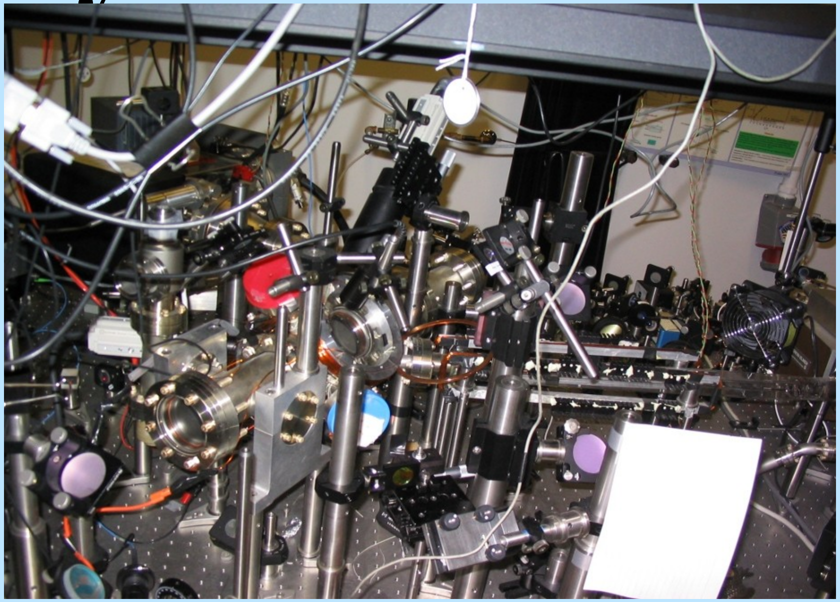
Atomové hodiny



Tomáš Opatrný
Přírodovědecká fakulta UP

Osnova:

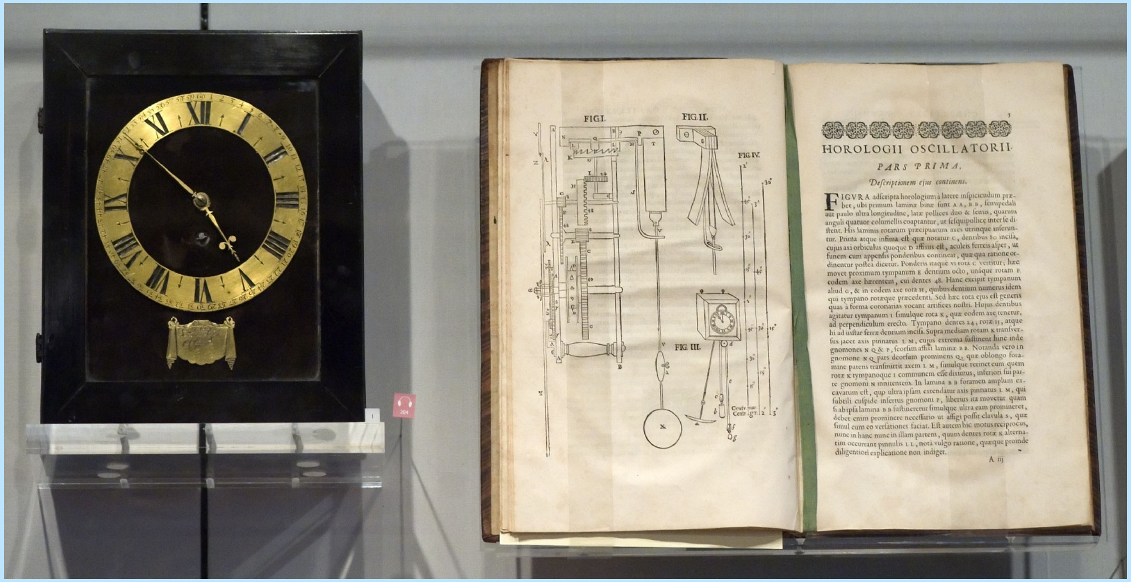
- **základní princip**
- **něco historie**
- **jak zpřesňovat měření času, definice sekundy**
- **k čemu se to hodí**
- **něco souvisejícího výzkumu z olomouckého pracoviště**

Princip hodin:
- zdroj periodických kmitů
- počítadlo kmitů

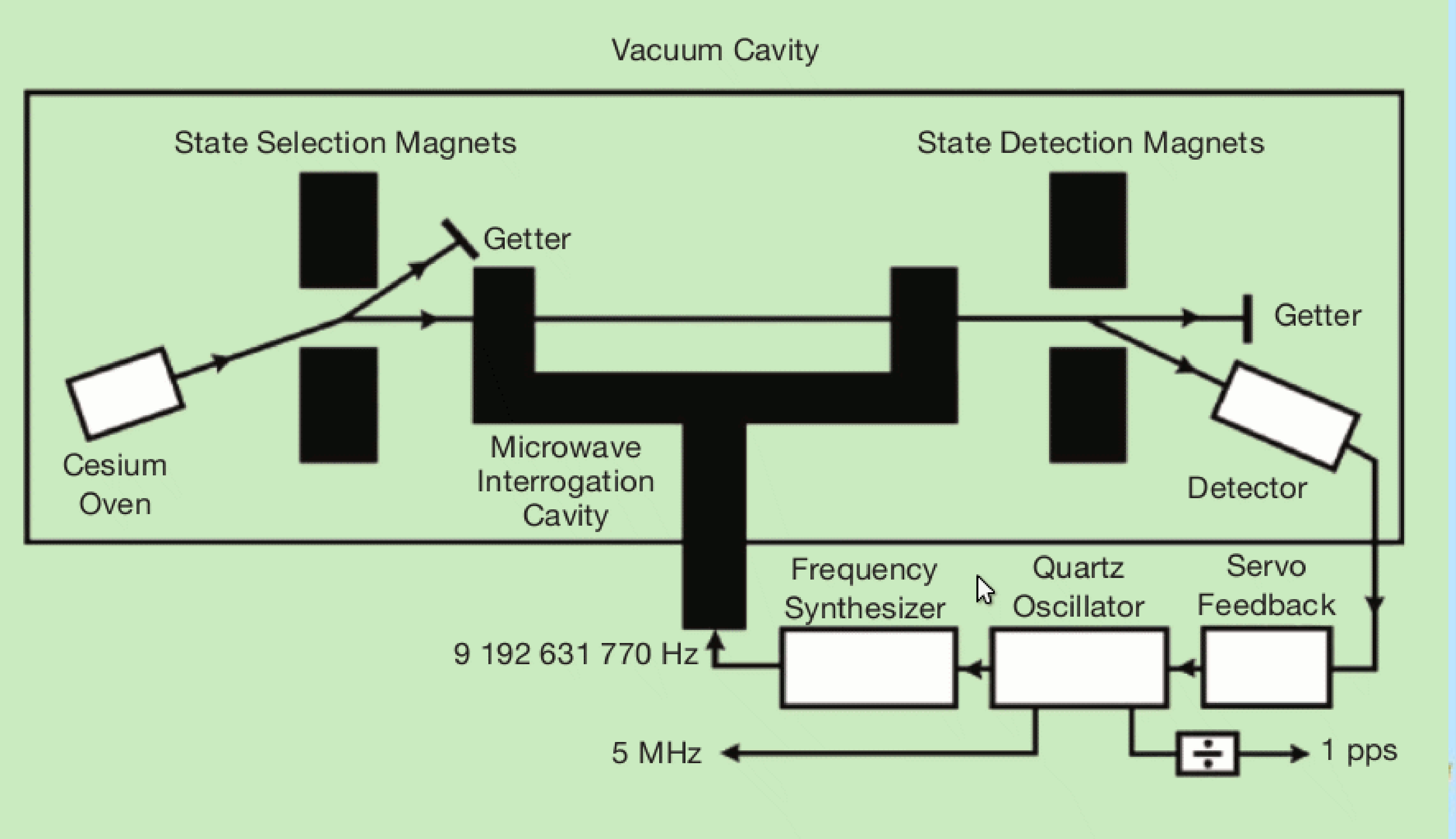
Oscilátory:
- kyvadlo
- pružina a závaží
- kondenzátor a cívka
- piezoelektrický krystal
- atom či molekula

Kyvadlové hodiny

Christiaan Huygens: patent 1657

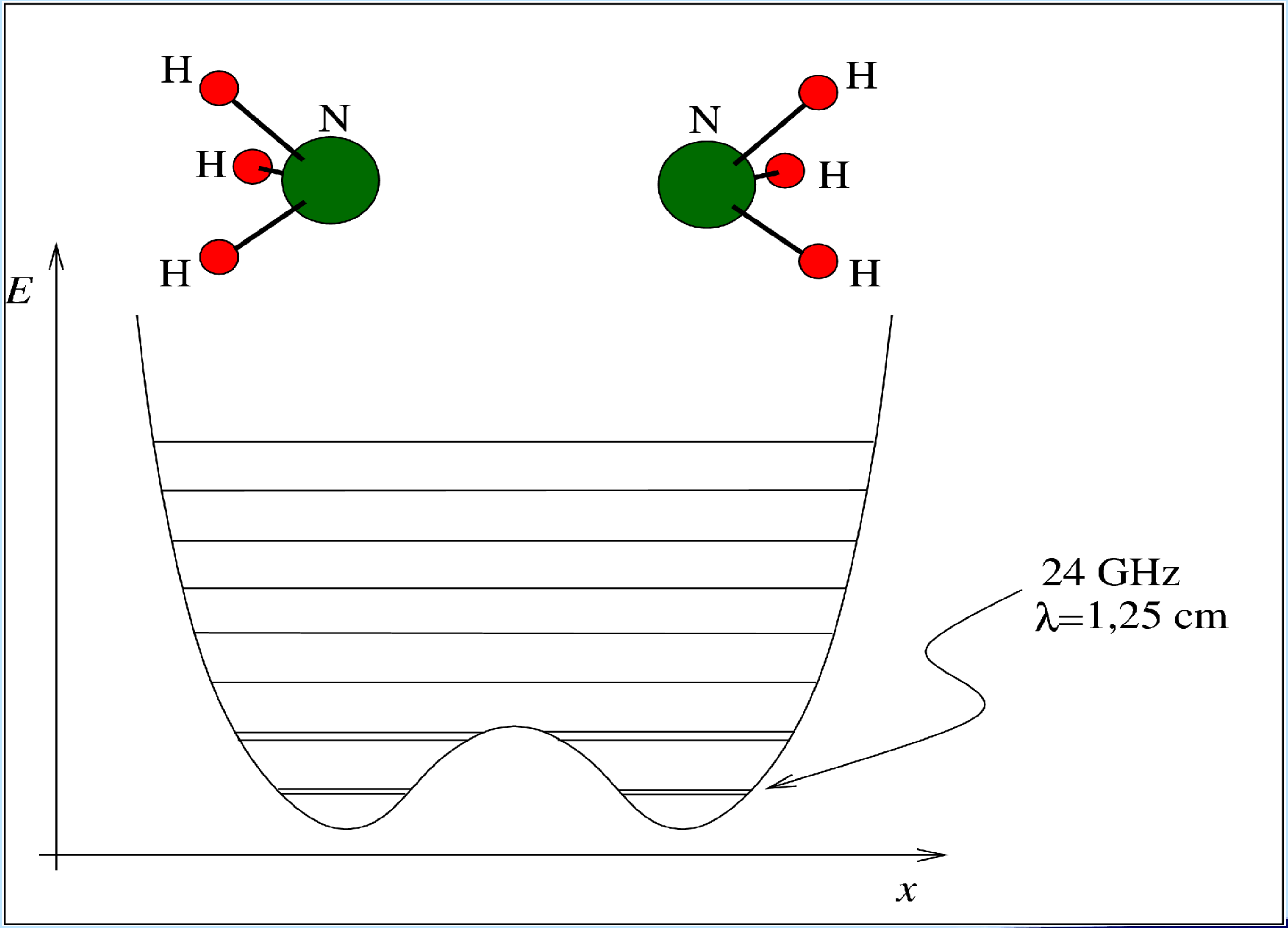


Princip atomových hodin

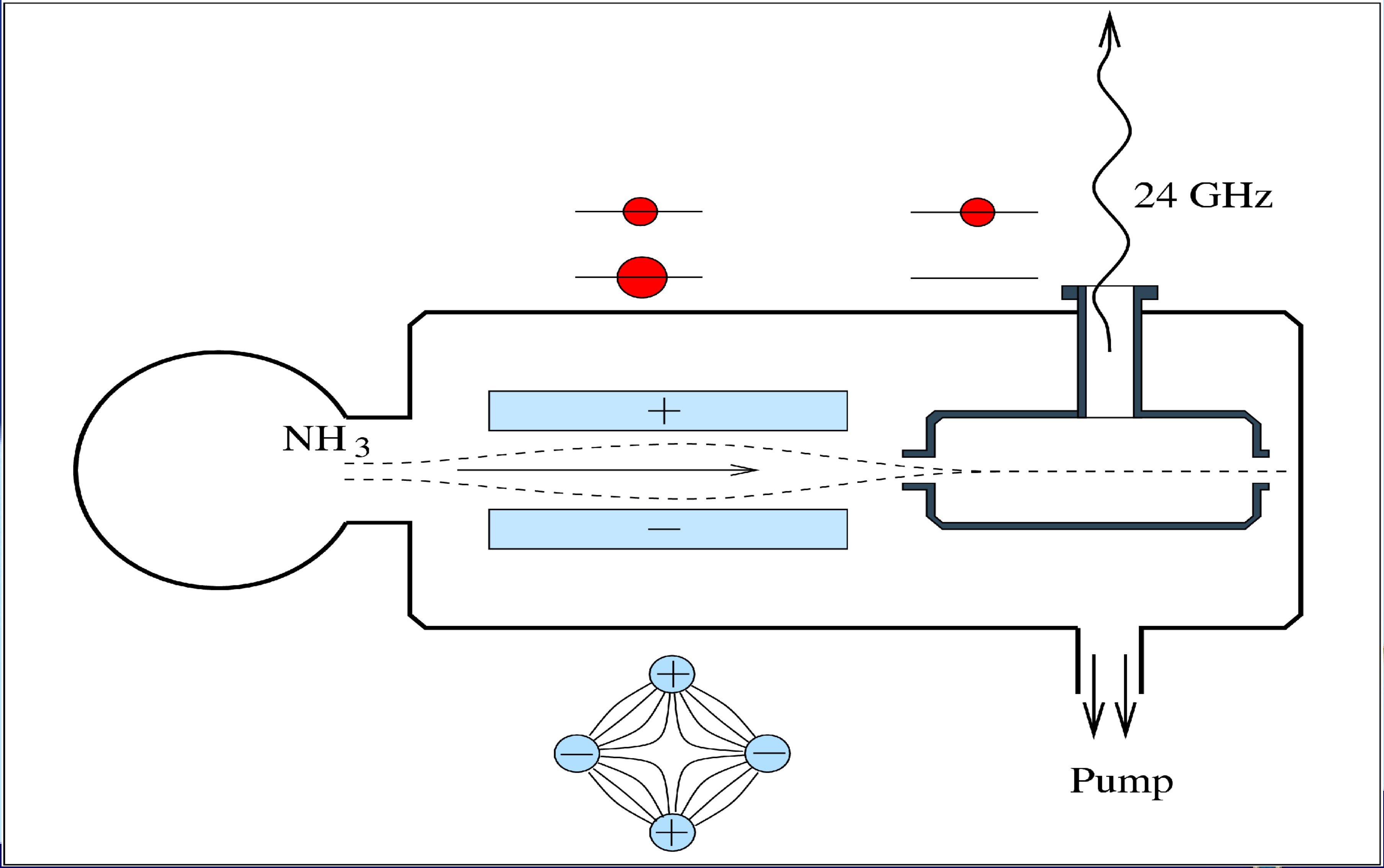


M.A. Lombardi & al. (NIST), Measure 2, 74 (2007).

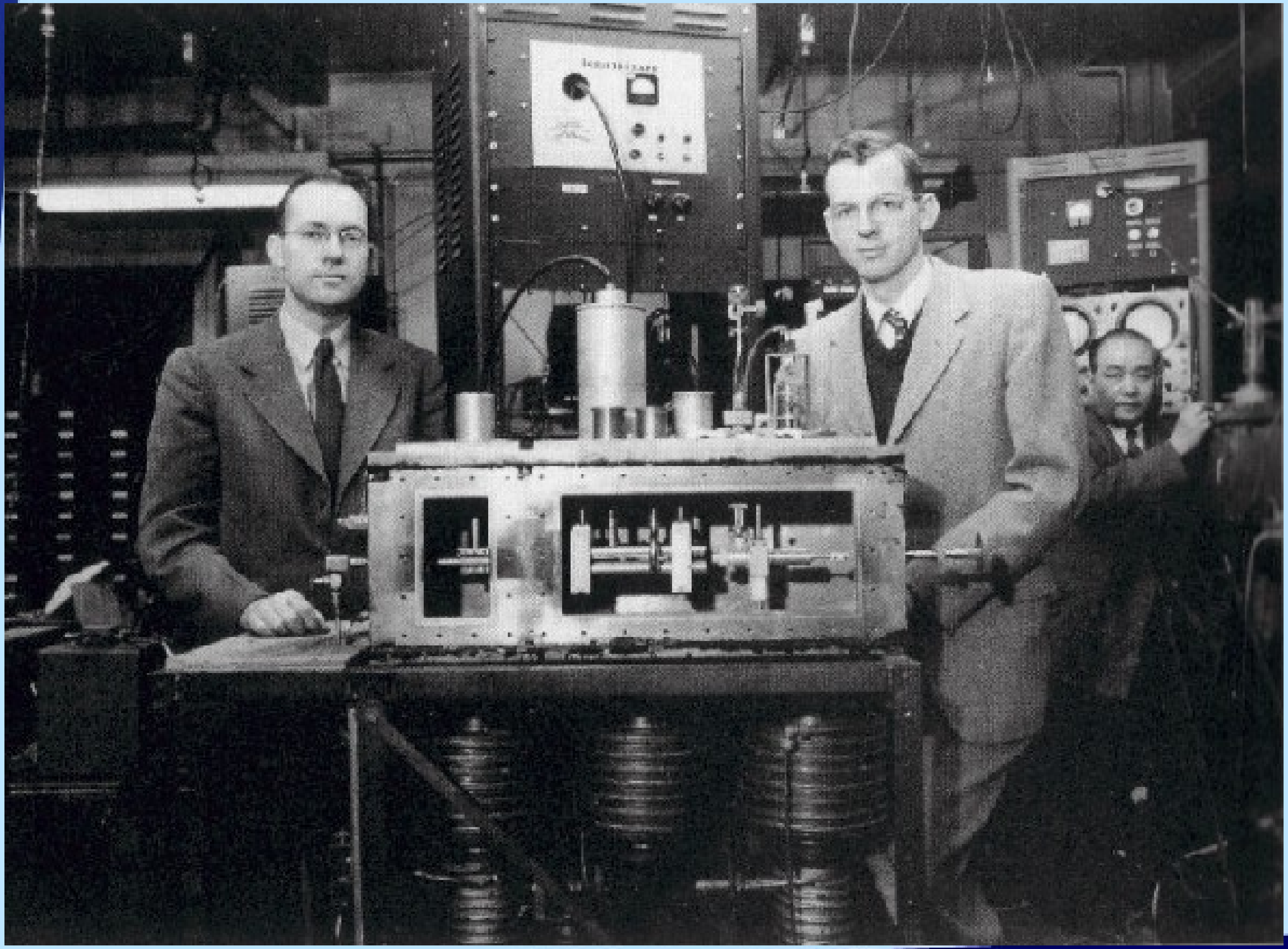
MASER: Kmity molekuly amoniaku



Amoniakový maser, schéma

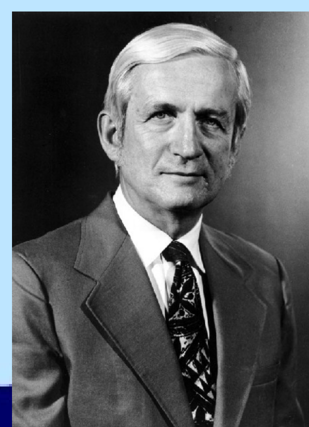


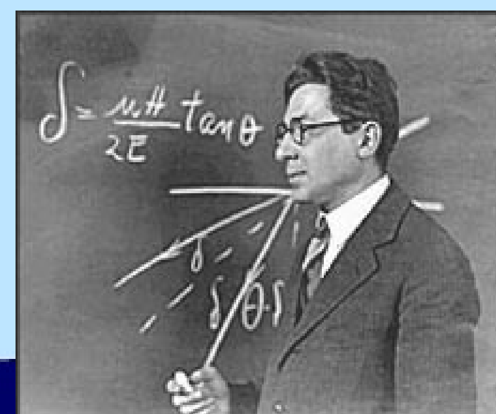
Amoniakový maser, 1954



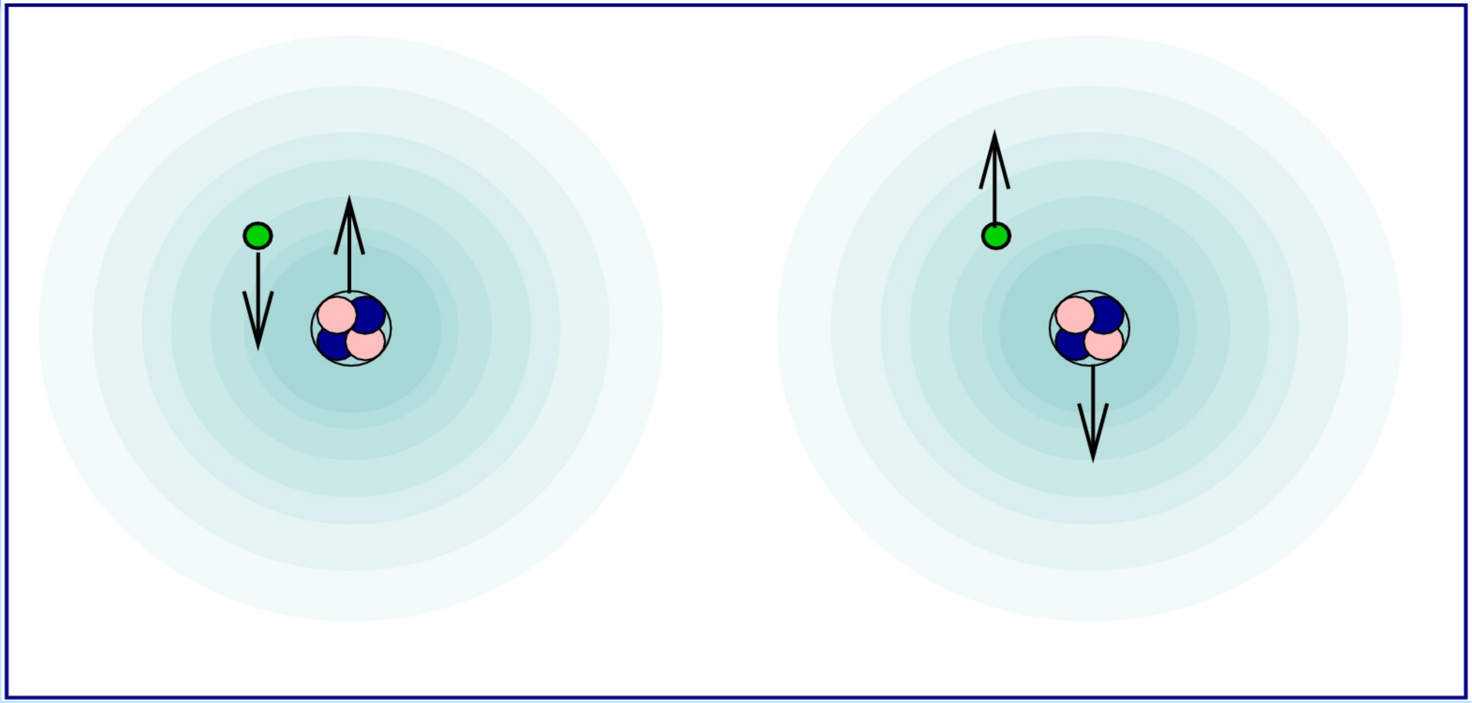
Historie atomových hodin

- 1937 přesné měření molekulárních frekvencí, I. Rabi
- 1949 molekulární hodiny na bázi plynného amoniaku H. Lyons
- 1951 první cesiové hodiny, NBS (NBS 1)
- 1953-1955 zdokonalený cesiový standard, N. Ramsey
- 1967 definice sekundy podle cesiových hodin
- 1985 první hodiny na bázi jontu v pasti NIST
- 1995 první atomové hodiny na bázi atomové fontány, Paříž



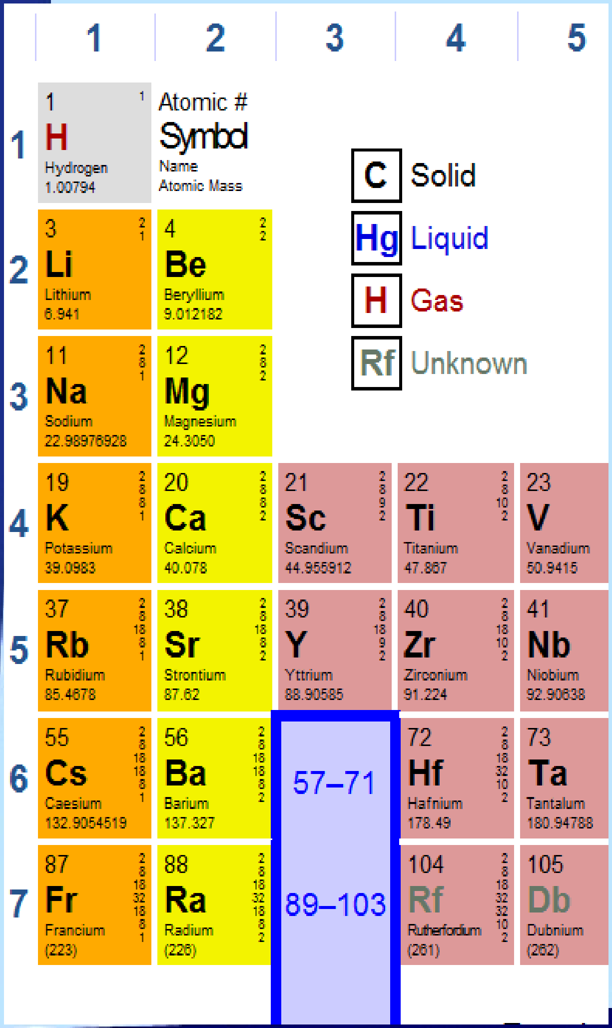


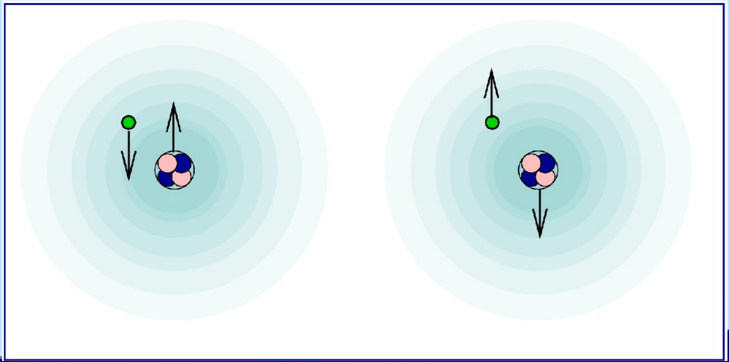
Atomové kmity



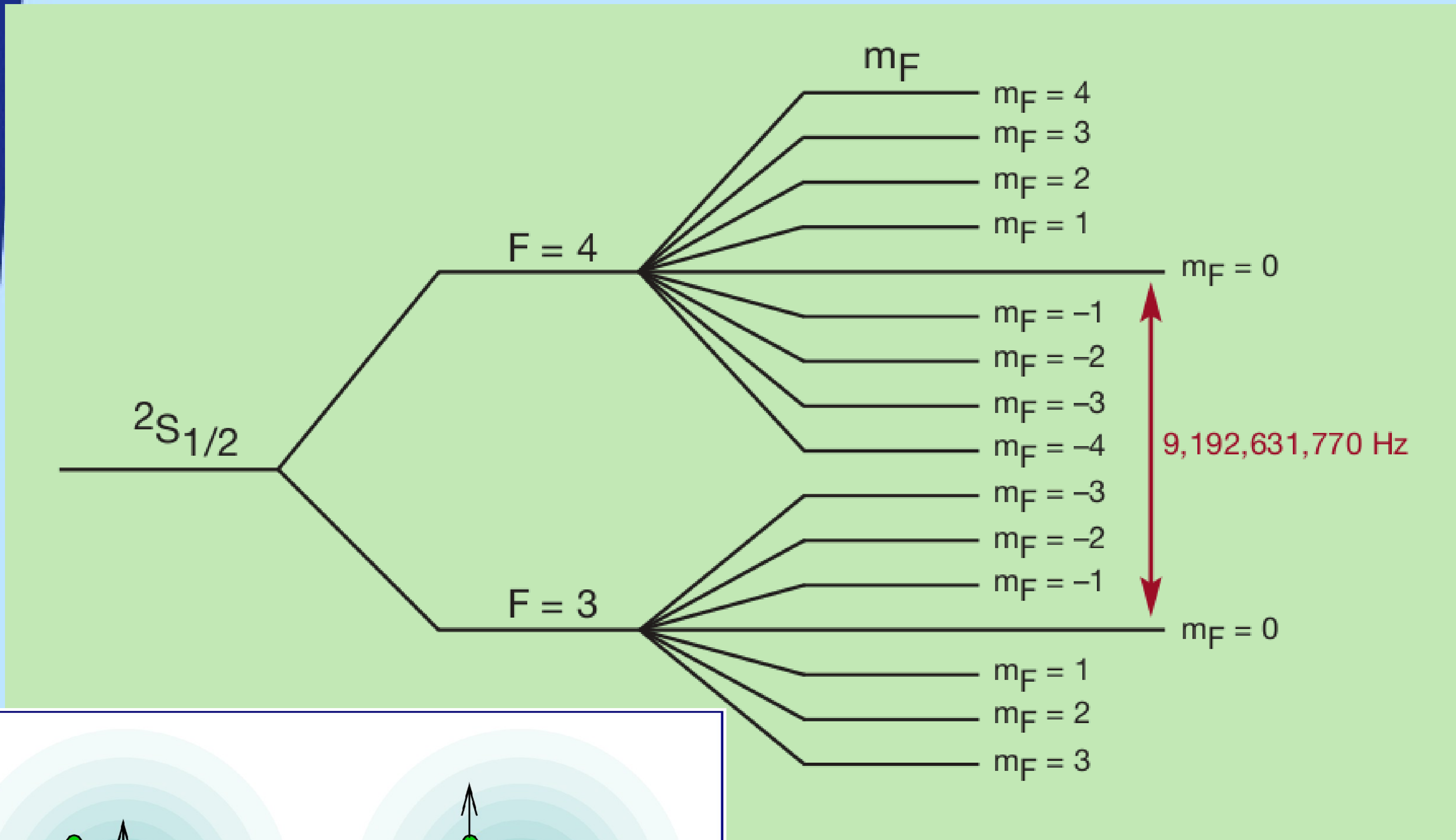
Cesium: definice sekundy

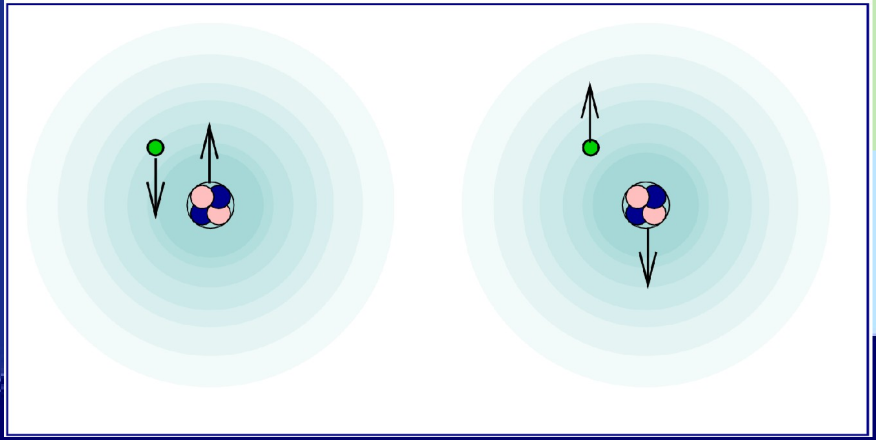
Frekvence hyperjemného přechodu Cs:
9 192 631 770 Hz
Definice metru: rychlost světla
c = 299 792 458 m/s

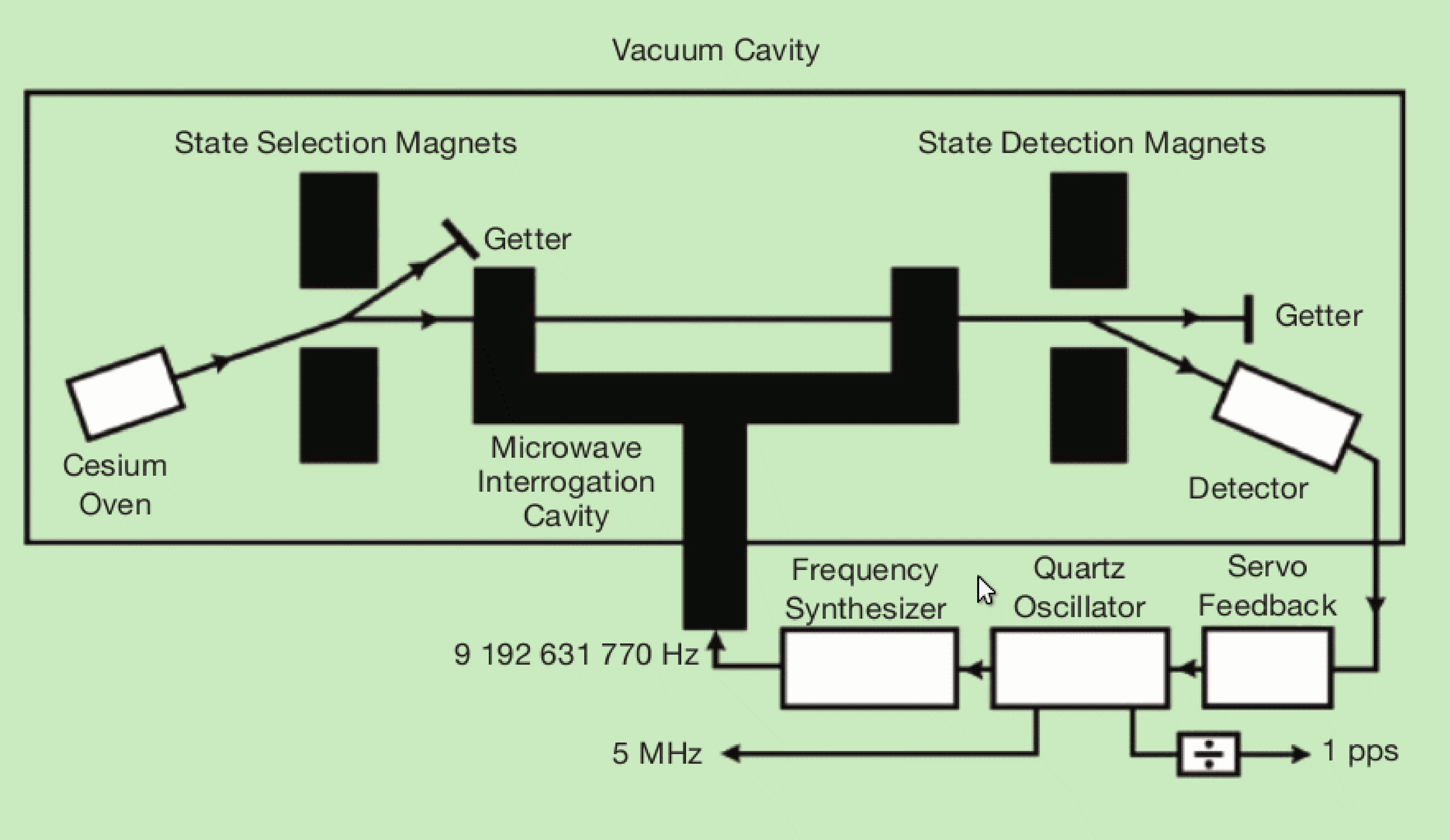




Cesium: definice sekundy, hyperjemná struktura



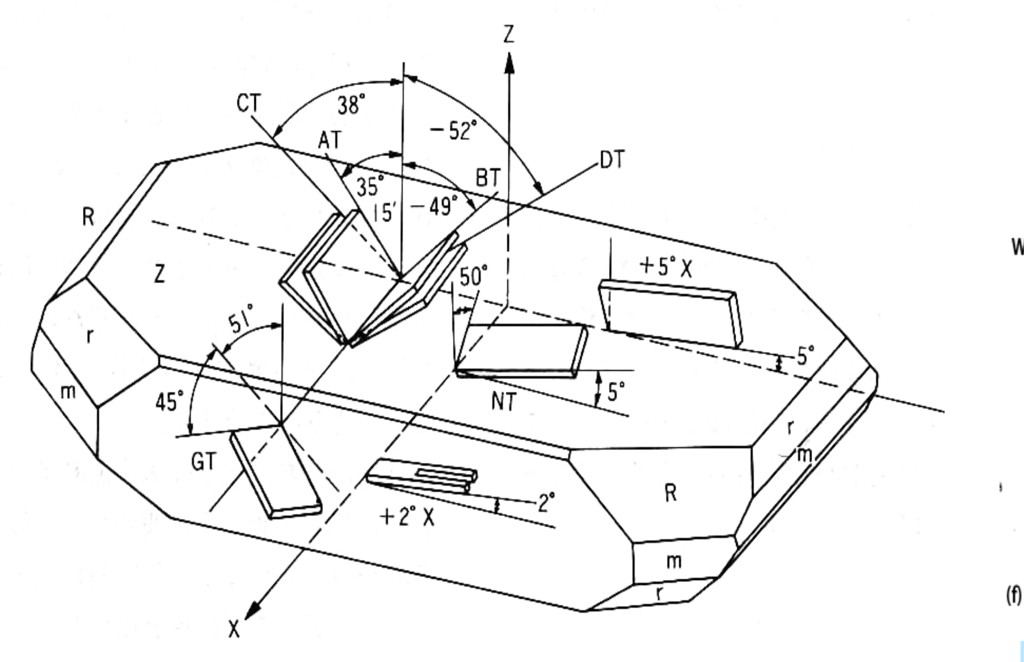


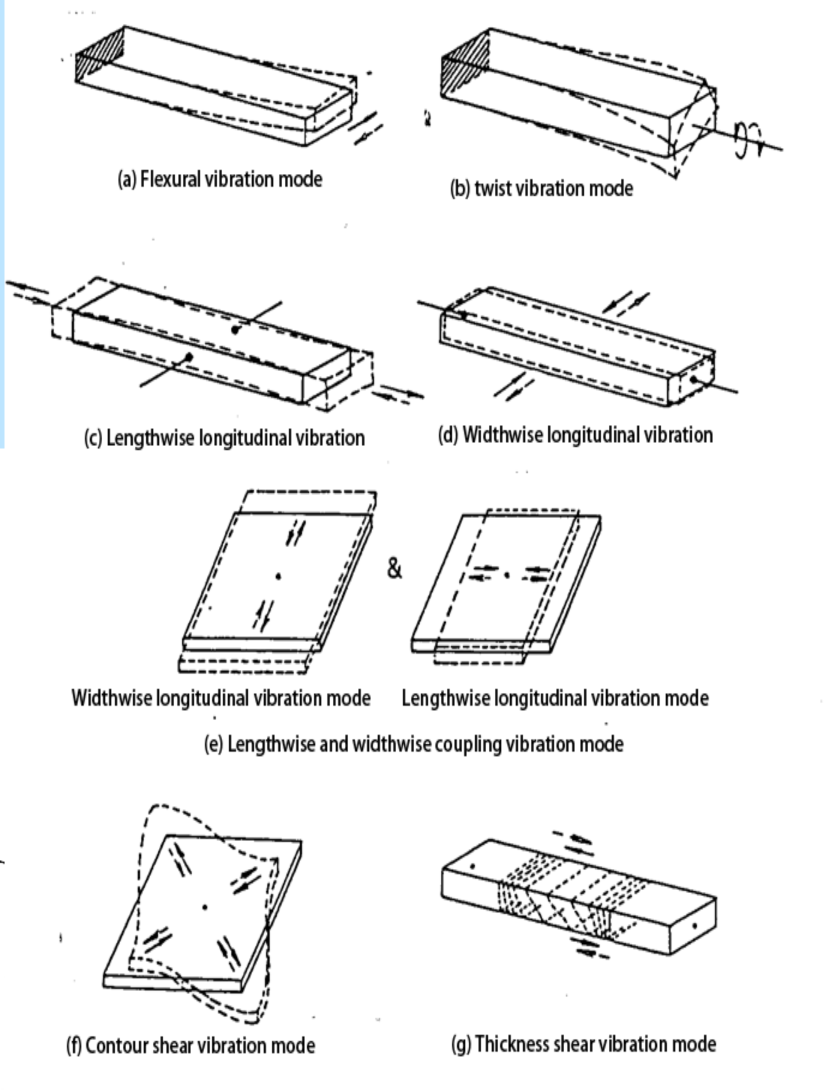


M.A. Lombardi & al. (NIST), Measure 2, 74 (2007).

Křemenný oscilátor

32 768 kHz



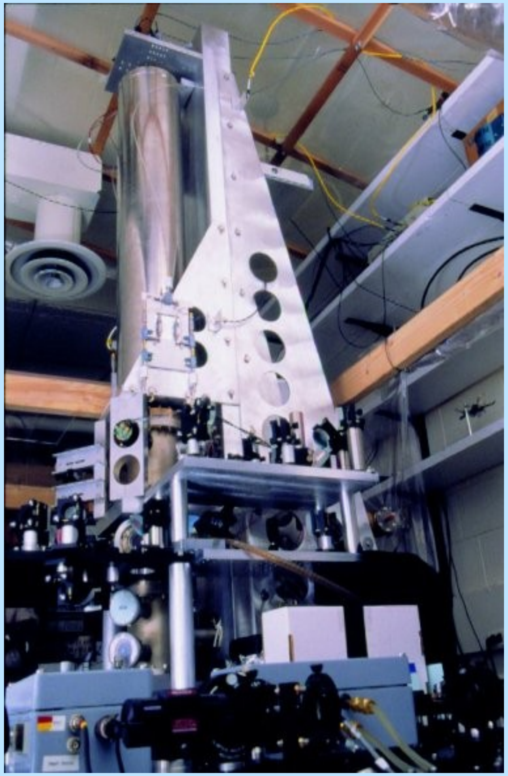


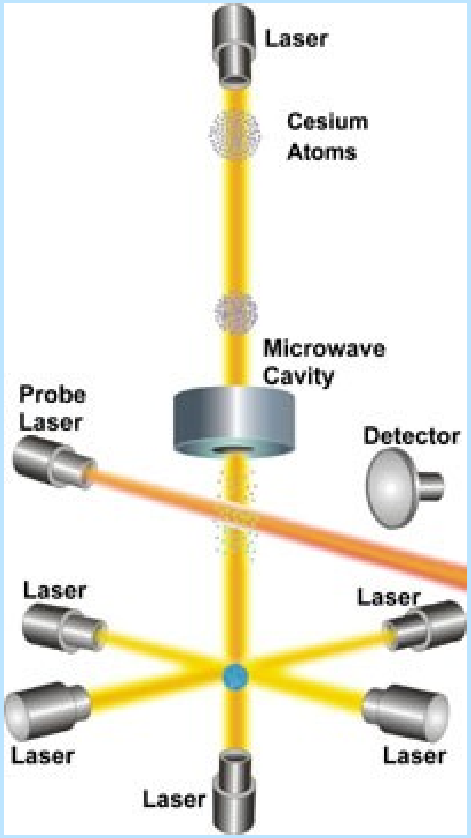
www.qiaj.jp/

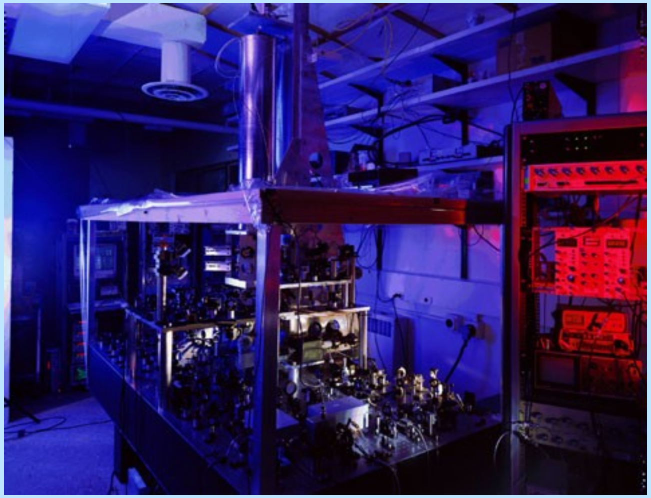
Cesiové atomové hodiny, NIST (Boulder, Colorado)

M.A. Lombardi & al. (NIST), Measure 2, 74 (2007).

Cesiové fontánové atomové hodiny, NIST



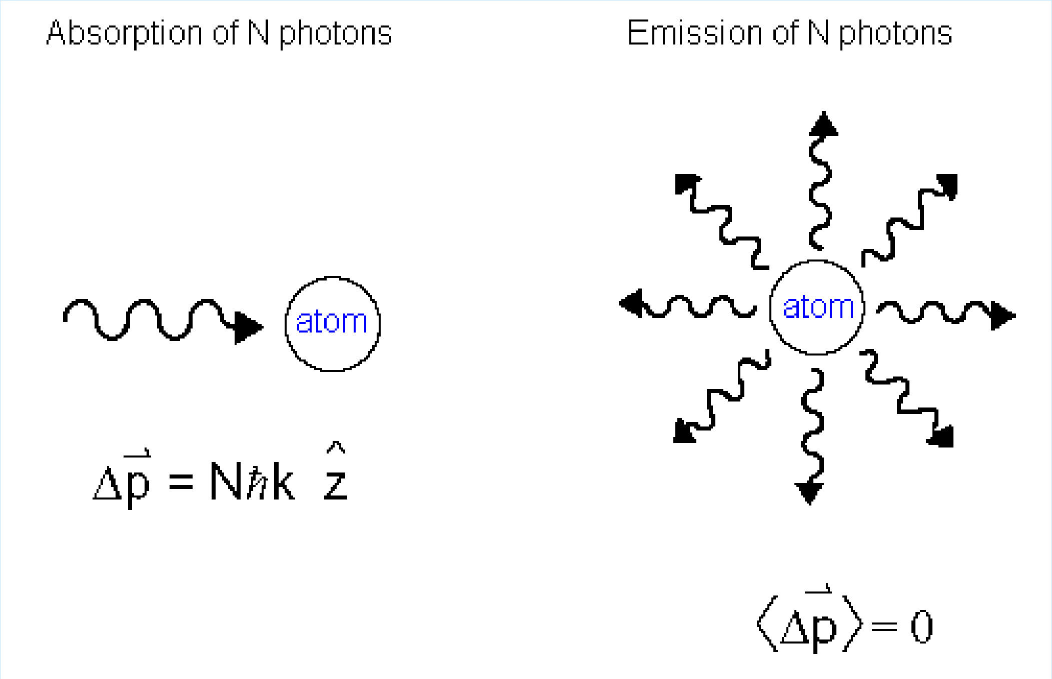




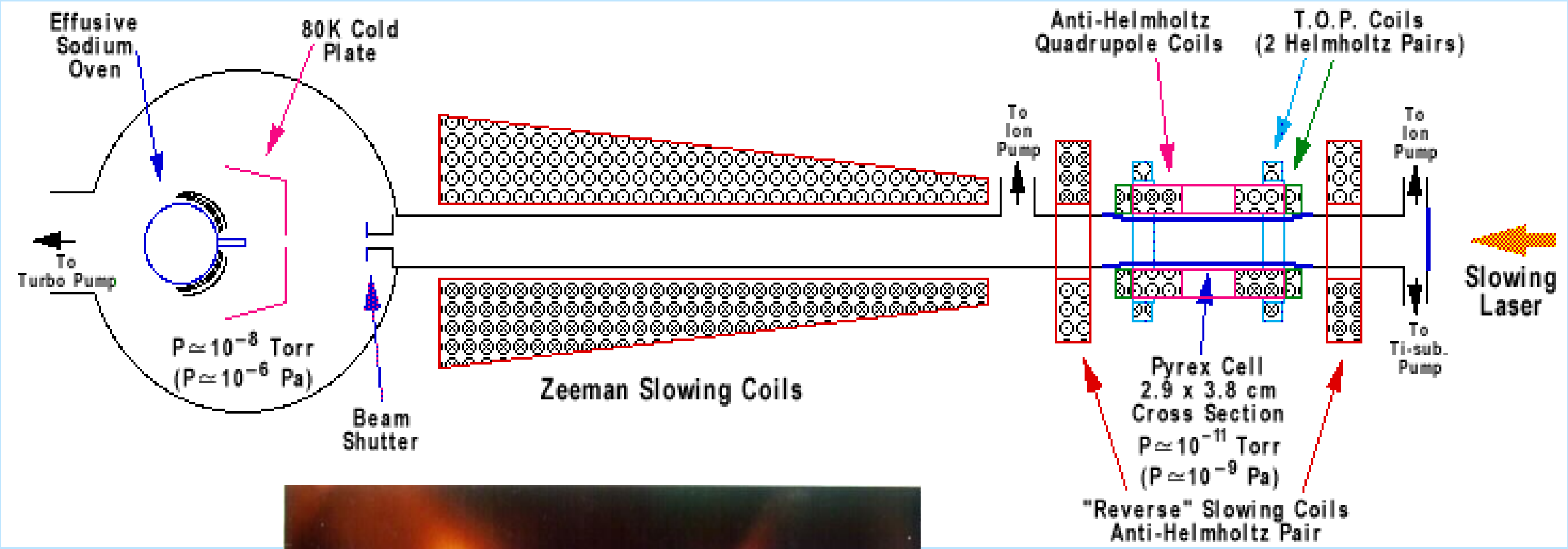
M.A. Lombardi & al. (NIST), Measure 2, 74 (2007), wikipedia

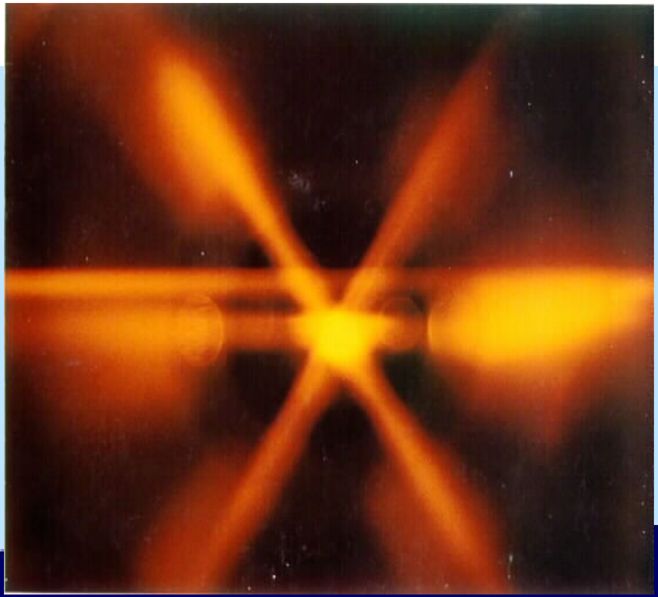
Laserové chlazení

Nobelova cena 1997: S. Chu, C. Cohen-Tannoudji, W. D. Phillips

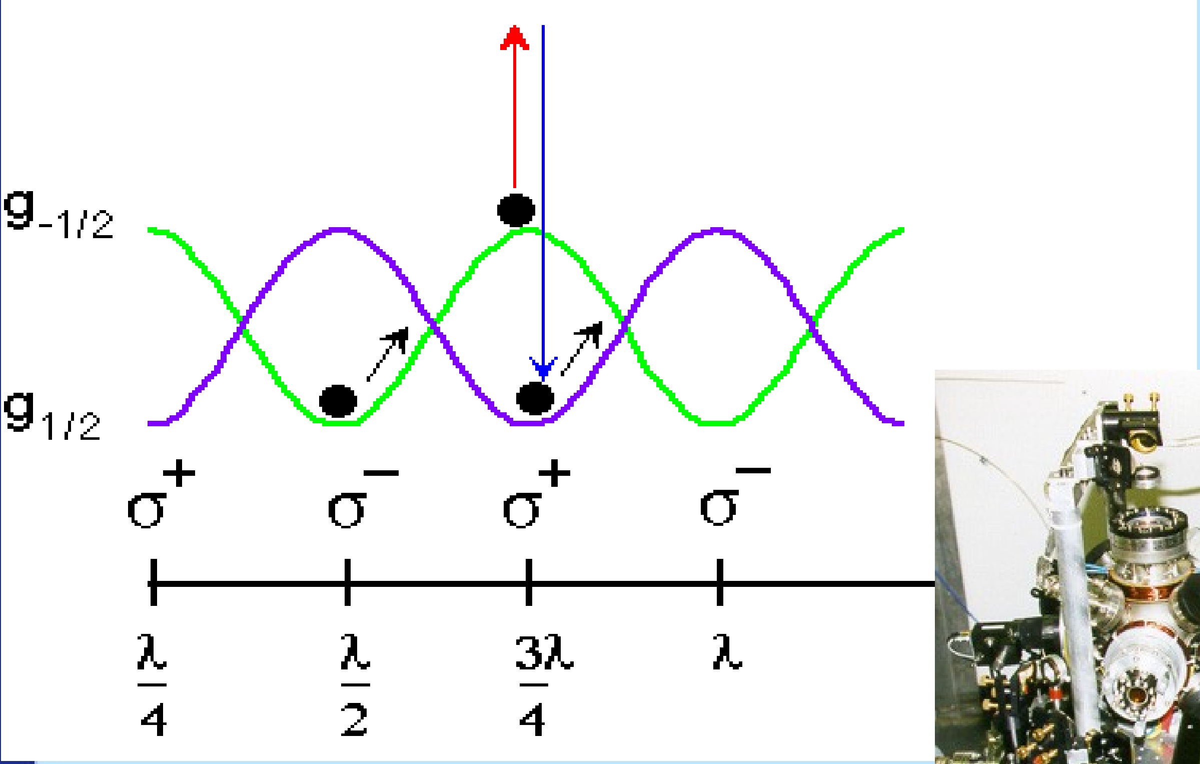


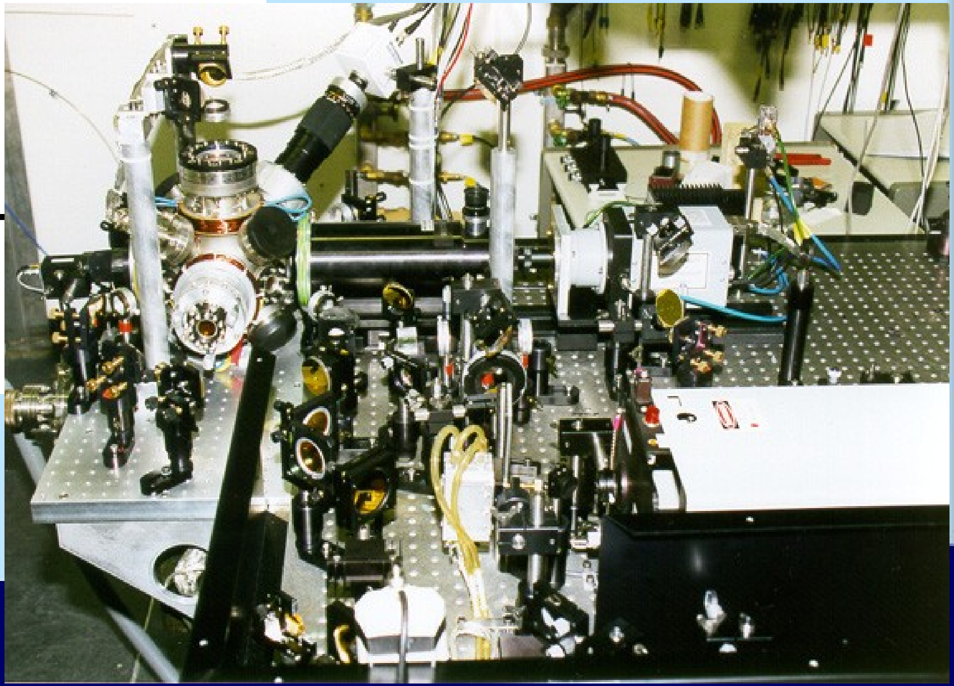
Laserové chlazení



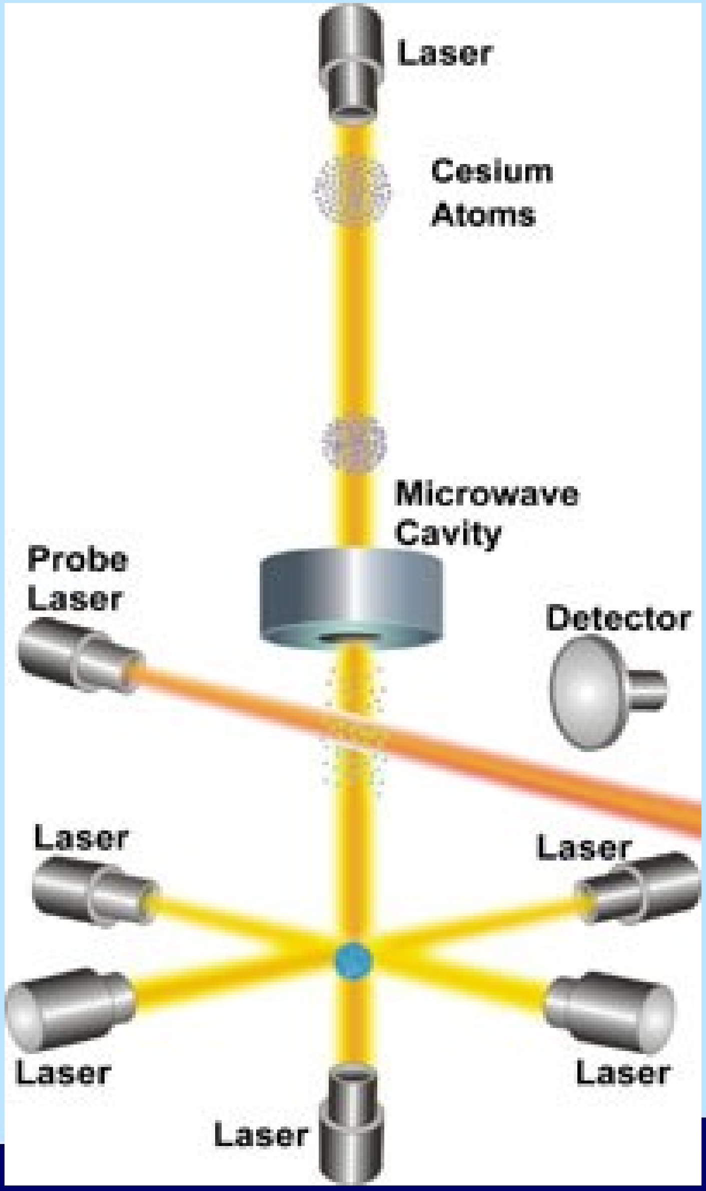


Laserové chlazení: Sisyfovská metoda

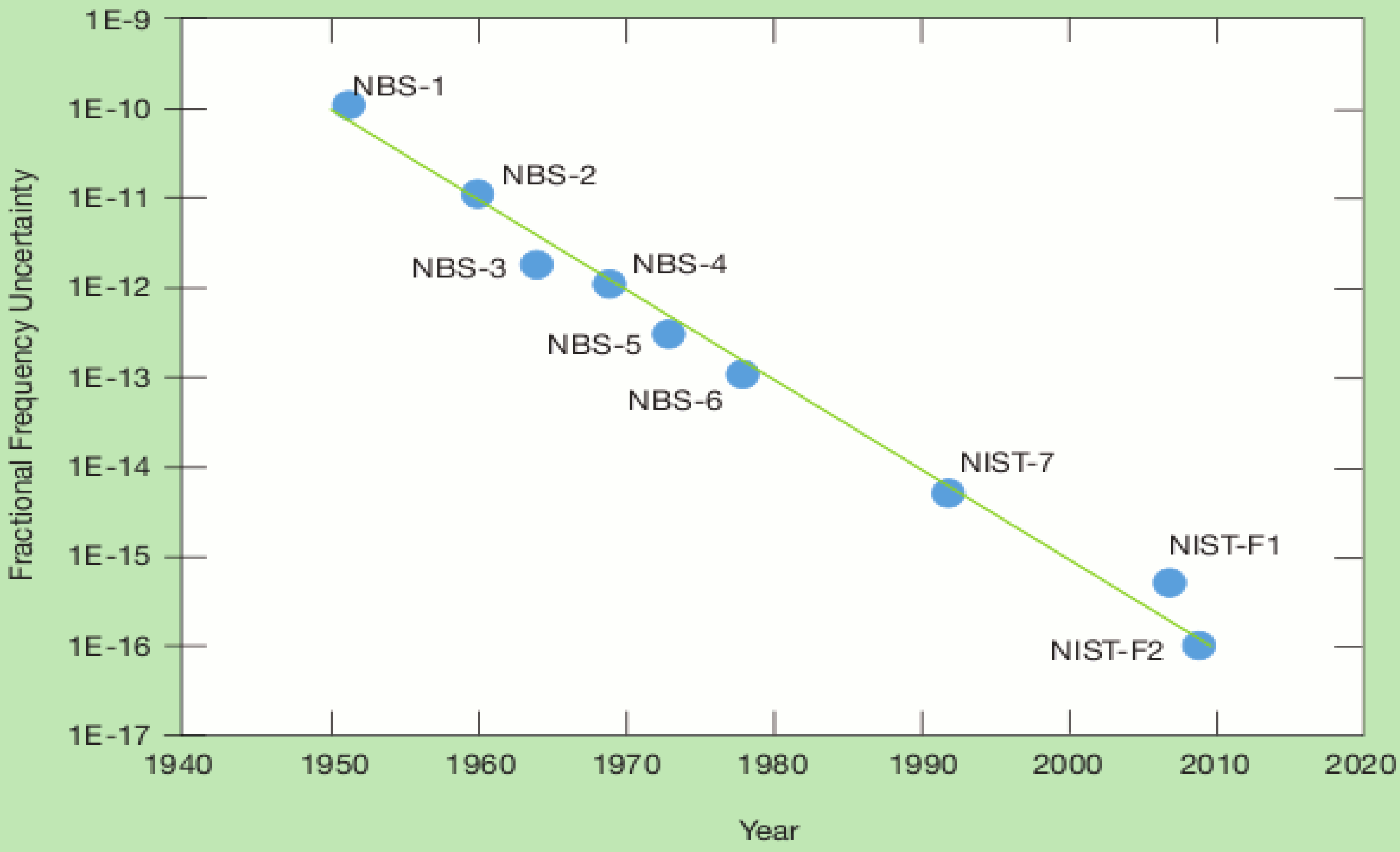




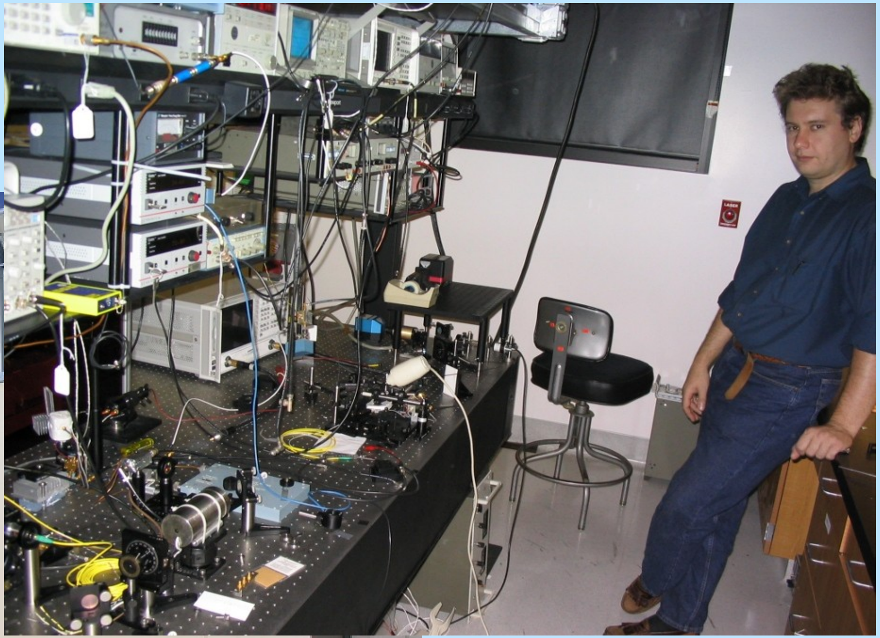
Fontánové atomové hodiny (NIST)



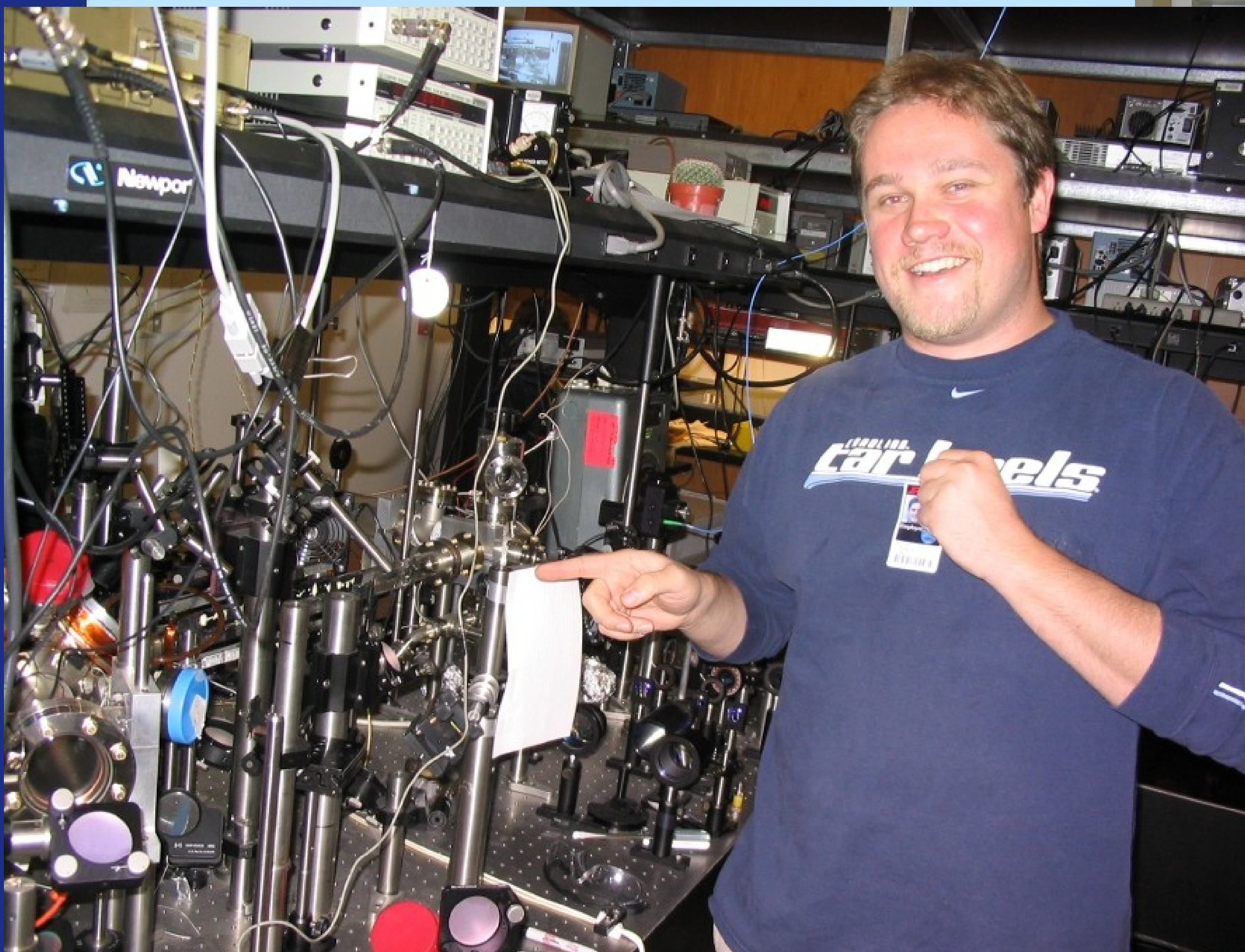
Přesnost atomových hodin



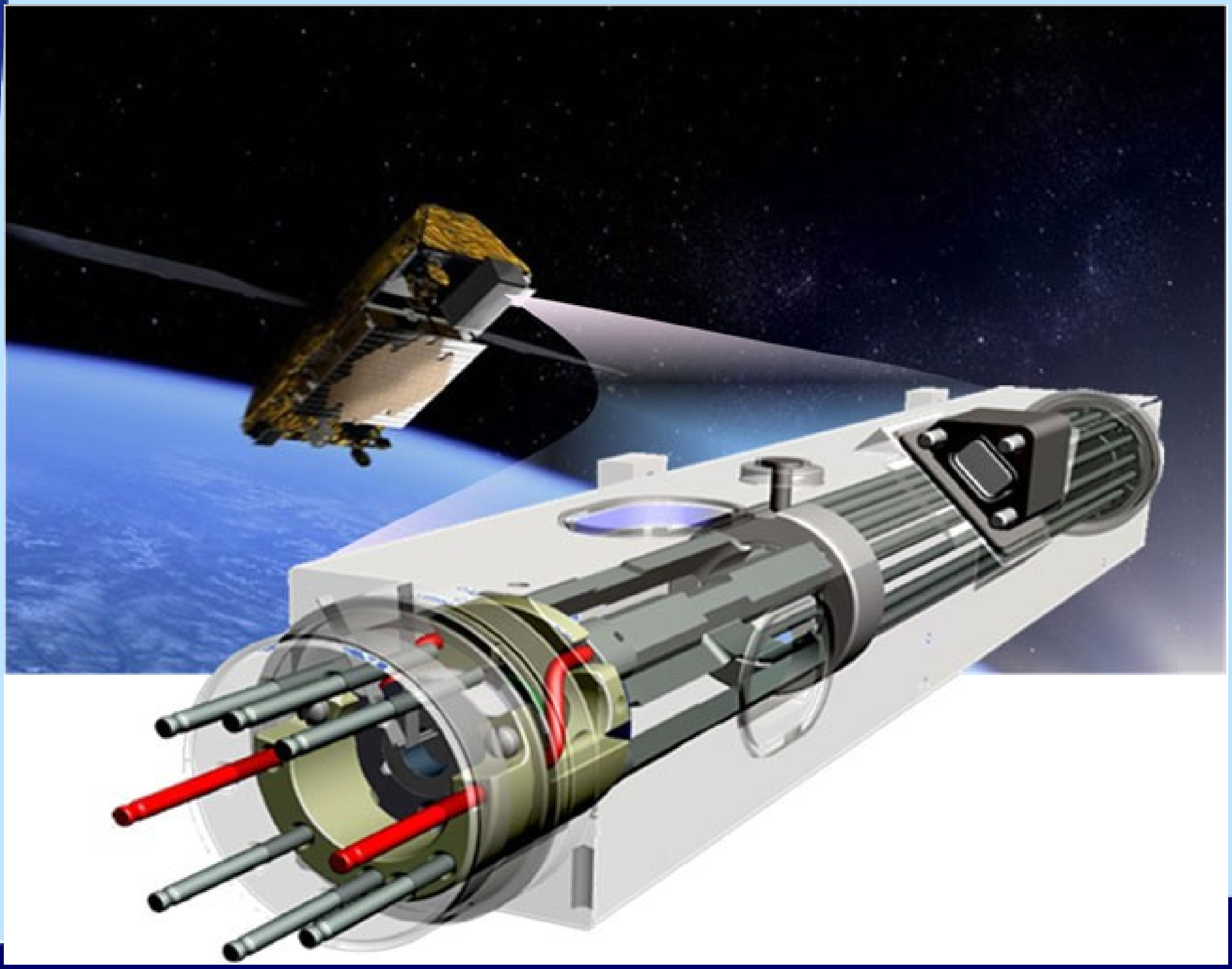
Atomové hodiny a frekvenční standardy v JPL



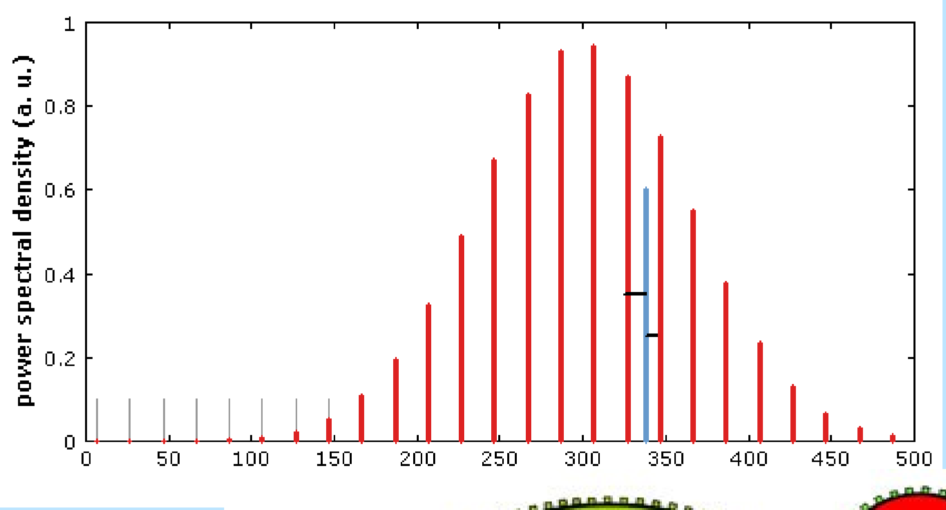
Atomové hodiny a frekvenční standardy v JPL



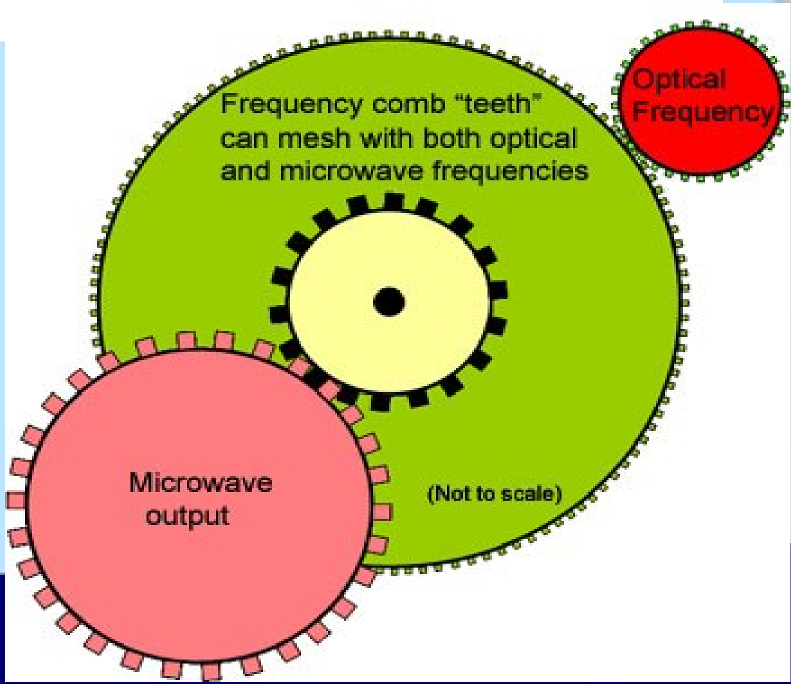
Atomové hodiny a frekvenční standardy v JPL
DSAC (Deep Space Atomic Clock, plán pro 2015)



Optické metody zpřesňování atomových hodin: frekvenční hřeben (frequency comb)



T. Haensch, Nobelova cena 2005



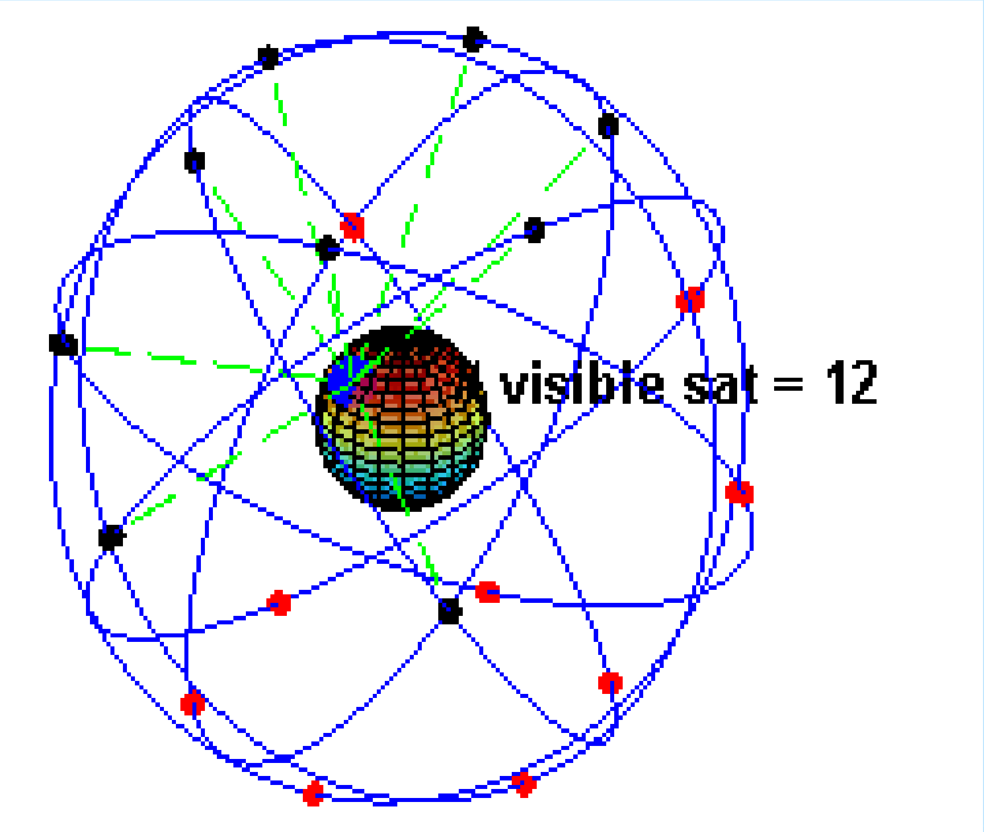
Physikalisch-Technische Bundesanstalt, Braunschweig

„Rádiové hodiny“
Zákon o určení času (SRN 1978)
informaci šíří vysílač v Mainflingen
u Frankfurtu
dlouhé vlny DCF77 (77,5 kHz)
dosah cca 2000 km

GPS: Global positioning system

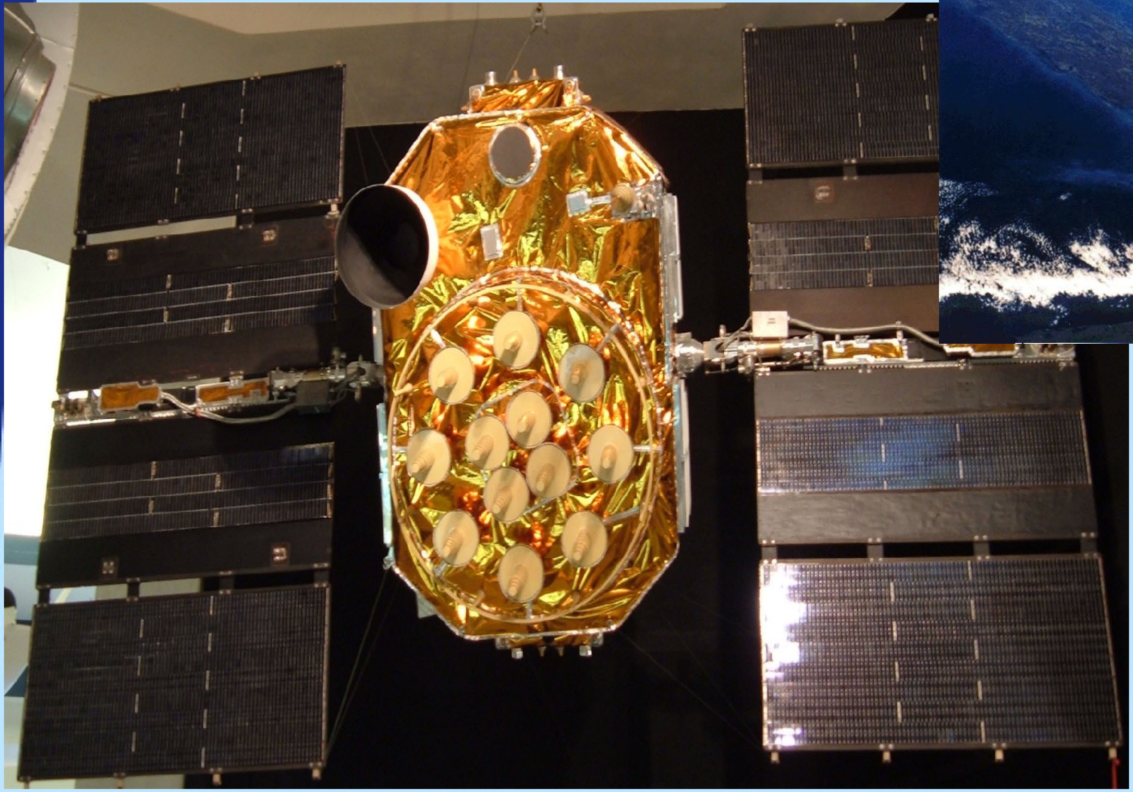
20,200 km výška,
26,600 km poloměr dráhy
31 vysílajících satelitů

L1 … 1575.42 MHz
L2 … 1227.60 MHz



http://en.wikipedia.org/wiki/GPS

GPS



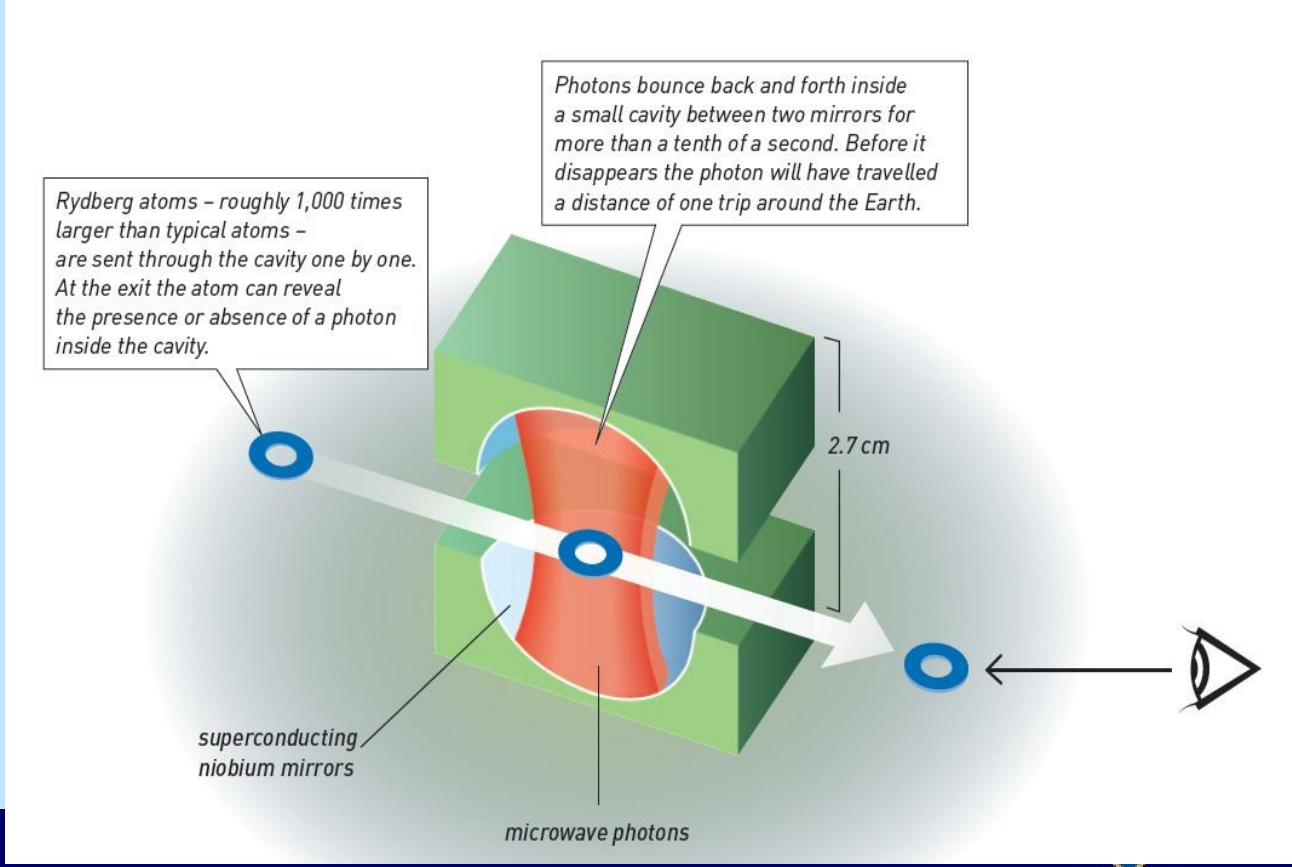
http://en.wikipedia.org/wiki/GPS

Aplikace přesné časomíry

- Přesné určování polohy – navigace, doprava, zemědělství
- Astronomická měření – interferometrické získávání informace o vzdálených objektech
- Testování teorie relativity
- Testování dalších teorií – jsou fyzikální konstanty opravdu konstantní?

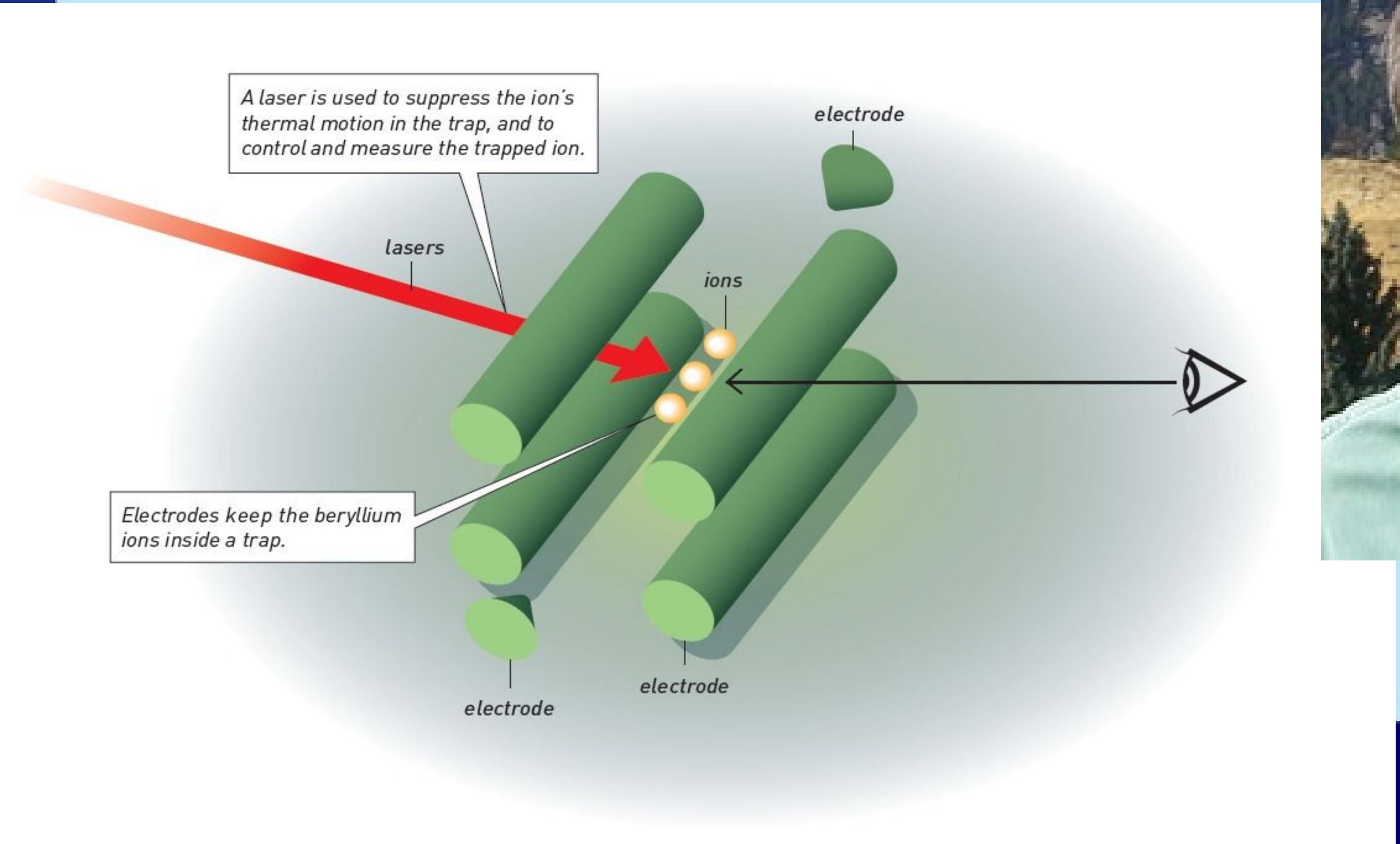
Nobelova cena za fyziku 2012

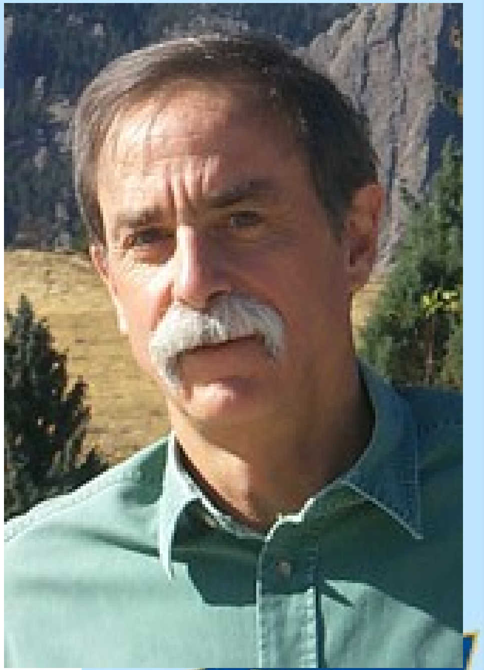
Serge Haroche a David Wineland
„za průlomové experimenty umožňující měření a manipulaci s jednotlivými kvantovými systémy“



Nobelova cena za fyziku 2012

Serge Haroche a David Wineland
„za průlomové experimenty umožňující měření a manipulaci s jednotlivými kvantovými systémy“





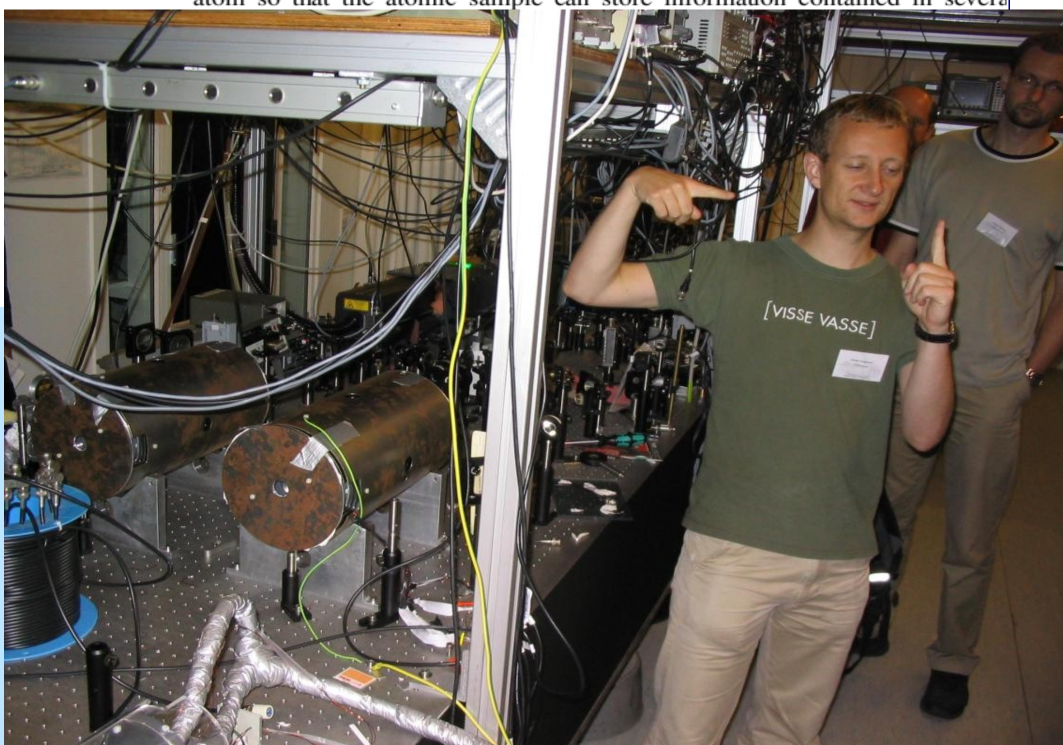
Kvantová informatika: kvantová paměť pro světlo

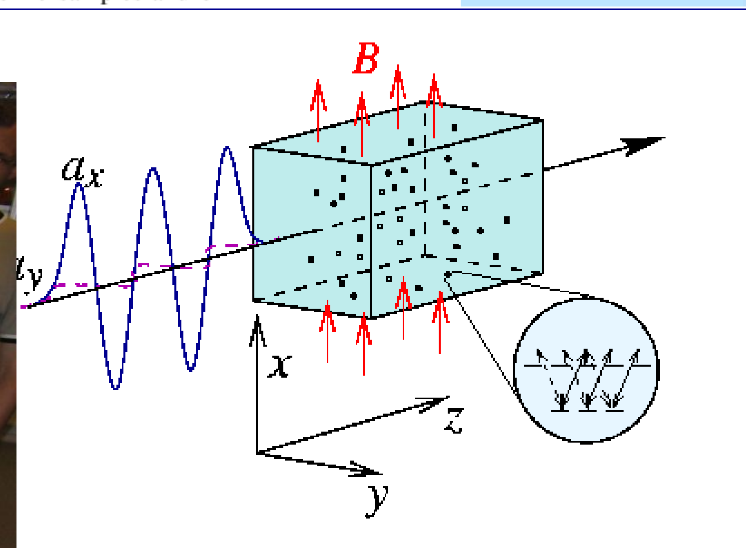
PRL **95,** 053602 (2005) PHYSICAL REVIEW LETTERS week ending 29 JULY 2005

Enhancing the Capacity and Performance of Collective Atomic Quantum Memory

Tomáš Opatrný[1] and Jaromír Fiurášek[2]
[1]*Department of Theoretical Physics, Palacký University, 17. listopadu 50, 77200 Olomouc, Czech Republic*
[2]*Department of Optics, Palacký University, 17. listopadu 50, 77200 Olomouc, Czech Republic*
(Received 22 February 2005; published 28 July 2005)

Present schemes involving the quantum nondemolition interaction between atomic samples and off-resonant light pulses allow us to store quantum information corresponding to a
(mode) in one multiatomic system. We discuss the possibility of involving
atom so that the atomic sample can store information contained in severa





Kvantová informatika: stlačení atomových stavů

PHYSICAL REVIEW A **86**, 023845 (2012)

Spin squeezing and Schrödinger-cat-state generation in atomic samples with Rydberg blockade

Tomáš Opatrný[1] and Klaus Mølmer[2]

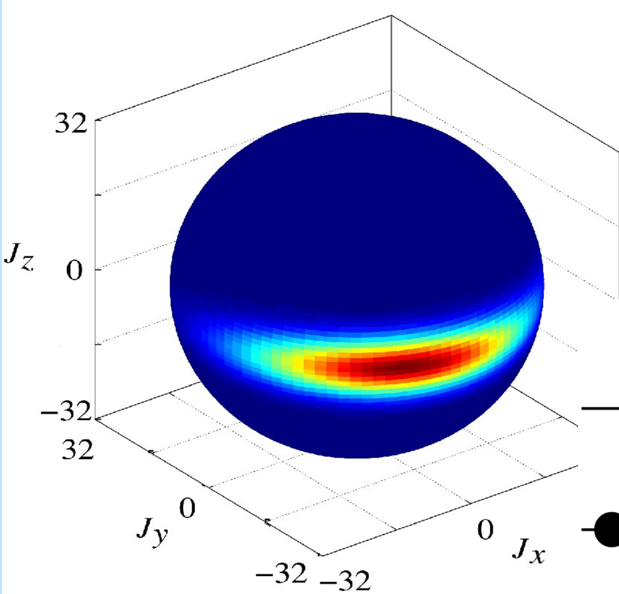
[1]*Department of Optics, Faculty of Science, Palacký University, 17. listopadu 12, 77146 Olomouc, Czech Republic*

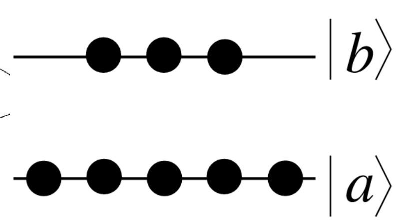
[2]*Lundbeck Foundation Theoretical Center for Quantum System Research, Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus C, Denmark*

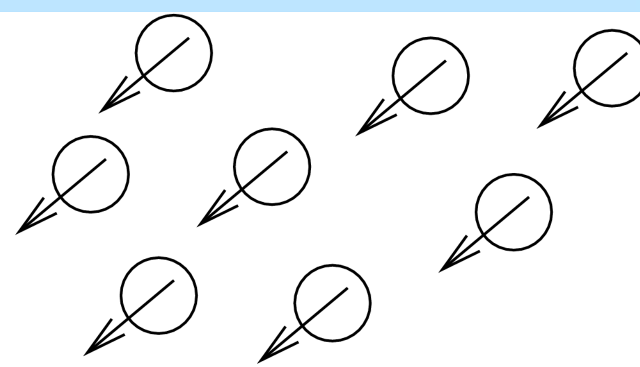
(Received 31 May 2012; published 27 August 2012)

A scheme is proposed to prepare squeezed states and Schrödinger-cat-like states of the collective spin degrees of freedom associated with a pair of ground states in an atomic ensemble. The scheme uses an effective Jaynes-Cummings interaction which can be provided by excitation of the atoms to Rydberg states and an effective J_x interaction implemented by a resonant Raman coupling between the atomic ground states. Dynamical evolution both with a constant Hamiltonian and with adiabatic variation of the two interaction terms is studied. We show that by the application of further resonant laser fields, we can suppress nonadiabatic transfer under the time-varying
: evolution towards a maximally squeezed, $J_z = 0$, collective spin state.

PACS number(s): 42.50.Dv, 37.10.Gh, 03.75.Nt, 37.25.+k







Kvantová informatika v Olomouci

Děkuji za pozornost