Laboratoire Kastler Brossel
Physique quantique et applications

ENS | PSL SORBONNE UNIVERSITÉ COLLÈGE DE FRANCE 1530 cnrs

A brief history of Laboratory Kastler Brossel in Paris
(1950 – 2000)

MICHELE LEDUC

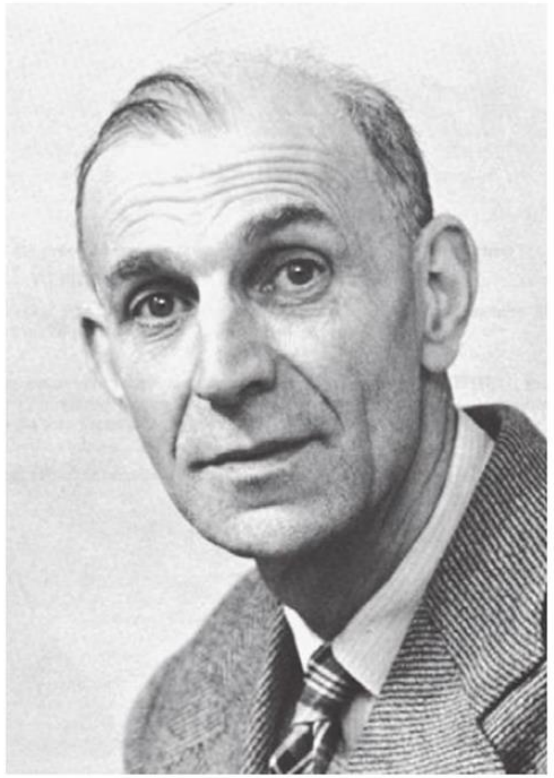
Research Director emeritus at CNRS

Member of the Bose-Einstein Condensate group

100 years of Quantum Physics. Colloquium in the honor of Serge Haroche. QuyNhon, October 6-9 (2025)

Nobel laureates of the laboratory

Three Nobel Prizes

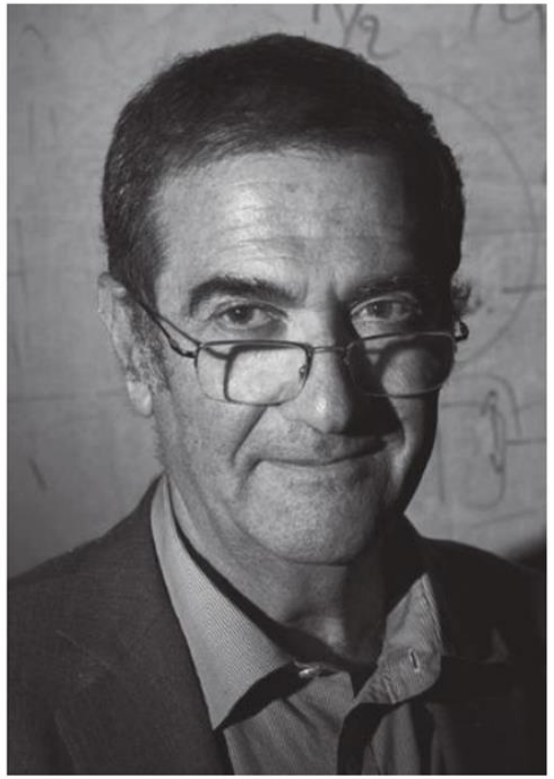


Alfred Kastler

1966

Claude Cohen-Tannoudji

1986



Serge Haroche

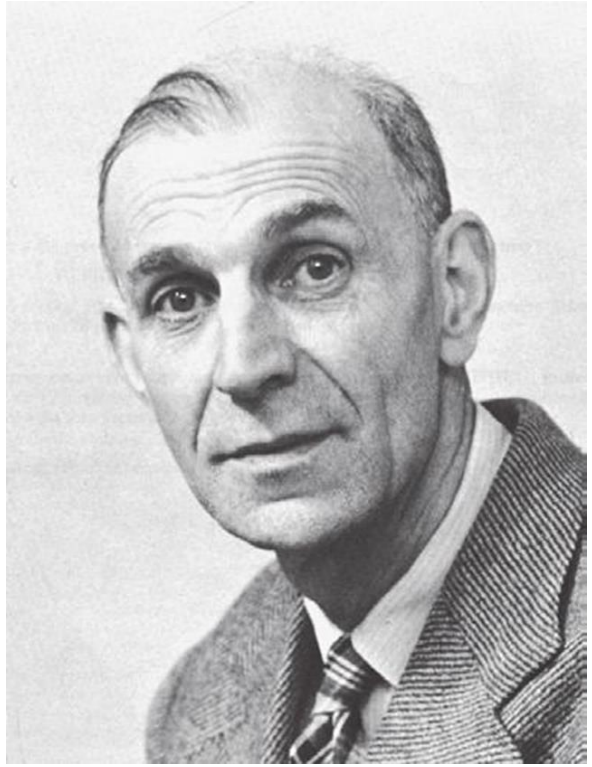
2012

1951: Foundation of the laboratory at ENS

Laboratoire de Spectroscopie Hertzienne de l'Ecole Normale Supérieure

Laboratoire Kastler- Brossel in 1994

Alfred Kastler
1902 - 1984

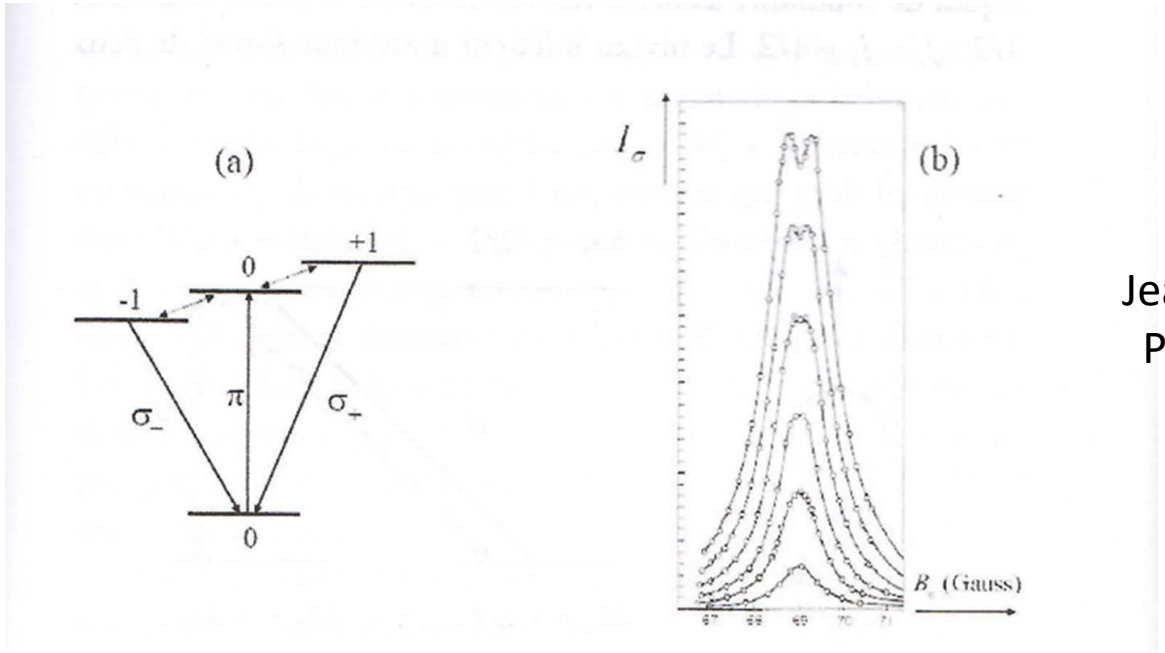


Jean Brossel
1918 - 2003

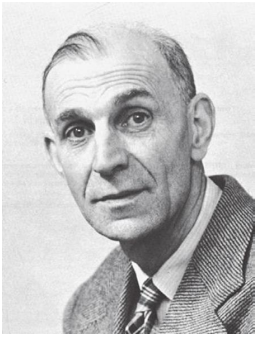
The early days

The double resonance

Optical and hertzian



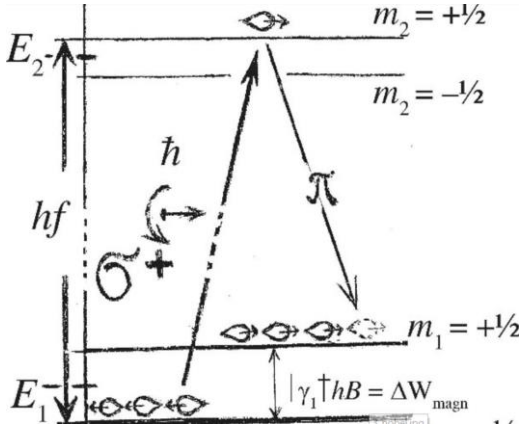
Jean Brossel
PhD 1951
Paris

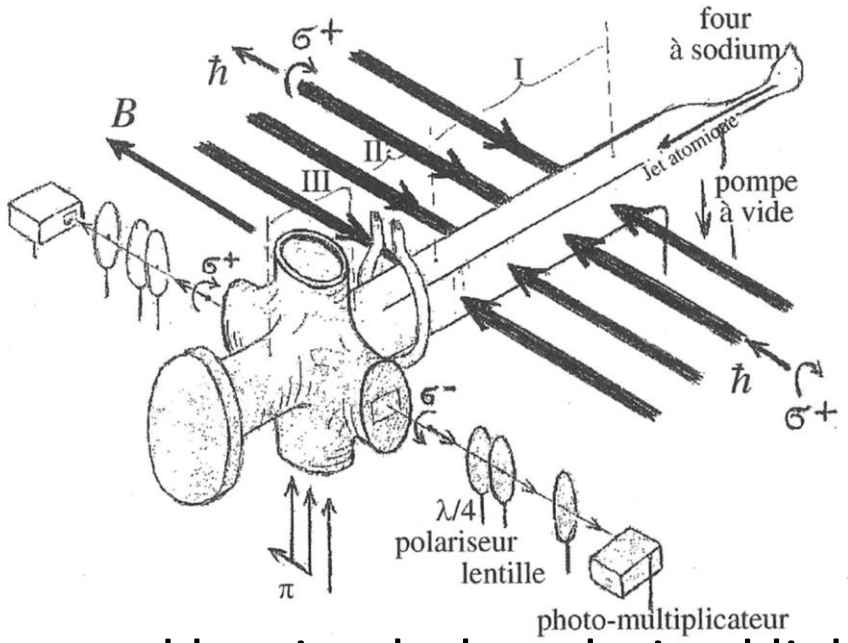


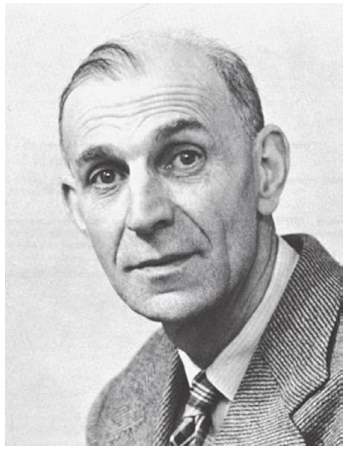
Magnetic resonance between Zeeman sublevels of an optically excited state of Hg atoms

Optical pumping

Orientation of spins of atoms in the ground state







Principle:
Alfred Kastler
(1950)

First expriment:
Jean Brossel +
Jacques Winter
(1952)

Atomic beam of Na illumated by circularly polarized light
Selection rules: only atoms in m=+1/2 are absorbed

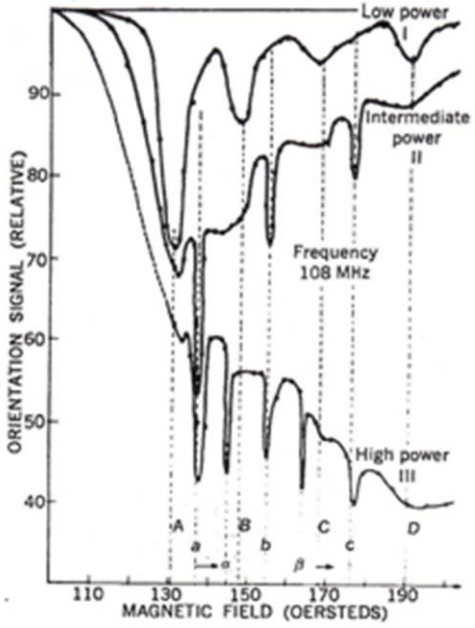
Later for atomic gases in glass cells (*with buffer gas or coating the cell walls)*

The early days

Multiple-quantum transitions

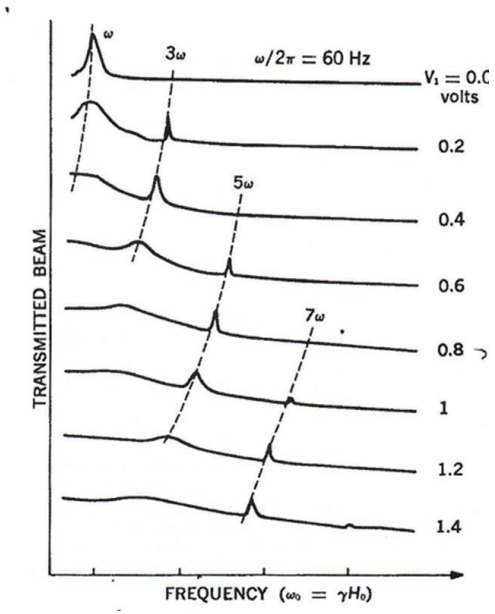
Brossel
Cagnac
Kastler
1954

Na



Magnetic resonance with increasing radio-frequency field

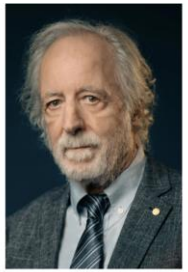
Bernard Cagnac



Claude Cohen-Tannoudji
Serge Haroche

Hg

Field revisited with attosecond generation (Nobel prize 2023)



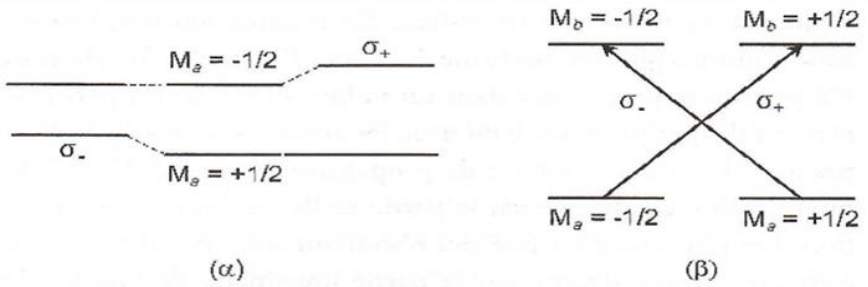
© Nobel Prize Outreach. Photo: Clément Morin
Pierre Agostini

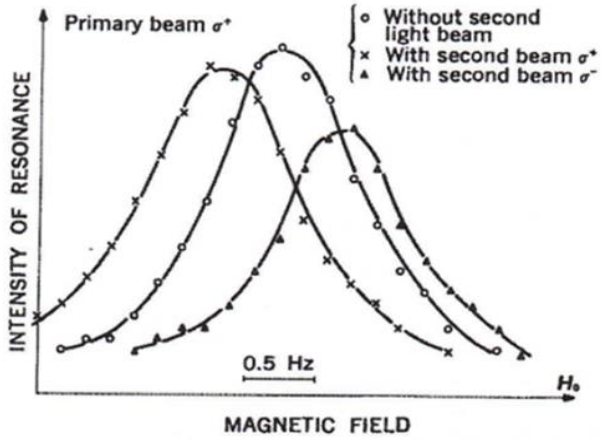
© Nobel Prize Outreach. Photo: Clément Morin
Ferenc Krausz

© Nobel Prize Outreach. Photo: Clément Morin
Anne L'Huillier

The early days

The light shifts





Claude Cohen-Tannoudji
PhD 1960

Irradiation by non resonant light circularly polarized
Frequency displacement of Zeeman sublevels

Further development: the « dressed atom »

Serge Haroche PhD 1971

Spreading of PhD students

New groups at several universities in France

Close collaboration with the ENS lab

Jacques Blamont *(Career in space)*

Jacques Winter *(NMR at Centre d'Etudes Nucléaires/ Saclay)*

Jean-Claude Pebay Peyroula *(Atomic spectroscopy in Grenoble)*

Jean Margerie *(Optical pumping of defects in solid crystals in Caen)*

The early days

Jean Margerie

LE JOURNAL DE PHYSIQUE TOME 24, OCTOBRE 1963, PAGE 717.

POMPAGE OPTIQUE DES CENTRES F DANS KBr

Par N. V. KARLOV,
Institut Lebedev, Moscou

J. MARGERIE,
École Normale Supérieure, Paris

et

Y. MERLE-D'AUBIGNÉ,
Laboratoire de Physique Générale, S. A. C. M., Grenoble.

1963

JEAN MARGERIE

1965

1re THÈSE

MÉTHODES D'ÉTUDE EXPÉRIMENTALE DE L'EFFET ZEEMAN DES RAIES LARGES DANS LE SPECTRE D'ABSORPTION DES SOLIDES

Jury: Kastler Jacquinot Brossel Friedel

The (very) early days

Kastler predicts the « effet lumino-frigorifique »

LE JOURNAL DE PHYSIQUE ET LE RADIUM TOME 11, JUIN 1950, PAGE 255.

1950

QUELQUES SUGGESTIONS CONCERNANT LA PRODUCTION OPTIQUE ET LA DÉTECTION OPTIQUE D'UNE INÉGALITÉ DE POPULATION DES NIVEAUX DE QUANTIFICATION SPATIALE DES ATOMES. APPLICATION A L'EXPÉRIENCE DE STERN ET GERLACH ET A LA RÉSONANCE MAGNÉTIQUE (1)

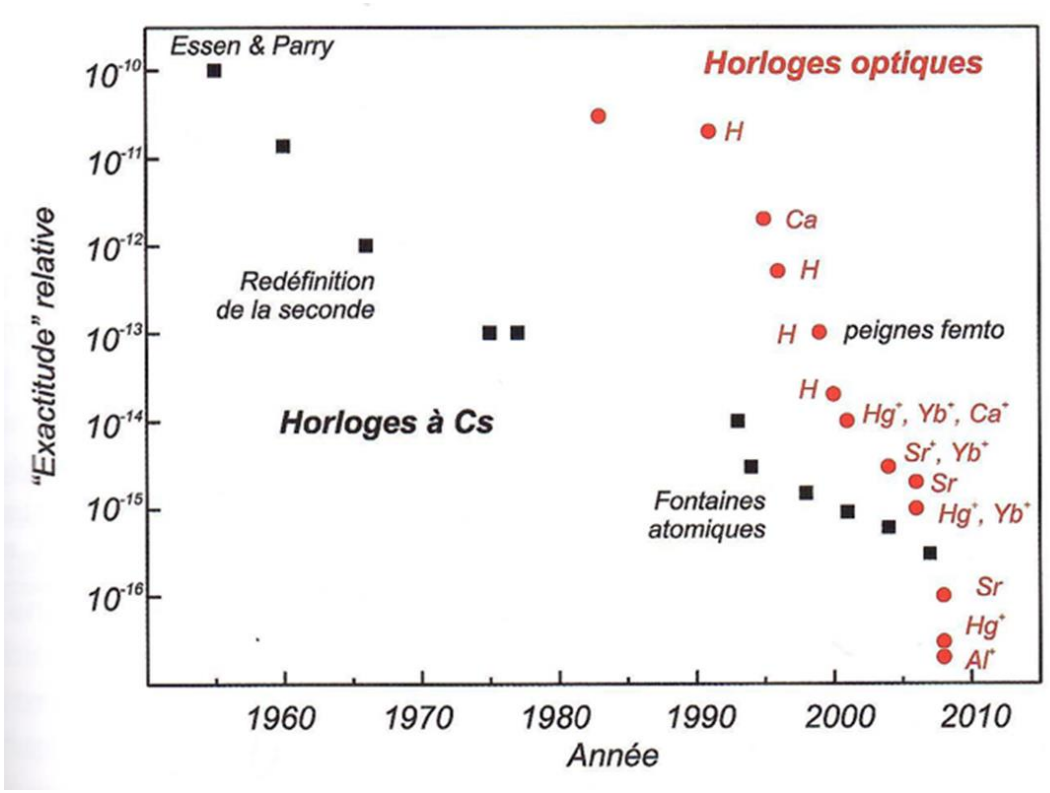
Par ALFRED KASTLER.
Laboratoire de Physique de l'École Normale Supérieure, Paris.

definitive, lorsqu'en irradiant un milieu il est possible d'obtenir l'emission, a côte de la radiation excitatrice, de radiations de fluorescence stokes sans emission simultanee de radiations antistokes, le milieu s'echauffera. Si, au contraire, les conditions sont telles qu'à côte de la radiation excitatrice le milieu ne puisse emettre que des radiations anti-stokes, sa temperature peut diminuer, *si le rendement de fluorescence est égal à l'unité.*

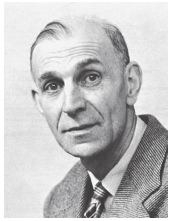
sel isomorphe le rendement de fluorescence à basse température doit s'approcher de l'unite. Il convient de remarquer qu'un tel effet lumino-frigorique reste une simple curiosite scientifique et ne peut guère être utilise pour refroidir pratiquement une substance, car, d'une part, l'effet est faible et lent, et, d'autre part, la necessite d'evacuer les radiations reemises par le milieu ne permet pas d'entourer la substance de parois refléchissantes. Cependant, en employant

The atomic clock

Implication of the ENS lab in the atomic clock development



Relative accuracy of atomic clocks



Alfred Kastler
President of the Atomic Clock Laboratory
1958 and on

Christophe Salomon
Contribution to the Atomic Fountain Clocks
at Paris Observatory

PI of the Pharao Clock on the ISS
Now in orbit since april 2025

Nobel Prize of Alfred Kastler 1966

Discovery and development of optical methods for studying hertzian resonances in atoms

Claude Cohen-Tannoudji

Serge Haroche

Alain Omont

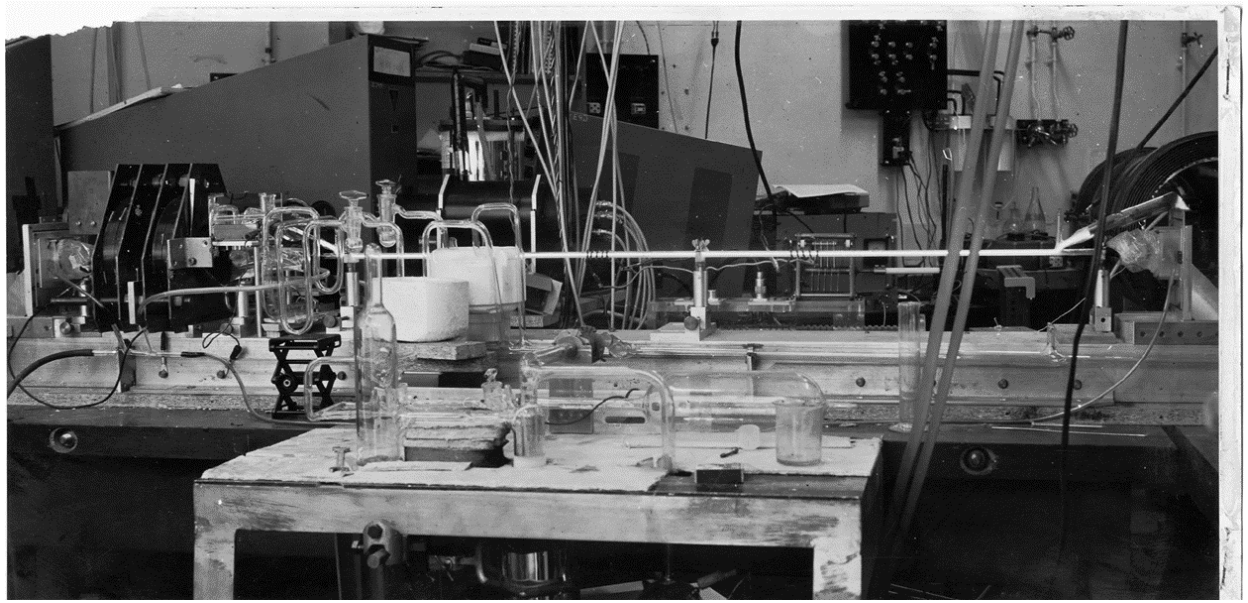
Franck Laloë

Jean Brossel

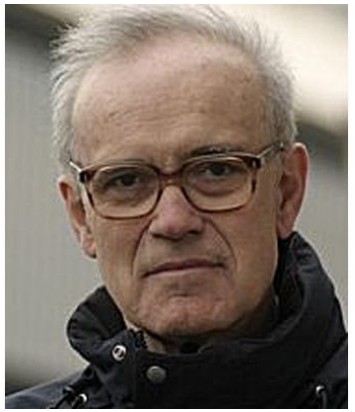
The first gas laser at ENS

1964

Helium-Neon laser



Built by Bernard Decomps



With Michel Dumont

SPECTROSCOPIE HERTZIENNE. — *Étude du niveau $2p_2$ du néon à l'aide d'une irradiation laser.* Note (*) de Mlle **Elisabeth Fournier**, MM. **Martial Ducloy**, **Bernard Decomps** et **Michel Dumont**, transmise par M. Alfred Kastler.

Elisabeth Giacobino

Optical pumping in semiconductors

1970 and on

Ionel Solomon Ecole polytechnique

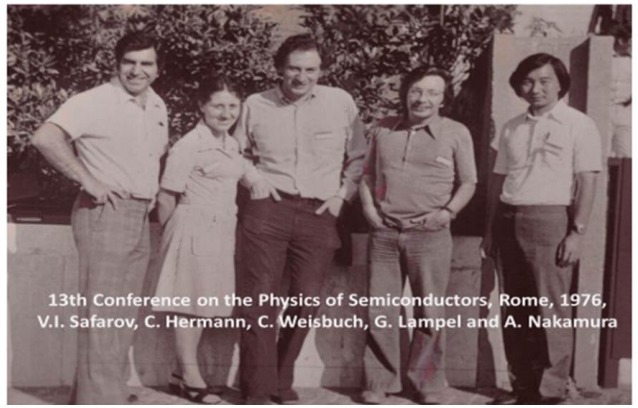
Connections with laboratories at ENS (Paris) and CEA (Saclay)

Alfred KASTLER
ENS

Jean BROSSEL
ENS

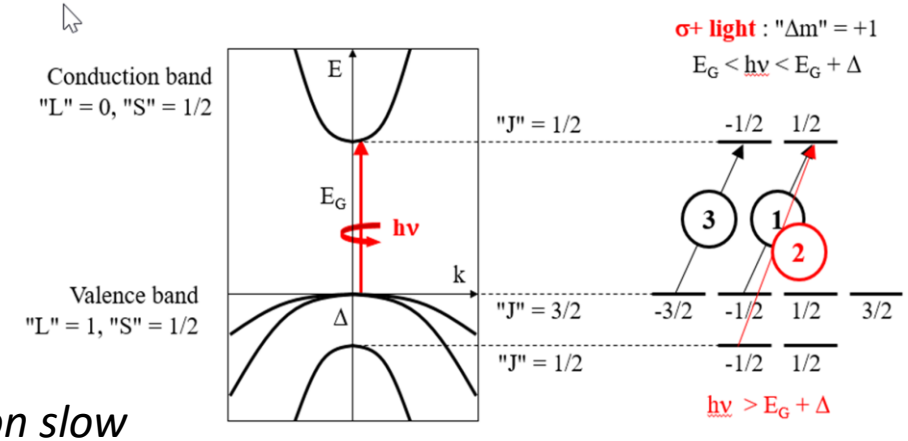
Anatole ABRAGAM
CEA et Collège de France

Claude Weisbuch



Claudine Hermann and Georges Lampel

Polarization for itinerant electrons



Spin relaxation slow

Measurement of the *g* Factor of Conduction Electrons by Optical Detection of Spin Resonance in *p*-Type Semiconductors

Phys. Rev. Lett. 27, 373 (1971)

Claudine Hermann and Georges Lampel

Analogy wih Brossel's double resonance

Generation of polarized electron beams

More space: new research groups

1967

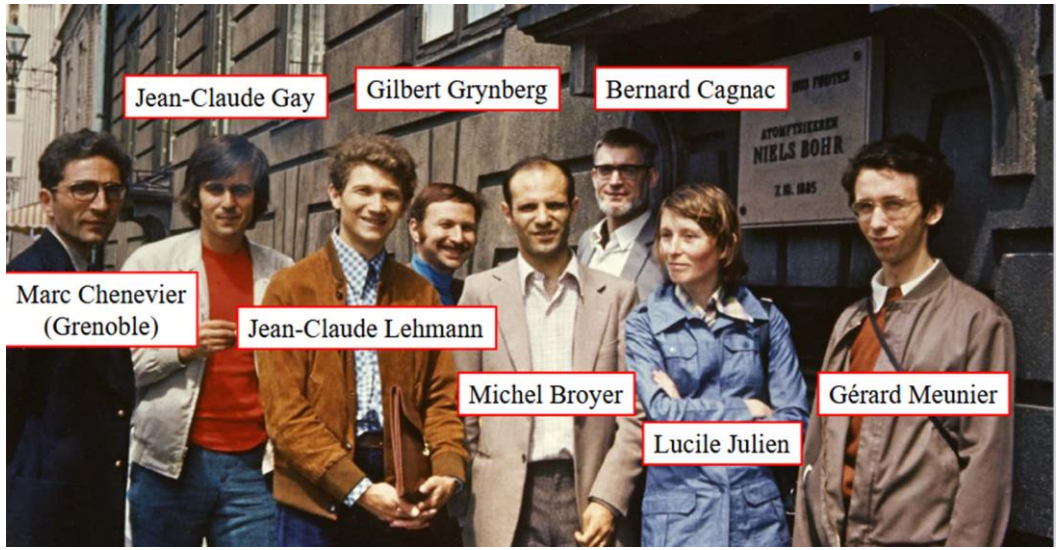
Lab expansion to Jussieu

« Halle aux Vins »

May 68

The lab survives…

Molecular spectroscopy
High precision measurements



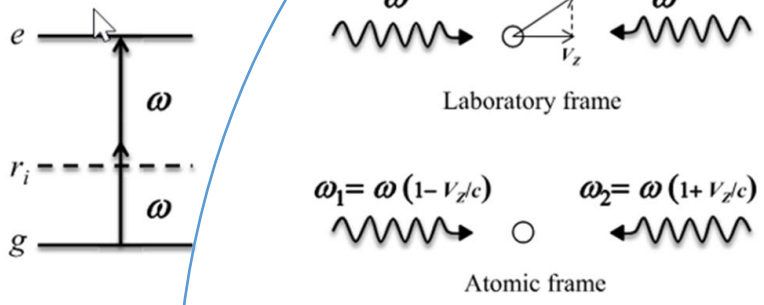
Quantum optics

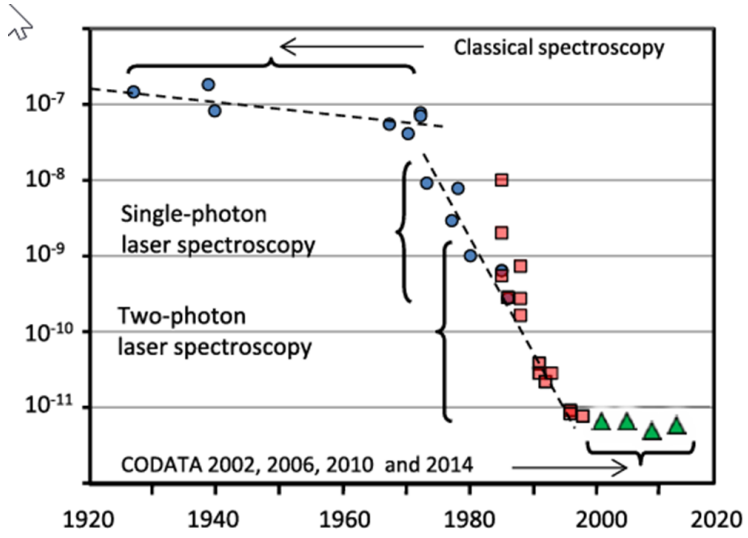
Claude Fabre and Elisabeth Giacobino

High precision metrology in Jussieu

Doppler-free spectroscopy

1973





Bernard Cagnac

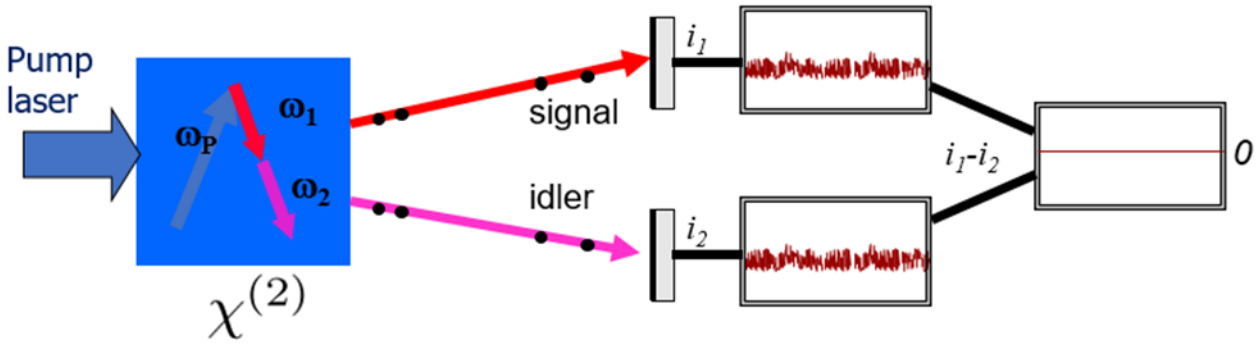
Gilbert Grynberg

François Biraben

Two-photon spectroscopy of Hydrogen atom
Rydberg constant improved accuracy

Quantum optics

Generation of quantum correlated twin beams by parametric down conversion



Energy conservation $\omega_p = \omega_s + \omega_c$

Phase matching $\vec{k}_p = \vec{k}_s + \vec{k}_c$

$$\Delta(N_1 - N_2) = 0$$

Predictions

Serge Reynaud

Intensity fluctuations perfectly correlated at the quantum levels

At low level: correlated photons

"Quantum fluctuations in a two-mode parametric oscillator"
Reynaud S., Fabre C., Giacobino E., *J. Opt. Soc. Am. B* **4** (1987) p.1520-1524:

Quantum optics

Generation of squeezed state of light

Photon reduction noise below shot noise

Squeezing with cold atoms

Lambrecht A., Coudreau T., Steinberg A. M., Giacobino E., *Europhys. Lett.* **36**, 93(1996)

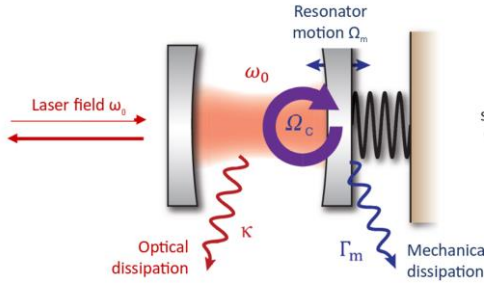
Squeezing by optomechanics

PHYSICAL REVIEW A VOLUME 49, NUMBER 2 FEBRUARY 1994

Quantum-noise reduction using a cavity with a movable mirror

C. Fabre, M. Pinard, S. Bourzeix, A. Heidmann, E. Giacobino, and S. Reynaud
Laboratoire de Spectroscopie Hertzienne de l'Ecole Normale Superieure, case 74, Université Pierre et Marie Curie, 75252 Paris Cedex 05, France
(Received 9 August 1993)

Optomechanics



Coupling between mechanical motion and light through radiation pressure

Control of mirror motion

Antoine Heidman

Parity Violation in Atomic Physics

Marie-Anne Bouchiat

prediction **1972 -**

Claude Bouchiat

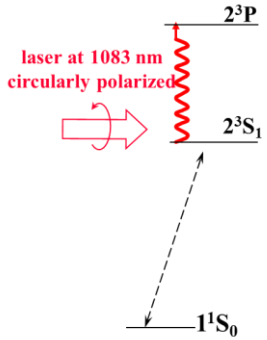
Chirality of interaction between light and atom.
Symmetry breaking in the absorption of light

A new force between the valence electron and the atomic nucleus
Due to exchange of the neutral boson Z^0

Later seen at CERN at high energy in collisions proton- antiproton

The ENS experiment pioneered the field and reached an impressive sensitivity 10^{-7}

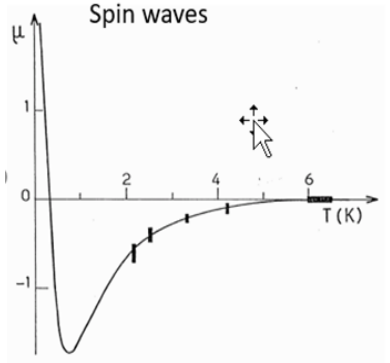
Nuclear polarization of He3

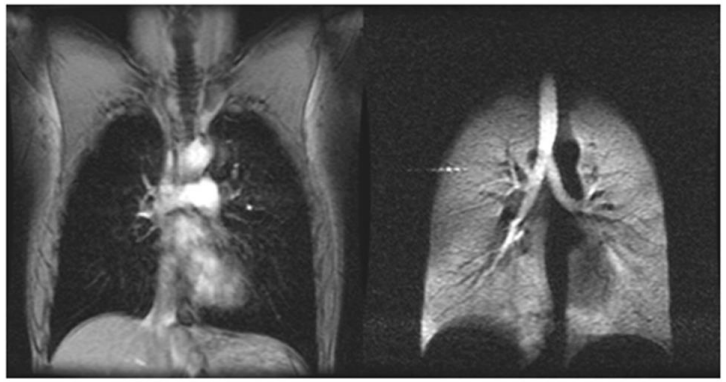


Optical pumping
via metastable state

Transport properties modified by nuclear polarization (identical particle effects) during binary collisions when $\lambda_{deBroglie} \sim a_0$ (potential range)

Predicted in 1980 (F. Laloë), computed in 1982 (F.L. & C. Lhuillier)



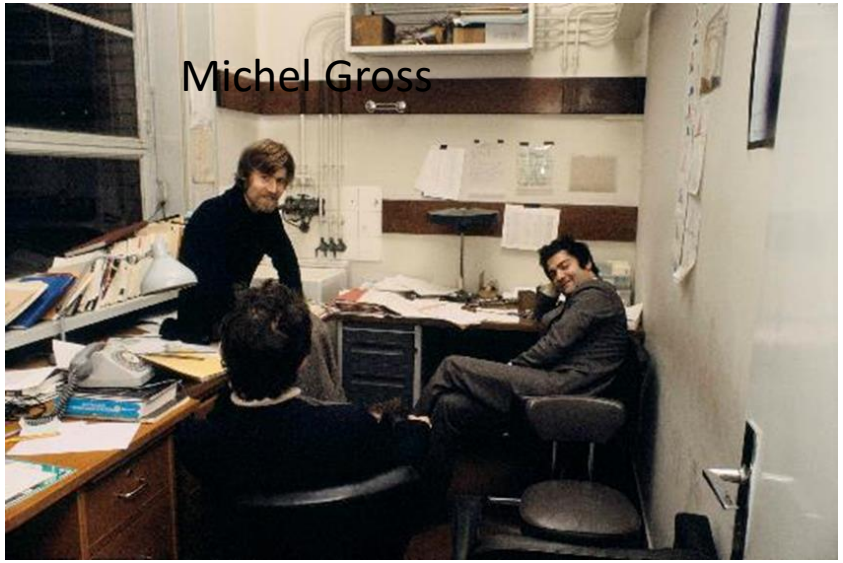


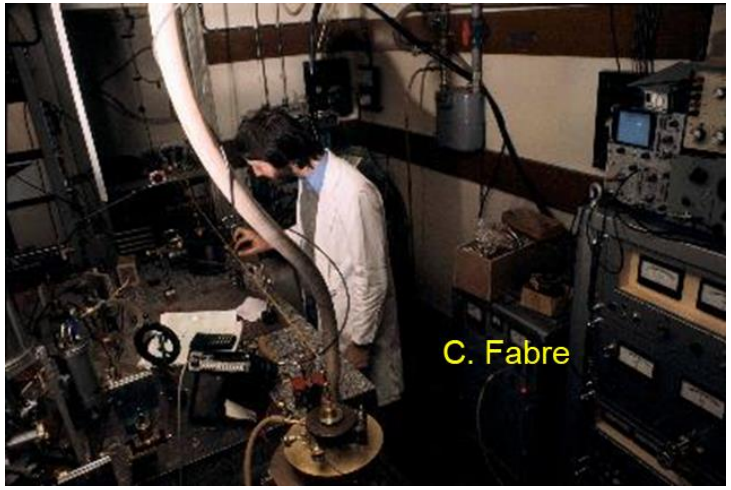
Proton Helium

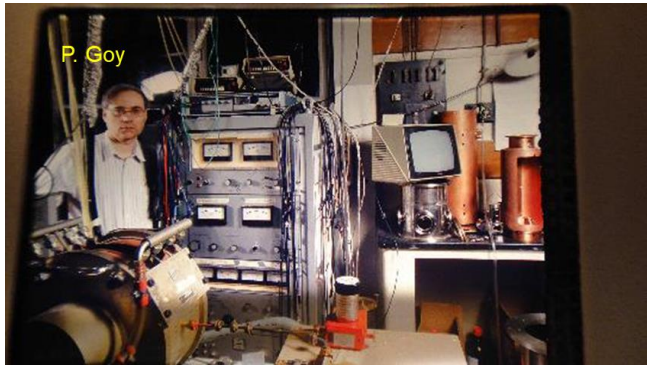
Field revisited with ultracold fermions by Eric Cornell (2002)- spontaneous segregation of spins

NMR of inhaled He3 gas
Collaboration with Ernst Otten

Atoms in cavity







The groups started by Serge Haroche in 1973

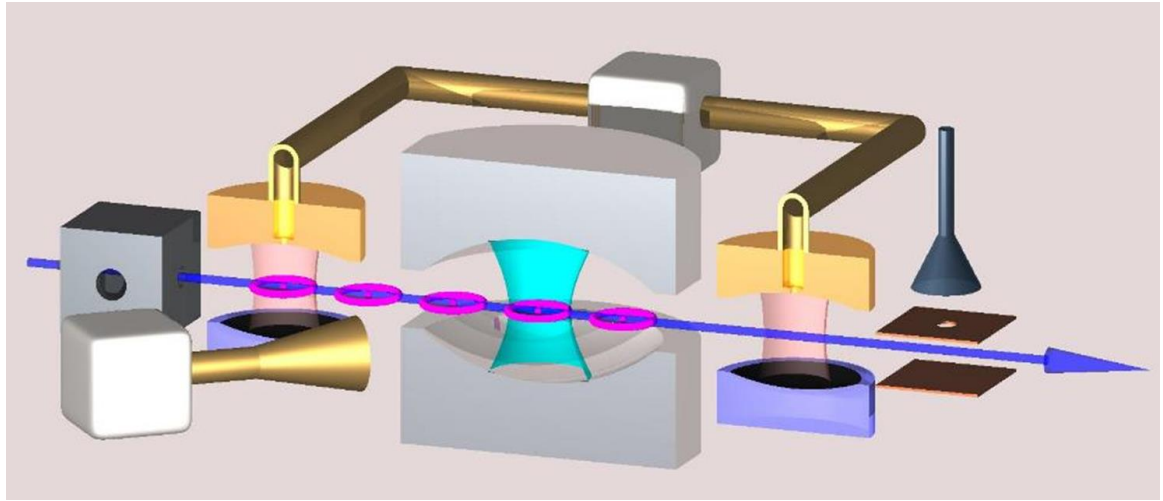
Jean Michel Raymond joined in1977

Michel Brune

Atoms in cavity

A long lasting quest…

With a « simple » experimental set-up



On the way to QND experiments

and to the Nobel Prize 2012

From the begining

A blossom of results

Rydberg atoms microwave spectroscopy

Near Infra-red superradience

Squeezing in a Rydberg atom maser

Spontaneous emission enhanced

The two-photon micromaser

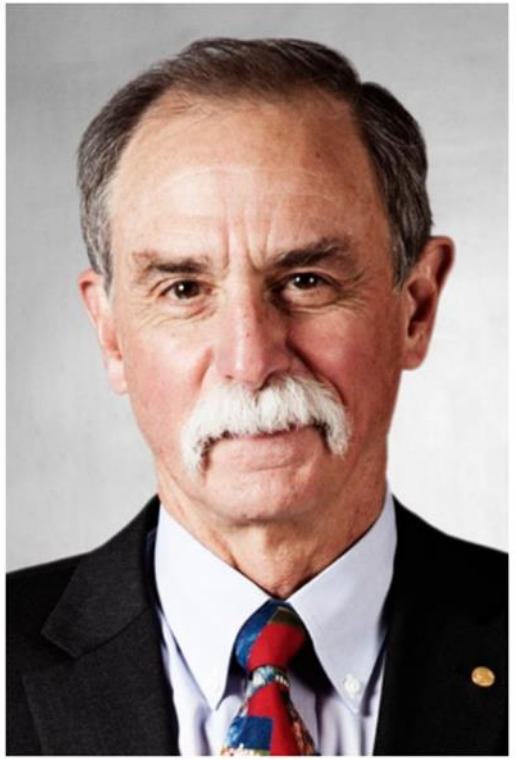
Quantum jumps of light

Physics Nobel Prize

© The Nobel Foundation. Photo: U. Montan

Serge Haroche

Prize share: 1/2



© The Nobel Foundation. Photo: U. Montan

David J. Wineland

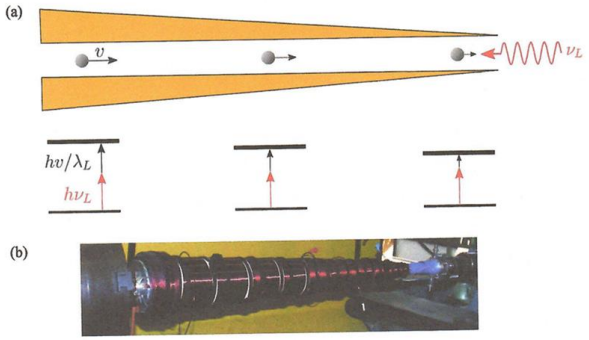
Prize share: 1/2

2012

“for ground-breaking experimental methods that enable measuring and manipulation of individual quantum systems”

Cold atoms

Stopping atoms with laser light



1985

First experiment at NIST

An atomic beam is decelerated by a counterpropating laser beam

In a variable magnetic field (Zeeman slower)

Doppler and Zeeman effects compensate along the atomic path

Jean Dalibard postdoc

In Bill Phllips Lab

VOLUME 54, NUMBER 10 PHYSICAL REVIEW LETTERS 11 MARCH 1985

Stopping Atoms with Laser Light

John Prodan, Alan Migdall, and William D. Phillips
Electricity Division, Center for Basic Standards, National Bureau of Standards, Gaithersburg, Maryland 20899

and

Ivan So and Harold Metcalf
Physics Department, State University of New York, Stony Brook, New York 11794

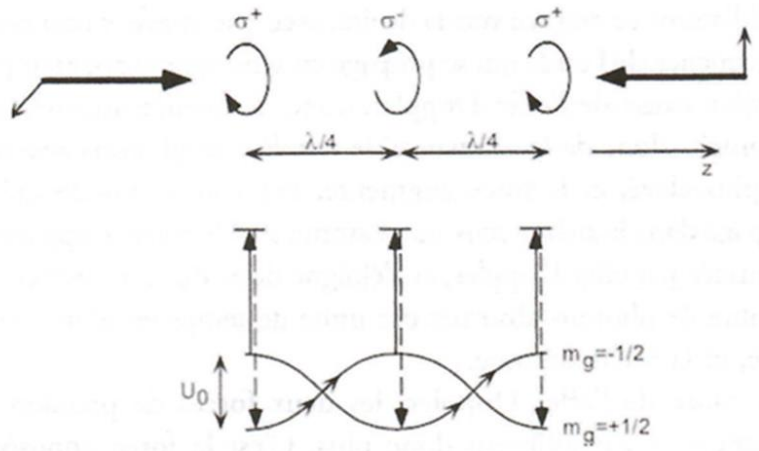
and

Jean Dalibard
Laboratoire de Spectroscopie Hertzienne de l'Ecole Normale Supérieure, F-75231 Paris Cedex 05, France
(Received 1 October 1984)

Cold atoms

Prediction of the Sisyphus effect

1985



A two-level atom in a standing wave

A succession of spontaneous absorption-emission cycles
The atom gradually loses its kinetic energy

Dressed-atom approach to atomic motion in laser light: the dipole force revisited

J. Dalibard and C. Cohen-Tannoudji

Collège de France and Laboratoire de Spectroscopie Hertzienne de l'Ecole Normale Supérieure [Laboratoire Associé au Centre National de la Recherche Scientifique [LA 18]], 24 rue Lhomond, F 75231 Paris Cedex 05, France

Received March 28, 1985; accepted June 6, 1985

J. Dalibard

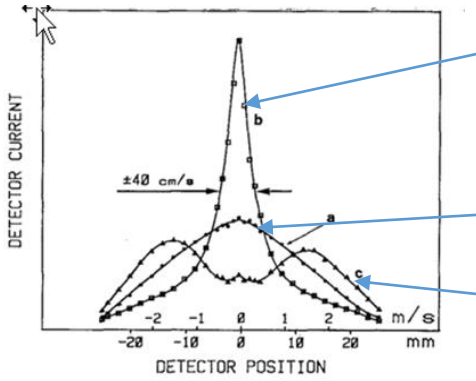
J. Dalibard was born in 1958 in Paris. Since 1979, he has worked at the Ecole Normale Supérieure with C. Cohen-Tannoudji. He obtained the *doctarat 3ème cycle* in 1981 and he is now working for the Ph.D. degree, devoted to the study of fluctuation processes in quantum optics and quantum electrodynamics. Since 1982 he has been a member of the Centre National de la Recherche Scientifique.

C. Cohen-Tannoudji

C. Cohen-Tannoudji, professor at the Collège de France, was born in 1933. Since 1960 he has been involved in research at the Ecole Normale Supérieure in Paris with Alfred Kastler and Jean Brossel. His principal research is in optical pumping, quantum optics, and the interaction of radiation with matter.

Cold atoms

Observation of the Sisyphus effect



Cooling beam **on**
(positive detuning)

Cooling laser beam **off**

Cooling beam on
(negative detuning)

VOLUME 57, NUMBER 14 PHYSICAL REVIEW LETTERS 6 OCTOBER 1986

Cooling Atoms with Stimulated Emission

A. Aspect, J. Dalibard, A. Heidmann, C. Salomon, and C. Cohen-Tannoudji
Laboratoire de Spectroscopie Hertzienne de l'Ecole Normale Supérieure et Collège de Fr...
F-75231 Paris Cedex 05, France
(Received 30 July 1986)

1986

VOLUME 61, NUMBER 7 PHYSICAL REVIEW LETTERS 15 AUGUST 1988

Laser Cooling below the One-Photon Recoil Energy by Velocity-Selective Coherent Population Trapping

A. Aspect, E. Arimondo,[a] R. Kaiser, N. Vansteenkiste, and C. Cohen-Tannoudji
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F-75231 Paris Cedex 05, France
(Received 11 July 1988)

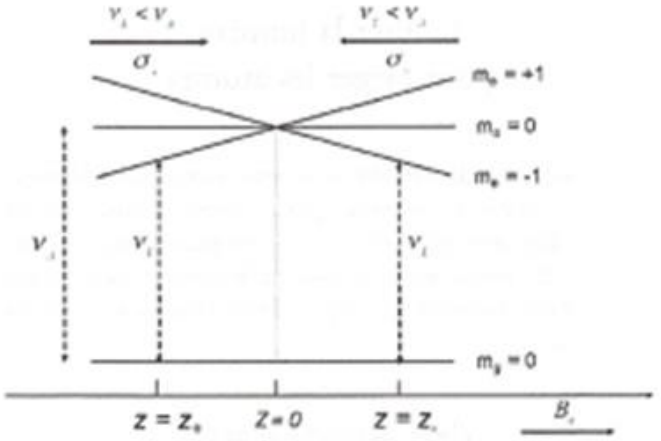
1988

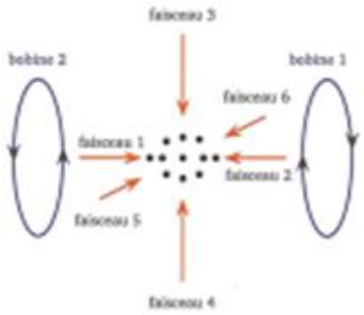
1987

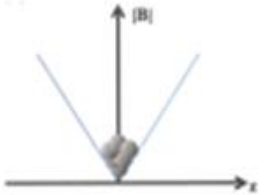
Xx, A. Aspect, C.Cohen-Tannoudji, N. Vantenkiste, R.Kaiser, J.Dalibard, H.Metcalf, C. Salomon

Cold atoms

The magneto optical trap







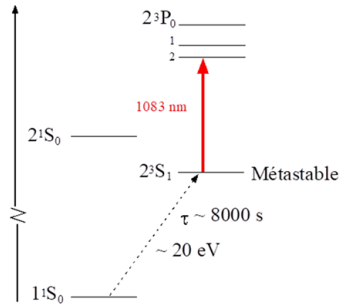
A restoring force pulls the atoms toward the center

Jean Dalibard: principle inspired by optical pumping

Stev Chu: experimental demonstration

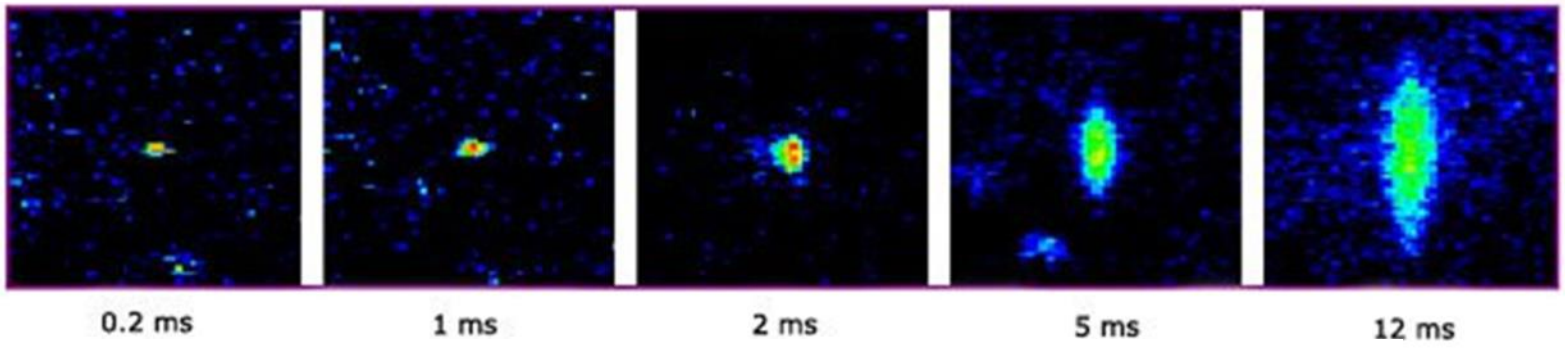
Cold atoms

Bose-Einstein Condensation of Metastable He4



The unique case of a BEC with atoms in an excited state

Time of flight experiment



Bose-Einstein Condensation of Metastable Helium

PRL 86, April 2001

F. Pereira Dos Santos, J. Léonard, Junmin Wang,* C. J. Barrelet, F. Perales,† E. Rasel,‡
C. S. Unnikrishnan,§ M. Leduc, and C. Cohen-Tannoudji
Collège de France, Laboratoire Kastler Brossel, Département de Physique, Ecole Normale Supérieure, 24 rue Lhomond, 75231 Paris Cedex 05, France
(Received 19 March 2001)

We have observed a Bose-Einstein condensate in a dilute gas of ^{4}He in the 2^3S_1 metastable state.

Franck Pereira Dos Santos

Cold atoms

Weekly seminar of
the cold atom group at ENS

The Nobel prize 1986

The directors of LKB

Jean Brossel
1972-1984

Jacques Dupont-Roc
1985-1994

Michèle Leduc
1994-1999

Elisabeth Giacobino
1999-2001

Franck Laloë
2002-2006

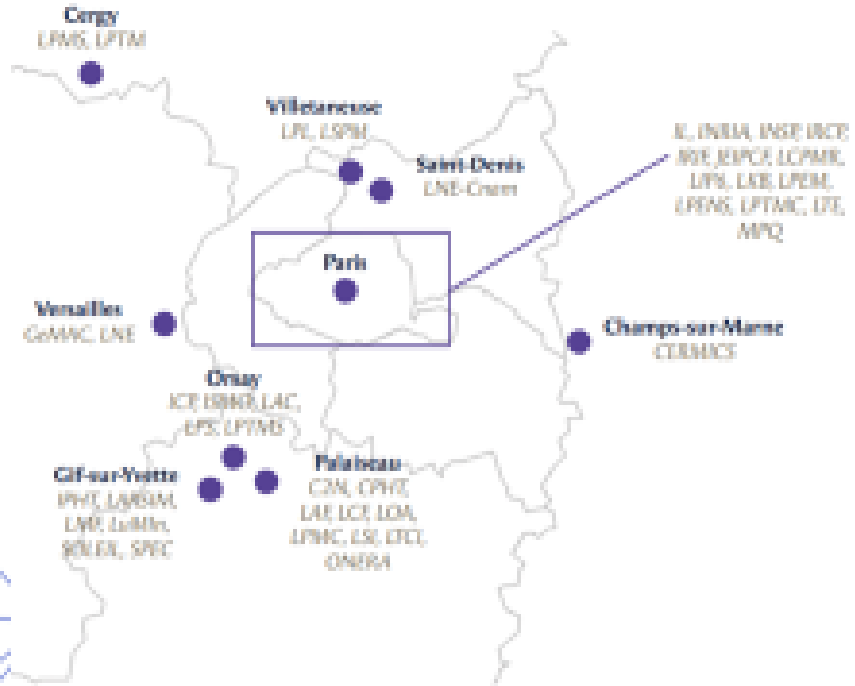
Paul Indelicato
2006-2012

Antoine Heidman
2012-2024

Nicolas Treps
2024 -

QuanTip network for quantum technologies in the Paris area

Academic members



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PhDs
Visitors
WELCOME

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Atom chips

Bose-Einstein condensates

Ultracold Fermi gases

Quantum theory, atoms and fields

Quantum optics and quantum information

Rydberg atoms

Quantum optics

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Complex media optics

Tests of fundamental interactions and metrology

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Quantum Tests with Hydrogen

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Trapped ions

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