EPS-9 PARALLEL SESSIONS

Techniques Dominate Advances

MANIPULATING ATOMS AND FEMTO-SECOND PROBING

The *Optics and Interferometry with Atoms* symposium provided an opportunity for a general audience to learn about developments of this new field. The goal of atom optics is to do with atoms what usual optics does with photons, *e.g.*, reflection, refraction, focusing, interference. Two techniques have been used up to now in order to act on atomic trajectories: interaction with quasi-resonant laser light and interaction with diffracting fabricated microstructures.

In his introduction, **J. Mlynek** (Constance) explained that several basic elements of atom optics have already been demonstrated (mirrors, lenses, beam splitters, interferometers) but many improvements are still expected. He also anticipated exciting applications. For instance, atomic microprobes will use particles much less energetic that electronic microscopes (meV instead of KeV) and atomic interferometers will permit highly sensitive measurements of gravitational or inertial effects, both for detection purposes and for fundamental tests of relativity.

An example of an atomic interferometer, based on a idea by C. Borde using Ramsey fringes, was described **F. Riehle** (PTB, Braunschweig). Sensitivity to rotations has been demonstrated, light-shifts measured, and a new experiment based on cold, trapped atoms instead of an atomic beam is in progress. **J. Robert** (Paris-Nord) reviewed the basic principles of Stern-Gerlach interferometry for application to the so-called "scalar Bohm-Aharonov effect"; a new scheme involving four interaction zones should yield new results.

Finally **J. Dalibard** (Paris) described the atomic cavity based on a concave mirror for bouncing atoms (Fig. 1). It opens the path to the observation of multiple atomic multiple interferences, *i.e.*, observing the modes of an atomic cavity. The ultimate goal would be to accumulate many bosonic atoms in the same mode to realise the atomic equivalent of a laser mode filled with many photons.

Introducing the *Femtosecond Spectroscopy* symposium, **G. Gerber** (Freiburg) pointed out that the short-duration light pulses now available have initiated many

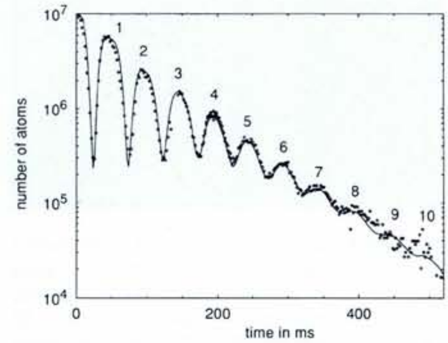

Fig. 1 — Bouncing atoms: a cloud of cold Cs atoms from a magneto-optical trap are released above a curved mirror formed by an evanescent light wave produced by internal reflection of a laser beam at a curved glass surface. Measuring the number of atoms above the mirror as a function of the time after release using fluorescence induced by a probe beam shows that the atoms bounce up 10 times. [Aminoff C.G. et al., Phys. Rev. Lett. ***71** (1993) 3083.]*

time-resolved laser spectroscopy experiments hitherto considered impossible, notably those involving the coherent superimposition of non-degenerate states to give wave packets. Typical experiments concern atomic collisions (10-100 fs duration), molecular relaxations in dyes (50-300 fs), molecular vibrations (100-1000 fs period), and interactions in liquids (≈ 1 ps). Most traditional work was done with 50 fs pulses, but systems with 9.5 fs pulses are emerging. **H.B. van Linden van der Heuvell** (FOM, Amsterdam) dealt with atomic-level problems by showing how wave packets in Rydberg atoms in an electric field can be detected using a two pump-probe method: the laser pumps, separated by a known delay, excite a packet and the probe pulse ionizes the electron (the conventional technique uses a single pump). The as-yet unexplained observation is that wave packets have many different orbiting times.

Moving to the molecular level, **T. Baumaert** (CalTech, USA) discussed the real-time observation of multiphoton ionization and fragmentation using the pump-probe method in combination with other techniques. For single excited Na_2^+ formed by photoassociation during ultracold associative ionization of laser-cooled Na atoms, the Na_2^+ signal modulates strongly with the delay time, indicating that the molecule contains a wave packet which is moving back and forth. As it is interesting to take advantage of the wave-packet motion to control chemical reactions, the next step was to show that one can adjust the production of dimer ions (the Na_2^+/Na^+ ratio depends on the probe delay). Adding one more atom gives a more complicated spectrum, but the three normal modes can be observed in Na_3^+ by applying Fourier transforms. Leaving stable systems, it was shown that decomposition pathways can be controlled during the rapid dissociation of (IHgl)* and atmospheric OClO.

D.A. Wiersma (Groningen) presented revealing insights into how femtosecond spectroscopy can be used in condensed matter, taking as his example the stochastic fluctuating forces arising in molecular collisions in solution (these forces determine the dynamics of chemical reactions). From the observation of beating patterns for stimulated photon echoes obtained using two successive laser pulses it is concluded that optical excitation affects the molecule's environment. Descriptions are more complicated in solutions than in isolated molecules because the wave-packet description cannot be used. Nonetheless, there is a coherent superimposition of the echoes depending on the number and type of oscillator modes in the solvent. The challenge is to relate this understanding to chemical reactions such as photochemical fragmentation (*e.g.*, when an iodine atom detaches from a benzene derivative). Some results are very surprising. For instance, in some molecules all the energy is dumped into rotational motion so that fragments spin away and combine unusually slowly. The ultimate aim of the work is once again to control chemical reactions, but this is a long way off.

Moving on up in scale, **D. von der Linde** (Essen) discussed what happens when a relatively high-intensity laser beam (albeit with 10^4 times less power per unit area than the state-of-the art described by P.L. Knight) ionizes and heats a solid surface. The motivation is straightforward (the development of microplasma systems to produce sub-ps soft x-ray pulses) but the processes involved are not, so his approach was to describe some results obtained using ultrafast optical probing of the plasma. Mysteries surround even quite basic features, such as why the expanding plasma shows a red shift and not a blue one.

From left to right, H.B. van Linden van der Heuvell, T. Baumaert, D.A. Wiersma, and D. von der Linde.

ENGINEERED SEMICONDUCTORS AND LIQUID HELIUM

The *Quantum Wells and Semiconductors* symposium aimed to present recent key achievements in the field of quasi 2-, 1- and 0-dimensional semiconductor microstructures to illustrate the extraordinary revival of semiconductor physics with the advent of novel, man-made structures. It was introduced by a general pedagogical talk by **M. Altarelli** (ESRF, Grenoble) on quantum wells, superlattices and other microstructures with confined electrons. They provide the means to explore the basic physics of quantized exitonic states while attracting conside-

From left to right, P. Pieranski, R. Holyst, B. Jerome, and R. Rothen.

From left to right, W. Helfich, R. Lipowsky, U. Olsson, and M.E. Cates.

rable attention because of potential application to non-linear optical devices.

Light scattering by phonons can be used to discriminate between homogeneous and inhomogeneous broadening in microstructures. At resonance, a microstructure is seen by electronic excitations as a disordered system (there is no translational invariance) and conservation in reciprocal space is lost. This leads to a series of interesting phenomena that were discussed by **M. Cardonna** (MPI, Stuttgart).

R. Nicholas (Oxford) described a new quantum structure, namely the InAs/GaSb superlattice. Tuning the superlattice period (typically 15 nm) and subjecting the structure to pressure variations and to different magnetic fields led to the observation of a semimetal to semiconductor transition in the two-dimensional electron gas. Experimental results can be interpreted in terms of theories describing the magnetic-field induced broadening (delocalization) of Landau levels. The experiments were executed in Japan using pulsed magnetic fields of up to 100 T (similar facilities are not available in Europe and P. Wyder discussed in a plenary talk studies that are underway to boost European capabilities).

While energy relaxation processes for excitons that are quantum confined in semiconductor quantum wells are well understood, this is not the case for spin relaxation processes. Spin-dependent effects in heterostructures were reviewed by **G.E. Pinkus** (Ioffe Institute, St. Petersburg) before **J.Y. Marzin** (CNET, Bagneux) wound up a highly stimulating session with an review of the impressive state-of-the-art concerning the fabrication of quantum wire and quantum dot structures.

Liquid ^{3}He and ^{4}He have been always considered as prototypes of quantum many-body systems of fermions and bosons. They exist in extremely pure phases, behaving like systems of point-like particles and interacting *via* a simple potential (of the Lennard-Jones type). Moreover, they show close analogies with other interesting many-body systems such as superconductors and nuclear matter.

The *Quantum Fluids* symposium aimed to focus on aspects of the inhomogeneous states of helium (*e.g.*, free surfaces, liquid-solid interfaces) with talks giving insights from different viewpoints into currently investigated topics.

The basic phenomena involved in the novel properties of liquid helium on weak-binding substrates were discussed by **J. Dupont-Roc** (ENS, Paris). It has been predicted recently that the surfaces of heavy alkali metals are not wetted by liquid ^{4}He, in contrast with all other known surfaces. In testing this prediction, it has been found that caesium surfaces are indeed not wetted at low temperatures. The possibility to study in detail the wetting and prewetting transitions, and also to explore the effect of ^{3}He on wetting phenomena, makes these systems particularly appealing from both theoretical and experimental viewpoints.

Density functional theory (DFT) has been used recently to predict the structure of helium films and to explore wetting phenomena. The same formalism is now extended to study dynamic properties of inhomogeneous states of ^{4}He. A time-dependent version of DFT was presented by **F. Dalfovo** (Trento). It gives estimates for the dispersion relation of surface modes in quantitative agreement with recent neutron scattering data. Since the theory treats bulk excitations, surface excitations, and free atoms on the same terms it is expected to provide a reliable description of quantum evaporation, *i.e.*, the evaporation of atoms induced by bulk excitations hitting the surface. This phenomenon, which has been investigated systematically by A.F.G. Wyatt and coworkers at Exeter, is a typical quantum process: it provides an alternative way to gain insight into the properties of elementary excitations in superfluids.

Two talks were devoted to on-going investigations of the properties of the liquid-solid interface in ^{4}He. **F. Chevalier** (ENS, Paris) presented new experimental results by S. Balibar's group for the stepped surface of helium crystals showing that, for a tilted crystal surface, a critical angle exists between the vicinal (stepped) behaviour and the rough behaviour. The value of the critical angle is close to theoretical estimates and measurements of the surface stiffness were interpreted on the basis of a repulsive interaction between steps. **S. Fantoni** (SISSA, Trieste) discussed the present status of microscopic theories for the liquid-solid interface. The most recent development is the application of variational Monte Carlo methods with shadow wave functions. The theory describes fairly accurately bulk liquid and solid phases, and is close to providing quantitative predictions for the structure and energy of the interface.

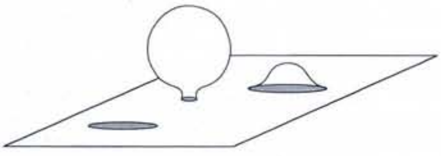

Fig. 2 — A membrane forms a bud when a domain reaches a certain size.

SOFT MATTER AND FLUID SURFACES

A special effort was made by P. Pieranski (Paris-Sud) to collect speakers in the *Soft Matters* session he chaired who would illustrate some of the new concepts being used in soft-matter physics. **F. Rothen** (Lausanne) first described conformal crystals (arrays of circles with periodic long-range order that fulfill certain constraints at boundaries) and how components of plants often show regular patterns called phyllotactic patterns. He then described a recent experiment showing that these patterns also exist in physical systems (it involved the spontaneous formation of conformal crystals in two dimensions when a ferrofluid drop was vibrated under the action of a vertical magnetic field).

B. Jerome (FOM, Amsterdam) described how the orientation of a liquid crystal (LC) in a device is often the basis for its operation so understanding what determines the orientation is vital. In the case of nematic LCs, the orientation is imposed by the walls of the device *via* a process called anchoring where molecules in the bulk above a 10 nm thick interfacial layer have the same mean orientation. It was realized that although an interfacial potential cannot be predicted, it can be measured using optical second-harmonic generation (SHG) to probe the orientational order of the interfacial molecules after, say, rubbing a surface. Knowing the surface orientation one can then calculate the effective interaction between the bulk and the interfacial layer to give the bulk orientation which is often, but not always, correctly predicted. A similar description is applied to smectic liquid crystals to determine the effect of LC properties.

It has been known for many years that smectic LCs form superb films and bubbles; less well known are their unusual properties. **R. Holyst** (Polish Academy of Sciences, Warsaw) described how vibrations in smectic LC films down to two molecules in thickness are quenched out owing to surface ordering (identified by electron diffraction). The film effectively freezes layer-by-layer from the surface, which is the opposite to what happens in ordinary solids. However this unusual property and many others, which probably arise from coupling between the surface and the bulk, are unexplained.

W. Helfich (Free Univ., Berlin) remarked in introducing the symposium on *Fluid Surfaces* that they are highly deformable 2-d objects in 3-d space found throughout nature as well as having important technical applications. Understanding their shapes, while mathematically challenging, is needed in order to analyze processes whereby vesicles (closed surfaces) fuse or form buds (small outgrowths). A lipid bilayer (a surfactant monolayer with oil or water on both sides) is particularly easy to work with since it does not crumple easily (high rigidity). **R. Lipowsky** (KFA, Jülich) explained that a theory has been developed based on the bending energy as a function of local curvature subject to volume and surface area constraints which predicts, for the simple case of spherical topology and axial symmetry, a large number of possible shapes depending on the reduced total area and the reduced volume. For toroidal topology, conformal transformations predict a large region in the area/volume phase diagram with axisymmetric shapes where the ground state is degenerate. Interesting things happen when a second hole is introduced into the torus, notably diffusion between shapes which, if observed, would be proof of conformal transformation. A simple way to monitor shape changes is to introduce a line discontinuity in a film. For a circular domain in a 2-d membrane, the domain forms a bud when it reaches a certain size in order to reduce the edge energy (Fig. 2); the same process can be modelled in spherical vesicles. It is believed that similar results apply in complex biomembranes where budding has been observed, but experiments are difficult.

M.E. Cates (Cambridge) invoked the bending energy model used for lipid bilayers to discuss bilayer aggregates made from surfactants. Since bending takes place over 10-100 nm rather than 100 μm, entropy effects mean that structures with a higher energy may be stable. Various phases (sponge, vesicle, onion) arise on tuning the rigidity by varying the alcohol/surfactant ratio in a alcohol-surfactant-water mixture, but he concentrated on the latter two. Huge (radius r = 5-20 m), stable multilayer vesicles can form (spontaneously or on shearing); the onion phase developed when the multilayer vesicles contact at high volume fractions is a viscoelastic solid (*i.e.*, it yields) having important potential applications as a stable, highly organic material. Among the many intriguing questions concerning mechanical and rheological properties (Fig. 3), there has been some success recently in confirming the prediction that the elastic modulus of the onion phase is proportional to $1/r$; whether it behaves like a glass with frozen disorder at large r remains unclear.

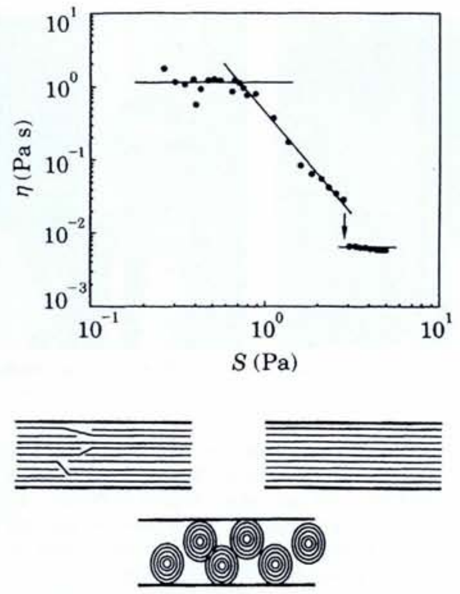

Fig. 3 — The viscosity of a sodium dodecyl sulphate-pentanol-dodecane-water mixture (71% of oil volume fraction). Multilayer vesicles (onion phase) form at intermediate shear rates S and the viscosity decreases rapidly as S increases (shear thinning). The layers (with and without dislocations: shown in the lower part) are parallel to the shear plates in the horizontal regions. [From Roux D. et al., *Europhys. Lett.* ***24*** *(1993) 53.]*

The $C_{12}E_5$-alcohol-water system remains one of the most popular for investigating the many different structures formed by fluid surfaces. **U. Olsson** (Lund) showed how understanding is based upon the "channels" and other features appearing in phase diagrams which are analyzed in terms of the diffusion of the various components in the mixtures.

The Editor wishes to thank A. Aspect, J.T. Devreese, F. Dalfovo and for their contributions.

EUROPHYSICS INTERNATIONAL HIGH ENERGY PHYSICS CONFERENCE
(Marseilles, 21-28 July 1993)

Issues Brought into Sharper Focus

A report taken from the EPS-9 plenary lecture entitled "The Quest for the Infitesimally Small" by C. Rubbia.

Some 40 years ago one could only probe down to 10^{-15} m and the proton was an elementary particle. Today, the success of colliders such as CERN's LEP and of the Standard Model (SM) with its fundamental interactions and 24 fundamental fermions (and their antiparticles) allows precision probing at the 10^{-18} m scale. Although the Standard Model works well, one cannot be completely satisfied. We need to understand the nature of symmetry breaking which is introduced and in doing so we shall hopefully be able to predict or relate some off the model's many parameters.

The main questions are associated with the structure of the vacuum for the SM is built on gauge theory that invokes the so-called Higgs mechanism to provide particles with masses while keeping the theory renormalisable. The mechanism is seen as involving a vacuum containing a field where fluctuations from a non-zero expectation value correspond to the presence of a neutral spin-zero particle (the Higgs meson). The temperature at which the vacuum returns to normal (and the masses of the W and Z particles disappear) is estimated to be of the order of 200 GeV. Dramatic new features are expected at energies well above this critical temperature for the weak interaction. An energy of the order of 1 TeV at the quark-gluon level is needed so the energy scale of future colliders is clear. In spite of some limitations, circular pp-machines such as CERN's proposed LHC and the discontinued SSC are preferred because one knows how to build them.

Looking beyond the SM, the similarity between the two coupling constants for the electroweak theory and the constant for the strong force, and the fact that all three converge with increasing energy, suggest they will meet (at 10^{16} GeV according to the latest LEP data). A Grand Unified Theory then takes over and quarks and leptons appear as different manifestations of the same field. The main question is the form that GUT should take. One would like to incorporate the SM into some GUT. Superstrings at much higher energies (the Planck scale at 10^{19} GeV) have guided thinking for over a decade (in superstring theory, fundamental fields appear as the many lowest excitation modes of a superstring visualised as a tiny loop closed upon itself, probably in more than three directions in space). What one has not succeeded to do is to extract from such a "theory of everything" compelling restraints which would apply to today's experimental domain at 10^2 GeV. Secondly, GUT mixes quarks and leptons so it implies proton decay which should be sought for as it is the only way we have to test the theory. The present limit of 10^{32} years relates to a particular decay mode: it is vital to push this limit and to look for other modes using more sophisticated detectors. Instead of increasing the energy of particle colliders, the approach here involves probing smaller scales through virtual reactions (*i.e.*, analyzing very carefully the rare processes implied in jumping large energy barriers). Recent results for double-decay where one seeks evidence for a direct route without the production of a neutrino illustrates the level of sensitivity that can be achieved.

Success Means Questions

The remarkably successful SM is therefore not the end of the road but is providing starting points for exciting new ventures. It is also raising challenging problems. One of the actors is still missing (the top quark); non-observation implies a mass greater than 108 GeV so the 2000 GeV pp-collider at Fermilab in the USA is the only place one can hope to find it. Fermilab reports "a number of interesting events", identification being difficult owing to the small cross-section, rapid decay, and a high background level. However, LEP data are now so accurate that one can extract values of the radiative corrections and compare them with theoretical estimates to obtain the mass of the top. The result is 160 ± 16 GeV which is similar to the value one infers from the number of Fermilab events if they are taken as top mediated, so the top seems to be around the corner.