relaxation, if the inner core deforms easily. But in this case, one may question how the heterogeneities or anisotropy variations observed by seismologists could persist in the inner core.

Will seismology be able to resolve this debate? Inner core rotation, if it exists, induces only slight travel time perturbations over the interval spanned by instrumental seismology. The key then is to analyze many data series over long time intervals. Much future research lies in the past. Just as long-term recordings in astronomical observatories detected the irregularities of mantle rotation, old records gathered over past decades in seismological observatories are essential for detecting inner core differential rotation. No definitive conclusion about inner core rotation will be drawn until a large number of these data can be processed, a task made difficult by the limited number of stations having run continuously for 30 years and having accessible archives.

Right now, the differential rotation of the inner core is not yet firmly established. Even if today's results are contradicted tomorrow, they represent an important step for deep-Earth science, because they have already provoked exciting questions in geomagnetism, seismology, and geodynamics.

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PERSPECTIVES: ATOMIC PHYSICS

Under Control

Philippe Grangier

During recent years, the control of atomic motion with forces induced by light has grown into a research field of major importance and sophistication. As they push these techniques to the extreme, researchers are facing an open question: Is it possible to trap an atom into the field of one single photon, or even in the so-called "vacuum field"? An important experimental step toward addressing this problem was recently made by Hood *et al.* (*1*).

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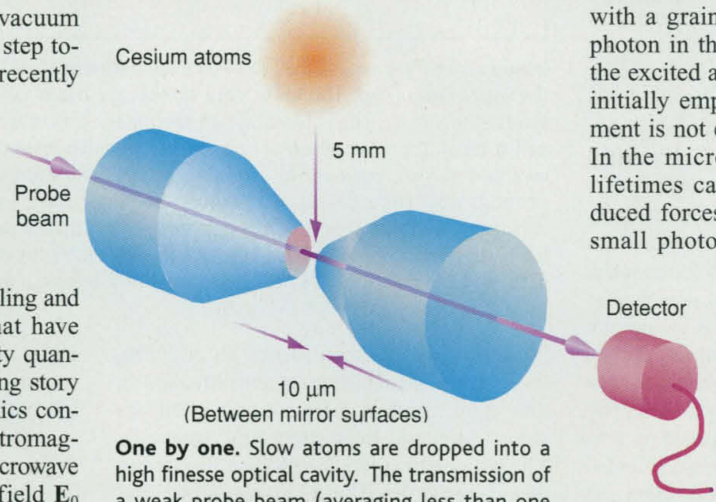
It may seem strange at first to speak about trapping atoms in the vacuum field, that is, in the absence of any light. Getting the right physical insight into this question requires consideration of not only the standard techniques of atom cooling and trapping but also the concepts that have been developed in the field of cavity quantum electrodynamics. To make a long story short, cavity quantum electrodynamics considers the situation where the electromagnetic field stored in an optical or microwave resonator is such that the electric field $\mathbf{E}_0$ corresponding to the ground state energy of the resonator mode is extremely large. The value of $E_0 = |\mathbf{E}_0|$ is obtained simply by noting that the electromagnetic energy $\varepsilon_0 E_0^2 V$ stored in the volume V of the cavity mode is equal to the energy of half a photon, $\hbar\,\omega/2$. Consequently, the coupling energy $\hbar\, g_0 = |\mathbf{D}{\cdot}\mathbf{E}_0|$ between an atomic dipole $\mathbf{D}$ and the field $\mathbf{E}_0$ can also be very large. Here, the relevant scale for a "large" coupling is set by the rates at which the energy is dissipated out of the system, either by spontaneous emission from the atom (rate γ) or by leaking out of the cavity (rate κ). The promised land in cavity quantum electrodynamics, often called "strong coupling regime," begins, therefore, when g_0 is much larger than both γ and κ.



One by one. Slow atoms are dropped into a high finesse optical cavity. The transmission of a weak probe beam (averaging less than one photon in the cavity mode volume) depends sensitively on the interaction between each individual atom and the cavity field. [Adapted from (*1*)]

A simple scheme to trap an atom into such a "vacuum" field was proposed a few years ago (*2*). Consider an excited atom entering a cavity where $g_0 >> \gamma$, κ. When the atom is within the cavity, one must describe the system by considering the coherent coupling between the atom and the cavity, which occurs at a rate g_0 much larger than the energy dissipation. In other words, the photon that is brought in by the atom is "ringing" between the atom and the cavity but does not belong to either of them. This atom + cavity system has its own energy levels ("dressed levels" in the jargon), and it can be shown that some of these levels correspond to an attractive atom-cavity potential. If the atom enters the right level—this can be done by an appropriate choice of the atom-cavity detuning—then it will be attracted to the cavity center. We note obviously that the name of "vacuum field trapping" has to be taken with a grain of salt: There is indeed one photon in the game, which comes in with the excited atom, even though the cavity is initially empty. However, such an experiment is not easy to do for several reasons. In the microwave domain, excited state lifetimes can be very long, but light-induced forces are very small owing to the small photon momentum. In the optical domain, forces are large, but the decay times are typically much shorter than the time it takes for an (slow) atom to cross the cavity. Then the photon is rapidly lost, and the force vanishes.

Present studies (*1*), therefore, consider the situation where the atom-cavity system is driven by a weak external field. Although the best way to implement that scheme is still under study, the question is certainly worth an experiment. Such an experiment requires not only a strongly coupled atom-cavity system but also the introduction of very slow atoms into the cavity. Slow atoms have many advantages indeed: They yield a long atom-cavity interaction time T, which is very useful for diagnostics, and they have a very small kinetic energy, which can "see" the shallow potential

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wells created by the vacuum field. All these conditions were achieved in the experiment of Hood *et al.* (*1*), which obtained the values (g_0, κ, γ, $1/T$)/2π = (120, 40, 2.6, 0.002) MHz in the optical domain. The cavity requirements to get these values are rather extreme: The cavity length is 10 μm, and the cavity finesse is F = 180,000. Slow atoms are dropped into the cavity from a magneto-optical trap 5 mm above the cavity mirrors (see figure). In the strong coupling regime, the presence of one atom within the cavity mode completely changes its optical properties: The usual Fabry-Perot peak of the empty cavity turns into two peaks shifted by $\pm g_0$, which are direct evidence of the coherent atom-cavity coupling. Moreover, the value of g_0 depends on the atom's position with respect to the cavity mode and changes from zero, when the atom is outside the mode or at a node of the standing wave, to a maximum obtained when the atom is centered at an antinode. It is, therefore, possible to monitor in real time the motion of the atom as it goes through the cavity, just by looking at the transmission of a weak probe beam fed into the cavity mode. Depending on the precise tuning of the probe beam, the transmitted beam either turns on or off when an atom enters the cavity.

By following in real time a large number of such single-atom trajectories through the cavity mode, Hood *et al.* come to the following conclusions. First, the standard cavity quantum electrodynamics theory for the atom-cavity coupling gives a good qualitative and quantitative account of the observations. Second, when the probe is detuned to the longer wavelength side of the atomic transition, more atoms achieve a large value of g_0 than when the probe is detuned to the shorter wavelength side. This novel result is attributed to a light-induced force at the single-photon level, which "channels" the atoms into the antinodes and therefore increases the apparent value of g_0.

It can reasonably be expected that this experiment will open the way to many others, which have several different but complementary objectives. First, the light-induced forces can presumably be exploited further and may go from the channeling effect observed here to an actual one-photon, one-atom trapping effect. Second, the atom-light interaction in the strong coupling regime also modifies the light itself: In particular, one may expect to produce light beams that would appear as regular streams of individual photons (*1*). Another possible objective is to achieve an extremely efficient two-beam coupling, for performing quantum measurements (*3*) or for implementing quantum logical gates (*4*, *5*). The objective here is to manipulate information stored at the quantum level with single photons or single atoms, keeping an eye on the possible implementation of simple quantum computational algorithms (*5*). In a deliberately optimistic view about the future of such experiments, this is the concrete; soon will come the bricks and maybe one day the house.

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PERSPECTIVES: CARCINOGENESIS

Another p53 Doppelgänger?

William G. Kaelin Jr.

Nature is an efficient employer—if it needs to fill a new position, it retrains an employee already on the books. And so, many proteins have relatives, similar in sequence and structure, but slightly different in function. Recent work is now redefining the tumor suppressor p53's previously solo act to show that it too belongs to a larger group of related proteins.

First detected in the 1970s, the p53 tumor suppressor protein is mutated in about 50% of human cancers. Even when the p53 allele is normal, the p53 protein can contribute to disease if it is inactivated through physical association with proteins such as MDM2 or sequestration within the cytoplasm. Thus, it is possible that p53 is absolutely crucial for cancer—that it is always inactivated, directly or indirectly, during all human carcinogenesis. Indeed, a variety of unrelated DNA tumor viruses, through convergent evolution, inactivate p53 during cellular transformation, and germ line *p53* mutations in humans predispose to cancer.

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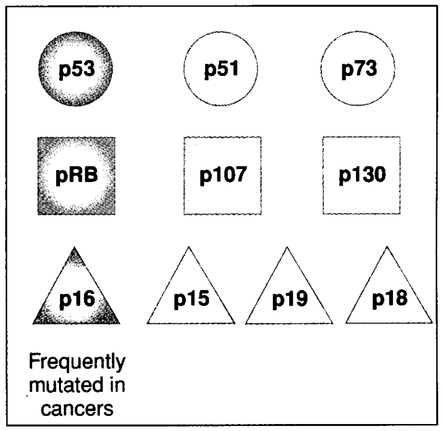
p53 is a sequence-specific DNA binding transcription factor. In model systems, reintroduction of wild-type p53 into p53-defective tumor cells leads to apoptosis or to blockade of the cell cycle, or it increases the cell's sensitivity to chemotherapeutic agents. If any of these outcomes could be triggered at will in actual tumors, the therapeutic benefit could be considerable. Thus, interest in p53 is intensive, particularly in restoring its function in human tumors.

Last summer, it became clear that there were other members of the p53 family when Caput and co-workers serendipitously identified a human p53 homolog called p73 (*1*). The primary sequence of p73 is very similar to that of p53, especially in the region corresponding to the p53 DNA binding domain. Indeed, p73 can bind to canonical p53 DNA binding sites in vitro (*2*). Furthermore, p73 can, like p53, activate p53-responsive promoters and induce apoptosis in tumor cells lacking p53 (*1*, *3*). In addition, *p73* maps to chromosome 1p36, a region that is deleted in a variety of human tumors. These findings suggest that *p73*, like *p53*, is a tumor suppressor gene.

To date, however, no mutations in the *p73* gene have been identified in human cancers. Thus *p73*, unlike *p53* and *RB-1*, does not conform to the classical "two-hit" model in which inactivation of both the maternal and paternal copies of a tumor suppressor gene are required for tumor development. It has been suggested, however, that *p73* is monoallelically expressed (*1*), that is, only one of its alleles is transcribed. If true, loss of the transcribed allele might contribute to carcinogenesis. Nonetheless, there are currently no genetic data that firmly establish *p73* as a bona fide tumor suppressor gene. The notion that *p73* is monoallelically expressed is currently being challenged (*4*), and mice lacking p73



Close cousins. Members of the p53 family, the pRB family, and the cdk4 inhibitor (INK4) family. p53, pRB, and p16 are frequently mutated in human cancers.