KVANTTIFYSIIKAN TOINEN KEVÄT

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KVANTTIFYSIIKAN ENSIMMÄINEN KEVÄT 1900-1930

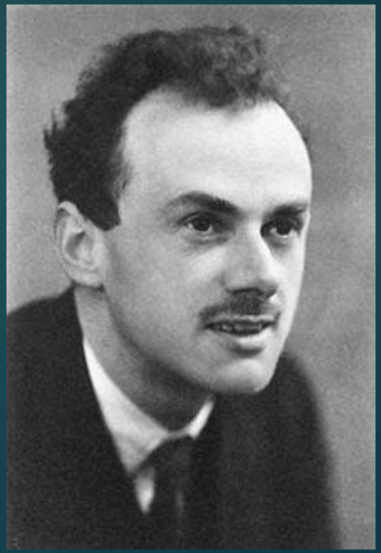
"The general theory of quantum mechanics is now almost complete. The underlying physical laws necessary for the mathematical theory of a large part of physics and the whole of chemistry are thus completely known, and the difficulty is only that the exact application of these laws leads to equations much too complicated to be soluble."

"It therefore becomes desirable that approximate practical methods of applying quantum mechanics should be developed, which can lead to an explanation of the main features of complex atomic systems without too much computation."

P.A.M. Dirac, 1929

1902-1984

Physics Nobel Prize 1933 (with E. Schrödinger)



Computation- and data-driven materials science

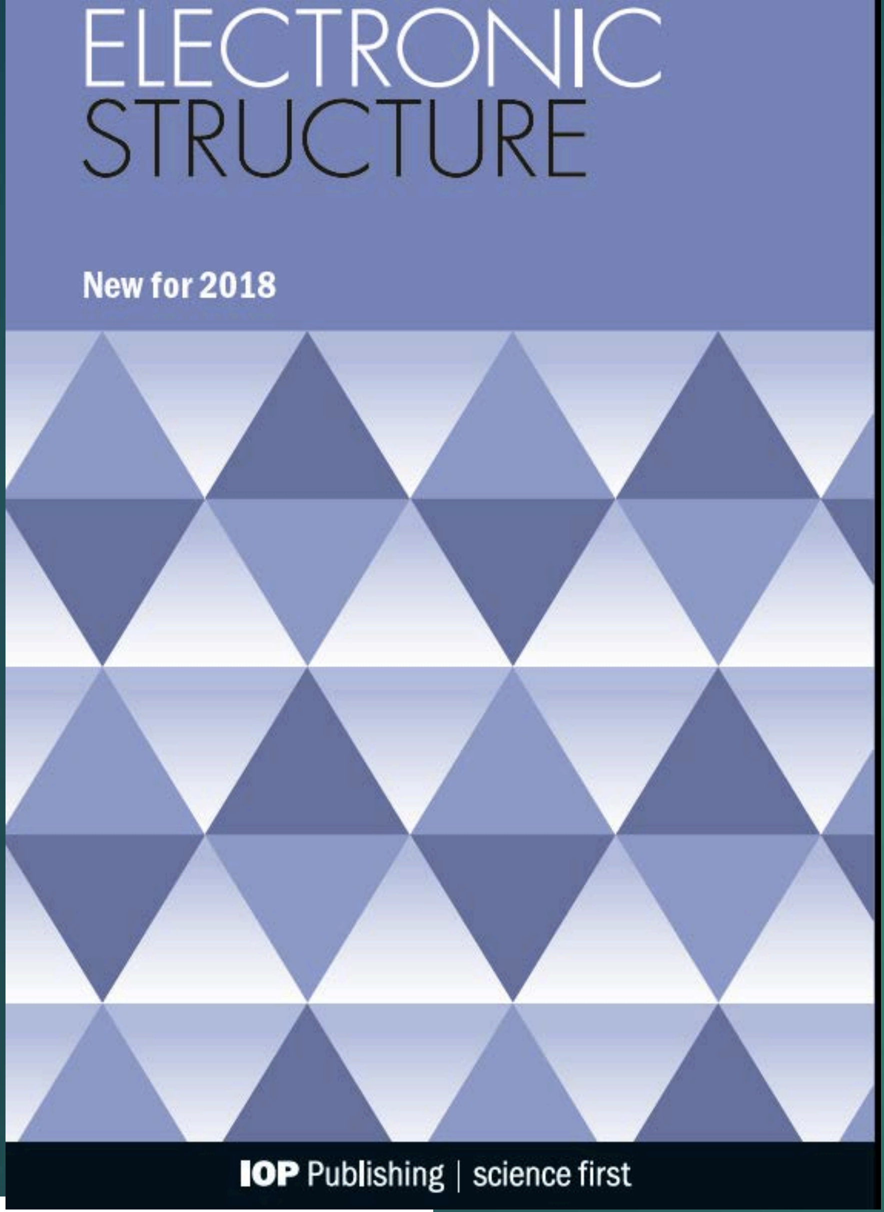
MARVEL

NOMAD
NOVEL MATERIALS DISCOVERY

MATERIALS PROJECT

MatNavi
NIMS Materials Database

Aalto University
School of Science



Aalto University
School of Science

Maamerkkejä 1967 - 2017

- BCS – suprajohtavuus
- Integroidut piirit
- Laserit
- Josephson-ilmiö, tunneloituminen
- Andersonin lokalisaatio
- Faasimuutosten teoria
- Elektroni-, tunnelointi- ja voimamikroskopia
- Kvantti-Hall-ilmiöt
- Korkean lämpötilan suprajohteet
- Atomien laserjäähdytys
- ^{3}He-supranesteet
- Bose-Einstein-kondensaatio
- Optiset kuidut
- Grafeeni
- Kvasikiteet
- Topologiset materiaalit
- …

Kvanttimekaniikka on tullut osaksi insinööritieteitä

- ✓ Puolijohteet ja elektroniikan miniatyrisointi
- ✓ Laserit ja optinen tietoliikenne
- ✓ Katalyyttinen kemia
- ✓ Molekyylibiologia ja bioteknologia

………

Tiedeidea	Teknologia	Sovellus
Materiaalitutkimus Miniatyrisointi Laskenta ja simulointi	Mikro- ja nanoteknologia	Tietokone Mikroprosessori Muistivälineet
Kvanttioptiikka Spektroskopia	Laserit	Informaation siirto ja tallennus , valaistus jne.
Tarkkuusmanipulointi	Tunnelointi-mikroskopia	Pinnat, nanorakenteet
Tarkkuusajoitus Kvanttisimulointi	Atomien jäähdytys	Atomikello, gravitometri
Suprajohtavuus	Kryogeniikka	SQUID, magnetometri

Kvanttisysteemin informaatiotiheys on valtaisa

Esimerkki: ”kolmen bitin rekisteri”

Klassinen rekisteri

000
001
010
100
101
110
111

Kvanttirekisteri $\Psi(x_1, x_2, x_3)$

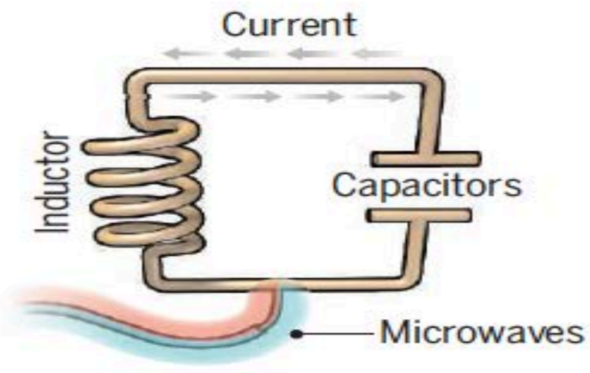
16-ulotteisen
pallon pinta

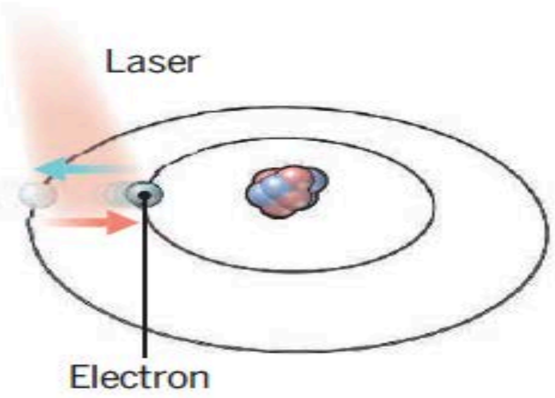
Toinen kevät:

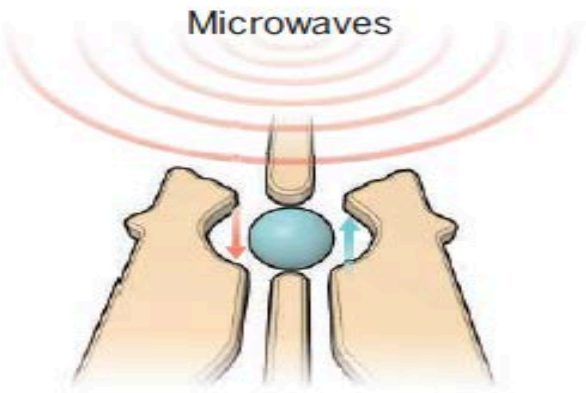
- Kvanttimekaanisten tilojen superpositio
- Kvanttimekaaninen lomittuminen
- Kvanttifluktuaatiot
- Koherenttien kvanttitilojen manipulointi

-> KVANTTITEKNOLOGIA

Kvanttibittien fysikaalisia realisaatioita







	Superconducting loops	Trapped ions	Silicon quantum dots
	A resistance-free current oscillates back and forth around a circuit loop. An injected microwave signal excites the current into super-position states.	Electrically charged atoms, or ions, have quantum energies that depend on the location of electrons. Tuned lasers cool and trap the ions, and put them in superposition states.	These "artificial atoms" are made by adding an electron to a small piece of pure silicon. Microwaves control the electron's quantum state.
Longevity (seconds)	0.00005	>1000	0.03
Logic success rate	99.4%	99.9%	~99%
Number entangled	9	14	2
Company support	Google, IBM, Quantum Circuits	ionQ	Intel
Pros	Fast working. Build on existing semiconductor industry.	Very stable. Highest achieved gate fidelities.	Stable. Build on existing semiconductor industry.
Cons	Collapse easily and must be kept cold.	Slow operation. Many lasers are needed.	Only a few entangled. Must be kept cold.

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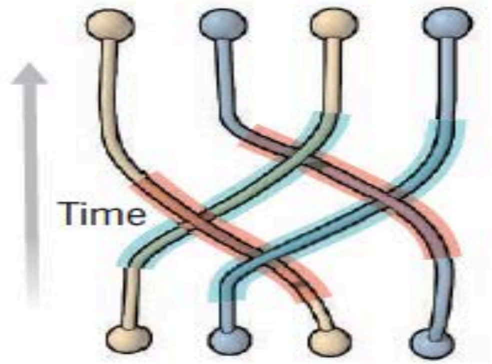

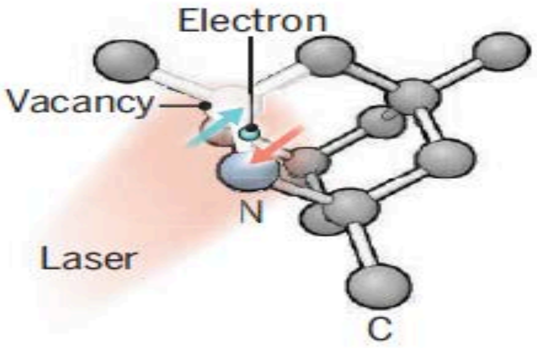

Topological qubits Quasiparticles can be seen in the behavior of electrons channeled through semi-conductor structures. Their braided paths can encode quantum information.	**Diamond vacancies** A nitrogen atom and a vacancy add an electron to a diamond lattice. Its quantum spin state, along with those of nearby carbon nuclei, can be controlled with light.
N/A	**10**
N/A	**99.2%**
N/A	**6**
Microsoft, Bell Labs	Quantum Diamond Technologies
Greatly reduce errors.	Can operate at room temperature.
Existence not yet confirmed.	Difficult to entangle.

Sovellusmahdollisuuksia

- Tietoliikenteen salaus (kvanttikryptologia)
- Kvantti-informaatio ("teleportaatio")
- Kvanttilaskenta ("kvanttitietokoneet")
- Ultraherkät sensorit
- Fotosynteesi?

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Sovellusmahdollisuuksia

- Optimointitehtävät ("quantum annealing")

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D-Wave Inc. (Burnaby, British Columbia, Kanada)

Quantum Technologies foster a new initiative in Europe

- ***The Quantum Flagship, a 1b€ and 10yr initiative, launches in Vienna, Austria on October 29th***
- ***The overall initiative will involve the quantum community at large, with over 5000 European researchers in academia and industry searching to place Europe at the forefront of Quantum innovation.***
- ***20 projects have been selected out of 140 submitted proposals for the ramp-up phase of the initiative.***

KIITOS!