Serge Haroche

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Curriculum Vitae of Serge Haroche

Present Position: Professeur at Collège de France (2001-), Chaire de Physique Quantique

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Personal status:
Born September 11, 1944 in Casablanca, Morocco; French citizen; Married, two children.

Academic Training and degrees:
Ecole Normale Supérieure, Paris 1963-1967
Doctorat de Troisième Cycle, Paris 1967 and Agrégation de Physique, Paris 1967
Thèse d'Etat de Physique (PhD in Physics), Paris 1971

Former Positions:
Attaché de recherches au CNRS, Paris, 1967-1971
Chargé de recherches au CNRS, Paris, 1971-1973
Maître de recherches au CNRS, Paris, 1973-1975
Maître de conferences at Ecole Polytechnique, Paris, 1973-1984
Visiting scholar at Stanford University, 1972-1973,1976 and 1979.
Visiting scientist at M.I.T. (Cambridge, USA) 1979
Visiting Professor at Harvard University (Cambridge, USA), 1981
Professor at Yale University (part time), (New Haven, CT, USA) 1984-93
Professeur de Physique at Université Pierre et Marie Curie, Paris, 1975 -2001
Professeur at Ecole Normale Supérieure, Paris, September 1982 -2001
Member of Institut Universitaire de France, December 1991-2001
Directeur du Département de Physique de l'Ecole Normale Supérieure, 1994-2000

Prizes and Awards:
Prix Aimé Cotton of the French Physical Society, 1971
Loeb Lecturer at Harvard University, 1980
Grand Prix de Physique Jean Ricard of the French Physical Society, 1983
Einstein Prize for Laser Science (Industrial and University Research Affiliates), 1988
Humboldt Award, Germany (1992).
Michelson Medal of the Franklin Institute, Philadelphia (1993).
EPS travelling lecturer (1993-94).
Manne Siegbahn Lecture, Stockholm (2000)
Tomassoni award of La Sapienza University, Rome (2001)
Quantum Electronics Prize of the European Physical Society (2002)
Quantum Communication Award of the International Organization for Quantum Communication, Measurement and Computing and Tamagawa University (Japan) (2002).
Townes Award of the Optical Society of America (2007)
Gra Cruz Ordem Nacional Do Merito Cientifico, Brazil (2007)
Médaille d'Or du CNRS (CNRS Gold Medal) (2009)
Advanced Research Grant from the European Research Council (2009)
Herbert Walther Award of the German Physical Society and Optical Society of America (2010)

Membership in Professional Institutions:
French Physical Society
European Physical Society (EPS)
American Physical Society, Member 1988, Fellow 1990

Membership in Scientific Academies
Member of Académie des Sciences, Paris, 1993
Member (Foreign associate) of the Brazilian Academy of Sciences, 2009
Member of the European Academy of Sciences, 2009
Member (Foreign associate) of the National Academy of Sciences of the USA, 2010

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Collège de France and Ecole Normale Supérieure, Paris, France

Short biographic note :

Serge Haroche was born in 1944 in Casablanca. He graduated from Ecole Normale Supérieure (ENS), receiving his doctorate from Paris VI University in 1971 (thesis advisor: Claude Cohen-Tannoudji). After a post-doctoral visit to Stanford University in the laboratory of Arthur Schawlow (1972-73), he became full professor at Paris VI University in 1975, a position he held until 2001, when he was appointed **Professor at Collège de France (in the chair of quantum physics)**. He has been Maitre de Conference at Ecole Polytechique (1974-1984), visiting professor at Harvard (1981), part time professor at Yale University (1984-1993), member of Institut Universitaire de France (1991-2000) and chairman of the ENS Department of Physics (1994-2000). His research has mostly taken place in laboratoire Kastler Brossel at ENS, where he now works with a team of senior coworkers, postdocs and graduate students.

Serge Haroche has received many prizes and awards, including the Grand Prix Jean Ricard of the French Physical Society (1983), the Einstein Prize for Laser science (1988), the Humbold Award (1992), the Michelson Medal from the Franklin Institute (1993), the Tomassoni Award from La Sapienza University (Rome, 2001), the Quantum Electronics prize of the European Physical Society (2002), the Quantum Communication Award of the International Organization for Quantum Communication, Measurement and Computing (2002), the Townes Award of the Optical Society of America, the CNRS Gold Medal (2009) and the Herbert Walter Prize of the German Physical Society and the Optical Society of America. He is a member of the French Academy of Sciences and a Foreign Member of the National Academy of Sciences of the United States. He has received in 2009 a five year advanced research grant from the European Research Council (ERC).

Short Summary of research

Serge Haroche main research activities have been in quantum optics and quantum information science. He has made important contributions to Cavity Quantum Electrodynamics (Cavity QED), the domain of quantum optics which studies the behaviour of atoms interacting strongly with the field confined in a high-Q cavity. An atom-photon system isolated from the outside world by highly reflecting metallic walls realizes a very simple experimental model which Serge Haroche has used to test fundamental aspects of quantum physics such as state superposition, entanglement, complementarity and decoherence. Some of these experiments are actual realizations in the laboratory of the "thought experiments" imagined by the founding fathers of quantum mechanics. Serge Haroche's main achievements in cavity QED include the observation of single atom spontaneous emission enhancement in a cavity (1983), the direct monitoring of the decoherence of mesoscopic superpositions of states (so-called Schrödinger cat states) (1996) and the quantum-non-demolition measurement of a single photon (1999). By manipulating atoms and photons in high-Q cavities, he has also demonstrated many steps of quantum information procedure such as the generation of atom-atom and atom-photon entanglement (1997), the realization of a photonic memory (1997) and the operation of quantum logic gates involving photons and atoms as "quantum bits" (1999).

In 2006, Serge Haroche and his ENS team have developed a super-high-Q cavity able to store photons between mirrors for times longer than a tenth of a second. Trapping light quanta in this cavity has allowed the ENS team to detect repeatedly and non-destructively the same field, to project it into states with definite photon numbers (so called Fock states) and to observe the quantum jumps of light due to the loss or gain of a single photon in the cavity (2007). This constitutes a completely new way to look at light. Whereas photons are usually destroyed upon measurement, they can now be counted and counted again in the cavity as one would do with marbles in a box. This non-destructive detection method has led Serge Haroche and his team to develop novel ways to generate and reconstruct non-classical states of radiation trapped in a cavity and to investigate in details their decoherence, the phenomenon essential to explain the transition from quantum to classical (2008). The ENS team has recently pushed these experiments further by demonstrating a quantum feedback procedure achieving the preparation of predetermined non-classical state of a field trapped in a cavity and counteracting the effects of decoherence on these states (2011).

Many of the ideas developed by S.Haroche and his research team in microwave cavity QED experiments have been exploited in other contexts to build new devices playing an increasing role in opto-electronics and optical communication science. Manipulating the emission properties of quantum dots embedded in solid state micro-cavities has become a widely exploited method to build solid state sources and generate non classical light of various sorts. Strong coupling of light emitters with micro-cavity structures is being developed to achieve operations useful for quantum communication and quantum information processing purposes. By coupling artificial atoms made of superconducting junctions with strip-line microwave cavities, many groups word-wide are now developing a new field of physics dubbed "Circuit QED" which borrows many of its concepts from microwave cavity QED experiments. These examples show the impact of fundamental Cavity QED work on areas of research which could lead to promising applications for technology.

A detailed summary of Serge Haroche's research achievements

Early work (1965-1979):

Serge Haroche's early work includes the elaboration of the « dressed atom » formalism and the experimental study of dressed atom properties in optical pumping experiments (thesis work from 1965 to 1971), the development of laser induced quantum beat spectroscopy (1973-76) and the study of superradiance of laser-excited atomic ensembles (1976-78). His research has then focused on the study of the radiative properties of Rydberg atoms, starting with the millimiter wave high resolution spectroscopy of these atoms and the first realization of Rydberg atom masers (1979).

First Cavity QED studies (1979-1992):

Serge Haroche's experiments with Rydberg atoms and microwaves stored in cavities led him, in the early 1980's, to become one of the main actors in the then emerging field of Cavity Quantum Electrodynamics (Cavity QED). This is the domain of quantum optics which studies the radiative behavior of atoms confined by reflecting boundaries in a limited region of space. The modification of the spectrum of the vacuum field surrounding the atom results in a change of the spontaneous emission rate of the atom, which can be either enhanced or inhibited. In a 1983 experiment, Serge Haroche and his team have observed the enhancement of the emission rate of a single Rydberg atom in a resonant cavity, an effect which had been predicted by Purcell forty years earlier. They have also observed, at about the same time, the fully symmetrical superradiance of an atomic ensemble in a cavity, an effect which had been theoretically predicted long before by R.Dicke but never observed under such simple conditions. Serge Haroche and coworkers have operated in 1987 the first two-photon maser oscillator, stimulating Rydberg atoms to emit photons by pairs in a very high Q superconducting cavity. Such a two-photon quantum oscillator has threshold and statistical properties very different from usual lasers operating on single photon atomic transitions. It had been proposed since the early days of quantum electronics, but its actual realization has been made possible only by the progresses of cavity QED physics. In the 1980's and early 1990's, during his stay at Yale University, Serge Haroche, working with E.Hinds and D.Meschede, has performed the first experiments on the inhibition of atomic spontaneous emission in a microcavity at optical frequencies and observed in a text book context the van der Waals shifts induced on the energy levels of atoms by their images in mirrors.

Cavity QED , Quantum Information and decoherence studies (1992-2005):

Exploiting cavity QED methods, Serge Haroche and his ENS team – including colleagues Jean-Michel Raimond and Michel Brune – have started in the early 1990's to investigate the interaction between single atoms and one or more photons stored in a very high Q supercondcting cavity (strong coupling regime of Cavity QED). This has led to unprecedented tests of quantum mechanics of relevance to quantum information and decoherence studies. Between 1996 and 2005, Haroche and his team have demonstrated various schemes of entanglement between atoms and photons, realized quantum gates and simple quantum logic operations. They have in 1996 observed the Rabi oscillation of an atom in a very small field made of a few photons and shown that the Fourier analysis of this oscillation directly reveals the photon graininess of the quantum field. The same year, they have observed the size-dependent progressive decoherence of a quantum system in an experiment exploring the quantum-classical boundary. They have performed in 1999 the first quantum non-destructive measurements of a single photon. Starting in 2001, they have developed and demonstrated new methods to directly measure with atoms the phase space distributions of non-classical fields stored in a cavity (the so called Q and Wigner functions). In later experiments (2003-2005), Serge Haroche and his group have shown that the Rabi oscillation of an atom in a coherent field made of many photons results in an atom-field entanglement which is directly

related to the collapse and revival of the Rabi oscillation. These studies opened the way to the investigation of quantum superposition and entanglement in mesoscopic systems of still larger sizes.

Quantum non-destructive observation of trapped photons, detection of field quantum jumps, reconstruction of non-classical field states, direct monitoring of decoherence and quantum feedback demonstrations (2006-2011):

Recently, Haroche and his team have developed super-high finesse cavities which hold microwave photons over more than a tenth of a second. This has led to experiments in which trapped photon fields are manipulated and detected with unprecedented sensitivity and accuracy. The stored photons are continuously detected in a non-destructive way (Quantum Non-Demolition or QND method) by having them interact dispersively with atoms crossing one by one the cavity. The progressive projection of the field into Fock states corresponding to definite photon numbers has been observed and the quantum jumps of a light field have been monitored in this way. For the first time, single photons are continuously observed in a box and the random times at which they are created or annihilated are directly recorded. The method, first applied to a single photon field, has been extended to fields made up of several photons, which are non-destructively counted in the cavity as if they were marbles in a box. The quantum Zeno effect has been observed by the ENS team on this system. Haroche and coworkers have shown that the coherent growth of the field when the cavity is coupled to a microwave source is frozen if the field is repeatedly watched by non-absorbing atoms. Combining QND photon counting with a homodyne mixing method, Haroche and his team have recently reconstructed the full quantum state of Fock and Schrödinger cat states of light whose classical components differ by up to 12 photons. By taking snapshots of these states at successive times, they have realized actual movies of the decoherence process in progress, which clearly illustrate the transition from quantum to classical in a microscopic system coupled to an environment. Extension of these experiments to two cavities coupled by an atomic beam are in progress. They will make it possible to study the non-local properties of mesosocopic systems made of tens of photons or atoms. The non-destructive QND method has very recently been used to implement a quantum feedback procedure steering the cavity field towards a predetermined target Fock state and subsequently reversing the effects of quantum jumps out of this state. The method relies on repeated weak measurements of the field allowing a fast computer to estimate in real time the state of the field and to compute the field to be injected into the cavity in order to bring its field closer to the target. The procedure, operating in loops has been used to stabilize Fock states with up to four photons.

In another set of experiments, Haroche and his group are developing novel kinds of atom chips in which cold atoms are trapped by the magnetic field produced by superconducting wires. These devices open perspectives for building new atomic sources of cold atoms for Cavity QED studies and for fundamental tests involving the coupling of atomic systems with mesoscopic circuits.

Selected papers of Serge Haroche (from 1982 to 2011)

1. J.M.Raimond, P.Goy, M.Gross, C.Fabre and S.Haroche, "Statistics of millimeter-wave photon emitted by a Rydberg atom maser; an experimental study of fluctuations in single mode superradiance", Phys.Rev.Lett. **49**, 1924 (1982).

2. P.Goy, J.M.Raimond, M.Gross and S.Haroche, "Observation of cavity-enhanced single atom spontaneous emission", Phys.Rev.Lett. **50**, 1903 (1983).

3. M.Brune, J.M.Raimond, P.Goy, L.Davidovich and S.Haroche, "Realization of a two-photon maser oscillator", Phys.Rev.lett. **59**, 1899 (1987).

4. W.Jhe, A.Anderson, E.Hinds, D.Meschede, L.Moi and S.Haroche, "Suppression of spontaneous decay at optical frequencies: test of vacuum field anisotropy in confined space", Phys.Rev.Lett. **58**, 666 (1987).

5. M.Brune, S.Haroche, V.Lefèvre-Seguin, J.M.Raimond and N.Zagury, "Quantum Nondemolition measurement of small photon number by Rydberg atom phase sensitive detection". Phys.Rev.Lett. **65** (1990) p. 976.

6. S.Haroche, "Cavity Quantum Electrodynamics" in "Fundamental Systems in Quantum Optics" les Houches session LIII J. Dalibard, J.M. Raimond et J. Zinn Justin éditeurs, Elsevier Science Publishers (1992).

7. M.Brune, S.Haroche, J.M.Raimond, L.Davidovich and N.Zagury, "Manipulation of photons in a cavity by dispersive atom-field coupling: quantum nondemolition measurements and generation of Schrödinger cats" Phys.Rev.A **45** 5193(1992).

8. V.Sandoghdar, C.Sukenik, E.Hinds and S.Haroche, "Direct measurement of the van der Waals interaction between an atom and its images in a micron-sized cavity". Phys.Rev.Lett. **68** 3432(1992).

9. M.Brune, F.Schmidt-Kaler, A.Maali, J.Dreyer, E.Hagley, J.M.Raimond and S.Haroche, "Quantum Rabi Oscillation: A direct test of Field Quantization in a cavity", Phys.Rev.Lett **76**, 1800 (1996).

10. M.Brune, E.Hagley, J.Dreyer, X.Maitre, A.Maali, C.Wunderlich, J.M.Raimond and S.Haroche, "Observing the progressive decoherence of the meter in a quantum measurement", Phys.Rev.Lett. **77**, 4887 (1996).

11. E.Hagley, X.Maître, G.Nogues, C.Wunderlich, M.Brune, J.M.Raimond and S.Haroche, « Generation of Einstein-Podolsky-Rosen pairs of atoms », Phys.Rev.Lett. **79**, 1 (1997).

12. X.Maître, E.Hagley, G.Nogues, C.Wunderlich, P.Goy, M.Brune, J.M.Raimond and S.Haroche, « Quantum memory with a single photon in a cavity », Phys.Rev.Lett. **79**, 769 (1997).

13. G.Nogues, A.Rauschenbeutel, S.Osnaghi, M.Brune, J.M.Raimond and S.Haroche, « Seeing a single photon without destroying it », Nature, **400**, 239 (1999).

14. A.Rauschenbeutel, G.Nogues, S.Osnaghi, P.Bertet, M.Brune, J-M. Raimond and S.Haroche, " Coherent Operation of a tunable quantum phase gate in Cavity QED ", Phys.Rev.Lett. **83**, 5166 (1999).

15. A.Rauschenbeutel, G.Nogues, S.Osnaghi, P.Bertet, M.Brune, J-M Raimond and S. Haroche, " Step by step engineered multiparticle entanglement ", Science, **288**, 2024 (2000).

16. P.Bertet, A.Rauschenbeutel, G.Noguès, A.Auffeves, M.Brune, J.M.Raimond and S.Haroche, "A complementarity experiment with an interferometer at the quantum-classical boundary", Nature, **411**, 166 (2001)

17. S.Osnaghi, P.Bertet, A.Auffeves, P.Maioli,M.Brune, J.M.Ramond and S.Haroche, "Coherent Control of an atomic collision in a cavity" Phys.Rev.Lett**. 87**, 037902-1 (2001).

18. P.Bertet, A. Auffeves, P.Maioli, S.Osnaghi, T.Meunier, M.Brune, J.M.Raimond and S.Haroche «Direct Measurement of the Wigner Function of a one-photon Fock state in a Cavity », Phys.Rev.Lett. **89**, 200402-1 (2002).

19. A.Auffeves, P.Maioli, T.Meunier, S.Gleyses, G.Nogues, M.Brune, J.M.Raimond et S.Haroche "Entanglement of a mesoscopic field with an atom induced by photon graininess in a cavity" Phys.Rev.Lett. **91**, 230405 (2003).

20. T.Meunier, S.Gleyzes, P.Maioli, A.Auffeves, G.Nogues, M.Brune, J-M.Raimond and S.Haroche, « Rabi oscillations revivals induced by time reversal : a test of mesoscopic quantum coherence », Phys.Rev.Lett. **94**, 010401 (2005).

21. T.Nirrengarten, A.Qarry, C.Roux, A.Emmert, G.Nogues, M.Brune, J-M.Ramond and S.Haroche "Realization of a superconducting atom-chip", Phys.Rev.Lett. **97**, 200405 (2006).

22. S. Gleyzes, S.Kuhr, C. Guerlin, J. Bernu, S. Deléglise, U. Busk Hoff, M. Brune, J-M. Raimond and S. Haroche **«**Quantum jumps of light recording the birth and death of a photon in a cavity **»**, Nature, **446**, 297 (2007).

23. C.Guerlin, J.Bernu, S.Deléglise, C.Sayrin, S.Gleyzes, S.Kuhr, M.Brune, J-M.Raimond and S.Haroche "Progressive field-state collapse and quantum non-demolition photon counting", Nature, **448**, 889 (2007).

24. S.Kuhr, S.Gleyzes, C.Guerlin, J.Bernu, UB.Hoff, S.Deléglise, S.Osnaghi, M.brune, J-M.Raimond, S.Haroche, E.Jacques, P.Bosland and B.Visentin "Ultrahigh finesse Fabry Perot superconducting resonator", Appl.Phys.Lett**. 90**, 164101 (2007).

25. S.Deléglise, I.Dotsenko, C.Sayrin, J.Bernu, M.Brune, J-M.Raimond and S.Haroche, "Reconstruction of non-classical cavity field states with snapshots of their decoherence", Nature, **455**, 510 (2008).

26. J.Bernu, S.Deléglise, C.Sayrin, S.Kuhr, I.Dotsenko, M.Brune, J-M.Raimond and S.Haroche "Freezing a coherent field growth in a cavity by quantum Zeno effect", Phys.Rev.Lett.. **101**, 180402 (2008).

27. M.Brune, J.Bernu, C.Guerlin, S.Deléglise, C.Sayrin, S.Gleyzes, S.Kuhr, I.Dotsenko, J-M.Raimond and S.Haroche "Process tomography of field damping and measurement of Fock state lifetimes by quantum non demolition photon counting in a cavity" Phys.Rev.Lett. **101**, 240402 (2008).

28. C.Sayrin, I.Dotsenko, XX.Zhou, B.Peaudecerf, T.Rybarczyk, S.Gleyzes, P.Rouchon, M.Mirrahimi, H.Amini, M.Brune, J-M.Raimond and S.Haroche "Real-time quantum feedback prepares and stabilizes photon number states", Nature **477**, 73 (2011).

Selection of review papers in general audience journals

29. S.Haroche and D.Kleppner, "Cavity Quantum Electrodynamics". Physics Today, **42**-1, January 1989.
30. S.Haroche and J.M.Raimond, "Cavity Quantum Electrodynamics" Scientific American (April 1993).
31. S.Haroche, « Entanglement, decoherence and the quantum-classical boundary », Physics Today, July 1998.
32. J.M.Raimond, M.Brune and S.Haroche, "Colloquium: Manipulating quantum entanglement with atoms and photons in a cavity", Rev.Mod.Phys. **73**, 565 (2001).

Books:

-La physique quantique (Fayard, Paris, 2004)

-**Exploring the quantum: atoms, cavities and photons**, Oxford University Press (2006). Co-authored with Jean-Michel Raimond.

Serge Haroche complete publication list
(1965-2011)

1. C.Cohen-Tannoudji and S.Haroche,"Pompage atomique transversal: mise en évidence d'un nouveau spectre de raies de résonance magnétique", Comptes Rendus Acad. Sciences, 261, 5400 (1965)

2. C.Cohen-Tannoudji and S.Haroche, "Modification et annulation du facteur de Landé d'un atome par couplage avec un champ de radiofréquence", Comptes Rendus Acad. Sciences, 262, 268 (1966).

3. C.Cohen-Tannoudji and S.Haroche, "Interpretation de diverses résonances magnétiques en termes de croisements et anticroisements de niveaux d'énergie du système global atome-photons de radiofréquence", Comptes Rendus Acad. Sciences, 262, 37 (1966).

4. C.Cohen-Tannoudji and S.Haroche, "Interprétation de divers spectres de raies de résonance magnétique basée sur une résolution par itération des équations d'évolution de la matrice densité atomique", Comptes Rendus Acad. Sciences, 264, 626 (1967).

5. S.Haroche, "Etudes théorique et expérimentale d'un nouveau spectre de raies de résonance magnétique observé en pompage optique transversal, thèse de troisième cycle, Paris, 1967 (non publié).

6. S.Haroche and C.Cohen-Tannoudji, "Interprétation quantique des diverses résonances observées lors de la diffusion de photons optiques et de radiofréquence par un atome", J.Physique, 30, 125 (1969).

7. C.Cohen-Tannoudji and S.Haroche, "Absorption et diffusion de photons optiques par un atome en interaction avec des photons de radiofréquence", J.Physique, 30, 153 (1969).

8. J.Dupont-Roc, S.Haroche and C.Cohen-Tannoudji, "Detection of very weak magnetic fields (10^{-9} Gauss) by 87 Rb zero-field level crossing resonances", Phys.Lett.A, 28, 638 (1969).

9. C.Cohen-Tannoudji, J.Dupont-Roc, S.Haroche and F.Laloe, "Detection of the static magnetic field produced by the oriented nuclei of optically pumped He^3 gas", Phys.Rev.Lett. 22, 758 (1969).

10. C.Cohen-Tannoudji and S.Haroche, "Le concept d'atome habillé par des photons" in "Polarisation, matière et rayonnement" (livre jubilaire en l'honneur de A.Kastler, P.U.F., Paris (1969).

11. C.Landré, C.Cohen-Tannoudji, J.Dupont-Roc and S.Haroche, "Etude expérimentale du diagramme d'énergie d'un atome habillé par des photons de radiofréquence", Comptes Rendus Acad. Sciences, 270, 73 (1970).

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13. C.Landré, C.Cohen-Tannoudji, J.Dupont-Roc and S.Haroche, "Anisotropie des propriétés magnétiques d'un atome habillé par des photons de radiofréquence", J.Physique, 31, 971 (1970).

14. C.Cohen-Tannoudji, S.Haroche, C.Audoin and J.P.Schermann, "Modified Zeeman hyperfine spectra observed in H and Rb ground states interacting with a non resonant rf field", Phys.Rev.Lett. 24, 861 (1970).

15. S.Haroche and C.Cohen-Tannoudji, "Resonant transfer of coherence in non zero magnetic field between atomic levels of different g-factors", Phys.Rev.Lett. 24, 974 (1970).

16. C.Cohen-Tannoudji, J.Dupont-Roc, S.Haroche and F.Laloe, "Diverses résonances de croisement de niveaux sur des atomes pompés optiquement en champ nul, I:Théorie", Rev.Phys.Appl. 5, 95 (1970).

17. C.Cohen-Tannoudji, J.Dupont-Roc, S.Haroche and F.Laloe, "Diverses résonances de croisement de niveaux sur des atomes pompés optiquement en champ nul: Application à la mesure des champs faibles", Rev.Phys.Appl. 5, 102 (1970).

18. S.Haroche, "Etude théorique et expérimentale des propriétés physiques d'atomes en interaction avec des photons de radiofréquence" (thèse d'état), Ann.Phys. Paris, 6, 189 and 327 (1971).

19. M.Le Dourneuf, C.Cohen-Tannoudji, J.Dupont-Roc and S.Haroche, "Résoance magnétique de type Raman observable en champ nul sur des spins pompés optiquement", Comptes Rendus Acad.Sciences, 272, 985 (1971).

20. M.Le Dourneuf, C.Cohen-Tannoudji, J.Dupont-Roc and S.Haroche, "Champ magnétique statique fictif associé à un champ rf tournant", Comptes Rendus Acad.Sciences, 272, 1048 (1971).

21. M.Le Dourneuf, C.Cohen-Tannoudji, J.Dupont-Roc and S.Haroche, "Interaction d'atomes alcalins dans leur état fondamental avec un champ de radiofréquence tournant non résonnant", Comptes Rendus Acad.Sciences, 272, 1131 (1971).

22. S.Haroche, "Etude théorique de la relaxation magnétique d'atomes habillés par un champ de radiofréquence", Comptes Rendus Acad.Sciences. 273, 1123 (1971).

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25. S.Haroche and F.Hartmann, "Theory of Saturated Absorption Lineshapes", Phys.Rev. A6, 1280 (1972).

26. G.Grynberg, J.Dupont-Roc, S.Haroche and C.Cohen-Tannoudji, "Un croisement de niveaux singulier: l'anticroisement empéché ou croisement de deuxième espèce", J.Physique 34, 523 (1973).

27. G.Grynberg, J.Dupont-Roc, S.Haroche and C.Cohen-Tannoudji, Exemples de croisements de deuxième espèce dans le diagramme d'énergie d'un atome habillé par des photons de radiofréquence", J.Physique 34, 523 (1973).

28. S.Haroche, J.Paisner and A.L.Schawlow, "Hyperfine quantum beats observed in Cs vapor under pulsed dye laser excitation", Phys.Rev.Lett. 30, 948 (1973).

29. S.Haroche and J.Paisner, "Quantum beat spectroscopy using tunable pulsed dye lasers" in "Laser Spectrsocopy I", G.Brewer editor (1973).

30. S.Haroche, M.Gross and M. Silverman, "Observation of fine structure quantum beats following stepwise excitation in Na nD states", Phys.Rev.Lett. 33, 1063 (1974).

31. S.Haroche, "Quantum beat spectrsocopy" in "High resolution spectroscopy", Shimoda editor, Springer Verlag (1975).

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