The unit of time and the International System of Units

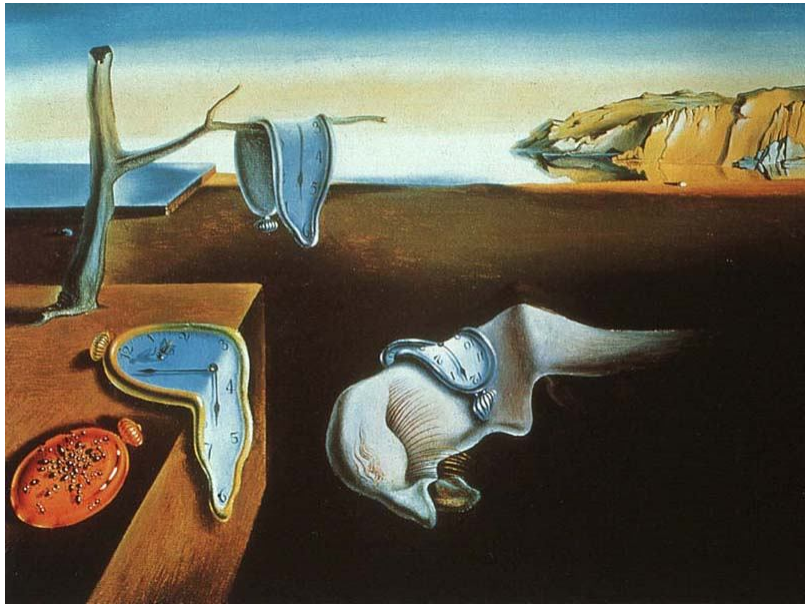
Mauricio López R.

Centro Nacional de Metrología
CENAM

The unit of time and the

International System if units

Out line



La persistencia de la memoria, Salvador Dalí, 1931

0. Introduction

1. The unit of time

2. The SI and the second

3. Frequency combs

4. Optical clocks

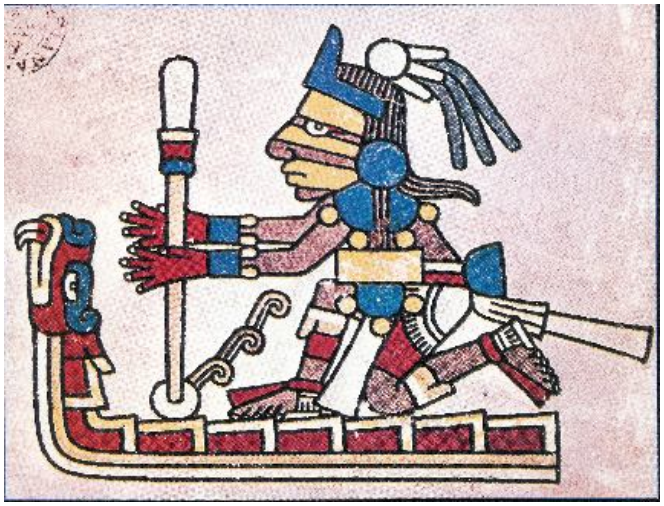
The unit of time and the

International System if units

0. Introduction

The unit of time and the

International System if units



The “new fire” icon

The unit of time and the

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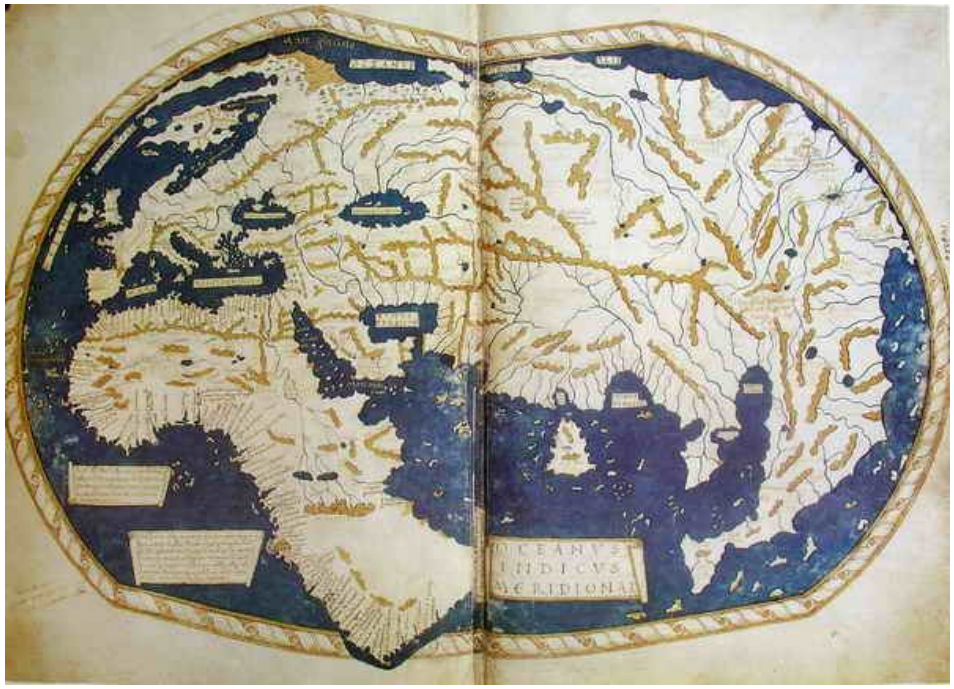
The world and the clocks

Harrison clock, 1736



Mapa de Henricus Martellus, latinizado de Heinrich Hammer Florencia (1489) Coloreado sobre papel, 300 x 470 mm.Fº 68 vº y 69 rº del Add. Ms. 15760 British Library, Londres

The unit of time and the

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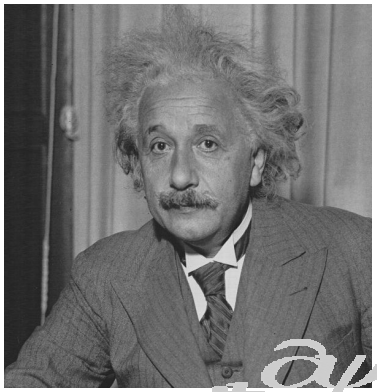
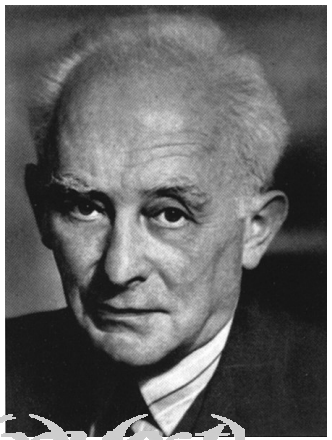
Albert Einstein



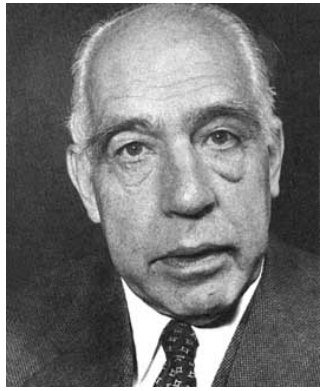
Max Born



$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial\psi}{\partial x^2} + V(x)\psi(x,t)$$

Erwin Schrödinger

Niels Bohr



The Quantum Mechanics the tool to built atomic clocks

The unit of time and the

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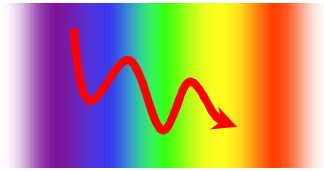
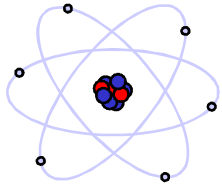
Light-matter interaction in the heart of the atomic clocks



Electromagnetism / Optics



Atomic Physics

The unit of time and the

International System if units

El principio para usar transiciones atómicas como referencias para construir patrones de frecuencia fue propuesto por primera vez por I. Isaac Rabi de la Universidad de Columbia en los años 1930s

I. Isaac Rabi

The Nobel Prize in Physics 1944

The unit of time and the

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La invención del método de los campos oscilantes separados y su aplicación en los relojes atómicos

Norman F. Ramsey

The Nobel Prize in Physics 1989

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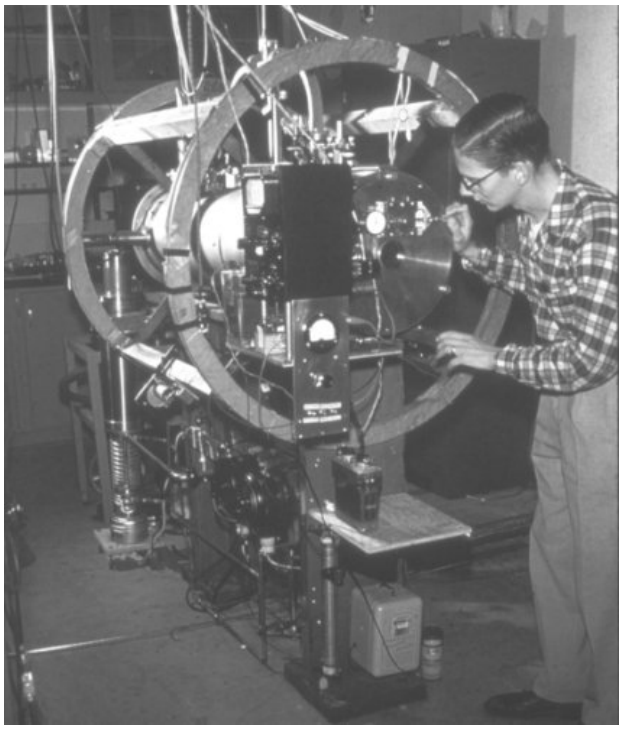
International System if units



NBS-1, 1952

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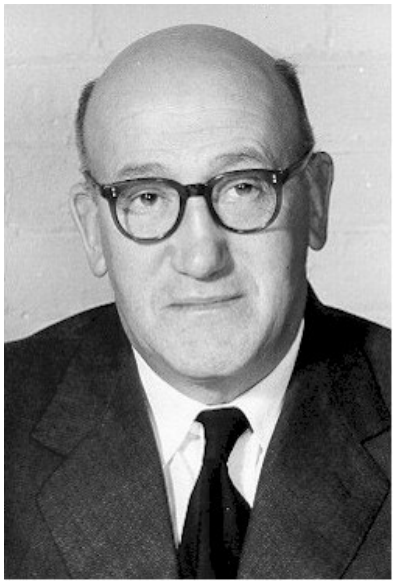
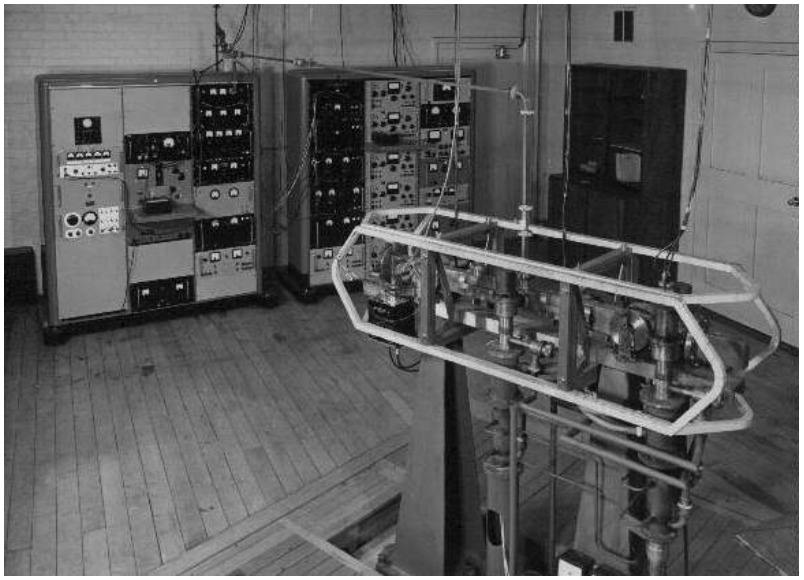
International System if units



Louis Essen



Caesium I, 1955 (NPL)

from one second in 300 years to about one second in 2000 years

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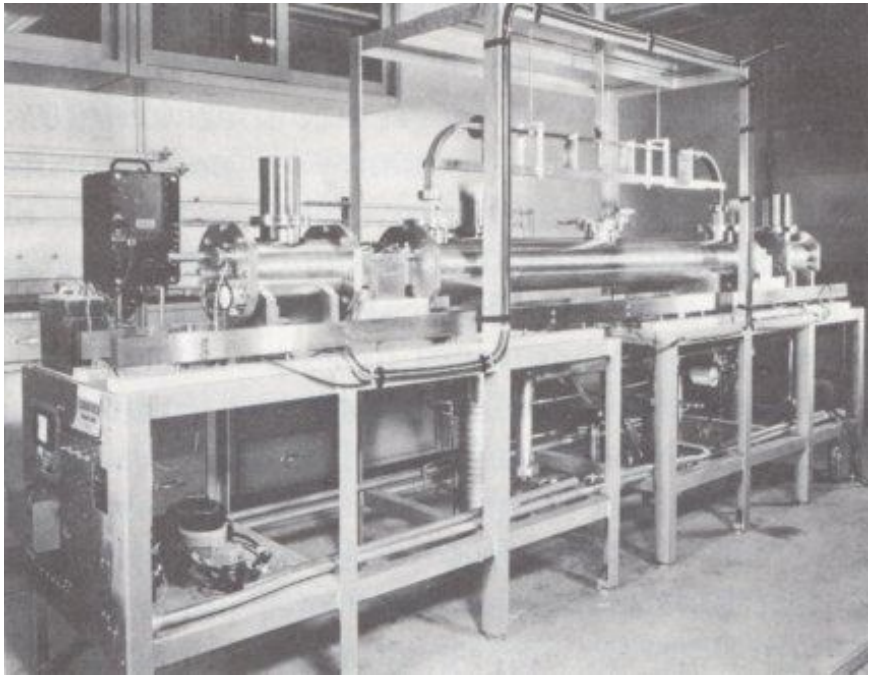

NBS-2, 1960

The unit of time and the

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Atomichron (Atomic-Cesium) Clock, 1960
National Company, Inc
Malden, Massachusetts
USD 20,000

1. The unit of time

The unit of time and the

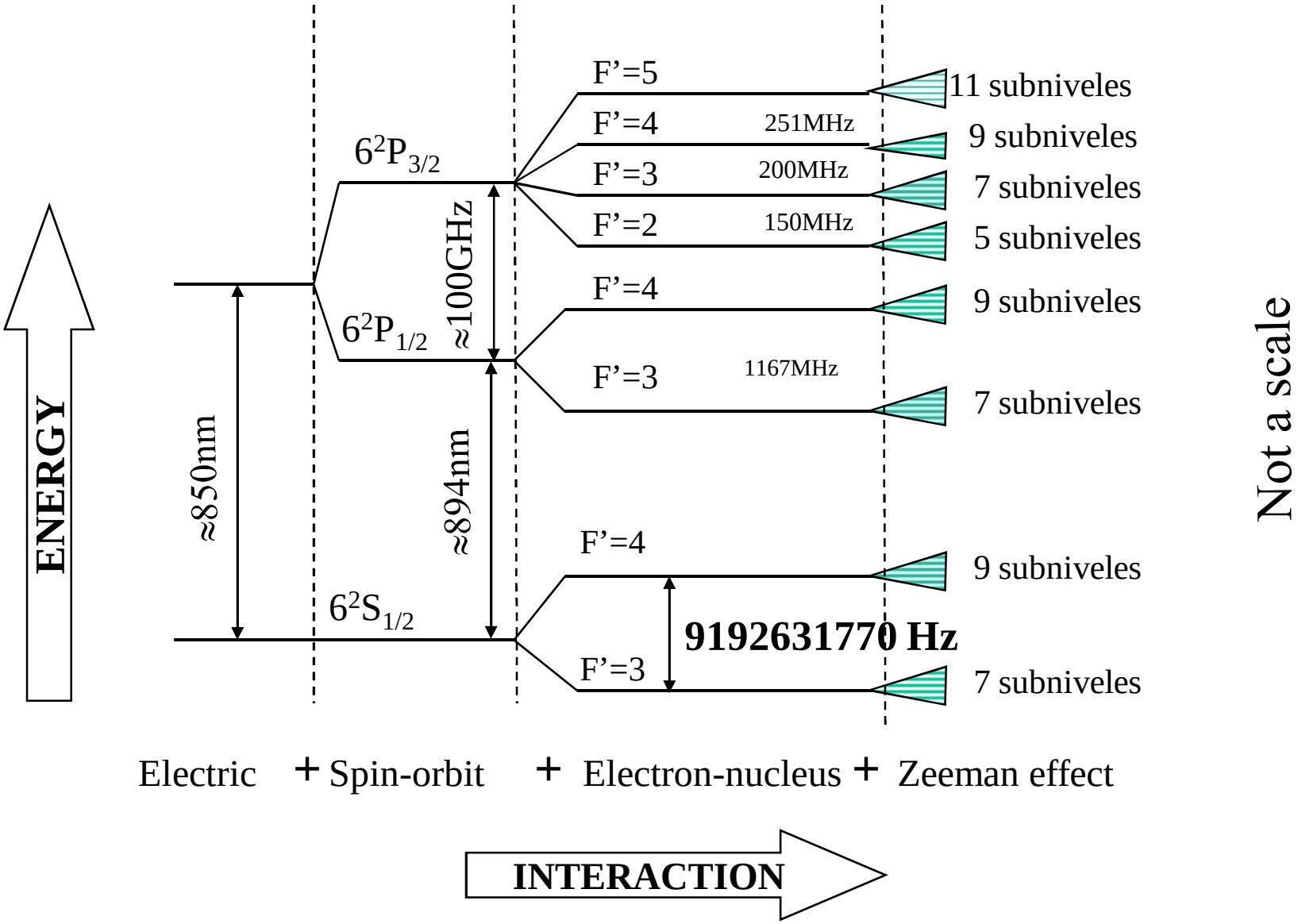
International System if units

Definition

The SI unit of time is the second defined as follows:

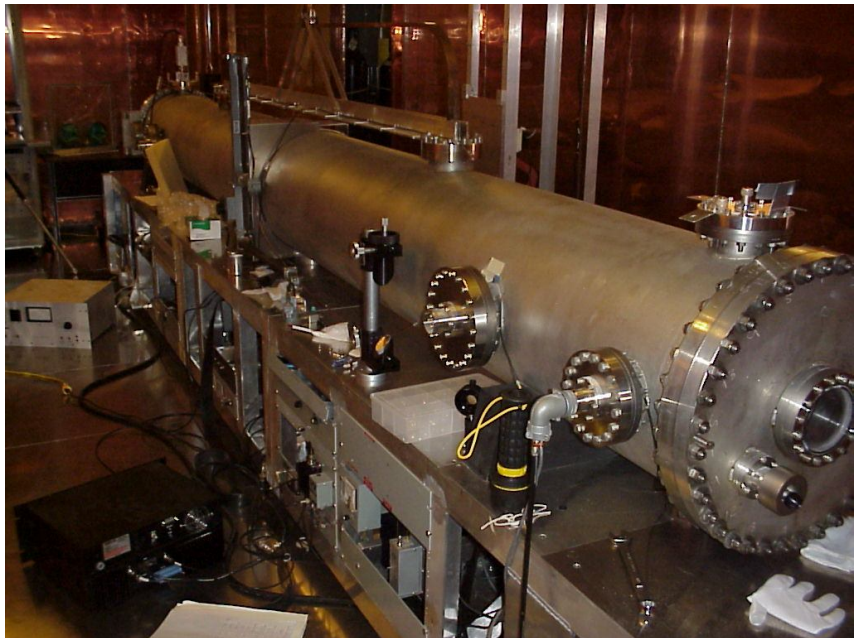
"The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom";

First energy levels of the Cesio-133 atom



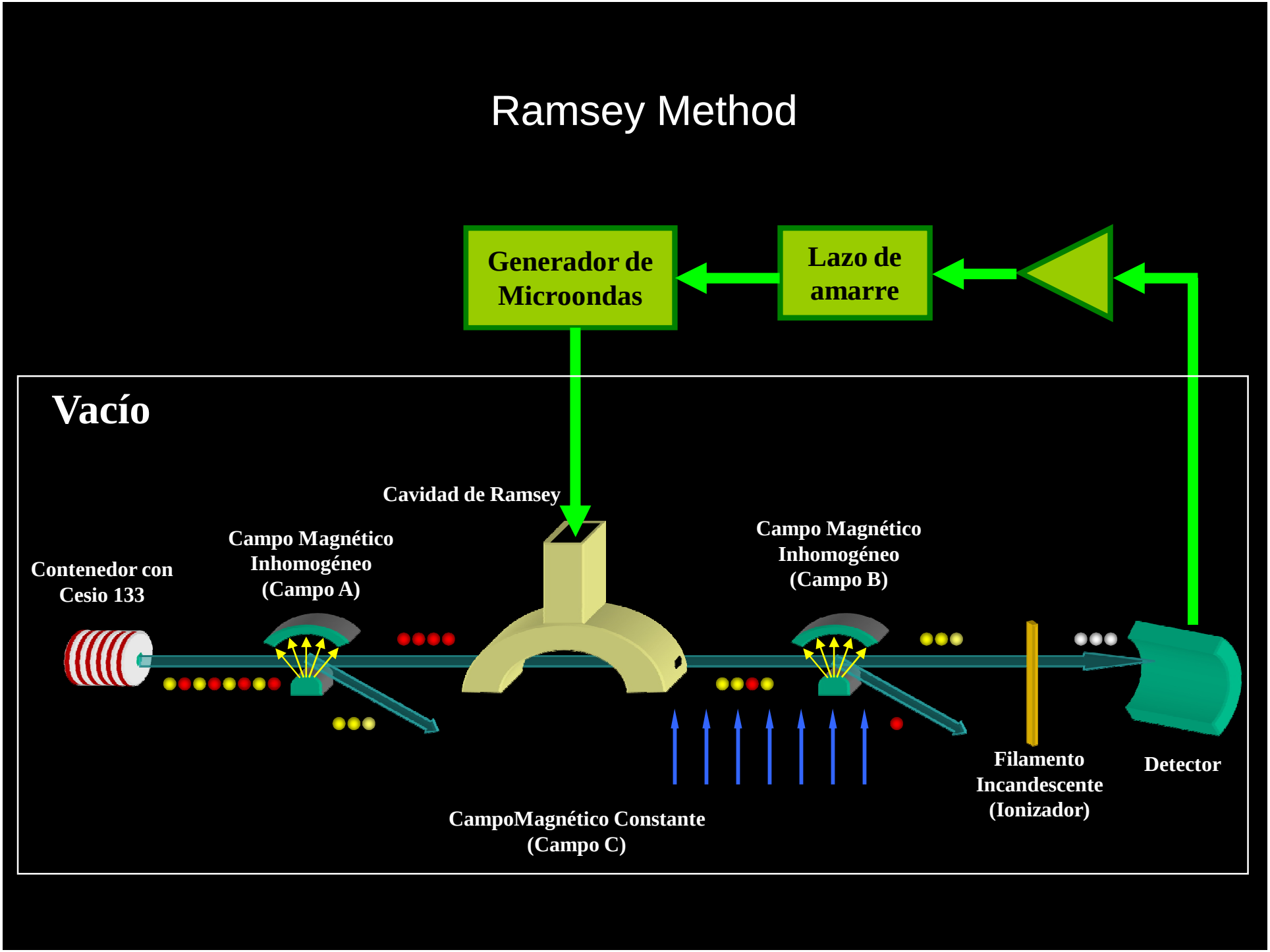
The unit of time and the

International System if units



CsV, NRC

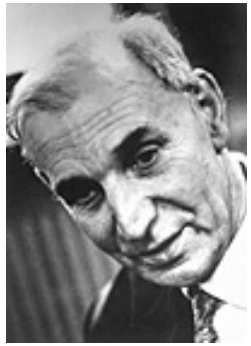
Ramsey Method



The unit of time and the

International System if units

Descubrimiento y desarrollo de métodos ópticos
para el estudio de resonancias de radio en átomos



Alfred Kastler

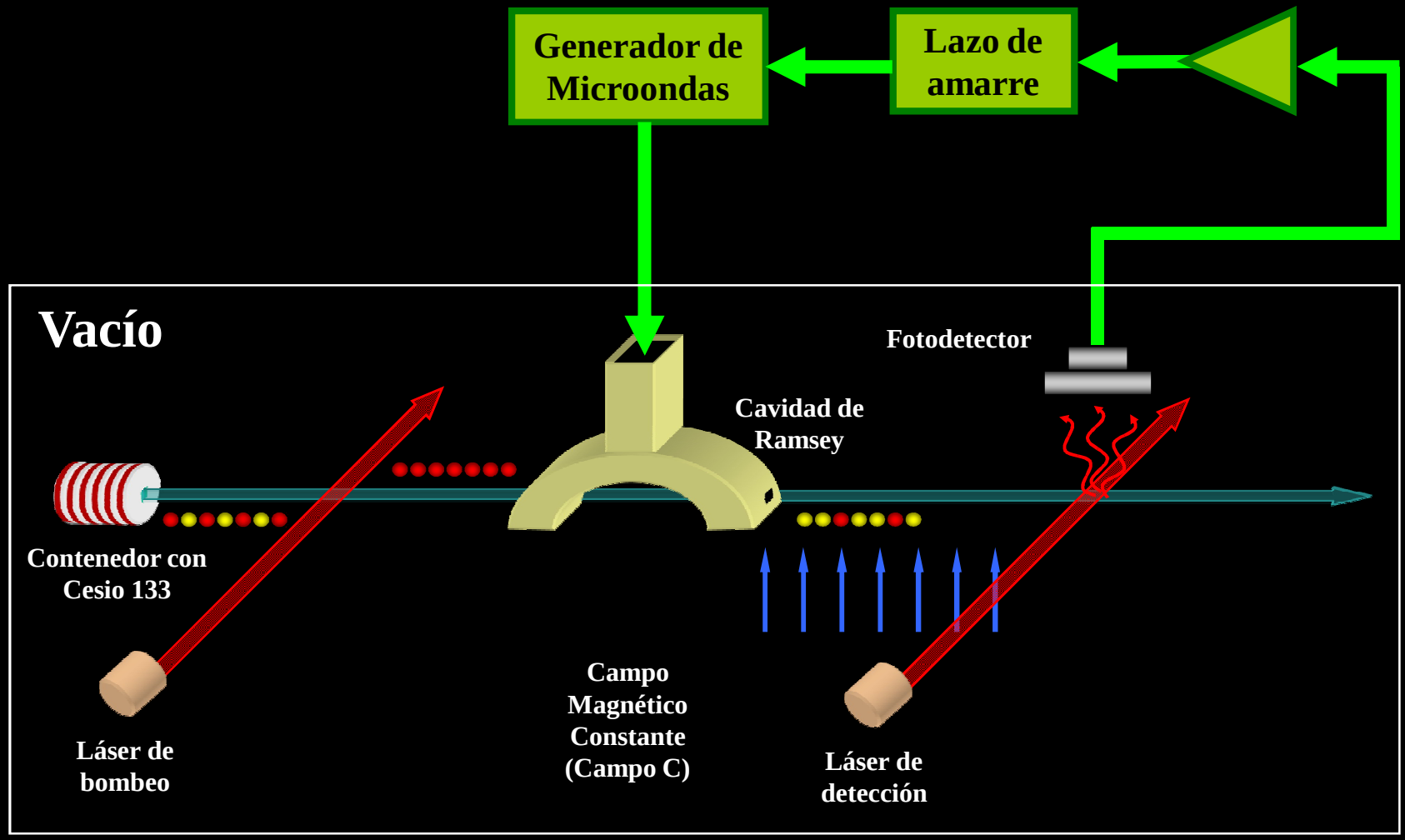
France

École Normale Supérieure, Université de Paris
Paris, France

b.1902
d.1984

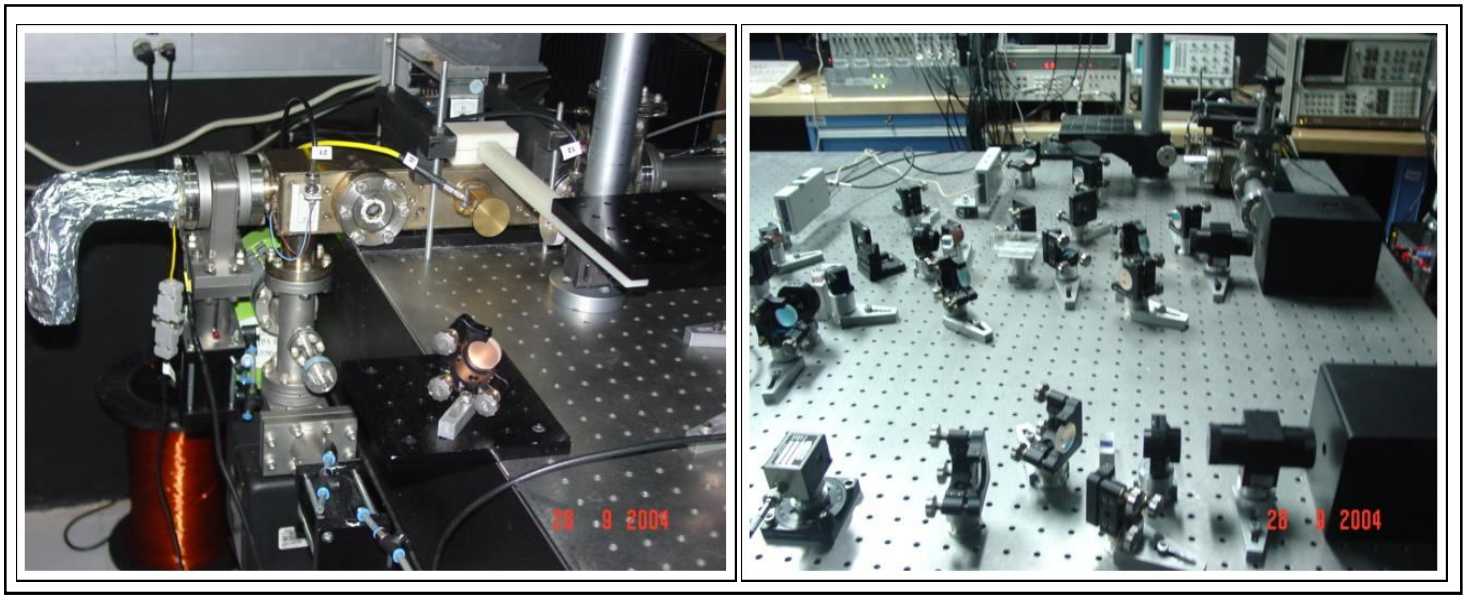
The Nobel Prize in Physics 1966

Ramsey method + optical pumping



The unit of time and the

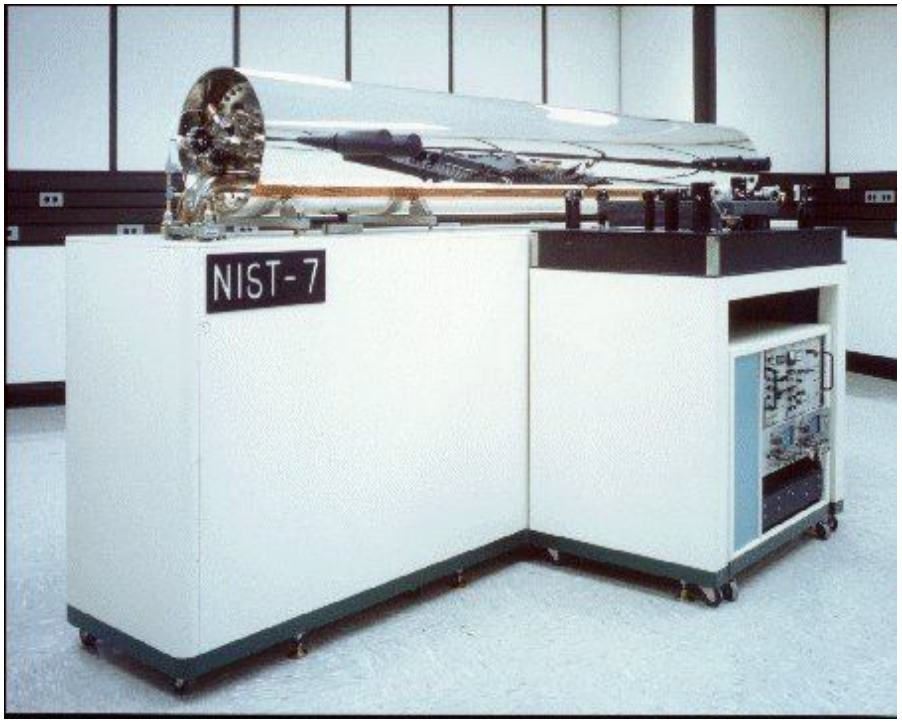
International System if units



CsOP-1, CENAM

The unit of time and the

International System if units



NIST-7, NIST

The unit of time and the

International System if units

Manipulation of atoms with light

Steven Chu

USA

Stanford University
Stanford, CA, USA

b.1948

Claude Cohen-Tannoudji

France

Collège de France; École Normale Supérieure
Paris, France

b.1933

William D. Phillips

USA

National Institute of Standards and Technology
Gaithersburg, MD, USA

b.1948

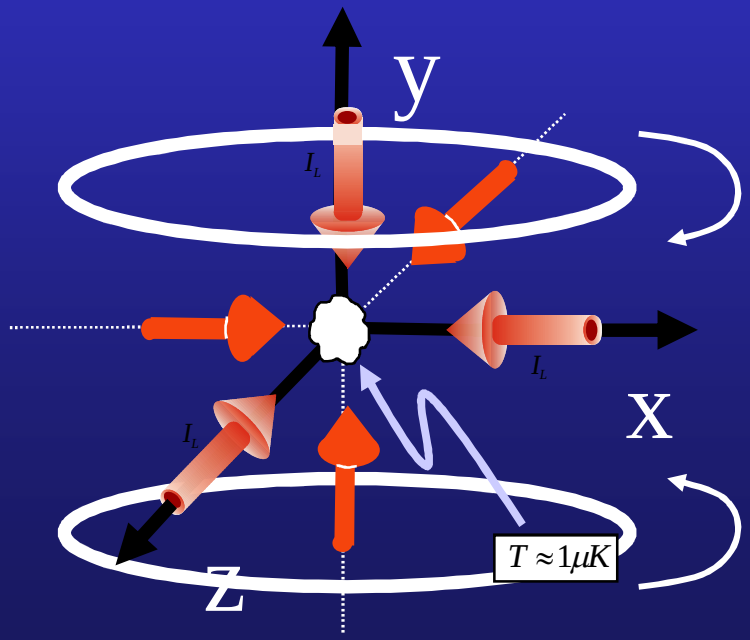
The Nobel Prize in Physics 1997

La Unidad de Tiempo y el

Sistema Internacional de Unidades

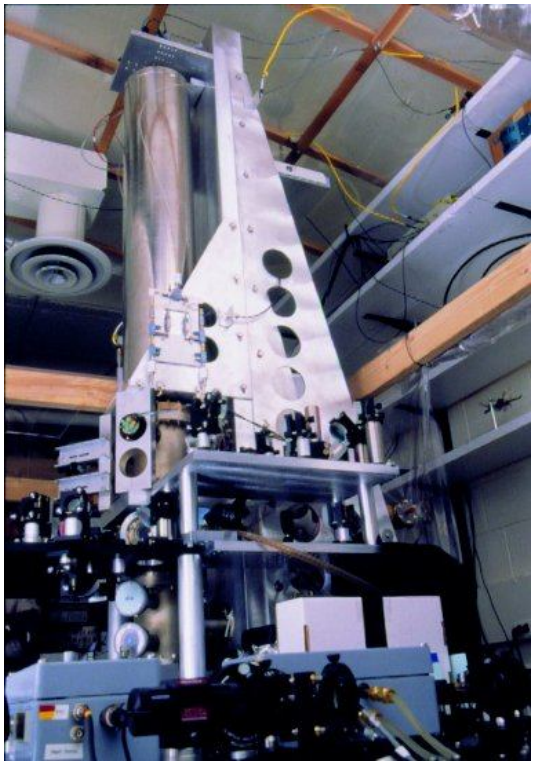
Optical molases

Friction type forces



The unit of time and the

International System if units

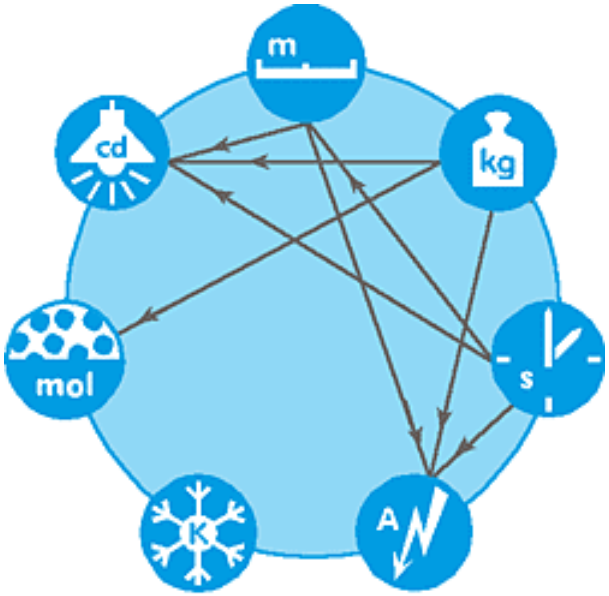


NIST-F1

2. The SI and the unit of time

The unit of time and the

International System if units

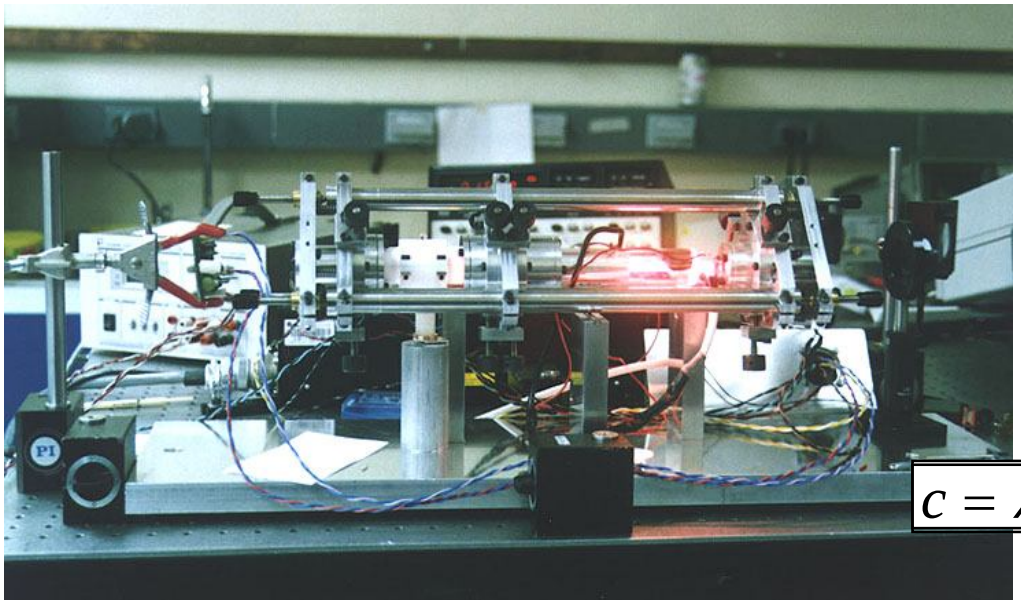


The seven base units of the SI

The unit of time and the

International System if units

The second and the meter



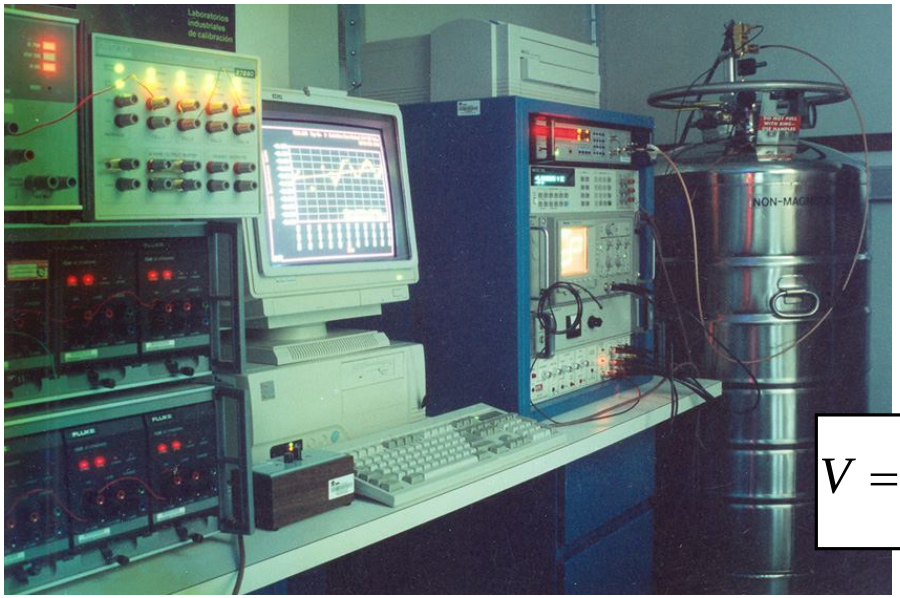
$$c = \lambda \upsilon$$

Stabilized HeNe laser to a Iodine molecule transition used for the realization of the meter

The unit of time and the

International System if units

The second and the Volt



$$V = 2nf\,\frac{e}{h}$$

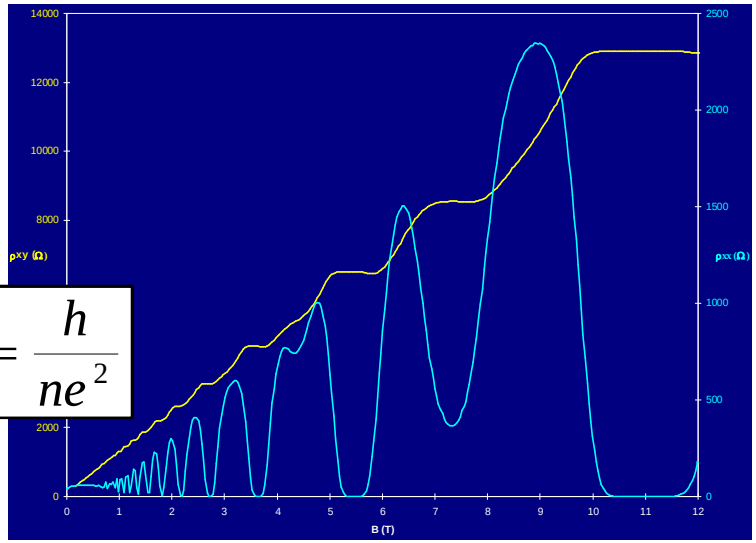
Josephson effect

The unit of time and the

International System if units

The second and the Ohm

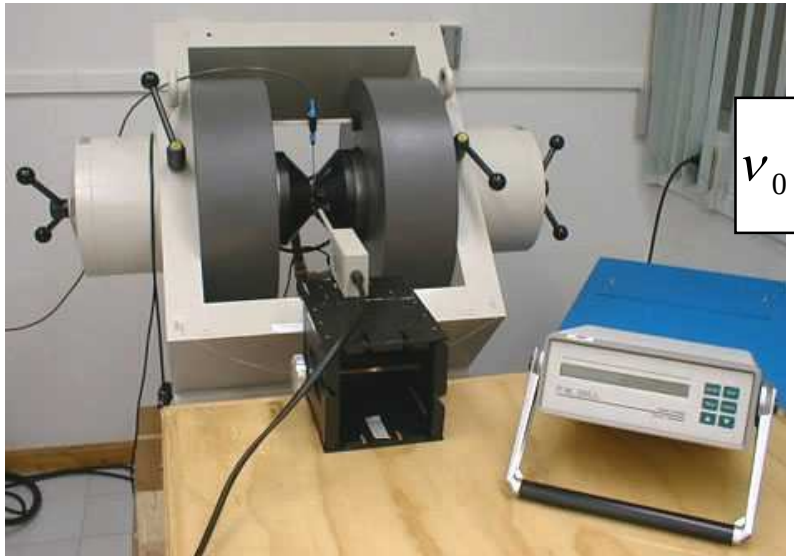
$$R_H = \frac{h}{ne^2}$$



Quantum Hall effect

The unit of time and the International System if units

The second and the Tesla



$$\nu_0 = \frac{1}{2\pi}\gamma B_0$$

Nuclear Magnetic resonance

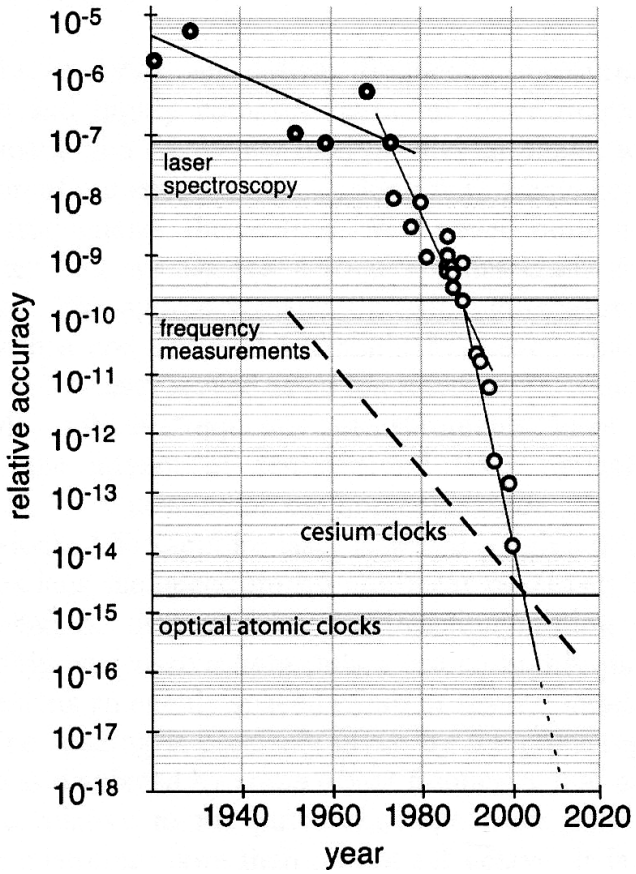
The unit of time and the

International System if units

3. Frequency combs

The unit of time and the

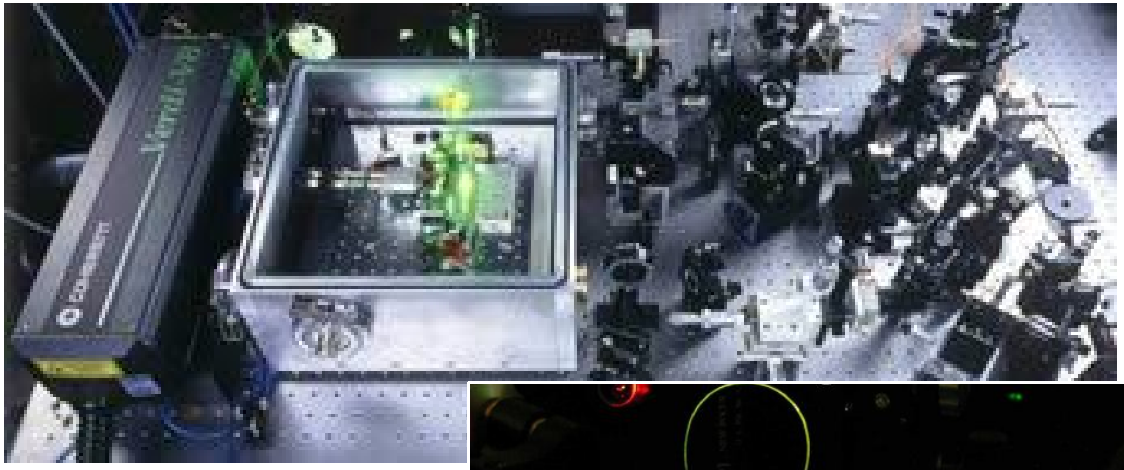
International System if units

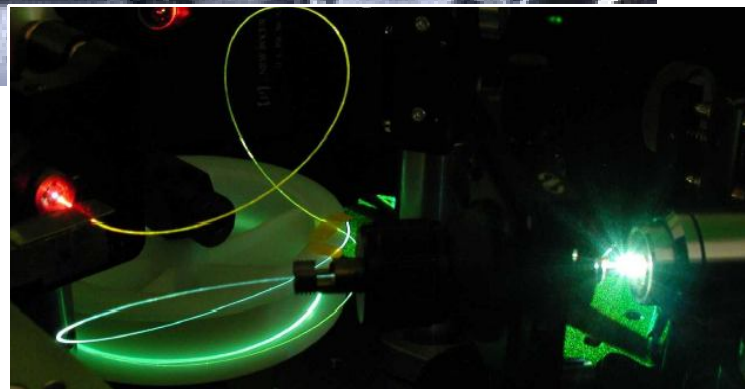


The unit of time and the

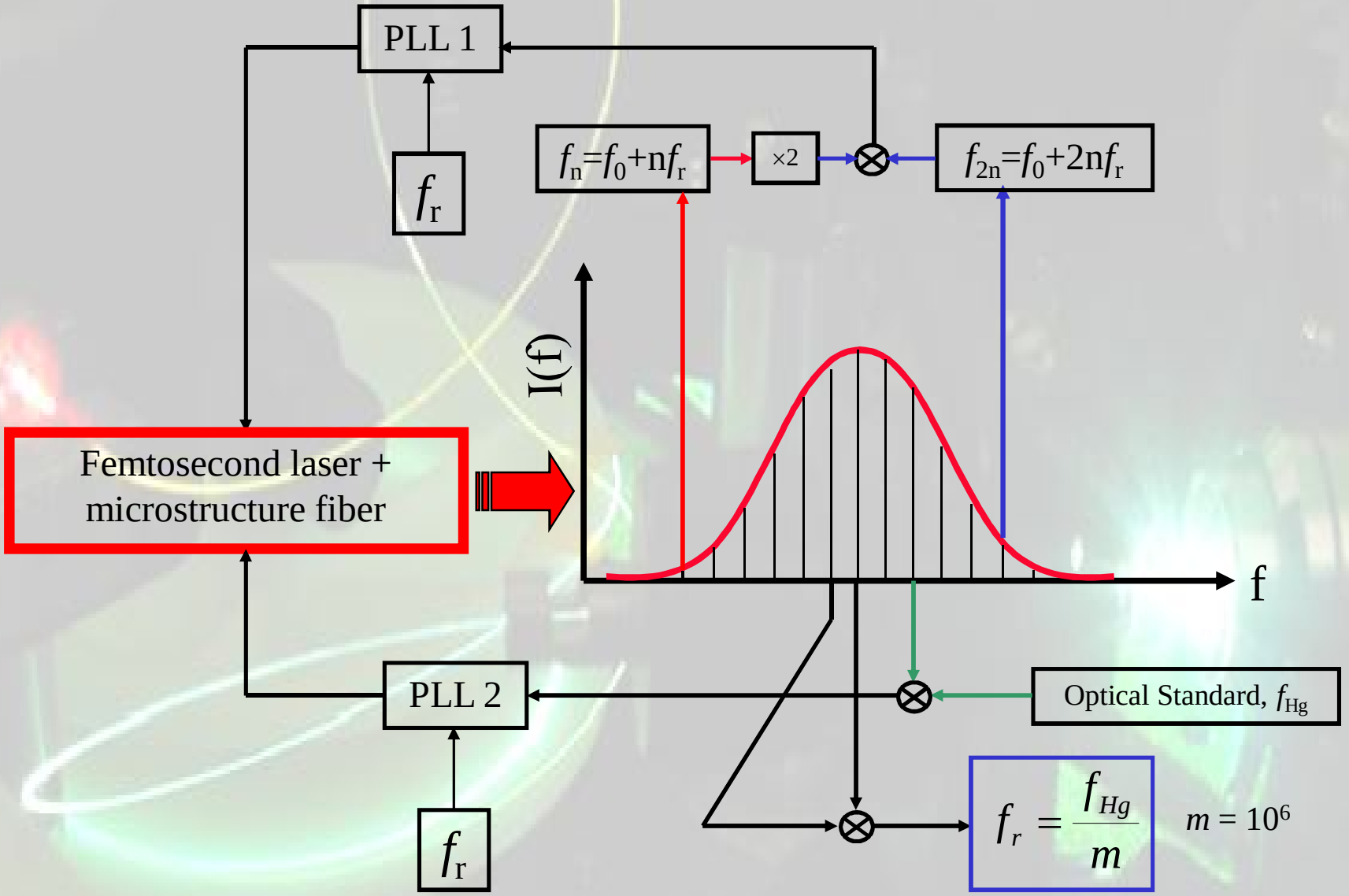
International System if units

Frequency comb

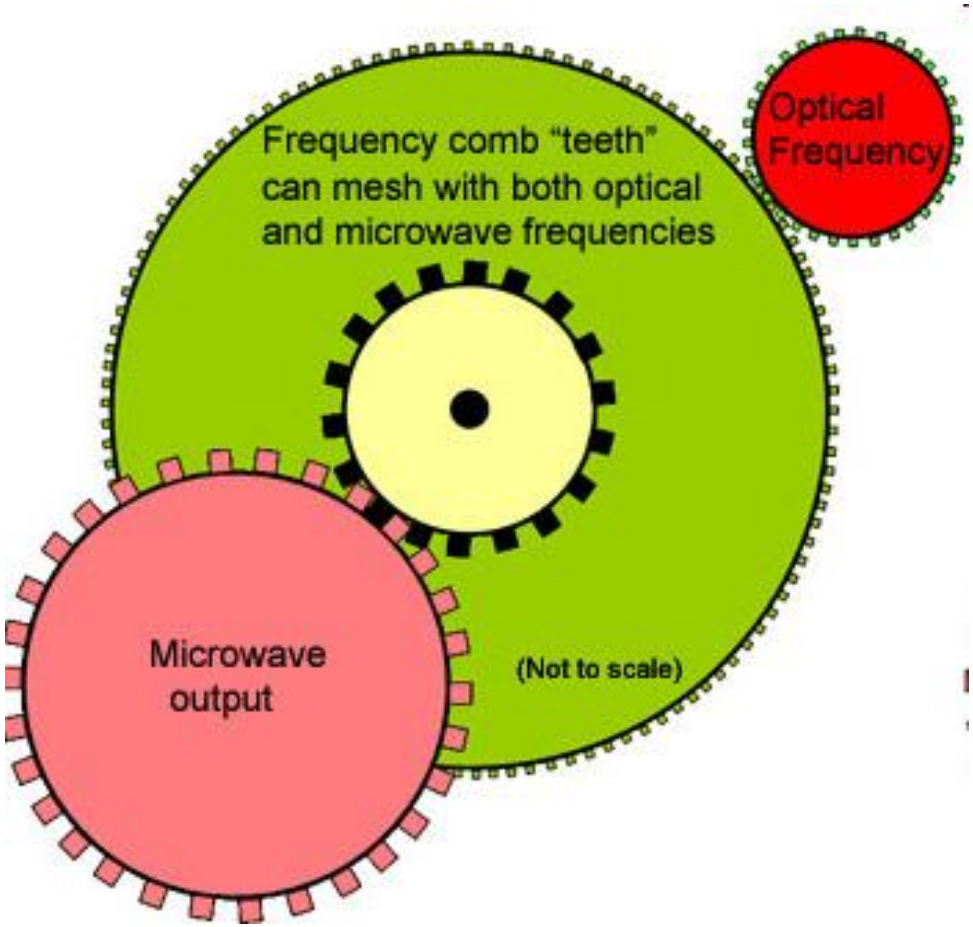




Frequency comb



Frequency comb



The unit of time and the

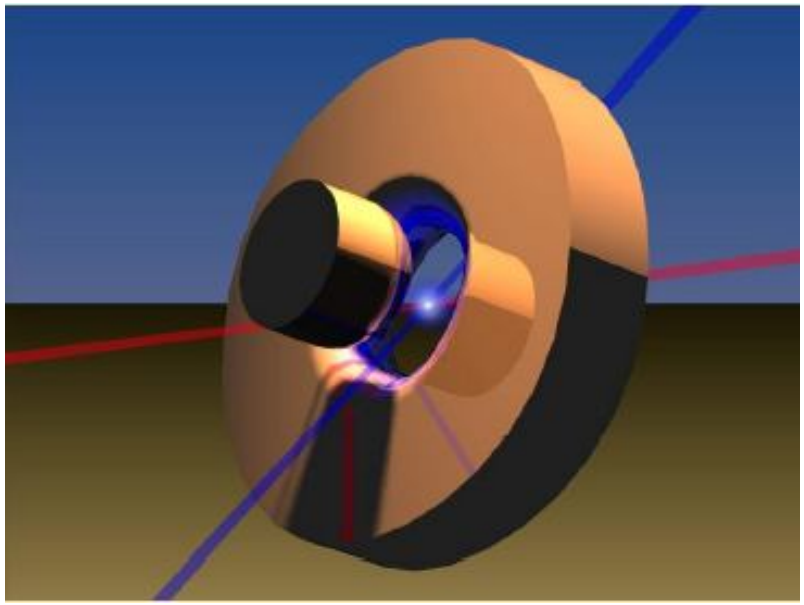
International System if units

4. Optical clocks

The unit of time and the

International System if units

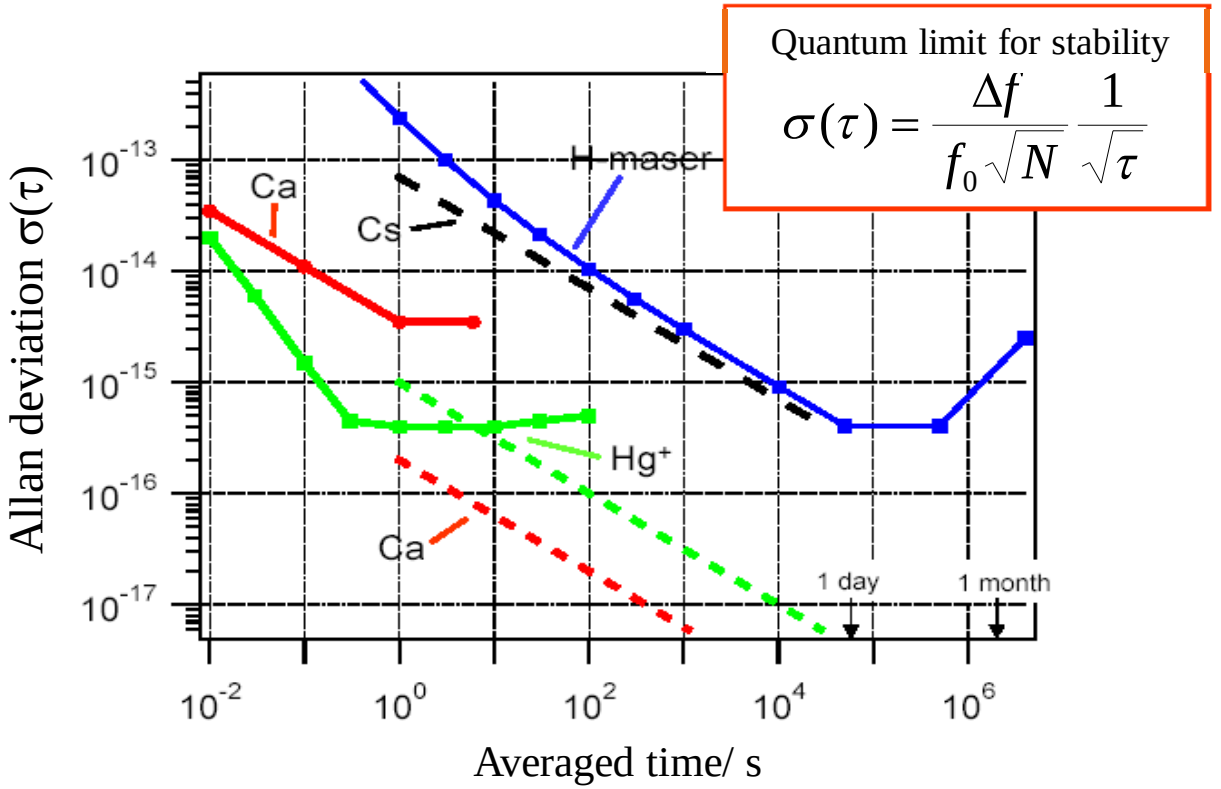
Optical clocks



Strontium ion trap at the NRC

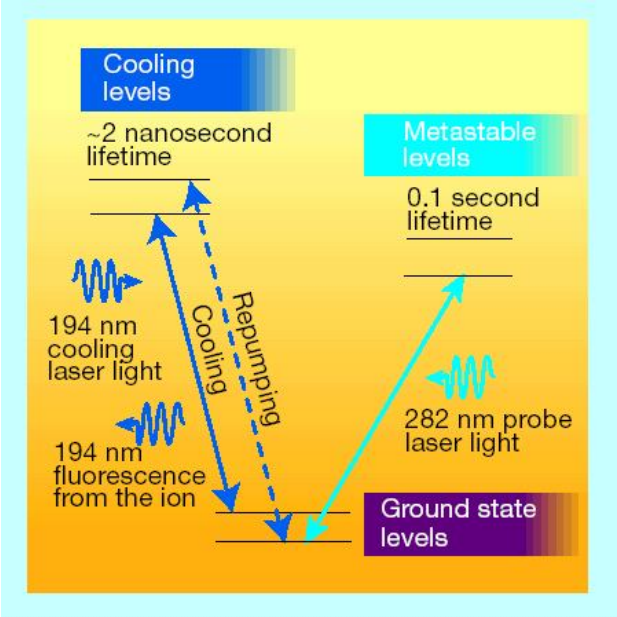
The unit of time and the

International System if units



The unit of time and the

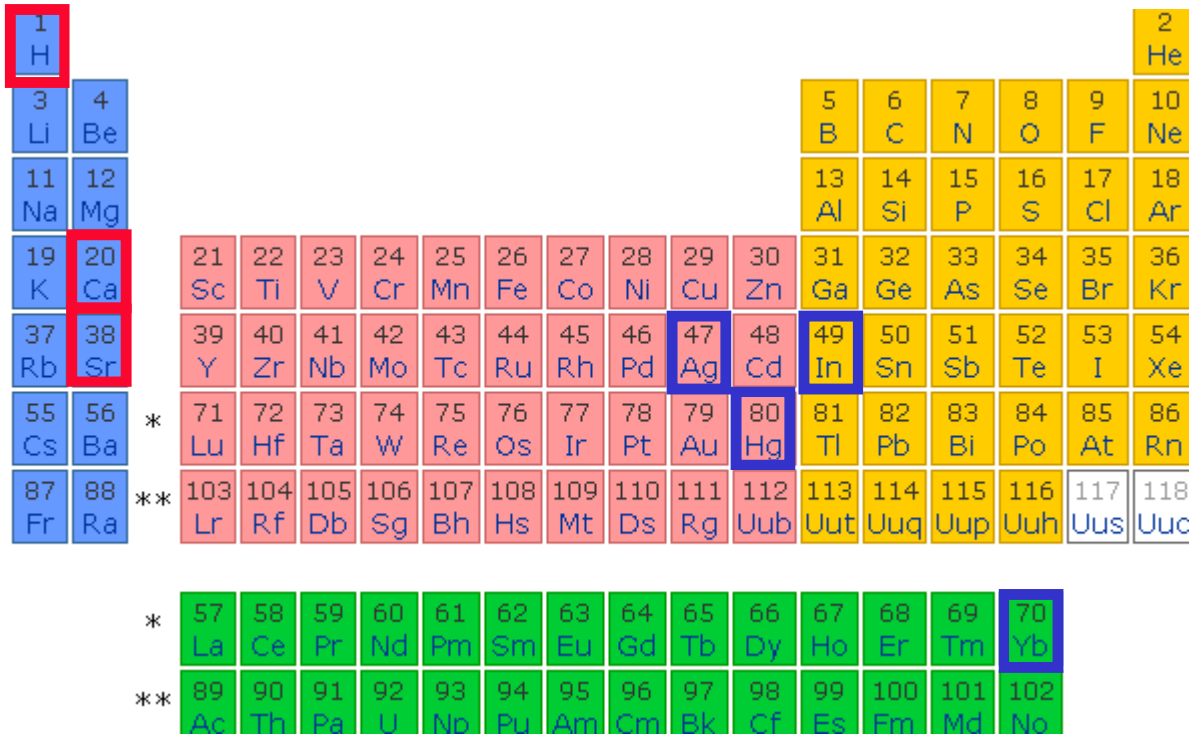
International System if units



Energy levels and clock transition of the Mercury ion

The unit of time and the

International System if units



Some atoms to built optical clocks

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