Atomok és fotonok
út a kvantumtechnológiához

DOMOKOS PÉTER

„There's Plenty of Room at the Bottom”

„An Invitation to Enter a New Field of Physics”, by Richard P. Feynman

APS meeting, Caltech, 1959

Going down — General Electric's minute new tunnel diode, capable of operating at frequencies above 4 billion cycles, and intended for use in computers, communications equipment, and nuclear controls.

Atoms in a small world

When we get to the very, very small world — say circuits of seven atoms — we have a lot of new things that would happen that represent completely new opportunities for design. Atoms on a small scale behave like *nothing* on a large scale, for they satisfy the laws of quantum mechanics. So, as we go down and fiddle around with the atoms down there, we are working with different laws, and we can expect to do different things. We can manufacture in different ways. We can use, not just circuits, but some system involving the quantized energy levels, or the interactions of quantized spins, etc.

Another thing we will notice is that, if we go down far enough, all of our devices can be mass produced so that they are absolutely perfect copies of one another. We cannot build two large machines so that the dimensions are exactly the same. But if

IQEC meeting, 1984

Quantum Mechanical Computers

By Richard P. Feynman

Introduction

This work is a part of an effort to

such. We see we really have two more logical primitives, FAN OUT when two wires are connected to one, and EX-

could be stored in an inductan other reactive element.
However, it is apparently ver

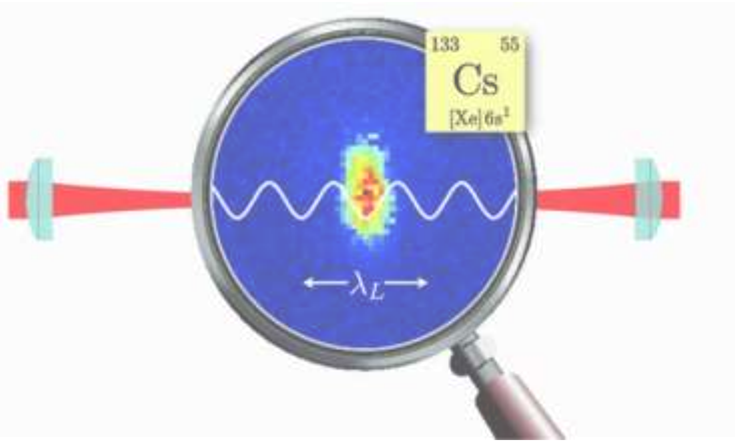
Why atoms?

- *Discrete energy levels*
- *Sensitive to fields (magnetic, lasers, …)*
- *Talk to photons*

Az atomok megszelídítése

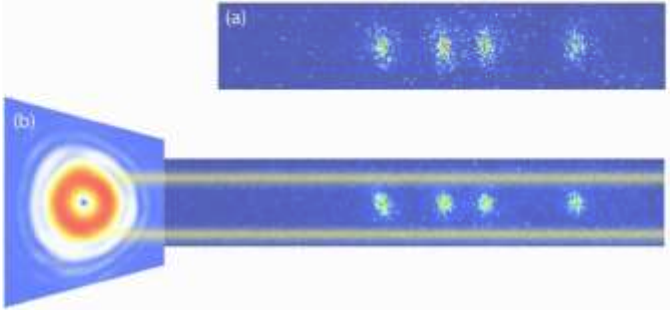
Egyedi atomok: kezelhetőek, és a kvantummechanika törvényeit követik

- **Láthatóak-e egyedi atomok? Igen!**
- **A környezettől való elszigetelés**
- **Megcímezhetőek (pl. lézerrel)**
- **Kontrollált pozícionálás, mozgatás**
- **Kontrollált kölcsönhatás**



Fizikai Nobel díj 1997

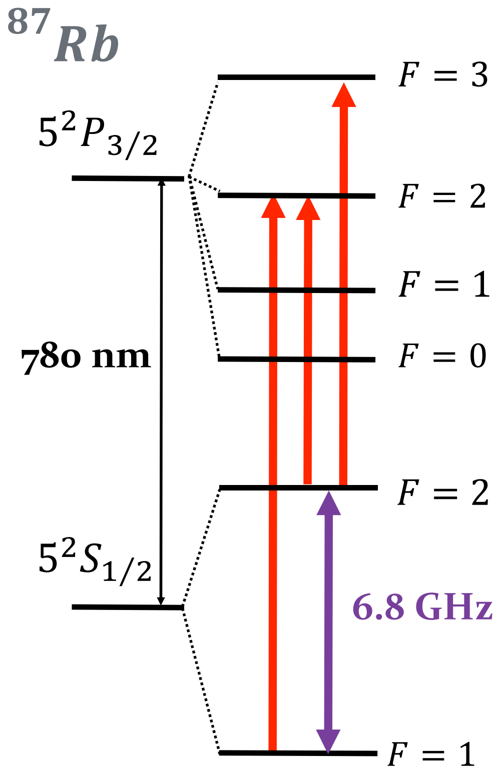
C. Cohen-Tannoudji, W. Phillips, S. Chu, "for development of methods to cool and trap atoms with laser light"

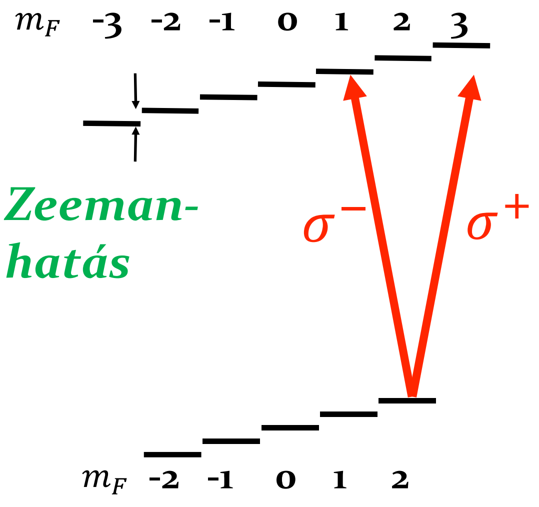


Alberti & Meschede 2015

Atomok a kvantumtechnológia „ügynökei”

atom = véges dimenziós Hilbert-tér



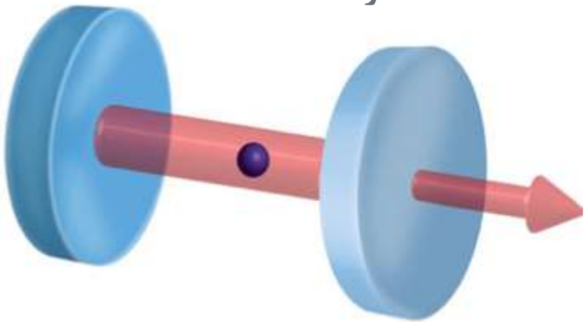


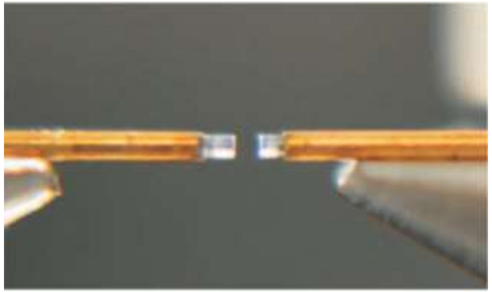
- *Átmenetek: lézer és mikrohullámú mezőkkel*
- *Finomhangolás: mágneses mező*
- *Óra- vagy memóriaállapotok*

Csapdába ejtett fotonok

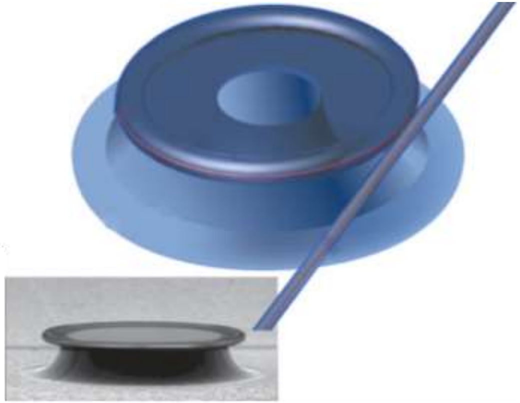
Térbeli és spektrális szűrés → sugárzási (foton)módus

Fabry-Pérot rezonátor

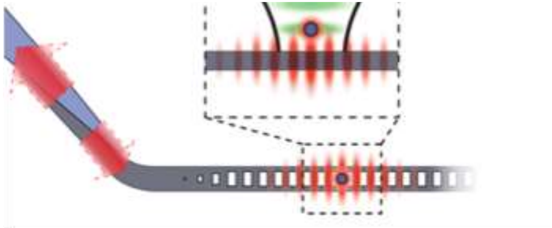




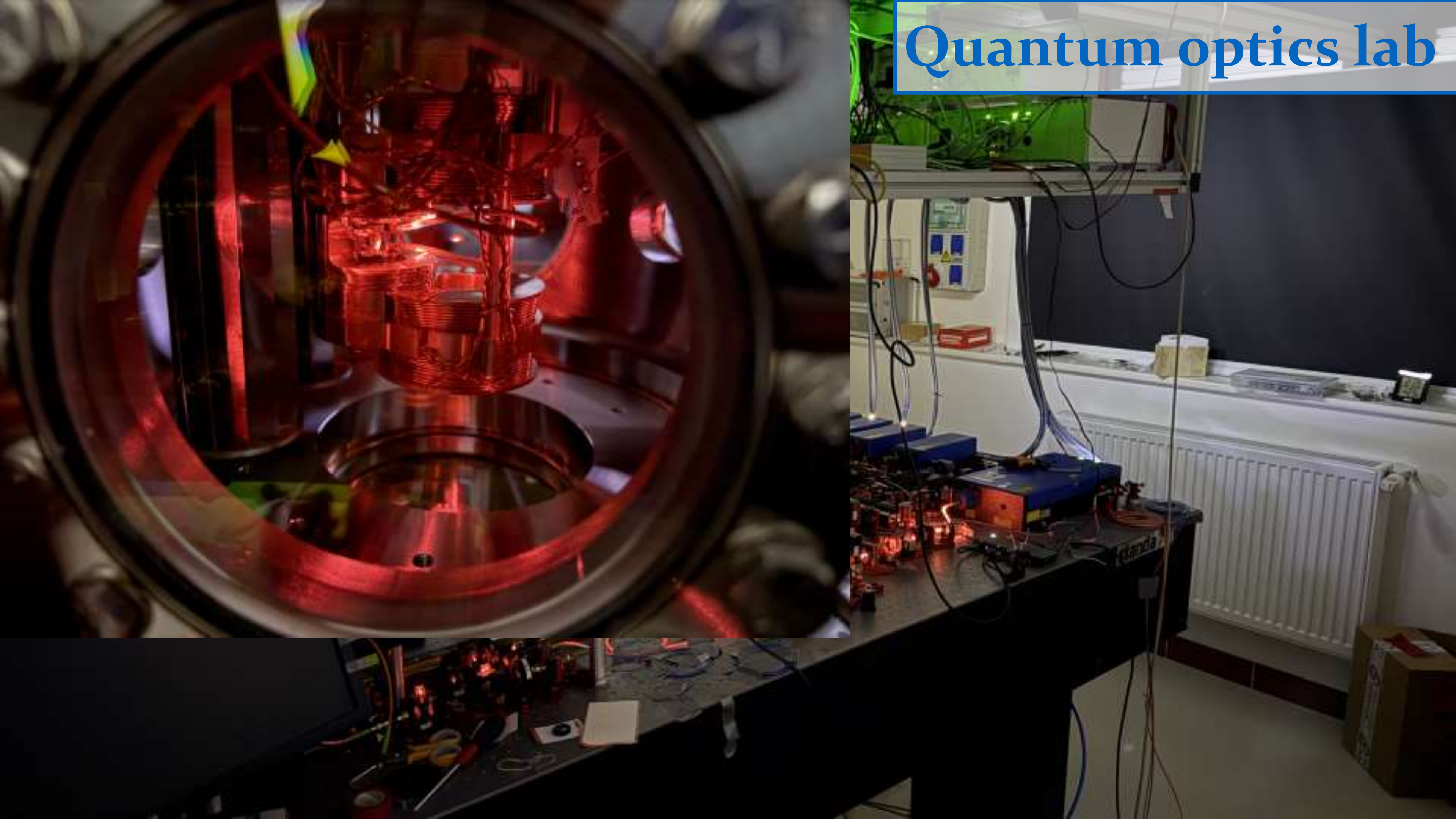
Mikrogyűrű rezonátor



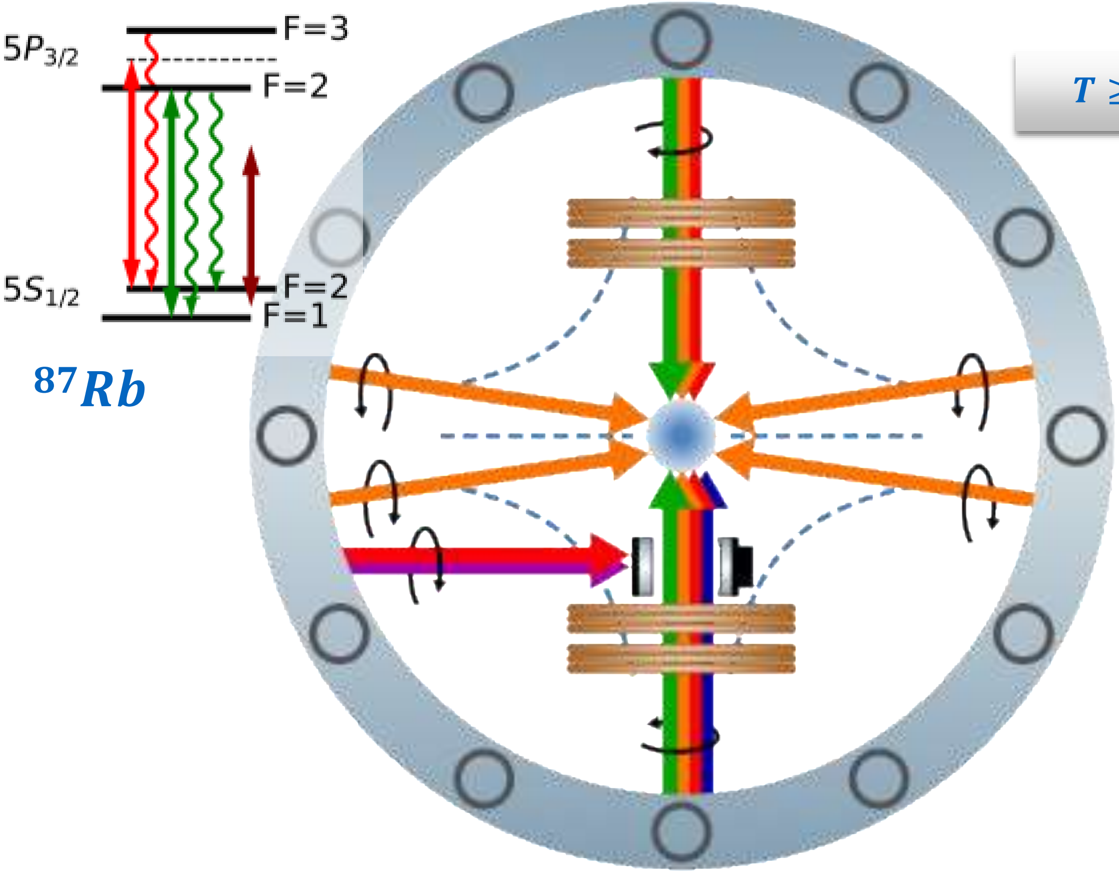
Fotonikus kristály rezonátor



Quantum optics lab

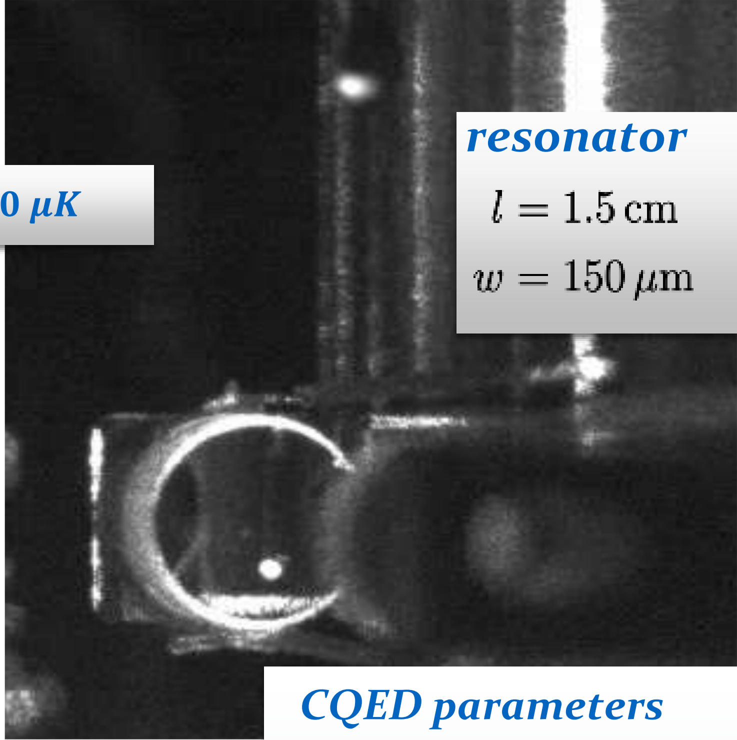


Cavity QED experimental setup



^{87}Rb

$T \geq 10\ \mu K$



resonator

$l = 1.5\,\mathrm{cm}$

$w = 150\,\mu\mathrm{m}$

CQED parameters

$\kappa = 2\pi \cdot 3.2\,\mathrm{MHz}$

$g = 2\pi \cdot 0.33\,\mathrm{MHz}$

$\gamma = 2\pi \cdot 3\,\mathrm{MHz}\ (^{87}\mathrm{Rb}$

$N \sim 10^5$

D. Varga, B. Gábor, B. Sárközi, et al, Physics Letters A 505, 129444 (2024)

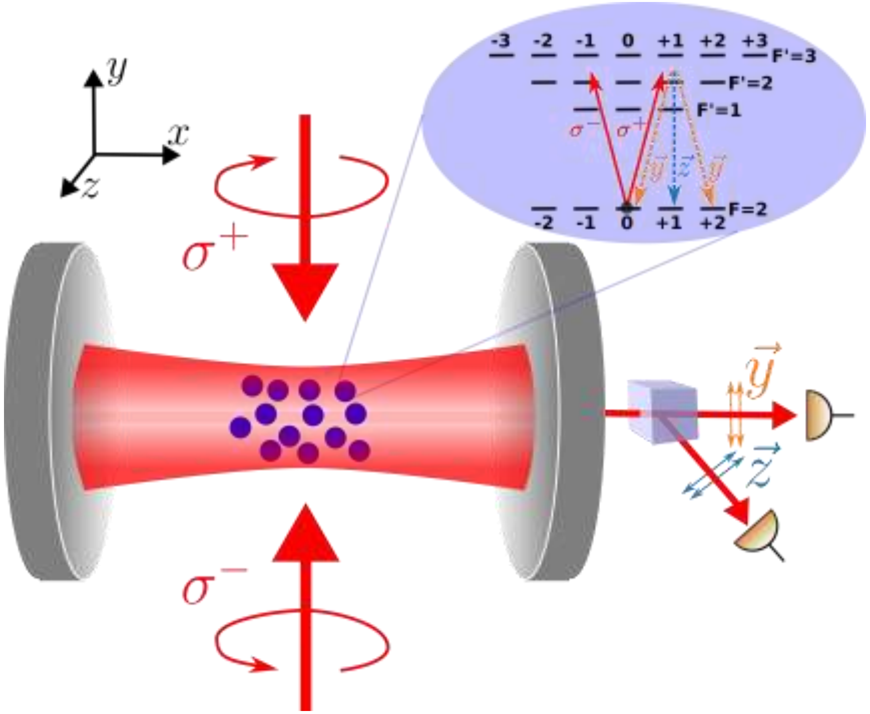
Kvantumoptika hideg atomokkal

elmélet → kísérlet

- Cold atoms in cavity-generated dynamical optical potentials by H Ritsch, P Domokos, F Brennecke, T Esslinger
  Reviews of Modern Physics 85, 553 (2012)
  > 1000 citations

- Demonstration of strong coupling of a subradiant atom array to a cavity vacuum, EPJ Quantum Technology 12, 1-13 (2025)

- Ground-state bistability of cold atoms in a cavity,
  Physical Review A 107, 023713 (2023)



BME TTK Fizika Intézet

kvantummechanika → kvantumtechnológia

- **konzorciumok vezetése**
- **kvantumoptika kurzus**
  → atom és foton alapú kvantumtechnológiák
- **új laboratóriumi gyakorlatok**
  → felkészítés a kvantumtechnológiára
- **elektronika és optomechanika gyakorlatok**
  → háttértechnológia

2017-2021

HUNQUTECH

2020-2025

QNL Quantum Information National Laboratory HUNGARY

Köszönöm a bizalmat!