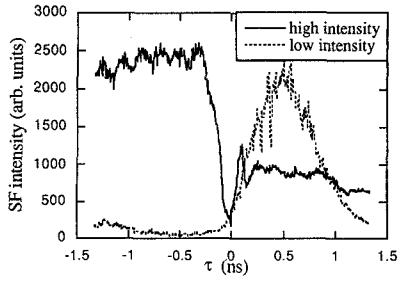

QThB4. Fig. 2. Yoked superfluorescence along the direction of pulse 2 as a function of delay τ between pulses 1 and 2. Solid line is for high-intensity and dashed line is for low-intensity excitation pulses (relative to the YSF threshold).

threshold). The latter case is surprising because the echo is maximum at a positive, relatively large value of τ. This is because, for small excitation pulse area, the ground-state grating is primarily generated by a two-photon yoked superfluorescence pulse (at both the 5*S*–6*P* and 6*P*–5*D* transition wavelengths) resulting from the application of the second pulse in the presence of an infrared seed from the first pulse. The action of the seed when the intensity is low can be inferred from Fig. 2, which shows little yoked superfluorescence along k_2 unless preceded by the pulse along k_1.

When the excitation pulses are strong, the echo behavior as shown in Fig. 1 changes dramatically. Now we believe the ground-state grating is primarily generated by direct two-photon resonant interaction of pulses 1 and 2 with the sample. The excitation pulses are intense; no seeding is necessary, and the echo is generated with little delay. Again, the YSF behavior as shown in Fig. 2 lends support to this interpretation.

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QThB5 **9:00 am**

Resonant van der Waals repulsion between free excited atom and dielectric surface: an experimental signature

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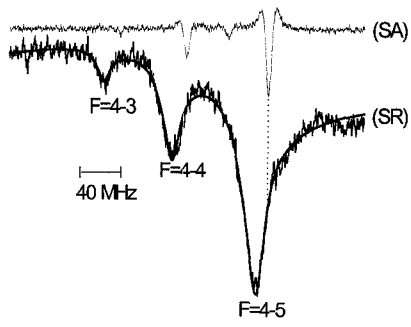
The van der Waals attraction between an atom (or molecule) and a surface is ubiquitous in physics, chemistry, and biology. This long-range interaction is an essential feature of numerous cavity QED processes. In the case of an excited atom lying close to a dispersive dielectric medium, it has been predicted that the interaction can be magnified, relative to the attraction by a perfectly reflecting surface, when part of the virtual emission of the atom is coupled to the absorption spectrum of the dielectric surface.[1] As an example of such a predicted coupling, one can quote the system Cs atom (in $6D_{3/2}$ state)/sapphire surface.[2] Indeed, the well-known spectrum of sapphire shows that $[\varepsilon(\omega) - 1]/[\varepsilon(\omega) + 1]$ is resonant around 12.21 μm (with a slight dependence on the sapphire crystalline orientation), whereas the $6D_{3/2}$ level can decay to a $7P_{1/2}$ level by a transition around 12.15 μm. For the probing of such an effect, selective-reflection (SR) spectroscopy appears quite convenient: it is one of the few methods enabling an excitation of the short-lived $6D_{3/2}$ level in the vicinity of the surface. Moreover, high-resolution (FM) SR spectroscopy, which typically probes the vapor one optical wavelength away from the surface, has been repeatedly demonstrated to be a sensitive tool of the surface van der Waals interaction.[3]



QThB5 Fig. 1. SR is the FM selective-reflection spectrum of the $6P_{1/2}(F = 4)$–$6D_{3/2}$ (F = 3,4,5) Cs transitions for a sapphire cell, as recorded at low temperature (T = 119°C). The line is a fit assuming a van der Waals shift of −32 Mhz at $\lambda/2\pi$; Sa is the reference spectrum (second derivative of FM saturated absorption), showing the position of the $6P_{1/2}(F = 4)$–$6D_{3/2}(F = 3,4,5)$ transitions. Note the large redshift, which is a signature of a repulsive potential in SR spectroscopy.[3]

In our work, the heated Cs vapor is excited by a pump beam tuned to the D_1 resonance ($6S_{1/2}$–$6P_{1/2}$ at 894 nm) and by a weak (frequency modulated) probe beam at 876 nm ($6P_{1/2}$–$6D_{3/2}$). The pump beam itself is sent off axis, has a large emission linewidth, and is often slightly detuned from the D_1 line, to populate the intermediate level in a broad velocity band. Hence, the reflectivity of the 876-nm laser, sent under normal incidence, can be interpreted directly via the theoretical model previously developed for a resonant transition.[4]

Experiments have been performed on several Cs vapor cells, with different input windows. In the case of a silica glass cell, the observed spectrum is interpreted with a relatively weak van der Waals surface attraction as the dominant surface mechanism. The van der Waals coefficient is experimentally found to be $C_3 = 10$ kHz · μm^3. This is in good agreement with the theoretical expectation of 9.5 kHz · μm^3 (perfect reflector prediction of 19 kHz · μm^3; dielectric image coefficient of 0.5, as determined through silica spectral data provided in literature). For a sapphire window, one observes a drastic change in the spectrum, affecting (i) the overall signal magnitude (much smaller than for glass or YAG window), (ii) the apparent width of the resonance (apparently even at low pressure), and (iii) the frequency shift relative to the reference frequency provided by volume-saturated absorption (Fig. 1 shows a shift of about −12 MHz, nearly as large as the resonance width, in conditions when collisional shift is negligible). All these specific features are to be interpreted by a repulsive van der Waals shift, with an estimated magnitude of ≈ −80 kHz · μm^3. This resonant coupling between the surface excitation and the atomic excitation, experimentally demonstrated for the first time, could also induce several other effects, including observation of forbidden transitions, as well as effects related with cavity QED at nonzero temperature.

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QThB6 **9:15 am**

Experimental study of quantum chaos with cesium atoms

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Ultracold atoms in a pulsed standing wave of light constitute an experimental realization of the δ-kicked rotor, a paradigm for classic and quantum chaos. One of the key predictions in this system is the phenomenon of dynamic localization, a quantum suppression of diffusion in a classically chaotic regime. Previous work by our group centered on the study of dynamic localization with ultracold sodium atoms and established atom optics as a new testing ground for this field.[1–3]

To go beyond the first generation of quantum-chaos experiments, we set up a similar experiment with cesium. The small recoil velocity of cesium relative to sodium ensures that the δ-kicked approximation is valid over a much larger range of momenta. The resulting momentum boundary in phase space is then pushed out much further, opening the door for experimental studies of noise-induced delocalization as well as other directions of fundamental interest.

Cesium atoms are first trapped and cooled in a magnetic-optical trap (MOT) via diode lasers. After this stage, the trapping fields are turned off, and the atoms are exposed to a standing wave from a Ti:sapphire that is tuned 5–10 GHz from the cesium resonance. The standing wave is turned on in a series of pulses with a period of ~20 μs and pulse widths of up to 400 ns. We observe dynamic localization in the momentum distribution, reproducing the earlier results found in sodium. We are now studying the effects of noise on dynamic localization to address the important issue of quantum decoherence in the context of quantum chaos. Intensity noise is imposed on the pulsed standing wave with an acousto-optic modulator. We observe a sharp increase in the momentum distribution width as a function of the noise amplitude. We plan to extend this

work to study the effects of phase noise and spontaneous scattering on dynamic localization. We also plan to implement stimulated Raman "tagging" combined with adiabatic evolution to prepare initial conditions that are well localized in phase space. This technique should enable a detailed study of quantum transport in mixed classic phase space, where islands of stability are surrounded by regions of chaos.

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QThB7 **9:30 am**

Potential measurement of evanescent-field-induced radiation pressure

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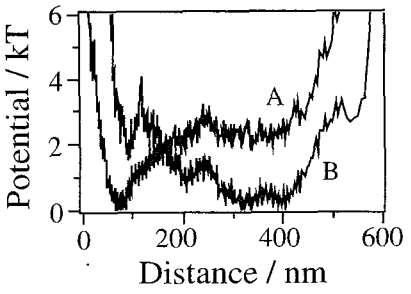
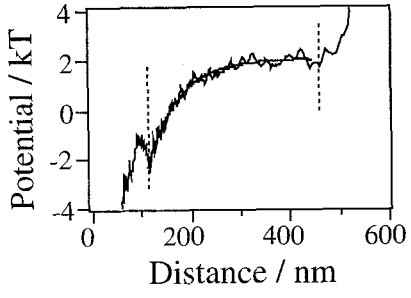
It has been reported that microparticles could be driven and aligned by an evanescent field induced at solid–liquid interfaces, based on radiation pressure caused by photon momentum transfer from the localized optical field to the particles.[1] For its applications to micromanipulation and micropatterning of particles, it is indispensable to quantitatively measure the strength and potential energy of the evanescent-field-induced radiation pressure. In this paper, we describe the direct observation of three-dimensional interaction potential between a single particle and the localized optical field.

A microparticle was irradiated with the evanescent field of a Nd:YAG laser (1064 nm, 200 mW) as well as a focused beam from the same laser that worked for positioning of the particle. For position detection, an He-Ne laser (3 mW) was used, which illuminated the particle under the total-internal-reflection condition. The scattered He-Ne laser light from the microparticle was detected by a quandrant photodiode, so that two differential outputs determined x and y positions with nanometer resolution and the total intensity gave the separation distance between the quartz surface and the particle on the basis of the exponential dependence of the scattered evanescent-field intensity. Temporal fluctuation of the particle position due to the thermal Brownian motion was sequentially measured to obtain a histogram. This spatial distribution could be analyzed with the Boltzmann expression so that a potential energy was determined as a function of three-dimensional position.[2,3]

Figure 1 shows a z-directional potential exerted on a polystyrene latex particle (4 μm). Curves A and B are potentials observed with and without irradiation of the Nd:YAG laser evanescent field. These potentials are composed of electric-double-layer interaction and



QThB7 Fig. 1. Laser trapping potentials exerted on a polystyrene latex particle (4 μm) in a sodium chloride solution. The potentials were observed with (A) and without (B) irradiation of the Nd:YAG laser evanescent field.



QThB7 Fig. 2. Potential curve of the evanescent-field-induced radiation pressure.

gravitational force, as well as the radiation pressure. By subtracting curve B from curve A, the potential of the evanescent-field-induced radiation pressure was obtained, as shown in Fig. 2. The exponential dependence of the radiation pressure on the separation distance could be clearly observed.

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QThB8 **9:45 am**

Optical torques align and rotate microscopic wave plates

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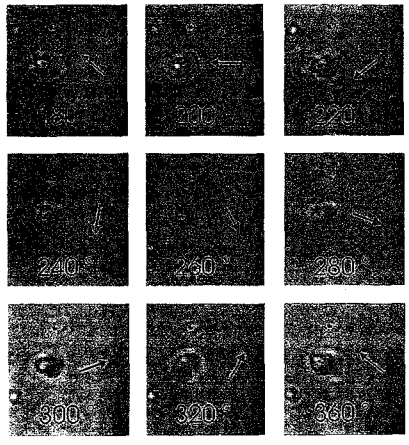
The angular momentum carried by polarized light was first measured in 1936 by Richard Beth, who measured the tiny reaction torque due to the change in polarization of light on passage through a quartz wave plate. Using the modern single-beam gradient optical trap, we can observe the reaction torque on a birefringent particle on a microscopic scale, where the observable effects are several orders of magnitude greater.

We trapped calcite fragments dispersed in



QThB8 Fig. 1. Photographs of a calcite crystal aligned to the plane of polarization of the trapping beam. Numbers show the angle of the λ/2 plate, and arrows show the angle through which the plane of polarization has been rotated in successive frames.

water in a single-beam gradient trap. The trapping beam is initially linearly polarized, and the plane of polarization can be rotated by a λ/2 plate. A λ/4 plate allows the ellipticity of polarization to be varied. Due to their birefringent nature, calcite particles can act as wave plates. The ordinary and extraordinary components of the incident light will undergo different phase shifts after traveling through the same thickness of the particle. If this results in a change in the angular momentum carried by the beam, there will be a corresponding torque on the material.

In general, an incident beam will be elliptically polarized. Elliptically polarized light produced by passage through a λ/4 plate can be written

$$\mathbf{E} = E_0 e^{i\omega x} \cos\phi \hat{\mathbf{x}} + iE_0 e^{i\omega x} \sin\phi \hat{\mathbf{y}}, \quad (1)$$

where ϕ determines the degree of ellipticity of the light. The torque per unit area exerted due to light passage through a birefringent material is

$$\tau = \frac{\varepsilon}{2\omega} E_0^2 \sin[kd(n_o - n_e)] \times (\sin^2\phi - \cos^2\phi)\sin 2\theta + \frac{\varepsilon}{2\omega} E_0^2 \{\cos[1 - kd(n_o - n_e)]\}\sin 2\phi, \quad (2)$$

where θ is the angle between the fast axis of the λ/4 plate and the fast axis of the microscopic wave plate.

Equation (2) predicts that, if a particle is aligned with its optic axis at some angle θ to the plane of polarization, it will experience a torque until $\theta = 0$, which will cause the particle to align to the plane of polarization. We trapped calcite fragments in a plane-polarized beam. The particles aligned in a particular direction and rotated as the plane of polarization was rotated. Figure 1 shows a calcite crystal