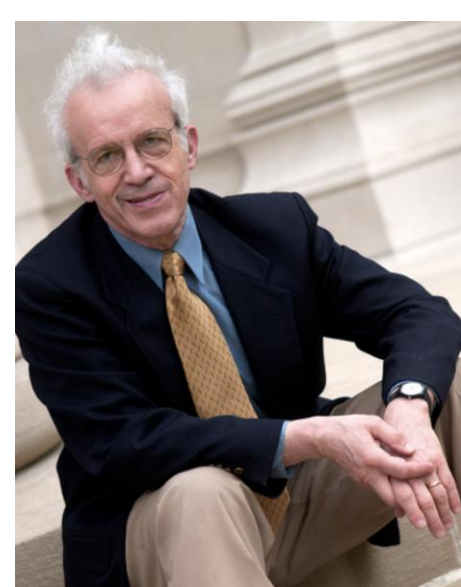


Remembering Dan as a
pioneer in AMO
physics, an
exceptional mentor and
a statesman of science

Serge Haroche,

*Laboratoire Kastler Brossel, Ecole Normale Supérieure
& Collège de France, Paris*

In memory of Daniel Kleppner, ICAP 2026, Wuhan, China



Daniel Kleppner passed away on June 16 2025, exactly one year ago, at the age of 92

A luminary in atomic physics who made fundamental contributions to:

The physics of the Hydrogen atom and its application to extreme precision measurements

The physics of Rydberg atoms

Cavity Quantum Electrodynamics

Bose Einstein Condensation and the physics of degenerate quantum gases



A Statesman of science
whose advices and opinions
deeply influenced generations
of students and scientists

REFERENCE FRAME



In his « Reference Frame »
opinion pieces in Physics Today
Dan expressed his views about
the beauty of science, the
moral values it carries, the

importance of the search for the truth and of the
transmission of knowledge between generations.

His sense of humour and elegant style illuminated
different aspects of the present and past history of
science, making his articles which always expressed deep
ideas, a real joy to read.

The Physics of Hydrogen, the simplest atom

The Hydrogen Maser
(Dan's PhD under the mentorship of N.Ramsey)

PHYSICAL REVIEW

VOLUME 126, NUMBER 2

APRIL 15, 1962

Theory of the Hydrogen Maser*

DANIEL KLEPPNER, H. MARK GOLDENBERG, AND NORMAN F. RAMSEY

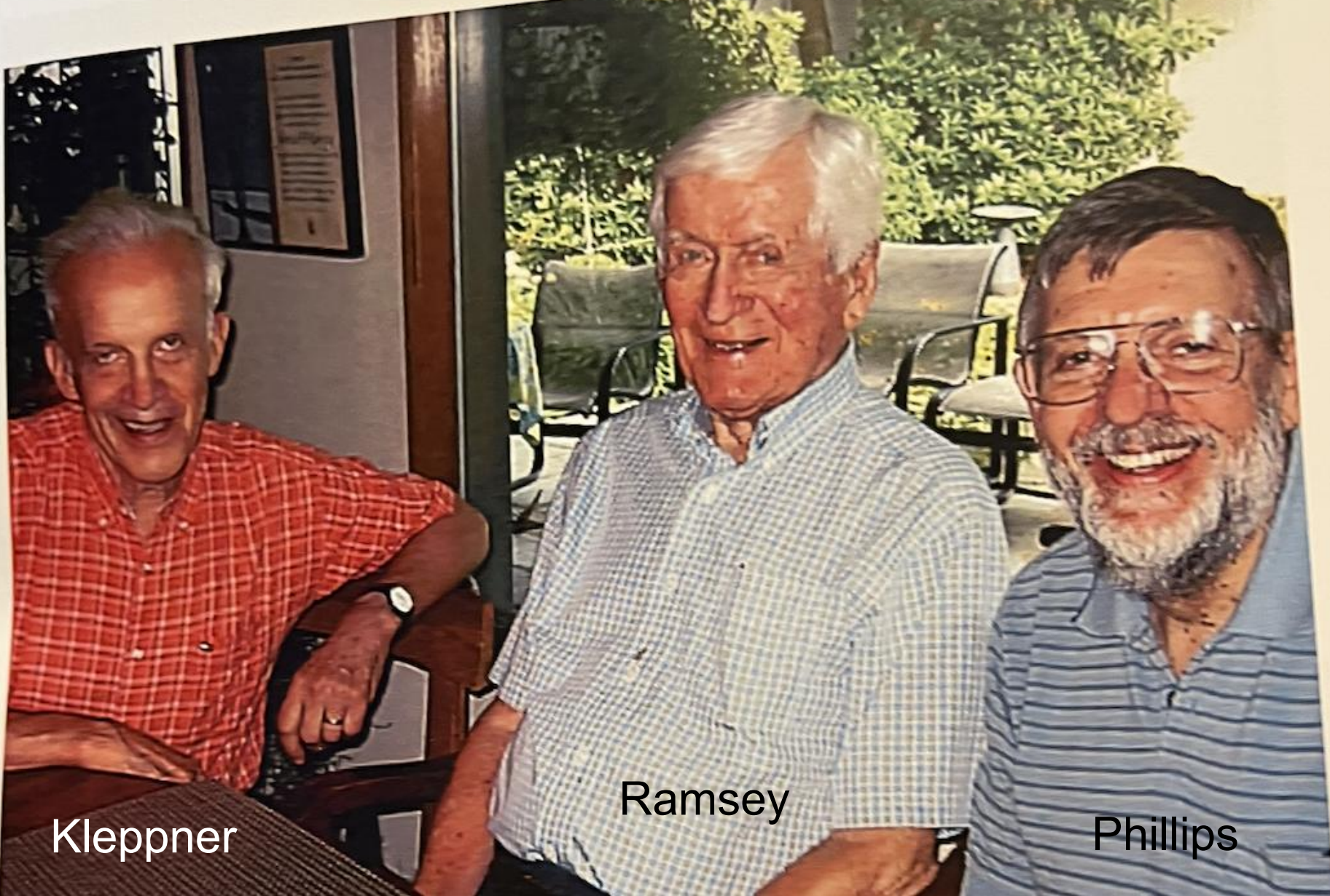
Harvard University, Cambridge, Massachusetts

(Received December 15, 1961)

The behavior of the atomic hydrogen maser is analyzed for both stationary and transient operation. An expression for noise in the signal from the maser oscillator is derived by applying the previously developed theory of Shimoda, Wang, and Townes. A variety of relaxation phenomena are analyzed, including effects of chemical reaction with the surface and magnetic field inhomogeneities. Several mechanisms leading to frequency shifts in the maser are also analyzed, including cavity pulling and the Doppler effect.

The proton magnetic moment
(the PhD of W.Phillips, one of the first Dan's student)

The importance of precision measurements



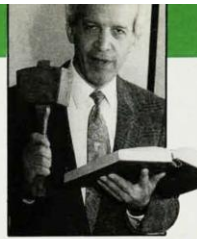
Kleppner

Ramsey

Phillips

Three generations of atomic physicists

REFERENCE FRAME



A PASSION FOR PRECISION

Daniel Kleppner

“Thought and action,” “mind and hand,” *mens et manus*—this theme of contemplation and activity is familiar among the mottos of academe. At the Massachusetts Institute of Technology *Mens et Manus* is both our motto and our logo. *Mens*, stalwart and fashionably dressed, contemplates a book of wisdom. The size of the tome suggests, perhaps, the *Science Citation Index*. *Manus*, more stalwart but less fashionably dressed than *Mens*, leans with a slight hint of fatigue upon a sledgehammer. His job appears to lie somewhere between rail-

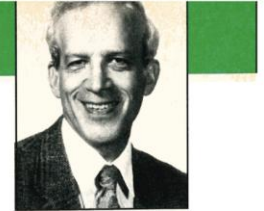
vance is fraught with peril. The game is all the more heady because it is dangerous.

My own particular delight in the precision measurement game was inherited from my teacher Norman Ramsey, who is sharing this year’s Nobel Prize in Physics for advancing the art of high-precision measurements. If you too have an urge to play the game, be prepared for high opening stakes. Today the game begins at an accuracy of roughly 3 parts in 10^7 . This is the accuracy with which most of your all-around, everyday funda-



Reference frames on precision measurements

REFERENCE FRAME



WHERE I STAND

Daniel Kleppner

To come directly to the point, where I stand is N 42° 24.538', W 71° 10.575', give or take thirty meters. I am reasonably confident about this

the GPS, it was a military navigation system that required racks of electronics costing roughly a hundred thousand dollars. A bucket of hand grenades would have seemed less out

better than 1 part in 10^{14} during the two-hour experiment.

As an atomic clock, the hydrogen maser paid off in numerous unexpected ways. For radioastronomers,

REFERENCE FRAME

On the Matter of the Meter

Daniel Kleppner



The various styles of physics are so diverse that even to an expert eye they can seem to stem from foreign disciplines. Rheology and cosmology, for instance, apparently have little in common. Nevertheless, essentially all physicists share certain beliefs. Among these are the primacy of quantitative reasoning and a general agreement about concepts such as space, time, and mass (assuming, at least,

Sèvres. However, two years earlier, Albert A. Michelson had discovered how to adapt his interferometer to measure distance to a fraction of the wavelength of light. His method was so precise that in 1889 the meter was obsolete at the moment of its redefinition.

In spite of the superiority of Michelson’s methods, the meter-bar in Sèvres remained the legal standard for 71 years. Finally, in 1960, the meter was redefined to be a certain

Reference Frame

Time Too Good to Be True

Daniel Kleppner

Without wishing to cause unnecessary distress, I would like to call attention to a couple of issues concerning time. The first is merely calendric but the second concerns the future of time itself.

The first issue is that we may have to say farewell to leap seconds. Leap seconds, as you might recall, are the occasional one-second adjustments of

hiccup in the phasing of North American power grids would likely cause a hemispheric blackout.

The days are growing longer

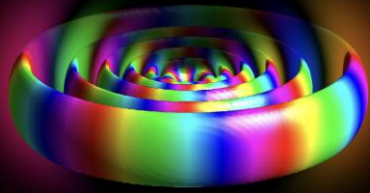
The underlying reason that leap seconds were introduced is the gradual lengthening of the day due to tidal friction. Tidal friction is caused by the lag between the tidal force of the Moon and

accuracy is expected to reach 1 part in 10^{16} . Furthermore, we are on the threshold of a new age of optical atomic clocks and optical frequency metrology and can look forward to clocks that will eventually achieve an accuracy of 1 part in 10^{18} .

The prospect of a major advance in clock accuracy brings me to the second issue concerning time. At accuracies



DONNA GOVERN/MIT



Dan and Rydberg atom physics

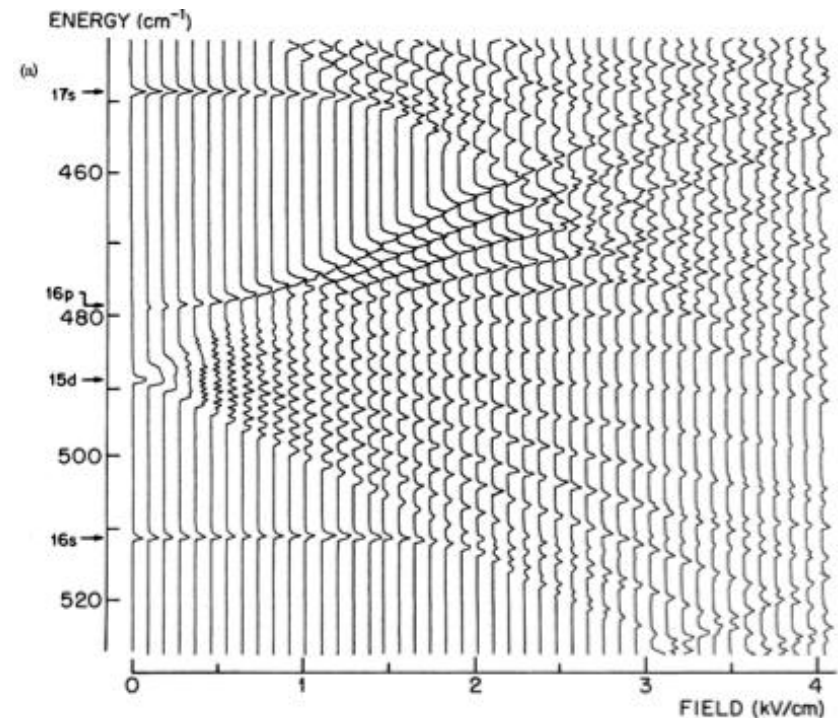
Very excited alkali atoms:
the simplest atoms
beyond hydrogen become
accessible with tuneable
lasers (1970's)

At MIT, Dan and his students
were captivated by their
sensitivity to electric and
magnetic fields

Structure of Sodium Rydberg States in Weak to Strong Electric Fields*

Michael G. Littman, Myron L. Zimmerman, Theodore W. Ducas,
Richard R. Freeman, and Daniel Kleppner

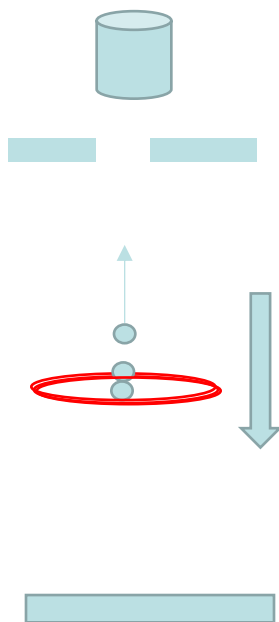
*Research Laboratory of Electronics and Department of Physics, Massachusetts Institute of Technology,
Cambridge, Massachusetts 02139
(Received 12 January 1976)*



Rydberg state selective detection by field ionization



D.Kleppner



Rydberg atom
ionization in
increasing E-
field

State
selective
ionization
in ramp
of
electric
field

Stark Ionization of High-Lying States of Sodium^{*†}

Theodore W. Ducas, Michael G. Littman, Richard R. Freeman, and Daniel Kleppner
*Research Laboratory of Electronics and Department of Physics, Massachusetts Institute of Technology,
Cambridge, Massachusetts 02139*

(Received 14 April 1975)

By using stepwise excitation in an atomic beam, we have excited slow-moving atoms to pure high-lying quantum states at densities low enough to avoid loss by collision. The atoms were detected with high efficiency by Stark ionization. Results are presented of a study of the threshold field for ionization for *s* states of sodium with principal quantum number *n* from 26 to 37.

A very sensitive and selective way to detect Rydberg states..

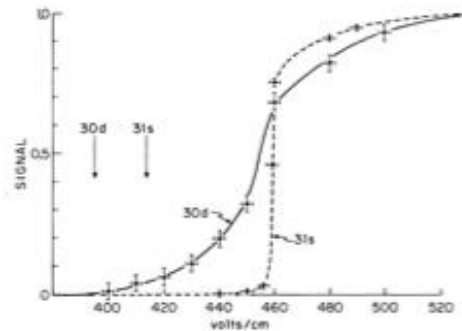
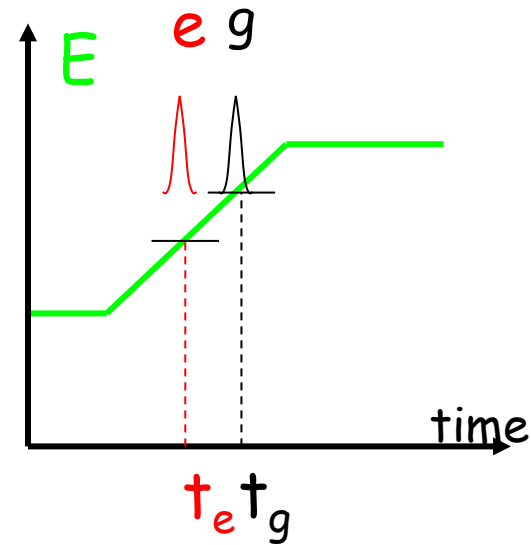


FIG. 2. Ionization signal as a function of the pulsed ionizing electric field. The onset of ionization is broader for the 30*d* level than for the 31*s*. This is due to the Stark splitting in the ionizing field of the 30*d*. The 31*s* remains a single-shifted level. The vertical arrows indicate the critical ionization field of the unshifted levels from Eq. (1).



Rydberg Atoms in "Circular" States

Randall G. Hulet and Daniel Kleppner

Research Laboratory of Electronics and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

(Received 5 August 1983)

The population of a beam of lithium atoms has been transferred from a low angular momentum Rydberg state to a state with $|m| = n - 1$, with nearly 100% efficiency. Selective field ionization is employed to detect the high $|m|$ state. Transfer occurs by a series of adiabatic rapid passages; it can also occur by a single multiphoton process.

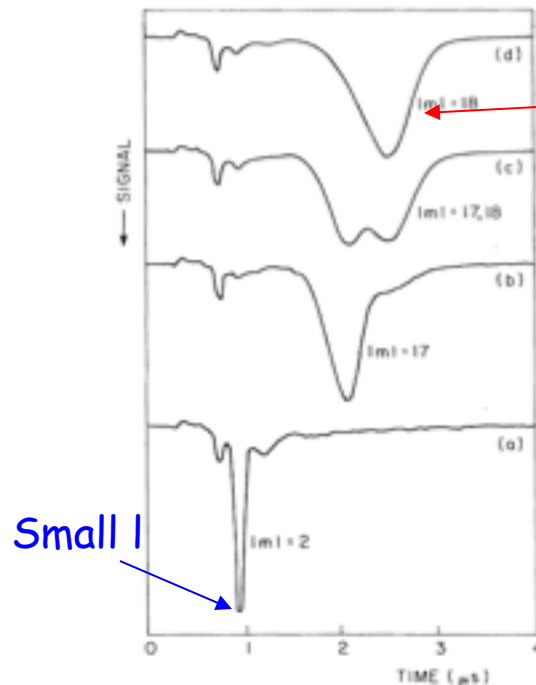
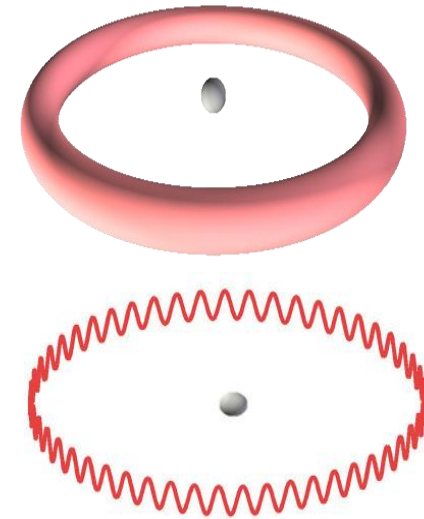


FIG. 2. Distribution of population in lithium for various values of $|m|$ as revealed by selective field ionization. States are $n = 19$, $n_1 = 0$. The ionization field in-

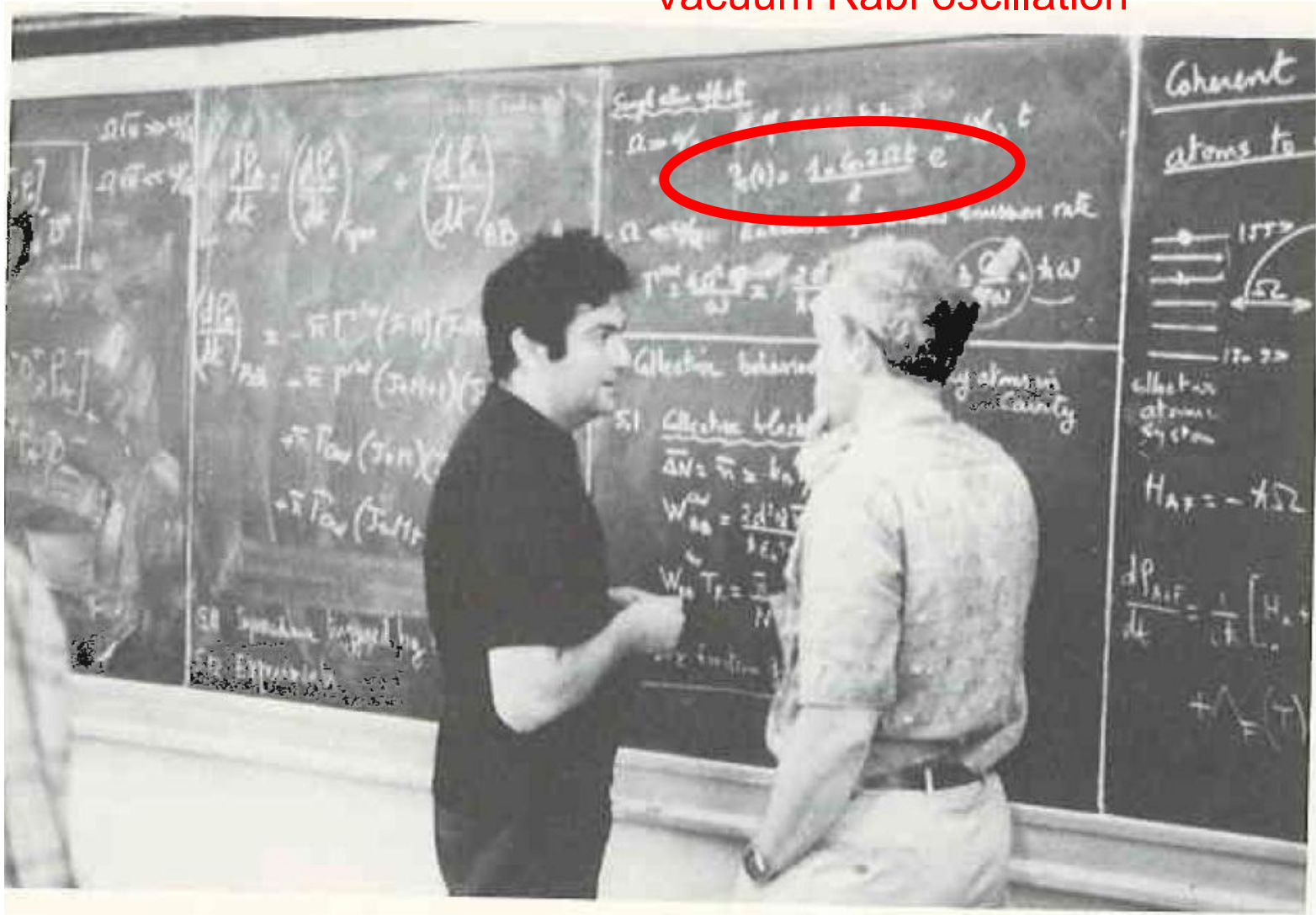
Maximum I
value



(a)

Field ionization occurs in higher field for the circular state: a way to detect it selectively

Vacuum Rabi oscillation



Dan and I at Les Houches Summer School in July 1982 discussing the physics of Rydberg atoms and Cavity QED

Inhibited Spontaneous Emission

Daniel Kleppner

*Research Laboratory of Electronics and Department of Physics, Massachusetts Institute of Technology,
Cambridge, Massachusetts 02139*

(Received 28 April 1981)

The radiative properties of an atom in a cavity differ fundamentally from the atom's radiative properties in free space. Spontaneous emission is inhibited if the cavity has characteristic dimensions which are small compared to the radiation wavelength, and enhanced if the cavity is resonant. The cavity causes slight shifts in the energies of the atom, analogous to radiative shifts. Experiments are proposed for observing these effects.

Inhibited Spontaneous Emission by a Rydberg Atom

Randall G. Hulet,^(a) Eric S. Hilfer, and Daniel Kleppner

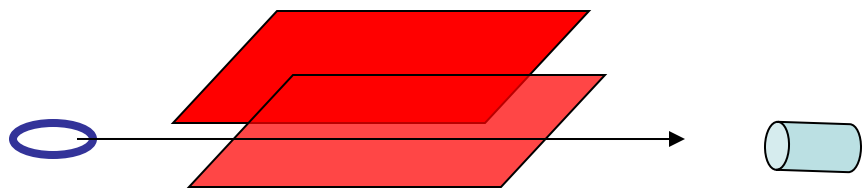
*Research Laboratory of Electronics and Department of Physics, Massachusetts Institute of Technology,
Cambridge, Massachusetts 02139*

(Received 29 July 1985)

Spontaneous radiation by an atom in a Rydberg state has been inhibited by use of parallel conducting planes to eliminate the vacuum modes at the transition frequency. Spontaneous emission is observed to "turn off" abruptly at the cutoff frequency of the waveguidelike structure and the natural lifetime is measured to increase by a factor of at least 20.

Inhibiting spontaneous emission of a circular Rydberg atom

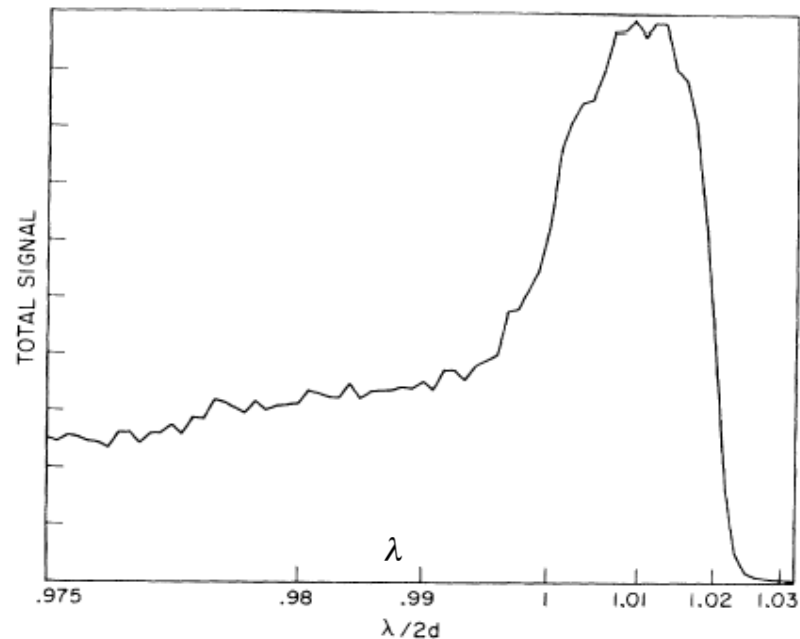
microwave transition



Atom prepared in circular Rydberg state $n=22$ (orbit parallel to metal plates)

Ionisation detector

Inhibited transition $n=22 \rightarrow n'=21$ at $\lambda = 0.45\text{mm}$



R.G.Hulet, E.S.Hilfer et D.Kleppner,
PRL 55, 2137 (1985).

Atomic transmission versus $\lambda/2L$: λ is swept by Stark effect, L being kept constant. The sharp signal increase for $\lambda/2L=1$ demonstrates the inhibition of s.e. of the Rydberg atom which survives longer in its initial state.

Observation of Cavity-Enhanced Single-Atom Spontaneous Emission

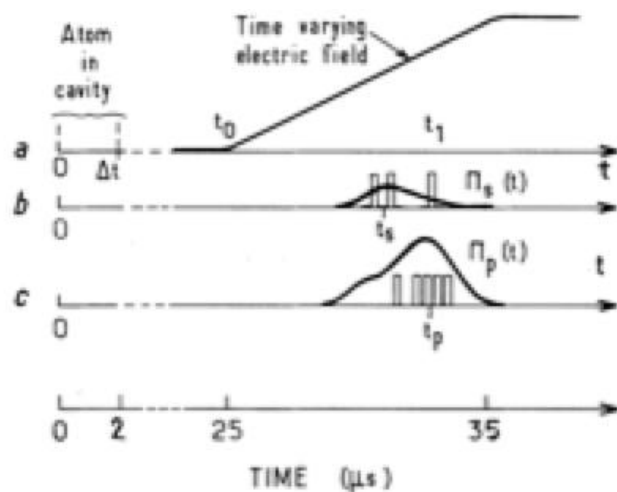
P. Goy, J. M. Raimond, M. Gross, and S. Haroche

Laboratoire de Physique de l'École Normale Supérieure, F-75231 Paris Cedex 05, France

(Received 1 April 1983)

It has been observed that the spontaneous-emission lifetime of Rydberg atoms is shortened by a large ratio when these atoms are crossing a high- Q superconducting cavity tuned to resonance with a millimeter-wave transition between adjacent Rydberg states.

PACS numbers: 32.80.-t, 32.90.+a, 42.50.+q



In this respect, the effect described in this Letter can be considered as the limiting case of a transient maser approaching threshold with only one or two atoms in the inverted medium.

With a tenfold increase in Q , Γ_{cav} and $2\pi\nu/Q$ would become of the same size and the emitted photon would be stored in the cavity long enough for the atom to be able to reabsorb it.

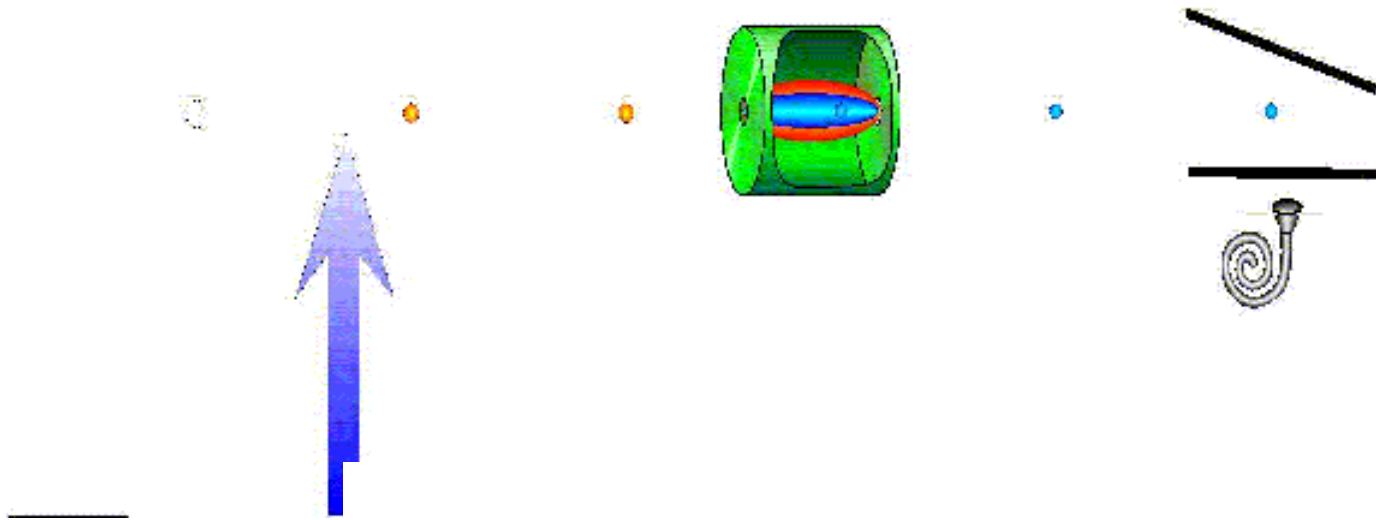
This would correspond to a regime of quantum mechanical oscillations between a two-level atom and a single electromagnetic field mode⁴ which should be observable with an improved version of our setup.

Our Holy Grail of the 1980's: achieving the strong coupling regime of Cavity QED with circular atoms.

Early Cavity QED: The micromaser (1984)



H. Walther
(1935-2006)



Physics Today, 42, 24 (1989)

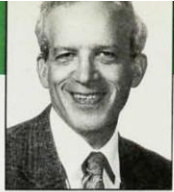
CAVITY QUANTUM ELECTRODYNAMICS

A new generation of experiments shows that spontaneous radiation from excited atoms can be greatly suppressed or enhanced by placing the atoms between mirrors or in cavities.

Serge Haroche and Daniel Kleppner

The importance of vacuum: the Casimir and Schrödinger cat « reference frames »

REFERENCE FRAME

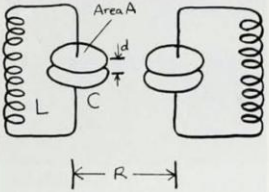


WITH APOLOGIES TO CASIMIR

Daniel Kleppner

The Casimir effect, in case you have forgotten, is an attraction between conducting planes that arises from the vacuum energy in the intervening space. The force is too weak to command great attention—in fact, it is barely detectable—but Hendrik Casimir's line of reasoning has nevertheless been extraordinarily productive. By encouraging a rather literal view of vacuum fluctuations, his approach unifies and simplifies phenomena such as the van der Waals force, resonance dispersion and the effects quantum electrodynamics produces in a cavity, such as inhibited sponta-

in the figure below, separated by some distance R and interacting via their electric dipole fields. The degeneracy



the system. The two descriptions, though they appear to have nothing in common, are both correct. Incidentally, although we considered identical oscillators, the result also holds for nonidentical oscillators, with suitable modifications of the constants.

If we had considered magnetic, rather than electric, coupling, the natural frequencies ω_{\pm} would have been $\omega_0/\sqrt{1 \pm \kappa}$ instead of $\omega_0\sqrt{1 \pm \kappa}$. The result would have been a van der Waals *repulsion*. Such a repulsion is not generally observed in atomic and molecular systems because magnetic dipoles are smaller than electric di-



H. Casimir
(1909-2000)

REFERENCE FRAME

Memoirs of Schrödinger's Cat

as told to Daniel Kleppner

Recently, a cat materialized in my study, a Cinnamon Tabby, who sat eyeing me with the cool look of a superior being. The situation was unnerving, and I finally said in jest, "Are you by any chance Schrödinger's cat?" To my astonishment, the cat replied.

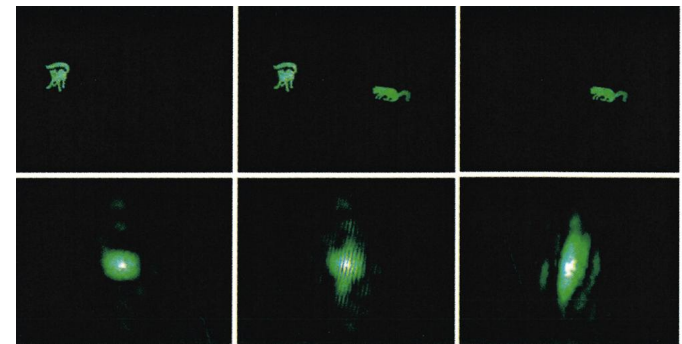


Schrödinger's cat? *Ganz absurd!* Ridiculous! Please to understand that I never belonged to Schrödinger. Schrödinger belonged to me. It was

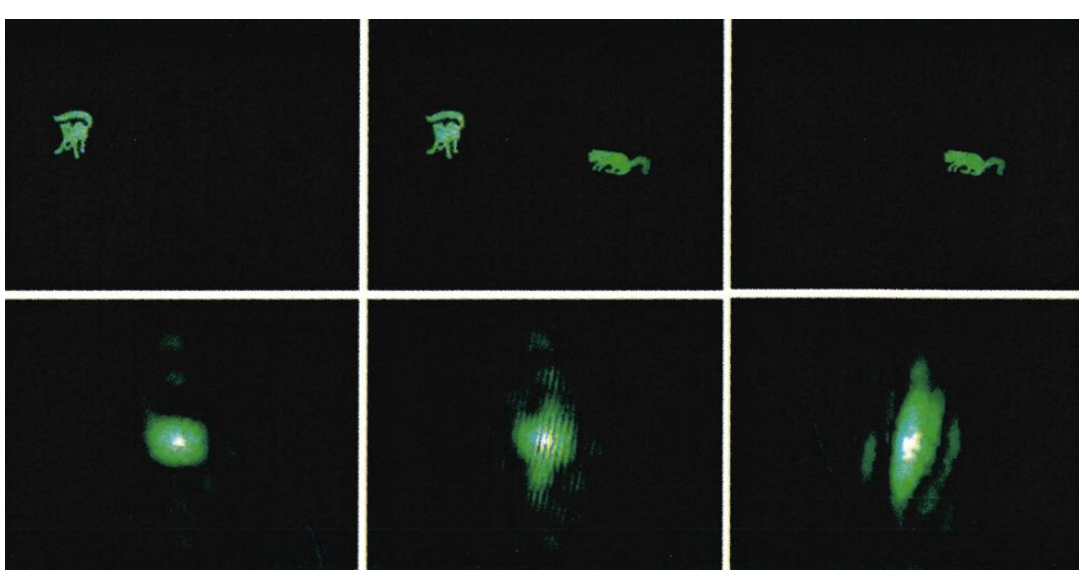
for Einstein, whose lap is heavenly, but he is busy thinking about gravity.

Finally I choose Erwin Schrödinger. Schrödinger is highly intelligent and in those days he is an excellent listener. Also, his lap is famous. So, I telegraph him to meet me in Munich, and together we will go to Arosa. Naturally, he comes at once.

That is in early December 1925. My work, of course, goes well. So simple it is once I see the way! If there is a



A « tongue-in-cheek »
interference experiment
inspired to T. Hänsch by Dan



KLEPPNER REPLIES: I was so impressed by the quality of Ted Hänsch's interferogram that I carried out a two-dimensional Fourier transform of it in an attempt to recover the original images. The cats reappeared with such astounding fidelity that the live cat actually started to walk away. To my dismay, it dropped dead after taking a few steps, and the dead cat jumped up and ran off. Apparently I somehow got the phase wrong. Whatever the cause, the moral is clear: Messing around with quantum measurement theory is dangerous.

DANIEL KLEPPNER

*Massachusetts Institute of Technology
Cambridge, Massachusetts*

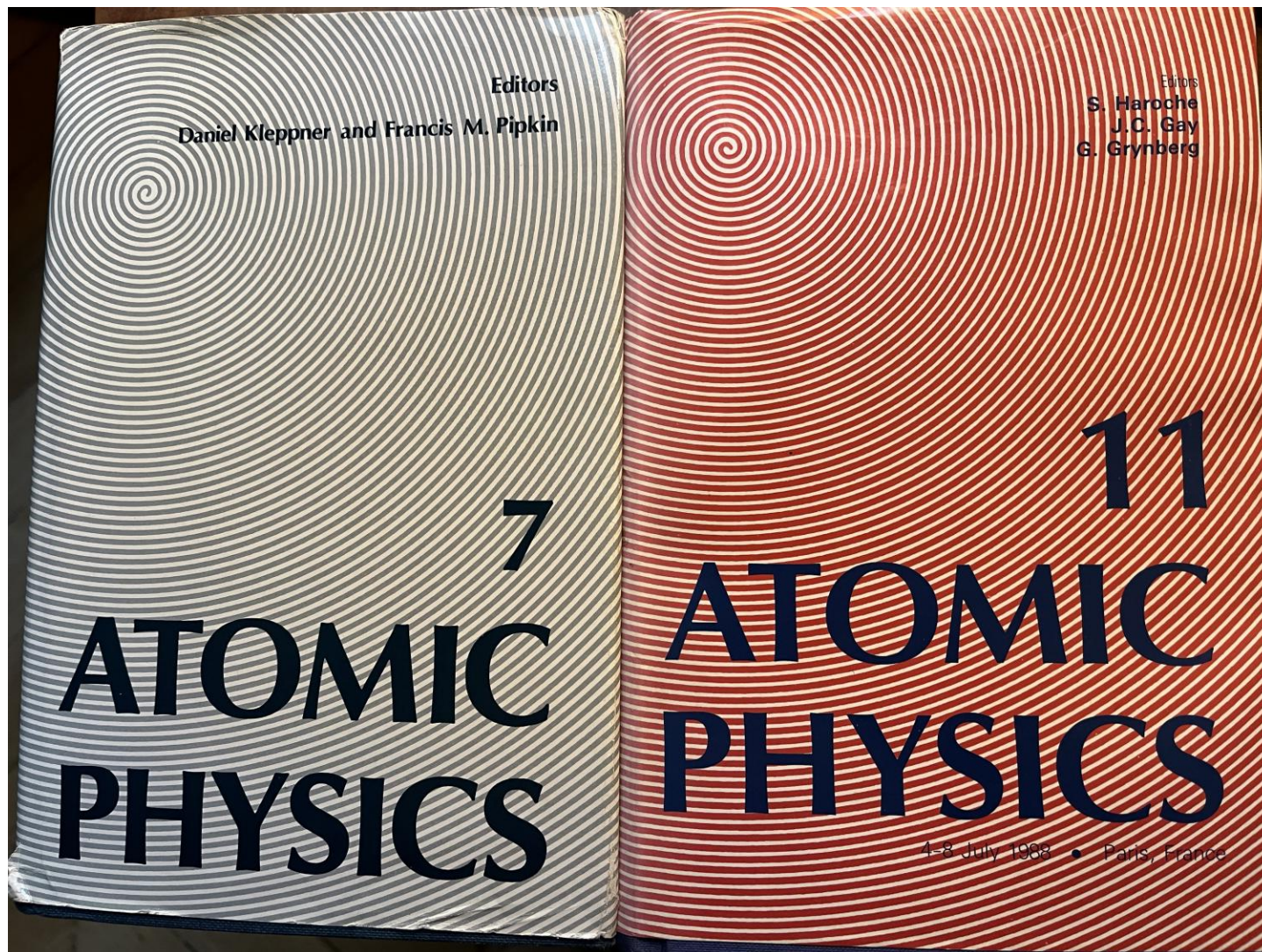


*Dan's ironical version
of Mermin's advice:
« shut up and
calculate »*

Dan and Ted (with W.Phillips) at ICAP 23 in 2014
(credit Steve Rolston)

Boston, 1980

Paris, 1988



Two ICAP meetings in the 1980's

Serge Haroche
 Ecole Normale Supérieure
 Paris 75231, France

1. INTRODUCTION

Most atomic physics experiments involve, in one way or another, the coupling of atoms with electromagnetic radiation. The order of magnitude of the atom-field interaction parameters thus sets the scale of the phenomena in the atomic physics world. These orders of magnitude can quite generally be obtained by simple back of the envelope calculations combining a small number of basic (non-independent) parameters such as the electron charge q , the fine structure constant α , the Bohr radius a_0 , the atomic electric field $F_A = q/4\pi\epsilon_0 a_0^2$. For example, the order of magnitude of the resonant optical frequencies ω or wavelengths λ are :

$$\lambda/2\pi = c/\omega \approx a_0 \alpha^{-1}, \quad (1)$$

whereas the radiative decay rate of an ordinary excited state coupled to lower states by electric dipole transitions is of the order of :

$$\Gamma = \alpha^3 \omega = c \alpha^4 a_0^{-1}. \quad (2)$$

In the same way, the monochromatic optical field \mathcal{E}_S required to saturate a standard optical transition is obtained by equating to Γ the Rabi frequency of an electric dipole $q a_0$ in that field :

$$\mathcal{E}_S = \sqrt{\Gamma/q a_0} = \alpha^3 F_A. \quad (3)$$

Equations (1) (2) (3) account for the fact that "typical atomic transitions have frequencies in the 10^{15} - 10^{16} Hz range with nanosecond

ICAP 7 in Boston (1980)

Daniel Kleppner
 Department of Physics
 Massachusetts Institute of Technology
 Cambridge, MA 02139

INTRODUCTION

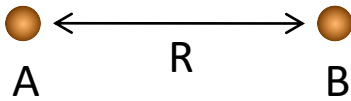
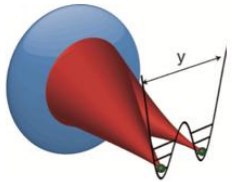
Participating in this Symposium to honor Professor Jean Brossel is a personal and professional pleasure: personal because of our long years of friendship; professional because of the great debt that atomic physics owes to Professor Brossel for his seminal research in optical pumping, for the school of outstanding physicists that he has trained, and for his scientific leadership in the general field of atomic physics. It is a particular pleasure because the experiment that launched his career and indeed that launched optical pumping as an experimental discipline—was actually carried out at my own institution. This is the famous Brossel-Bitter optical double resonance experiment^{1,2}. Since then the name of Jean Brossel, along with that of his illustrious colleague and collaborator, Alfred Kastler, has become synonymous with atomic physics. However, as everyone acquainted with Professor Brossel knows, he would prefer to hear about new research and thoughts of the future rather than be regaled with words of praise and thoughts of the past. So here are some thoughts for the future.

In the world of physics "hydrogen" stands for more than the first element in the Periodic Table: it is a metaphor for all systems whose structure is so simple that they can be employed with confidence to test basic theory and search for new effects. In the world of atomic physics one could cite in this spirit such as

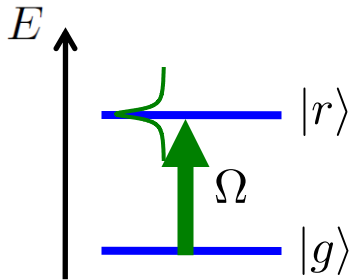
ICAP 11 in Paris (1988)

The rebirth in 2000 of Rydberg atom Physics: the Rydberg Blockade effect

Cold Atoms
trapped by optical
tweezers



Zoller, Lukin et al



$$|\psi\rangle = \frac{1}{\sqrt{2}}(|r,g\rangle + |g,r\rangle)$$

Blockade \Rightarrow **entanglement and gates!!**

Collective oscillation between $|gg\rangle$ and $\frac{1}{\sqrt{2}}(|rg\rangle + |gr\rangle)$

Pillet et al

Browaeys et al

Saffman et al

Pfau et al

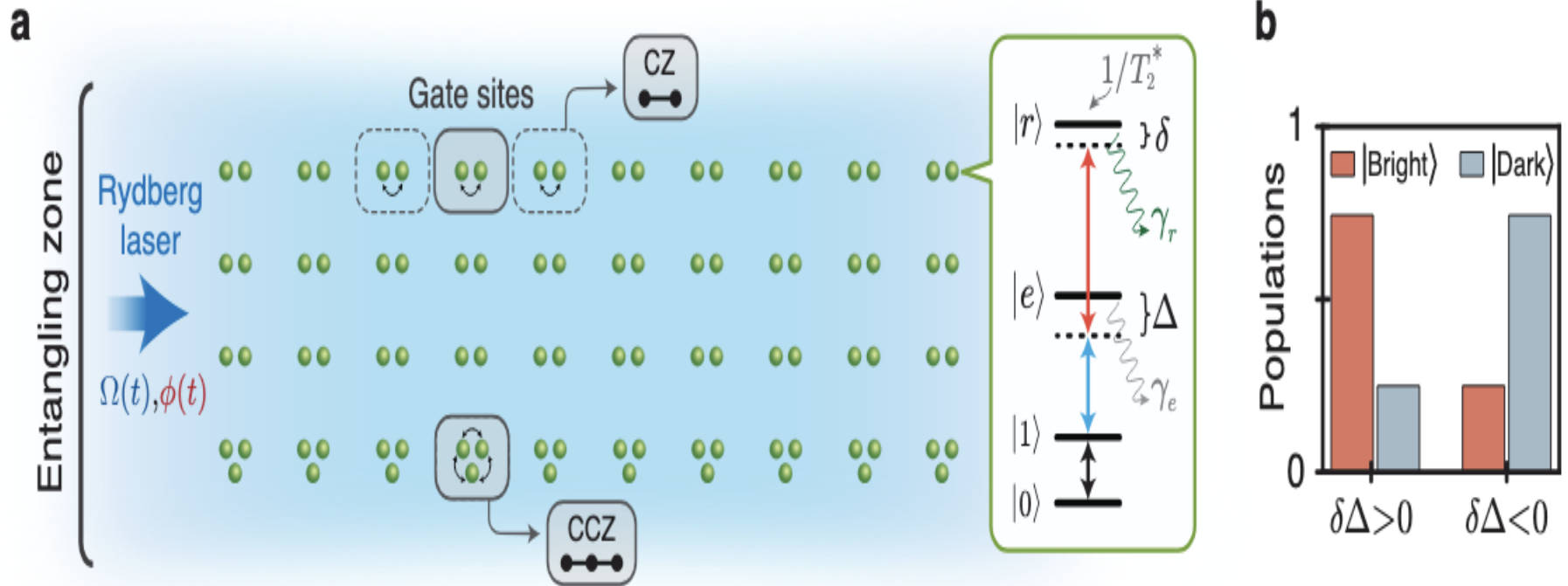
Bloch et al

Brune et al

.....

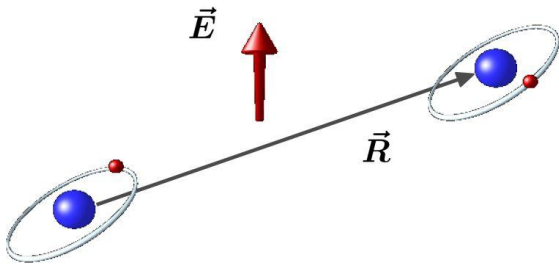
A Rydberg atom entangling machine: towards a neutral atom quantum computer?

MIT-Harvard Center for Ultra cold Atoms (CUA)
M.Greiner, M.Lukin and V.Vuletic groups

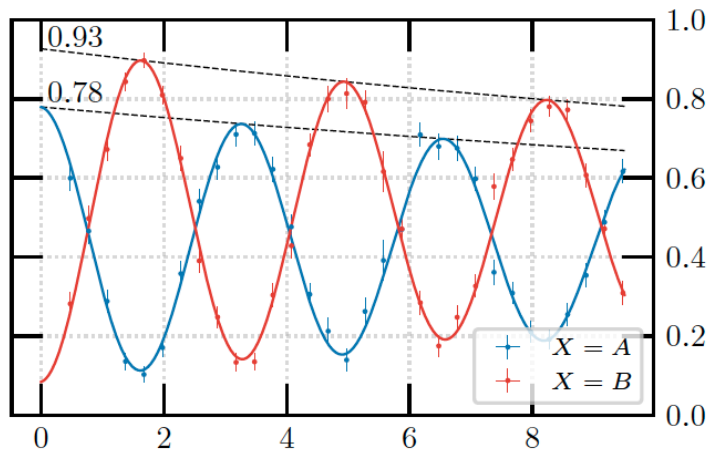


Dan was the cofounder of the CUA in 2001

Spin exchange between two trapped circular Rydberg atoms (Forster resonance)

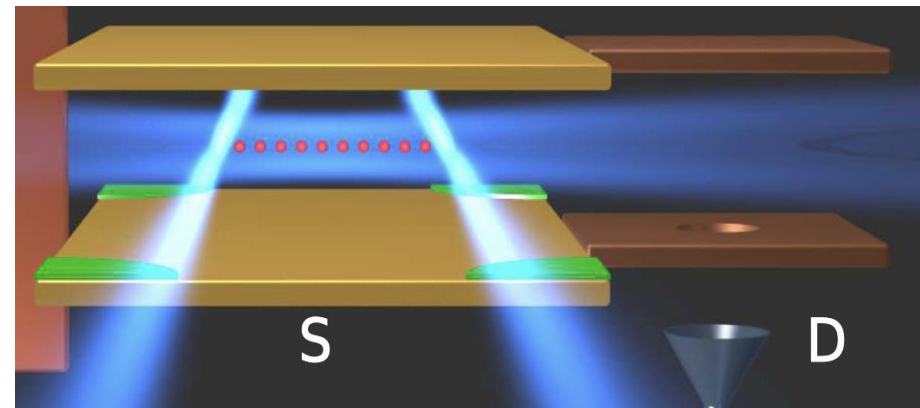


$$|\Psi(t)\rangle = \cos\left(\frac{\Omega t}{2}\right)|53C, 54C\rangle + \sin\left(\frac{\Omega t}{2}\right)|54C, 53C\rangle$$



Brune et al
(2025)

Quantum simulation with circular Rydberg atoms whose spontaneous emission is inhibited between metallic mirrors (a project in progress)

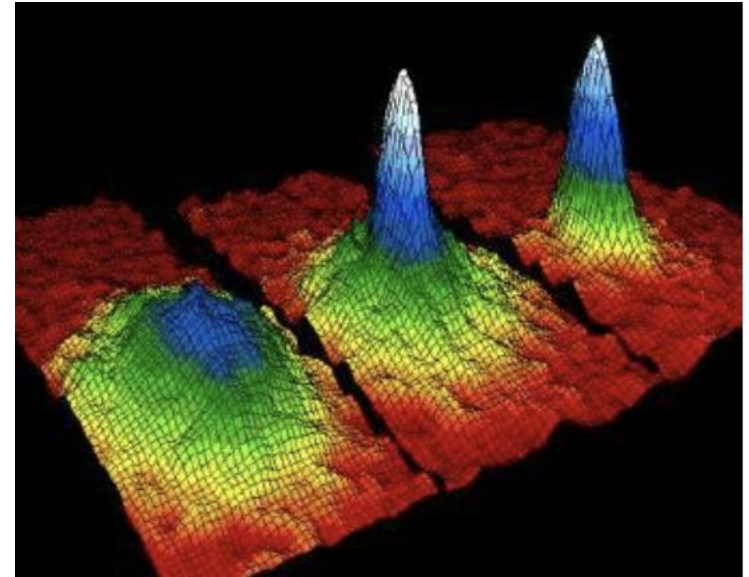
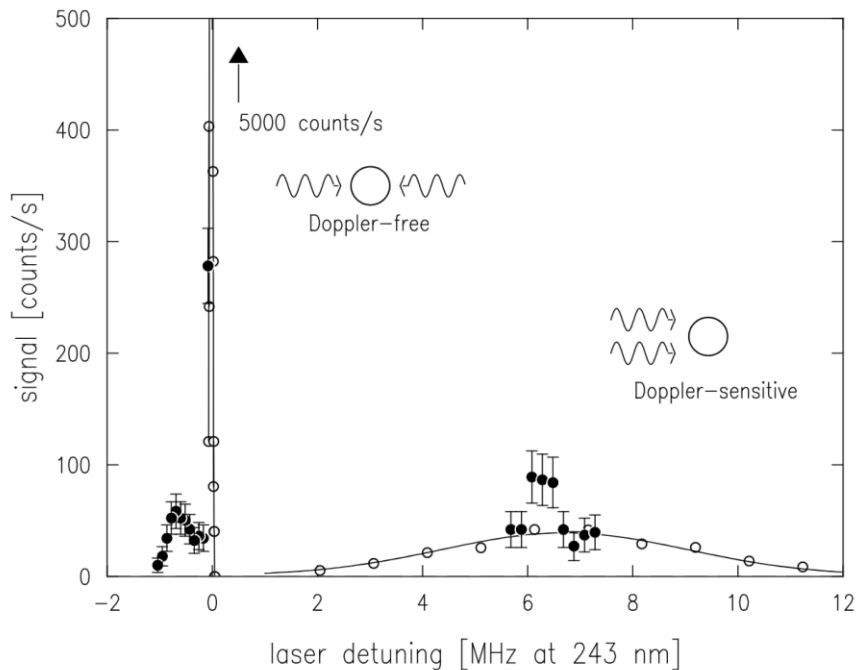


Dan and the promised land of BEC

Twenty years of hunting for the Holy Grail in Hydrogen with T.Greytag, which succeeded in 1998, three years after the discovery of BEC in alkali atoms by Cornell, Weiman and Ketterle..

BOSE-EINSTEIN CONDENSATION OF ATOMIC HYDROGEN

17



BEC in H by Dan et al (1998)

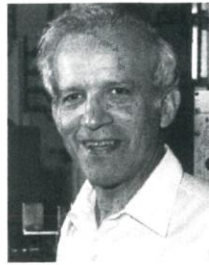
BEC in Rb and Na in 1995
(Cornell, Weiman and Ketterle)

Bose Einstein Condensation in « Reference Frame »

REFERENCE FRAME

The Fuss About Bose–Einstein Condensation

Daniel Kleppner



Einstein thought little of his prediction. “It is pretty, but is it correct?” he wrote to Paul Ehrenfest, and turned his back on the problem forever.

During its first ten years, BEC was a scientific ugly duckling. In 1927, George Uhlenbeck argued in his doctoral thesis that statistical mechanics could not predict a discontinuous phase transition and that BEC was a mere artifact. According to Laszlo Tisza, now an emeritus professor at MIT but in the period 1935–37 a postdoc with Lev Davidovich Landau in Moscow BEC

peratures below a millionth of a degree
is almost enough to make one shiver

Dan at les Houches school
in 1996:

« *I feel like the Moses of
BEC* »

(as reported by W.Ketterle)

REFERENCE FRAME

A Beginner’s Guide to the Atom Laser

Daniel Kleppner



The atom laser is here and before long folks will probably want to own one. If you are the neighborhood physicist, your neighbor may ask for your advice on the best model. Your neighbor may even ask what an atom laser is. If you haven’t kept up with the literature, this little guide could be helpful.

The first step in explaining the atom laser is to define “laser.” In former years, this question wracked the laser community: ink was spilled, friendships lost. Today, things are fairly peaceful and you will not run into too much argument if you define a laser as simply a device that puts out laser

can be characterized by a hierarchy of coherences that govern the probabilities for observing twofold, threefold etc. coincidences in the detection

could be argued that thermal radiation also produces interference fringes, but that is only for light from a single source. For all practical purposes, separate thermal sources do not interfere. Light from two lasers can interfere, however, and so, Ketterle found, can atoms from two Bose condensates.

To put the interference fringes in perspective, their real significance is in confirming that the Bose condensate has long-range order, which suggests that the condensate atoms form a superfluid atomic gas. A superfluid gas is something new to physics. The atom laser is essentially a by-product of this discovery.

« *Inventing the
atom laser* » is a
much more exciting
title than
« *Discovering
degenerate atoms* »

REFERENCE FRAME

Nibbling the Bullet

Daniel Kleppner

At the age of 95, Professor X passed away peacefully while working in his laboratory, just as he had desired. His obituary touched me deeply, and I would like to share a portion with you.

"Professor X was a physicist's physicist who never lost his passion for science, his imagination, or his irrepressible enthusiasm. Although the years dimmed his vision, stiffened his fingers, and, one must admit, somewhat dulled his mind, his students revered him. Following his wishes, there was no funeral. Instead, colleagues and friends gathered at the interment for a moving ceremony conducted according to his own instructions. X was buried surrounded by his notebooks, his laboratory equipment, his stores of supplies and spare parts, and his students."

X's devotion to science was total. By refusing to let death itself interfere with his research, he has added yet another first to his illustrious record: First physicist to pursue posthumous research. Although it will take a little time to judge the ultimate success of his final career choice—a year or two is usually required to restart a laboratory, and there may be additional delays due to special problems of death—the prognosis is good. His equipment is excellent, his supplies are ample, and his students are all first rate.



teachers have become profoundly disengaged, and may subject them to ridicule. Young scientists may turn their backs on academic careers when they notice that the faculty positions are all filled, for eternity.

In spite of these misgivings about X's career decision, in fairness I should

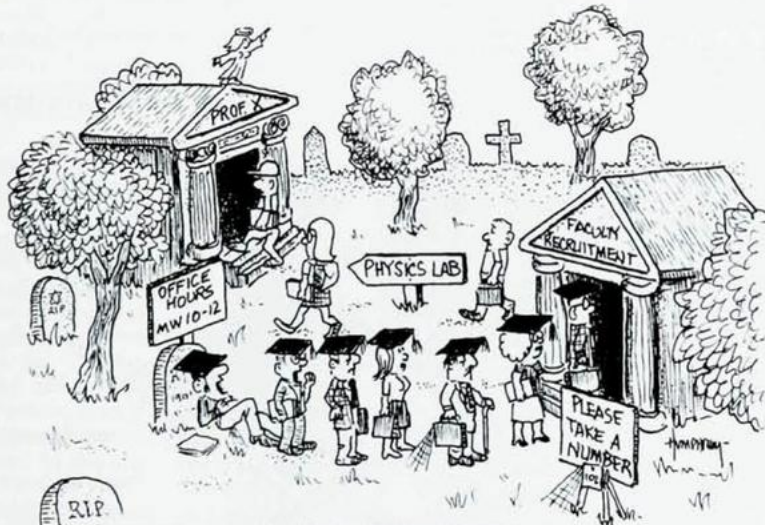
Congress amended it to totally eliminate mandatory retirement. Mere age is no longer a reason to stop working: as long as you can do the job, you have the job.

The ADEA permitted exceptions for a few occupations in which errors in judgment can have tragic consequences—airplane pilots, police, and judges, for instance—but aging professors pose little risk, and academia was given no special consideration save for a grace period of a few years. Finally, in 1994, mandatory retirement was abolished in US universities and colleges.

Only a cold heart would argue that someone whose work is satisfactory should be forced to stop because of age. There is no great mystery in determining whether a person's work is satisfactory. Good management practice dictates that supervisors periodically

review their employees' performances. Employees whose work is good should be rewarded, but if their work is unsatisfactory, they should be let go regardless of their age.

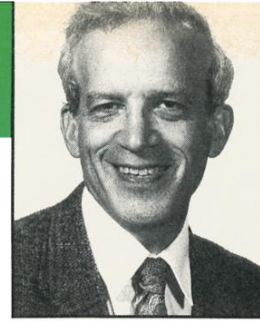
The problem is that although good management practice may dictate periodic evaluation, the tenure system essentially forbids it. Academic tenure is usually awarded only after a demanding, even harsh, evaluation process, but once tenure is awarded, evaluation ceases.



THE NEW UNIVERSITY?

The importance of leaving space to the young generation illustrated by a nightmarish dystopia

REFERENCE FRAME



KUDOS FOR A RADICAL COLLEGE

Daniel Kleppner

An utopian
college

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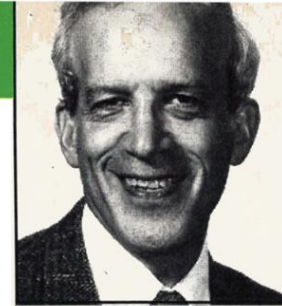
breathing new life into the ultraconservative university, King Francis I decided (with some prompting from his head librarian) to appoint a few Royal Lecturers to spread the new learning. He started off by attempting to hire Erasmus. As academic stars are wont to do even today, Erasmus hemmed and hawed and eventually declined. Finally, in 1530, Francis I elected a faculty of six Royal Lecturers—three in Hebrew, two in Greek and one in mathematics—to give public lectures. The lectures flourished. Over the years new chairs were added, and a little college took form. Its popularity became so great that it sailed through the French Revolution, the only royal institution to be preserved intact. Eventually it acquired its present title, the Collège

Paul Langevin, Francis Perrin and Frédéric Joliot. On the faculty today are Claude Cohen-Tannoudji, Pierre-Gilles de Gennes, Marcel Froissart and Phillippe Nozières. The faculty of the Collège de France is peppered with France's intellectual and artistic leaders. Pierre Boulez holds a chair of Invention, Technique and Language in Music. Claude Lévi-Strauss, Roland Barthes and Michel Foucault were all members of the Collège de France in recent years.

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The Collège de France described by Dan after his sabbatical year
in Paris

REFERENCE FRAME



THOUGHTS ON BEING BAD

Daniel Kleppner

In the days of my youth, science, scientists and the quest to understand nature were unquestionably good. Now, however, according to a clutch of science critics—journalists, philosophers, politicians and simple science bashers—science is no longer good, nor are scientists. The issues are matters not of scientific misconduct or mismanagement but of the morality of science itself.

It is unsettling to find oneself sud-

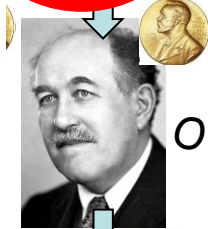
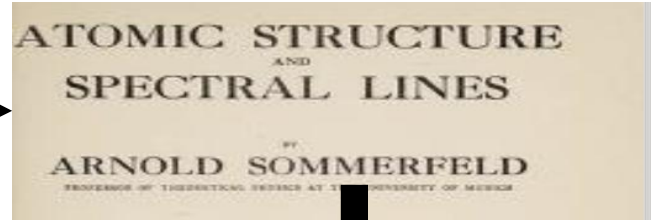
Appleyard, a writer for the *London Sunday Times*, is versed in history and philosophy and obsessed by the belief that science is responsible for most of the evils of the last 400 years: the decay of religious authority, the death of romantic poetry, the coming nightmare of artificial intelligence, and superstring theory. Quantitative reasoning terrifies him. He recalls being left dumbstruck and uneasy as a young boy when his father

lution and the destruction of medieval moral authority. He is most comfortable sitting on a throne of scientific ignorance. In reality, of course, he occupies no throne, but a modern chair at a comfortable desk. There he has the leisure to pursue his ideas—a far cry from the brutish peasant life that would likely have been his lot before the creation of the modern world.

A more serious attack on science

Reflexions
about
attacks
against
science...
which
became
much worse
recently

A. Sommerfeld



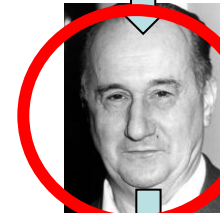
O. Stern



A. Kastler

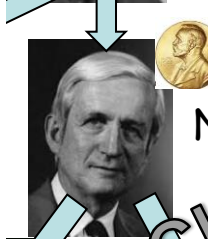


I. Rabi



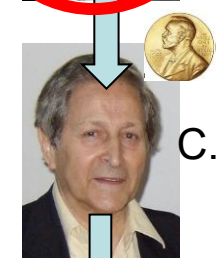
J. Broedel

OP

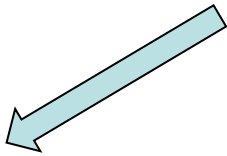


N. Ramsey

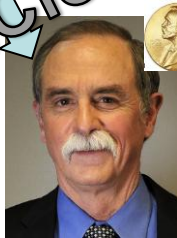
QClocks



C. Cohen-Tannoudji



Dan



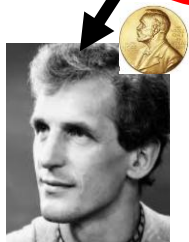
J. Wineland



S.H

W. Ketterle

BEC



W. Phillips

CA

Dan in a lineage of atomic physicists spanning a century

A.Sommerfeld



What do these four great scientists have in common?



V.Weisskopf



J.Brossel

Dan



Enormous influence
Exceptional mentors of
bright students
Pioneers in their fields...

I have had an amazing discussion with ChatGpt to clarify this paradoxical fact of science sociology



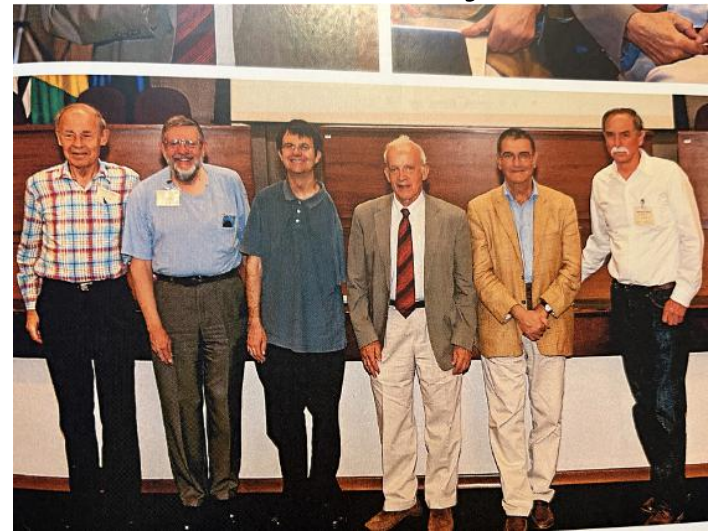
Dan and I in 2012

Dan and Vanderlei
Bagnato



Dan and Claude

Celebrating Dan's 80th
birthday



*A friendship since
1968*



Dan with Claudine
in Arizona (?) in
the 1970's



Dan, Bea, I, Dan's Father,
& my children
Judith and Julien in Vermont (1979)

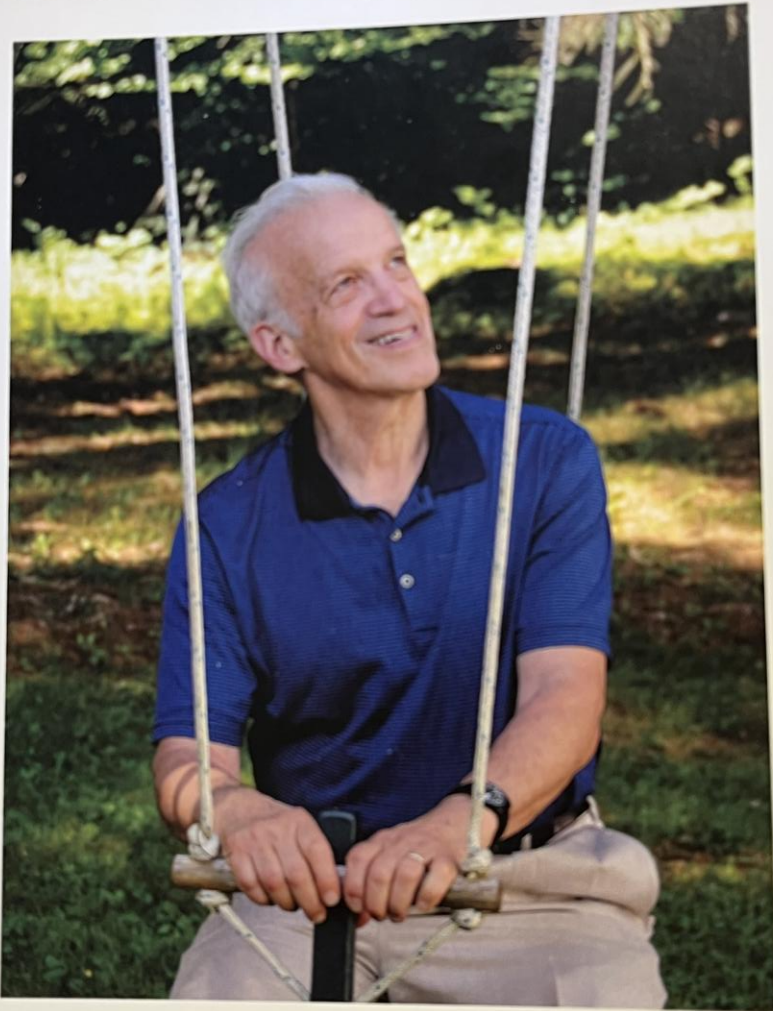


Visiting Dan and Bea in Belmont, March 2025



70 years of happy life with Beatrice!

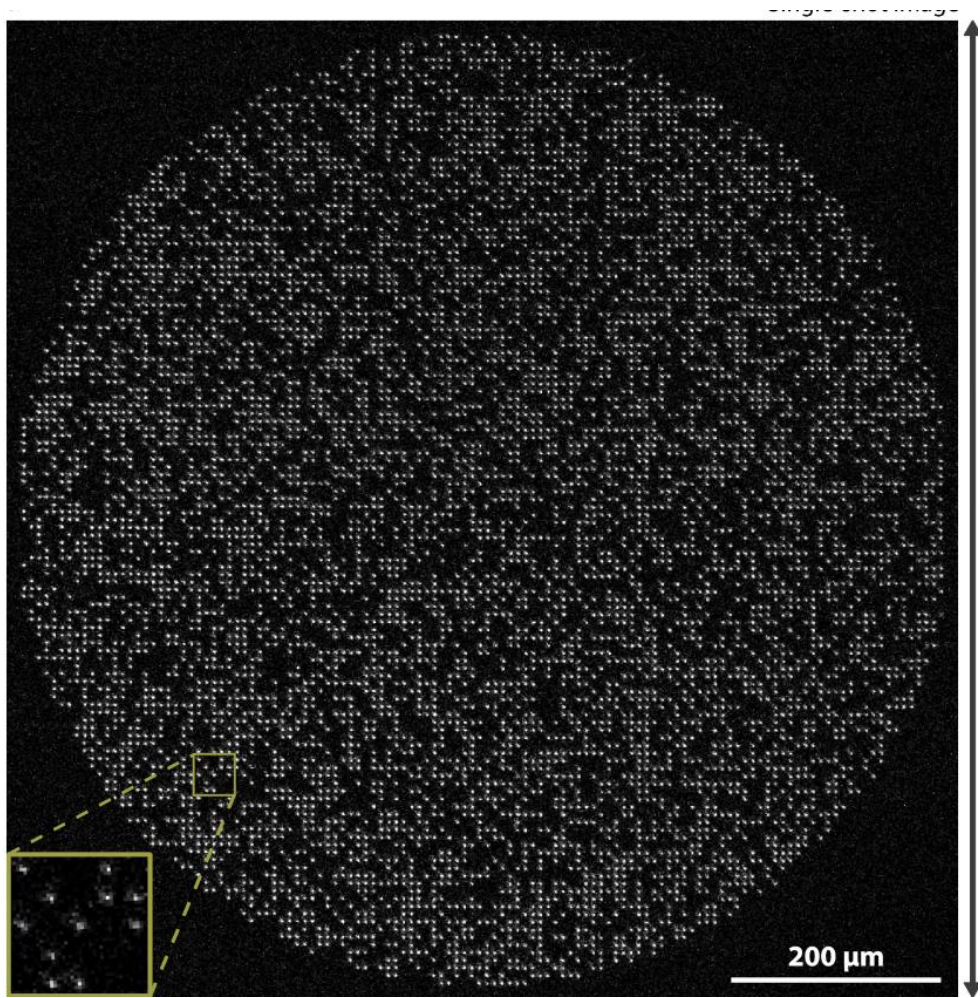
A Memorial to Celebrate
Daniel Kleppner



Massachusetts Institute of Technology
Saturday, March 14, 2026

Thank you Dan,

I had the privilege of sharing with you a long friendship and the joy and excitement of doing blue sky science during this particularly fruitful epoch in atomic physics. You looked to the future with confidence. It is now up to the next generations to take further the physics you loved so much!



The 1970's: Using lasers to excite atomic Rydberg states with exotic properties

In Paris, I was fascinated by their high sensitivity to microwave radiation

Millimeter spectroscopy in sodium Rydberg states: Quantum-defect, fine-structure, and polarizability measurements

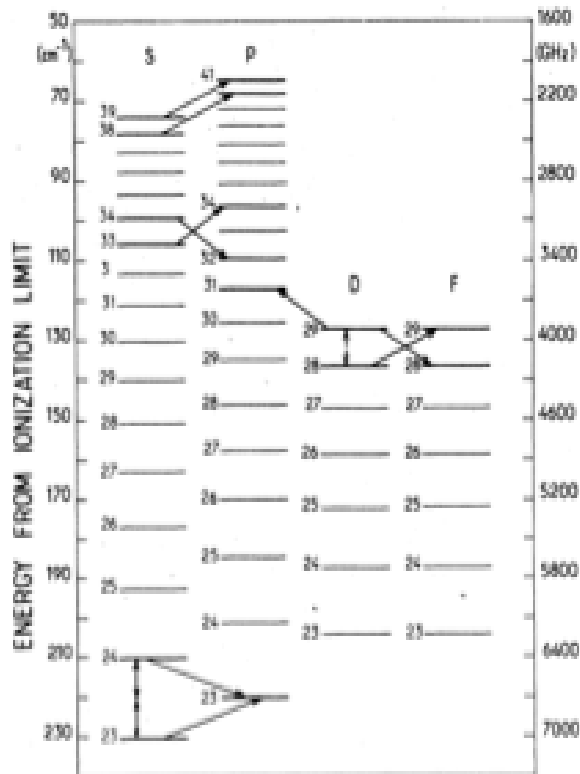
C. Fabre and S. Haroche

Laboratoire de Spectroscopie Hertzienne de l'ENS, 24, rue Lhomond, 75231 Paris Cedex 05, France

P. Goy

Groupe de Physique des Solides de l'ENS, 24, rue Lhomond, 75231 Paris Cedex 05, France

(Received 14 June 1977)



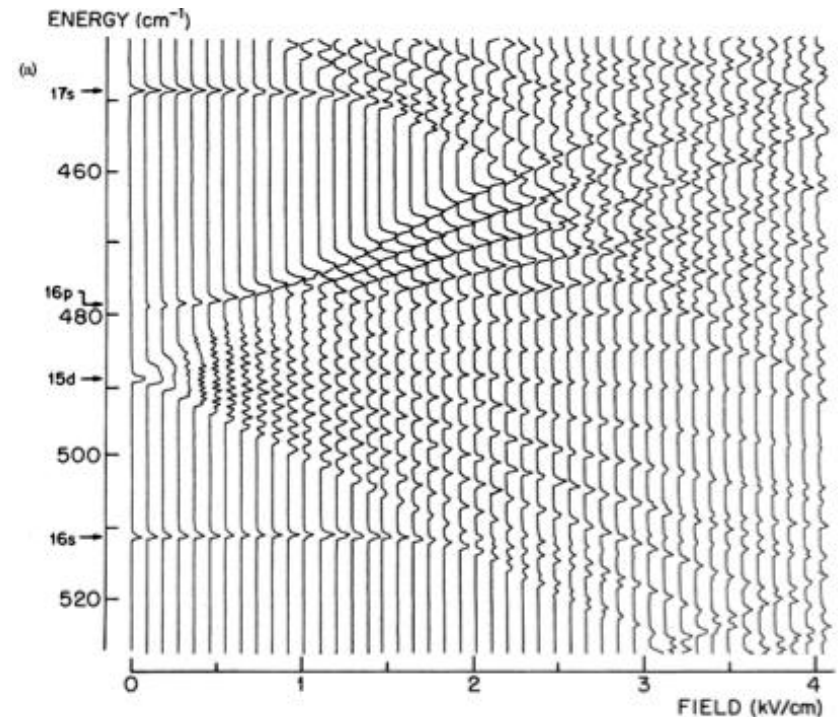
At MIT, Dan and his students were captivated by their sensitivity to electric and magnetic fields

Structure of Sodium Rydberg States in Weak to Strong Electric Fields*

Michael G. Littman, Myron L. Zimmerman, Theodore W. Ducas, Richard R. Freeman, and Daniel Kleppner

Research Laboratory of Electronics and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

(Received 12 January 1976)



Inhibited Spontaneous Emission

Daniel Kleppner

*Research Laboratory of Electronics and Department of Physics, Massachusetts Institute of Technology,
Cambridge, Massachusetts 02139*

(Received 28 April 1981)

The radiative properties of an atom in a cavity differ fundamentally from the atom's radiative properties in free space. Spontaneous emission is inhibited if the cavity has characteristic dimensions which are small compared to the radiation wavelength, and enhanced if the cavity is resonant. The cavity causes slight shifts in the energies of the atom, analogous to radiative shifts. Experiments are proposed for observing these effects.

Inhibited Spontaneous Emission by a Rydberg Atom

Randall G. Hulet,^(a) Eric S. Hilfer, and Daniel Kleppner

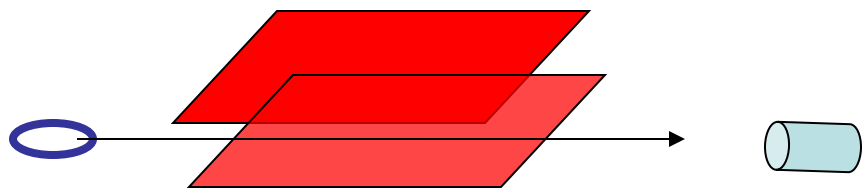
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Spontaneous radiation by an atom in a Rydberg state has been inhibited by use of parallel conducting planes to eliminate the vacuum modes at the transition frequency. Spontaneous emission is observed to "turn off" abruptly at the cutoff frequency of the waveguidelike structure and the natural lifetime is measured to increase by a factor of at least 20.

Inhibiting spontaneous emission of a circular Rydberg atom

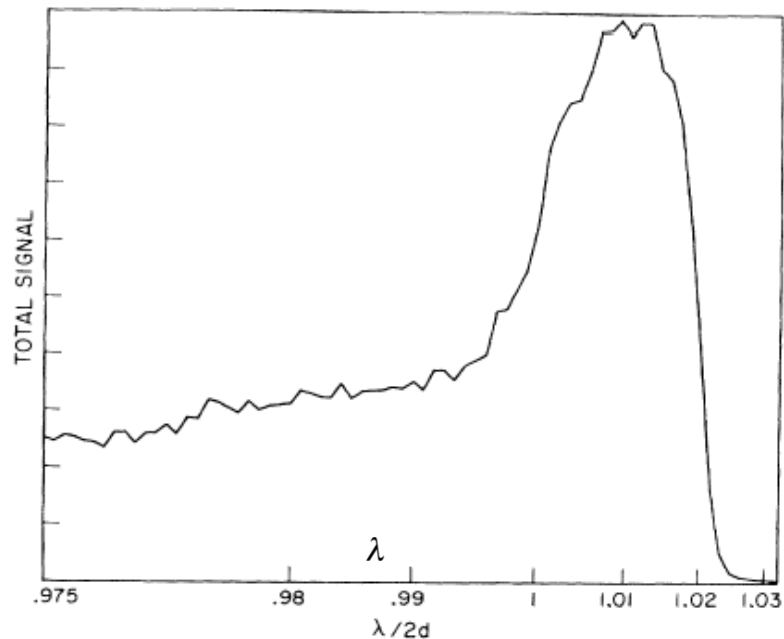
microwave transition



Atom prepared in circular Rydberg state $n=22$ (orbit parallel to metal plates)

Ionisation detector

Inhibited transition $n=22 \rightarrow n'=21$ at $\lambda = 0.45\text{mm}$



Atomic transmission versus $\lambda/2L$: λ is swept by Stark effect, L being kept constant. The sharp signal increase for $\lambda/2L=1$ demonstrates the inhibition of s.e. of the Rydberg atom which survives longer in its initial state.

R.G.Hulet, E.S.Hilfer et D.Kleppner, PRL 55, 2137 (1985).

Observation of Cavity-Enhanced Single-Atom Spontaneous Emission

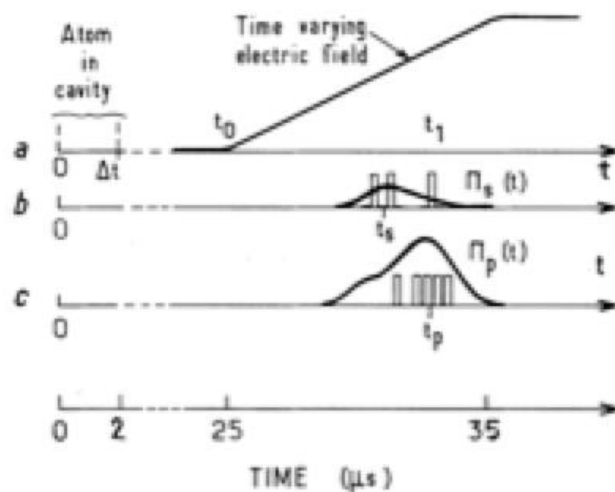
P. Goy, J. M. Raimond, M. Gross, and S. Haroche

Laboratoire de Physique de l'École Normale Supérieure, F-75231 Paris Cedex 05, France

(Received 1 April 1983)

It has been observed that the spontaneous-emission lifetime of Rydberg atoms is shortened by a large ratio when these atoms are crossing a high- Q superconducting cavity tuned to resonance with a millimeter-wave transition between adjacent Rydberg states.

PACS numbers: 32.80.-t, 32.90.+a, 42.50.+q



In this respect, the effect described in this Letter can be considered as the limiting case of a transient maser approaching threshold with only one or two atoms in the inverted medium.

With a tenfold increase in Q , Γ_{cav} and $2\pi\nu/Q$ would become of the same size and the emitted photon would be stored in the cavity long enough for the atom to be able to reabsorb it.

This would correspond to a regime of quantum mechanical oscillations between a two-level atom and a single electromagnetic field mode⁴ which should be observable with an improved version of our setup.

Our "Holy Grail" of the 1980's: The search for the strong coupling regime of Cavity QED!

Spontaneous emission inhibition and the beginning of Cavity QED

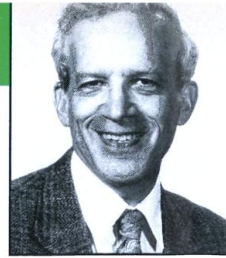
The cat experiments in Cavity QED and
circuit QED experiments

Rydberg atoms born again in quantum information science

BEC in Hydrogen in 1998

Reference frames about BEC and the atom laser

REFERENCE FRAME



SOME SMALL BIG SCIENCE

Daniel Kleppner

Can one say kind words about small science without being classified as an enemy of big science? I hope so. The important issue is not which is better but how much of each we need. Unfortunately today's helter-skelter science policy climate makes tackling that problem almost impossible. Big science runs into trouble because it is attractive to politicians; small science runs into trouble because it is unattractive to politicians.

astronaut—that such a parity violation should occur in hydrogen. But Michel's effect was far too small to inspire experiments. With the advent of the Weinberg–Salam–Glashow electroweak theory, however, the search for neutral-current parity violations in atomic physics became serious.

The bible for the atomic experiments was written in Paris in the early 1970s by an experimental and

What makes the parity-violating effects observable is a process that is as important to physics as compound interest is to banking: interference. If A is some known transition amplitude, and B is the small, unknown parity-violating amplitude, then the total transition rate is proportional to $|A \pm B|^2$, where the sign depends on the relative phase of the amplitudes, which ideally can be varied in an experiment. The fractional change in

*A friendship since
1968*

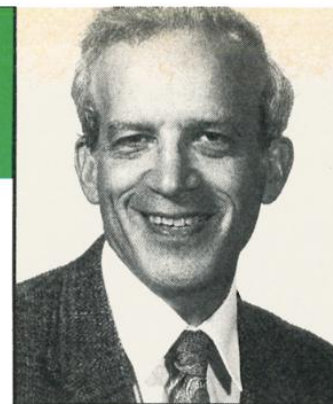


Dan with Claudine
in Arizona (?) in
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Dan, Bea, I, Dan's Father,
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REFERENCE FRAME



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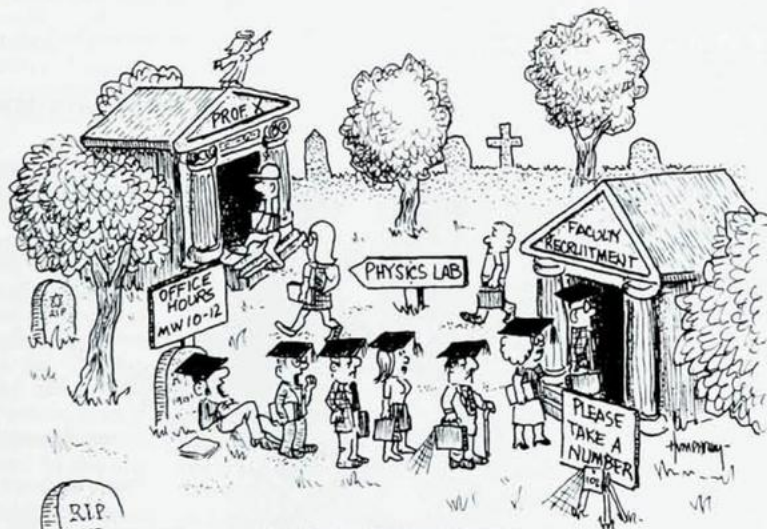
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THE NEW UNIVERSITY?

REFERENCE FRAME

Memoirs of Schrödinger's Cat

as told to Daniel Kleppner

Recently, a cat materialized in my study, a Cinnamon Tabby, who sat eyeing me with the cool look of a superior being. The situation was unnerving, and I finally said in jest, "Are you by any chance Schrödinger's cat?" To my astonishment, the cat replied.

Schrödinger's cat? *Ganz absurd!* Ridiculous! Please to understand that I never belonged to Schrödinger. Schrödinger belonged to me. It was I—Beatrix Ottoline Sophia von Schnurr—who made Schrödinger immortal. Schrödinger, however, did not return my favor. In fact, as you will appreciate, he made bizarre efforts to ensure my mortality.

So, let me set aside false modesty.



a friend at the Château de Broglie. The young de Broglie has proposed that a particle has a wavelength and it is inversely proportional to the momentum, and the proportionality constant is that of Professor Planck.

for Einstein, whose lap is heavenly, but he is busy thinking about gravity.

Finally I choose Erwin Schrödinger. Schrödinger is highly intelligent and in those days he is an excellent listener. Also, his lap is famous. So, I telegraph him to meet me in Munich, and together we will go to Arosa. Naturally, he comes at once.

That is in early December 1925. My work, of course, goes well. So simple it is once I see the way! If there is a wave, there is a wave equation. It takes me practically no time to find it. To tease Erwin a little, I do not tell him at once but give him a few clues each day until he finds it also. It takes him almost two weeks, and he is so happy when I give in and tell him his

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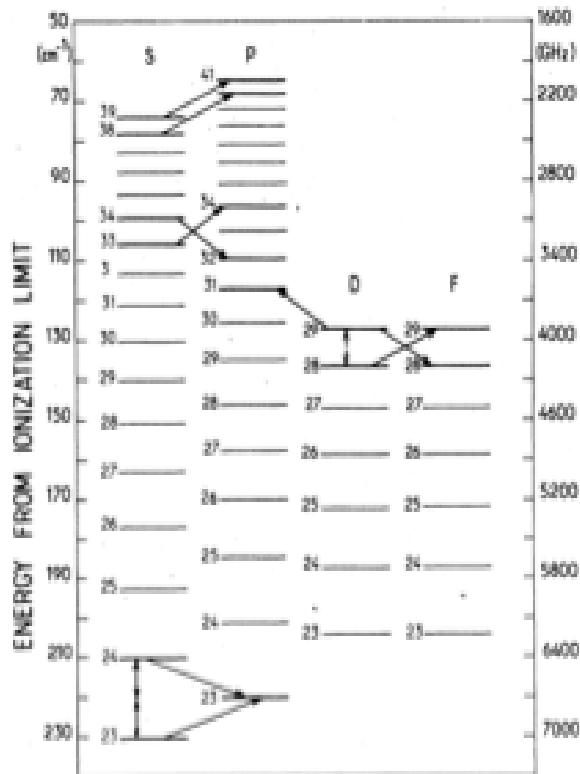
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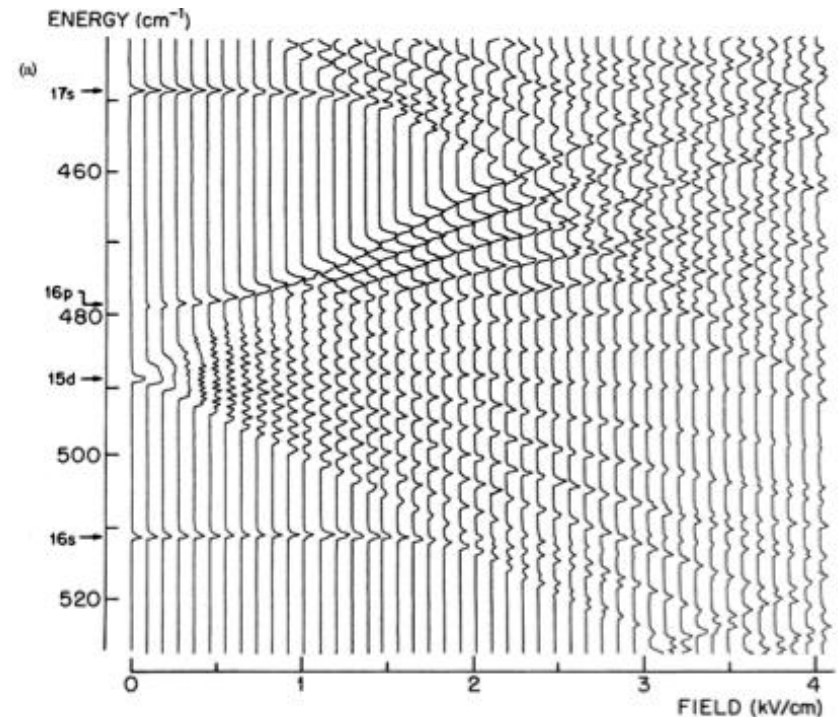
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(Received 12 January 1976)



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Daniel Kleppner

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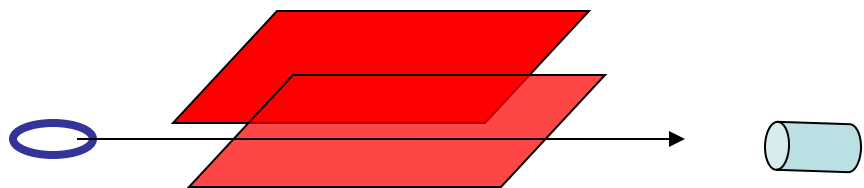
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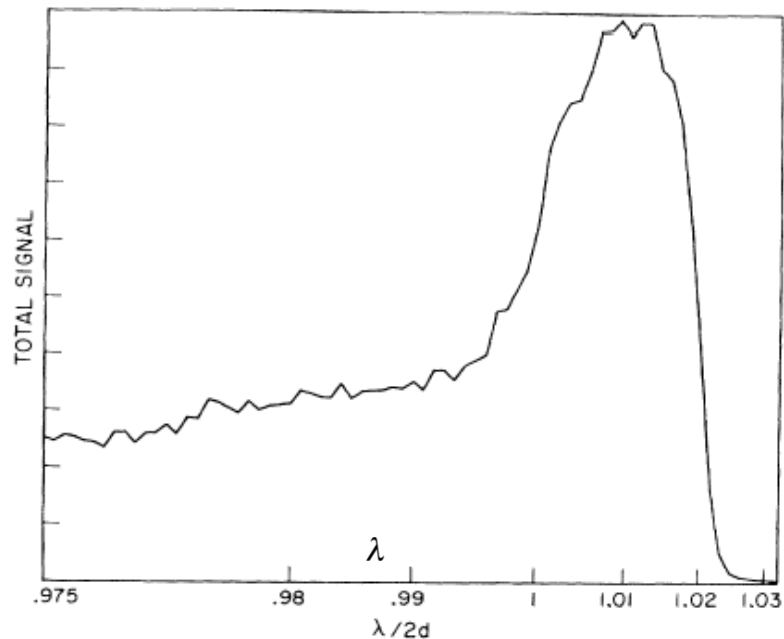
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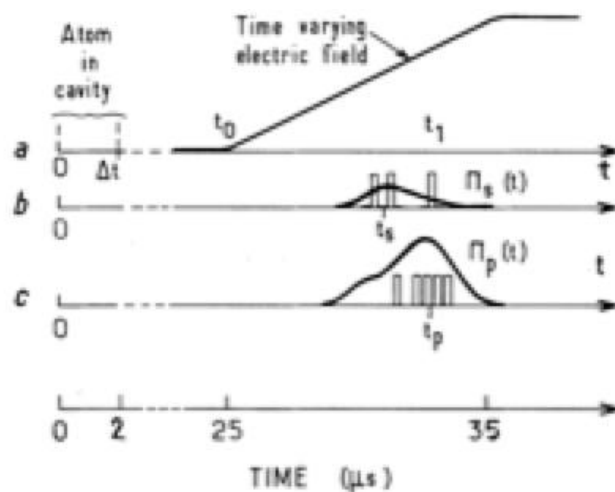
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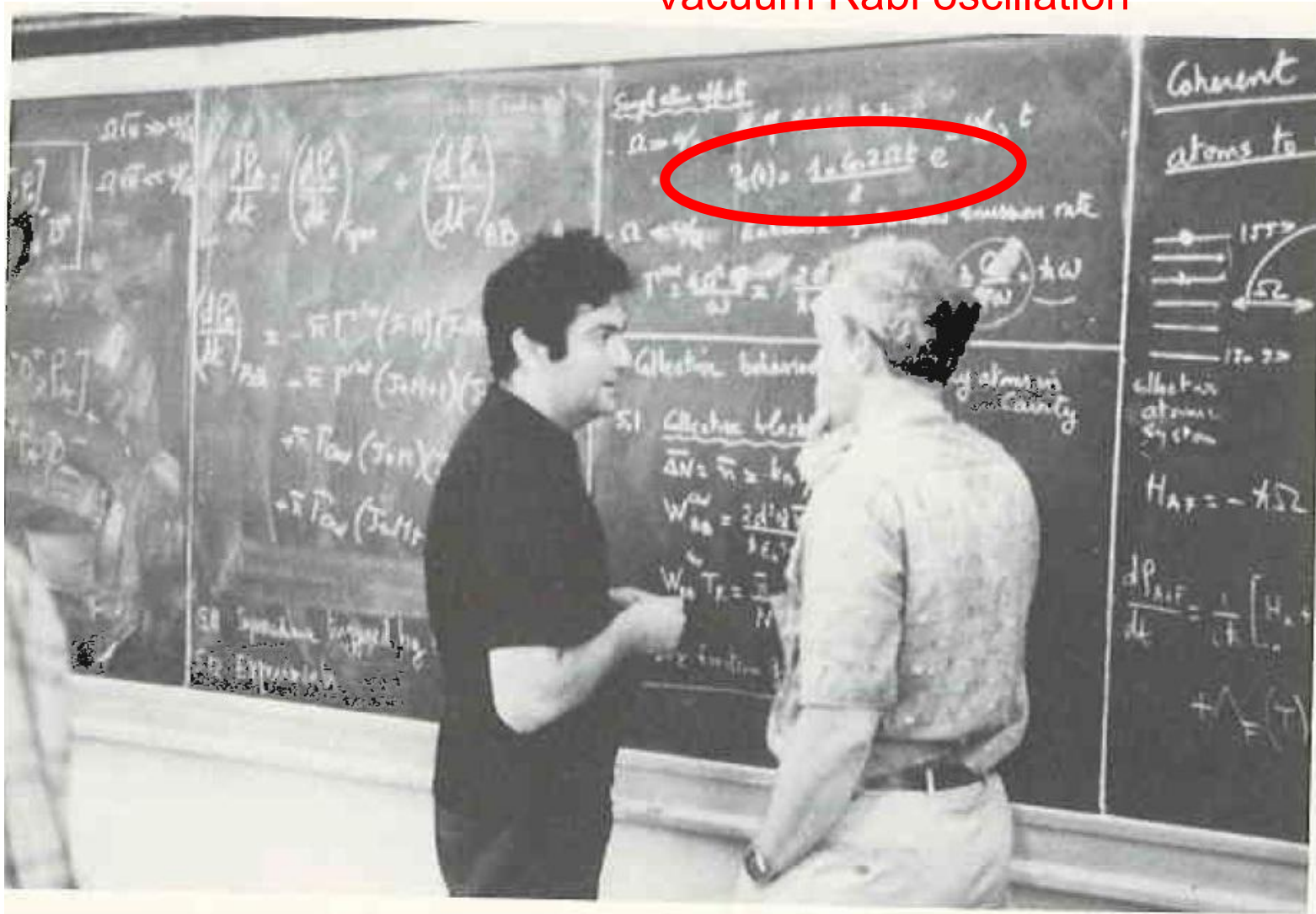
In this respect, the effect described in this Letter can be considered as the limiting case of a transient maser approaching threshold with only one or two atoms in the inverted medium.

With a tenfold increase in Q , Γ_{cav} and $2\pi\nu/Q$ would become of the same size and the emitted photon would be stored in the cavity long enough for the atom to be able to reabsorb it.

This would correspond to a regime of quantum mechanical oscillations between a two-level atom and a single electromagnetic field mode⁴ which should be observable with an improved version of our setup.

Our "Holy Grail" of the 1980's: The search for the strong coupling regime of Cavity QED!

Vacuum Rabi oscillation



Dan and I at Les Houches Summer School in July 1982 discussing the physics of Rydberg atoms and cavities

Physics Today, 42, 24 (1989)

CAVITY QUANTUM ELECTRODYNAMICS

A new generation of experiments shows that spontaneous radiation from excited atoms can be greatly suppressed or enhanced by placing the atoms between mirrors or in cavities.

Serge Haroche and Daniel Kleppner

Cavity Quantum Electrodynamics:

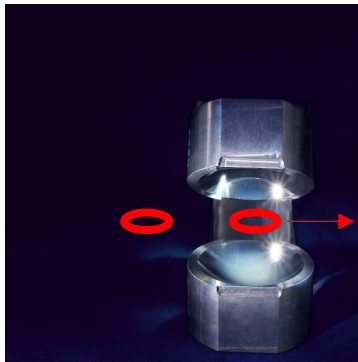
a stage to witness the interaction between light and matter at the most fundamental level

One **atom** interacts with
one (or a few) **photon(s)**
in a box

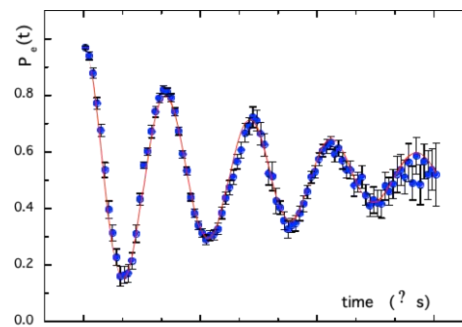


A **sequence of atoms** crosses the
cavity, couples with its field and
carries away information about the
trapped light

Vacuum Rabi oscillation (resonant atom-field interaction)



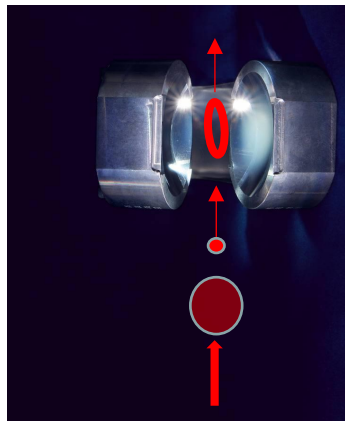
1996



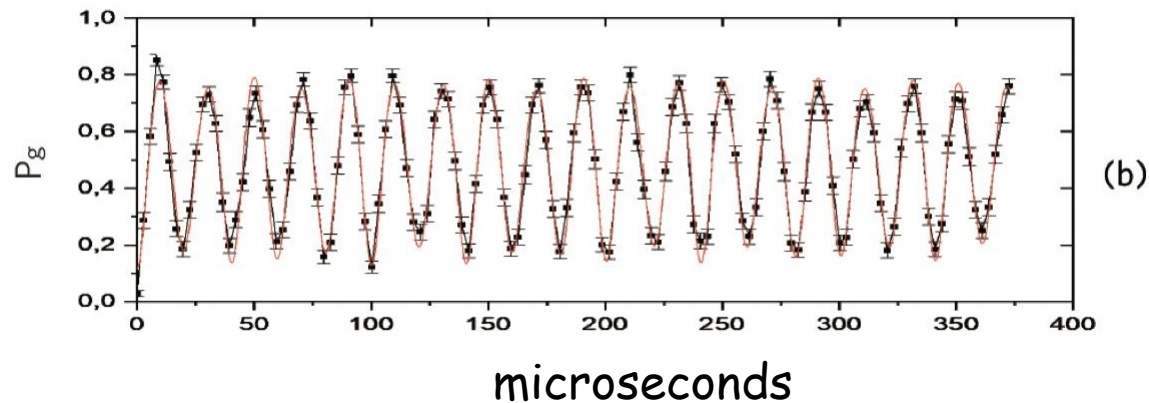
microseconds

Periodic exchange
between circular states
 e ($n=51$) and g ($n=50$)
with 0 and 1 photon
 $\cos\Omega t/2|e,0\rangle + \sin\Omega t/2|g,1\rangle$

Atom-photon and atom-atom
entanglement in Cavity QED
experiments:
realization of quantum gates



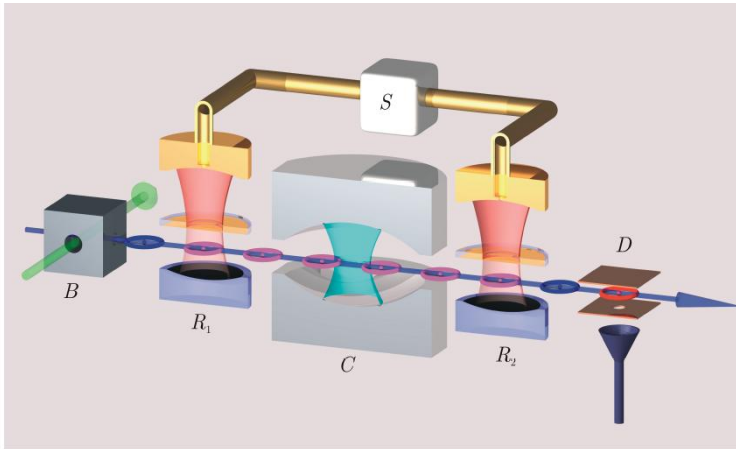
2015



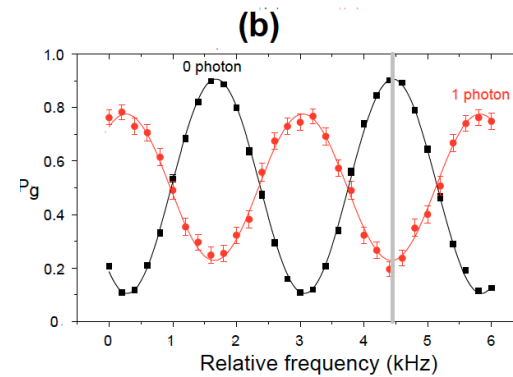
microseconds

(b)

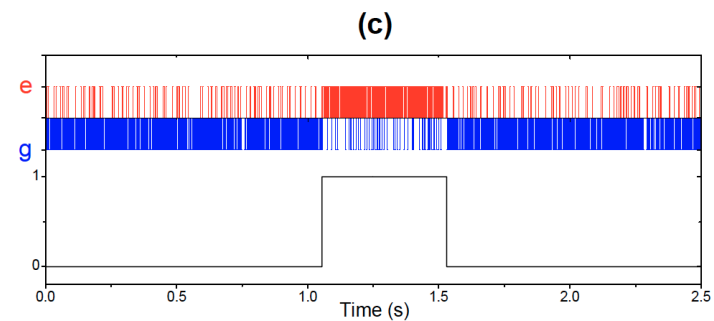
Quantum Non Demolition counting of photons trapped in a non-resonant cavity by a Rydberg microwave clock extremely sensitive to light shifts



A Ramsey interferometer set-up



One photon fringe shift



Birth, life and death of a photon

Movie of Schrödinger cat state decoherence

Phase space representation:
Wigner function of cat state in cavity: the two peaks correspond to fields with opposite phases



J-M. Raimond &
M. Brune



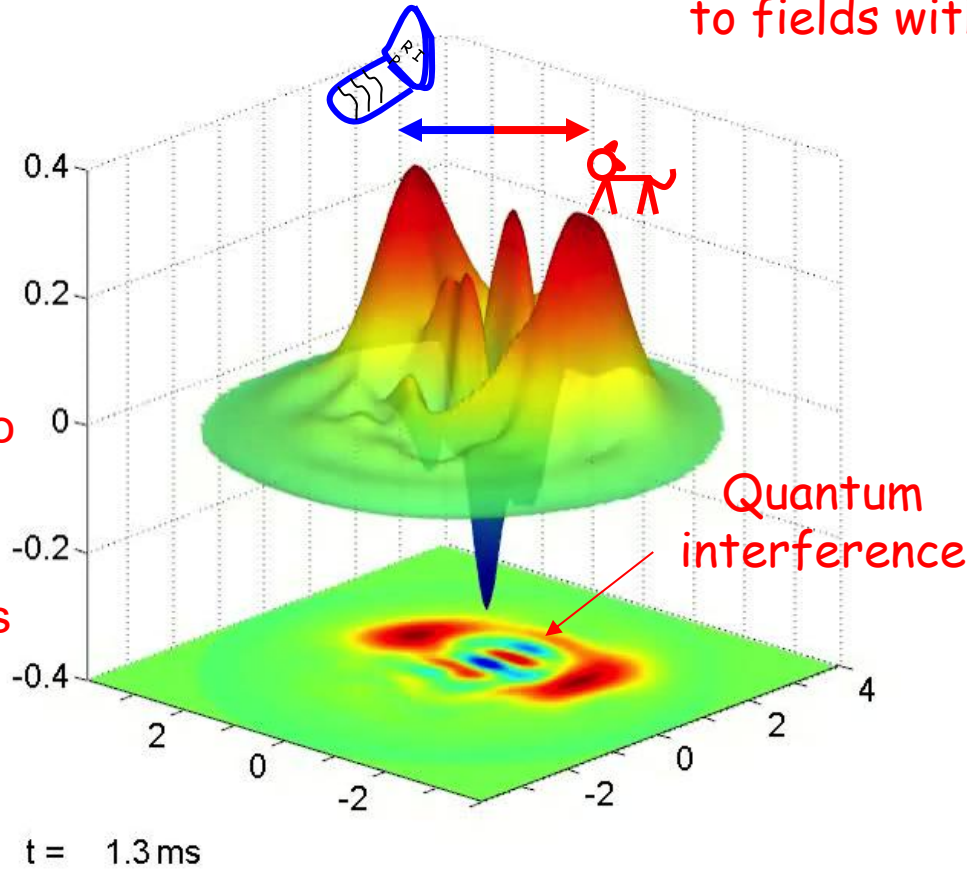
I. Dotsenko



S. Gleyzes



C. Sayrin



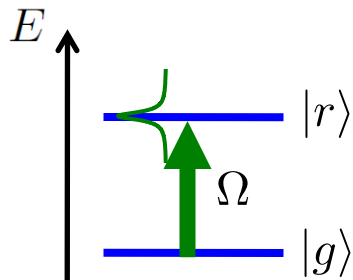
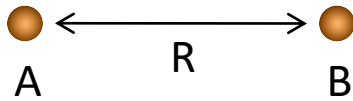
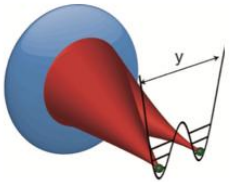
Decoherence
rate proportional
to mean photon
number:

quantum to
classical
transition

*An illustration of Dan's Reference Frame «
Memoirs of Schrödinger's cat*»

The rebirth of Rydberg atom Physics in Quantum Information: the Rydberg Blockade effect

Cold Atoms
trapped by optical
tweezers



$$|\psi\rangle = \frac{1}{\sqrt{2}}(|r,g\rangle + |g,r\rangle)$$

Blockade \Rightarrow **entanglement and gates!!**

Collective oscillation between $|gg\rangle$ and $\frac{1}{\sqrt{2}}(|rg\rangle + |gr\rangle)$

Zoller, Lukin et al

Pillet et al

Browaeys et al

Saffman et al

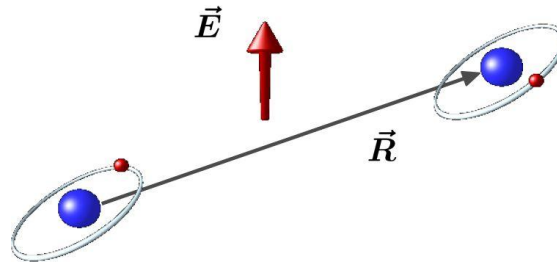
Pfau et al

Bloch et al

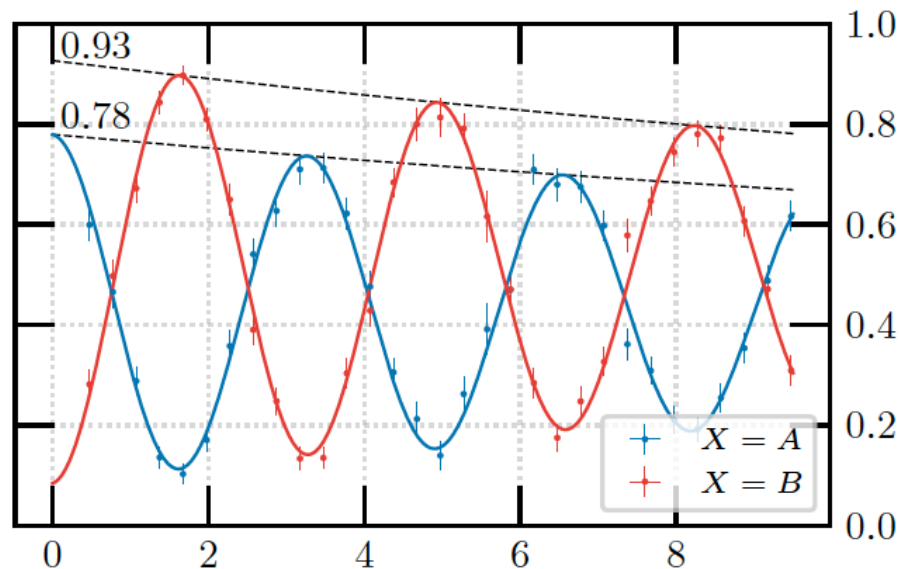
Brune et al

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Spin exchange between two circular Rydberg atoms (Forster resonance)



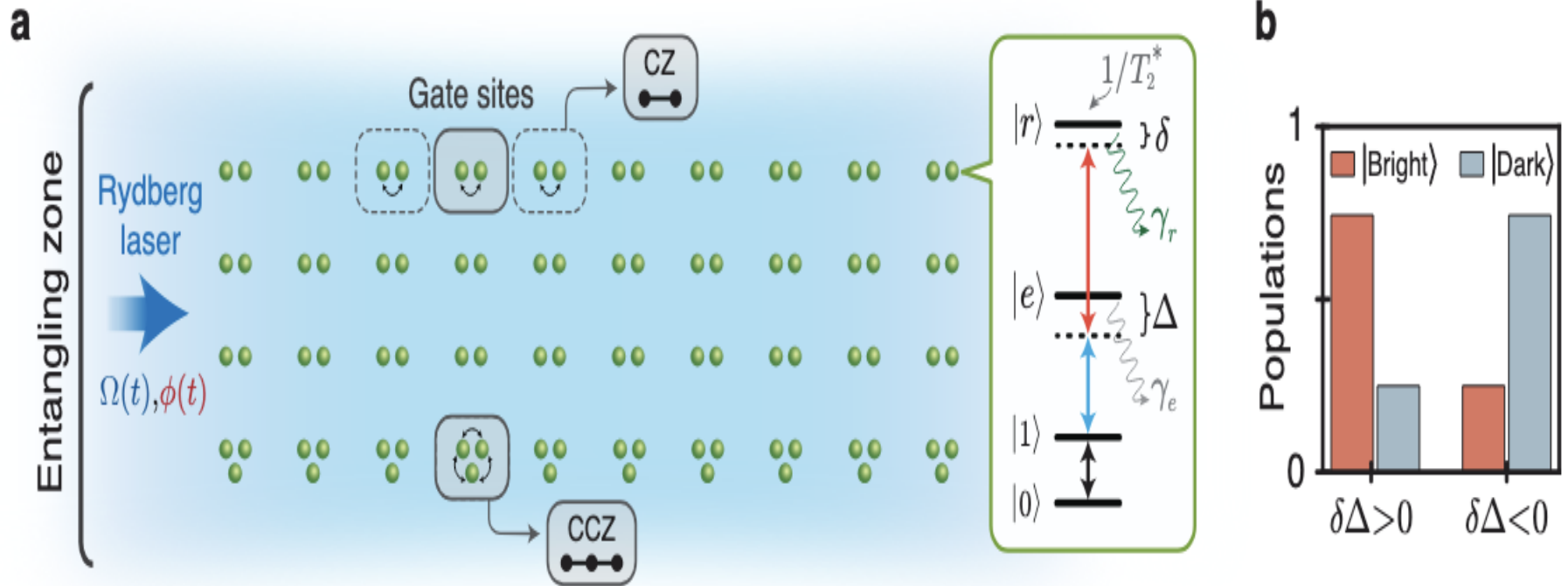
$$|\Psi(t)\rangle = \cos\left(\frac{\Omega t}{2}\right) |53C, 54C\rangle + \sin\left(\frac{\Omega t}{2}\right) |54C, 53C\rangle$$



Brune et al
(2025)

A Rydberg atom entangling machine: towards a neutral atom quantum computer?

MIT-Harvard Center for Ultra cold Atoms (CUA)
M.Greiner, M.Lukin and V.Vuletic groups



Dan was the cofounder of the CUA in 2001