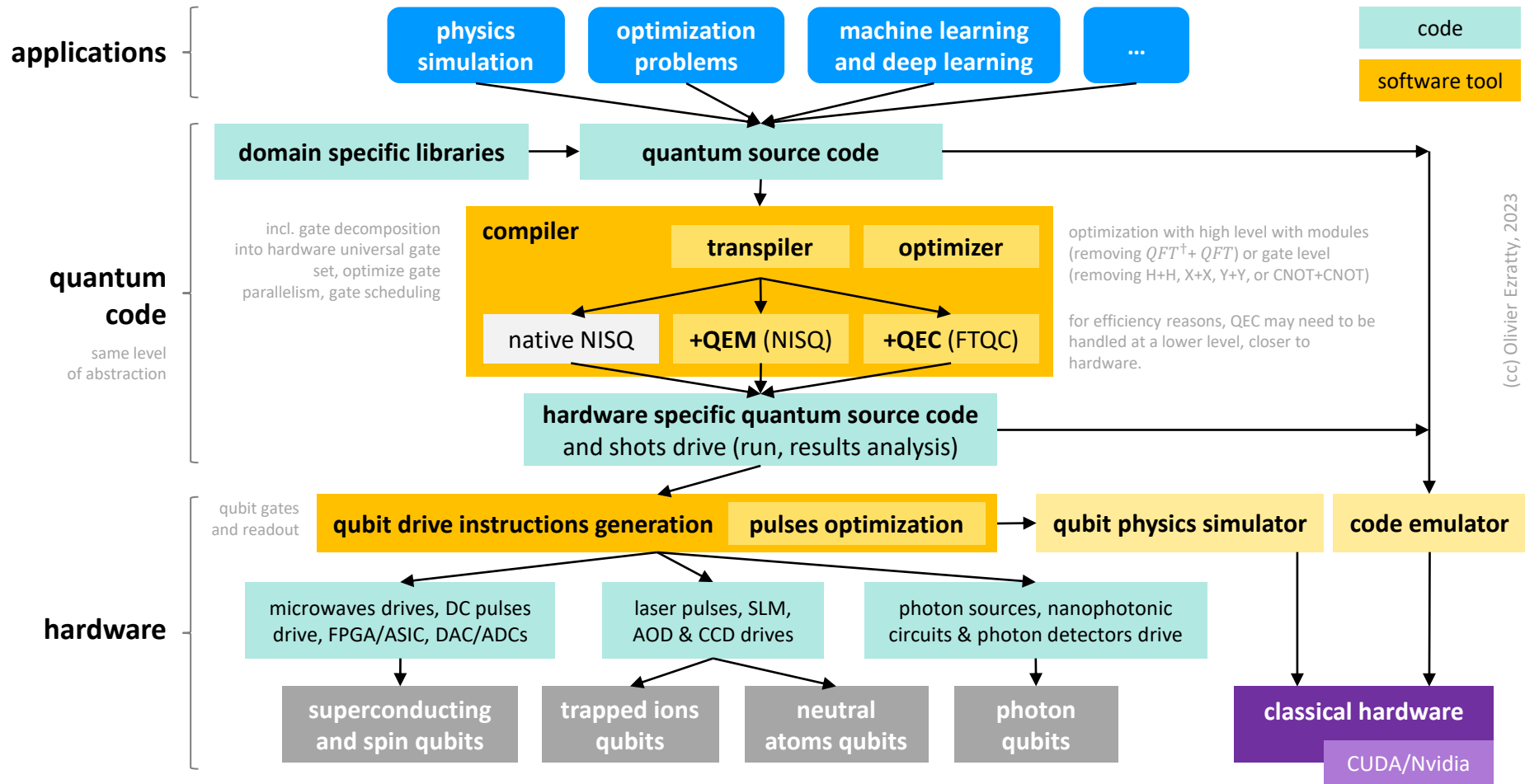
rubidium : used in cold atom qubits and in quantum sensing

cesium : used in atomic clocks

1 H Hydrogen 1.008	2 He Helium 4.003																	
3 Li Lithium 6.94	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180	
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.085	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.948	
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.630	33 As Arsenic 74.922	34 Se Selenium 78.97	35 Br Bromine 79.904	36 Kr Krypton 83.798	
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium [97]	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.293	
55 Cs Cesium 132.905	56 Ba Barium 137.327	* 57 - 70	71 Lu Lutetium 174.967	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine [210]	86 Rn Radon [222]
87 Fr Francium [223]	88 Ra Radium [226]	** 89 - 102	103 Lr Lawrencium [262]	104 Rf Rutherfordium [261]	105 Db Dubnium [270]	106 Sg Seaborgium [269]	107 Bh Bohrium [270]	108 Hs Hassium [270]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [281]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [293]	118 Og Oganesson [294]
*Lanthanide series		57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.045			
**Actinide series		89 Ac Actinium [227]	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium [237]	94 Pu Plutonium [244]	95 Am Americium [243]	96 Cm Curium [247]	97 Bk Berkelium [247]	98 Cf Californium [251]	99 Es Einsteinium [252]	100 Fm Fermium [257]	101 Md Mendelevium [258]	102 No Nobelium [259]			

copper, silver, gold: used in cryostats for cold plates and cabling

(cc) Olivier Ezratty, September 2023
elements table: (cc) Wikipedia



quantum computing cloud offerings

quantum computing emulation

hybrid
computing
centers



40 qubits EVIDEN	EVIDEN QUANDELA	36 qubits	34-50 qubits	30 qubits	40 qubits
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hybrid
quantum



in 2023



...

and also



XANADU



32 qubits



80 qubits



8 qubits



COMPUTING INC. XANADU



32 qubits



80 qubits



QUANTINUUM

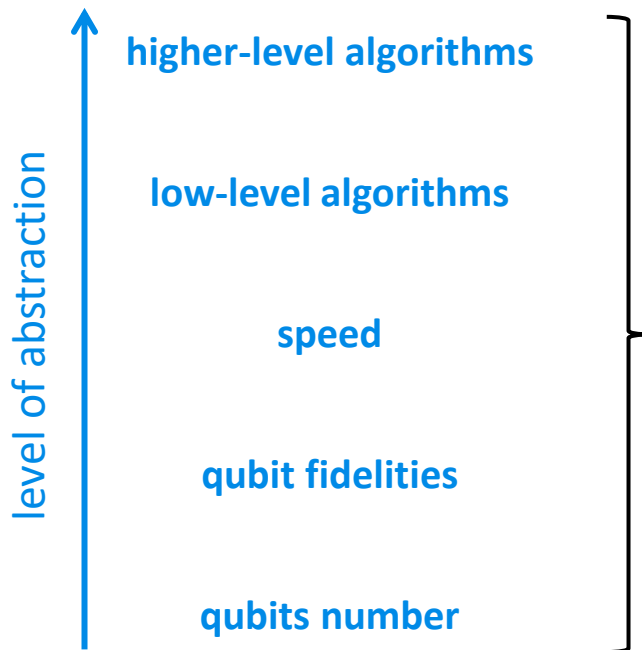
12-20 qubits



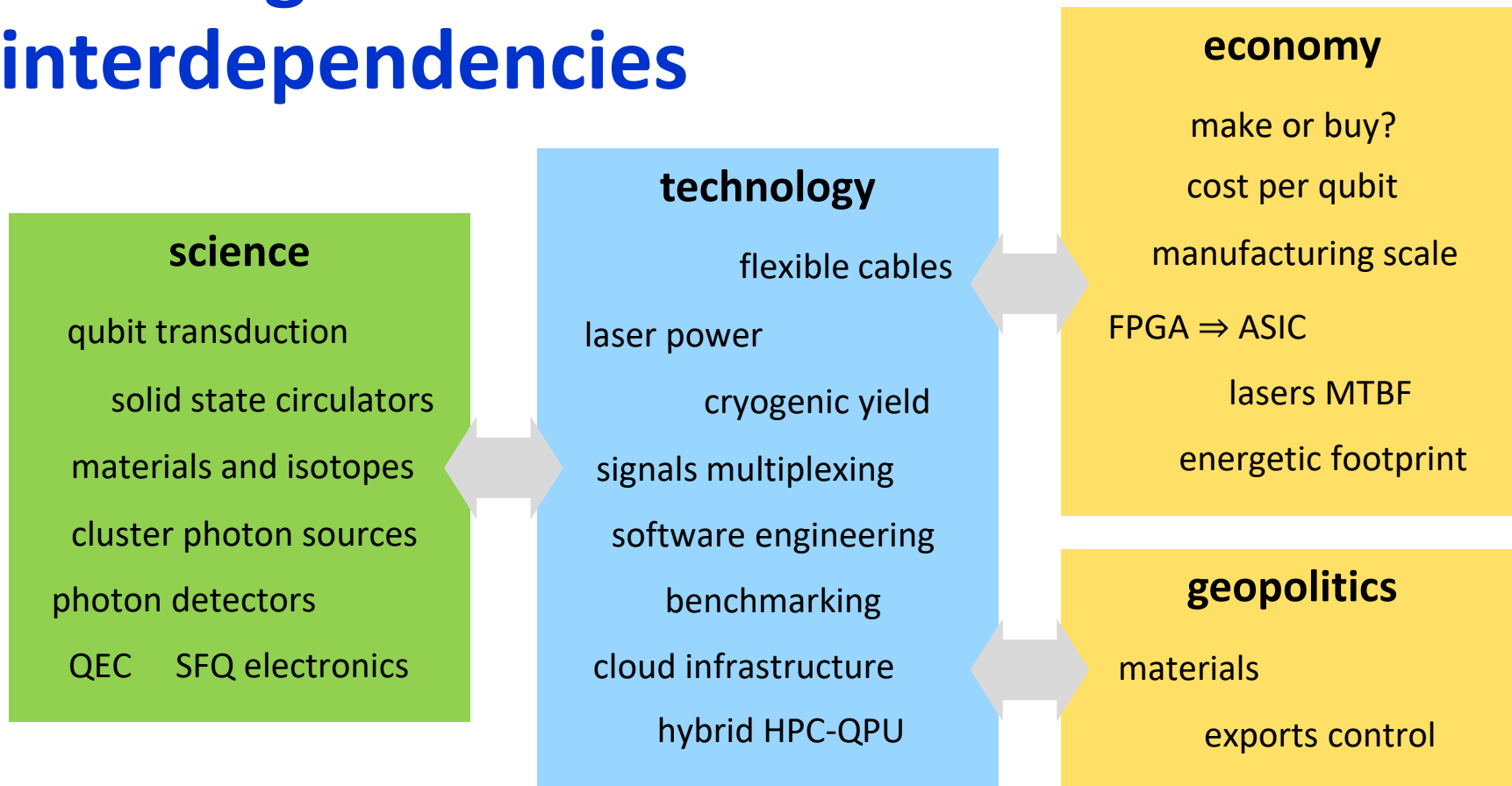
11 qubits

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benchmarking is an enabling technology



challenges and interdependencies



projets clés

CHIPS Act

Proqcima

grand défi LSQ

HQI - EuroHPC

i-Demo *et al*

EU Quantum Flagship

Académie des Technologies

