cal manifestations seem radically different. Why? The conventional answer is that, unlike leptons, quarks are confined, i.e. they cannot be separated from the colour-neutral states that they form (the quark-antiquark and the three-quark states that populate the hadronic world). Here we have a very strange notion: a "constituent" which is fundamentally inseparable from its "compound". The long road that from macroscopic objects, passing through molecules, atoms and nuclei, brought us to protons, neutrons and electrons, seems to stop with quarks! How is that possible? Nobody knows, even though some recent calculations with Quantum Chromodynamics (QCD) on a lattice give some encouraging indications. But the calculations involved are so terribly complicated, that one wonders how the beautiful simplicity of the quark-model of hadrons could arise from such a contrived dynamical scheme.

(β) *Gluons*

In the popular theoretical scheme of today (the QCD paradigm), in addition to quarks one should also have eight coloured (perhaps confined) vector mesons, the gluons. These new dynamical degrees of freedom are then expected to generate a very rich spectrum of colourless states, much in the same way as quarks are known to produce the great variety of hadronic particles, But up to now, no firm evidence has been produced for the existence of such states, and perhaps naively (but probably truthfully) we might conclude that gluons are unlikely to have the same dynamics as quarks. And, if this conclusion is correct, we must admit that we are still missing some really fundamental notion.

Many other difficulties afflict those who try to account *quantitatively* for the observations in high energy physics; it is my feeling that all can be traced to α and β above. What then can we conclude? To me it seems necessary to admit that whilst we have met with remarkable success in isolating many profound and important aspects of particle physics, like quarks, colour and the "standard group", we are still unable to grasp the origin of the bizarre and tantalizing phenomena of quark confinement.

It is in the successful effort to understand this, that we may expect far reaching progress in the future.

Against this background, the Symposium led by **P.A.M. Dirac, A. Salam and V. Weisskopf** which will take place in Istanbul on the Wednesday morning (9 Sept.) promises to be exceptionally rewarding. Remembering also Dirac's distrustful attitude towards renormalization processes (*EN* **8** (1977) 10) one can be confident that the mood will not be one of complacency. (Ed.)

Quantum Electronics

Changes in Emphasis

D.S. Chemla, Bagneux

Although research in quantum electronics devoted to atoms and molecules is still very active, it has shown no spectacular breakthroughs of late, whereas it seems that interest in solids is expanding. This can be attributed to several causes. First, the methods of quantum electronics and non-linear spectroscopy are now highly developed and solid state physicists are using them on a daily basis; second, as simple systems are well understood, most effort is directed toward the more complex ones, which might prove also to be richer. Finally one can point to the influence of device applications. A number of problems encountered in modern components for microelectronics and microoptonics are related to the intrinsic limitations in the response of solids to an electromagnetic perturbation. As examples one can quote those related to: ballistic carriers dynamics, ultra-fast relaxation of energy and phase, intrinsic or defect-related saturated absorption and dispersion ... etc. Investigations of these phenomena require new tools, some of which belong to the field of quantum electronics. Research tendencies that can be singled out are indicated in the Table. Special mention must also be made of fibre optics, integrated optics and related areas which, because of their huge development potential, command an intense research effort.

Two topics have attracted a lot of interest recently, both because they give rise to new concepts in quantum electronics and because of their possible applications. These are phase conjugation and optical bistability, where intense experimental work on gases, liquids and solids as well as theroretical studies are making headway.

Laser Developments

Turning now to recent achievements, in the domain of new lasers and new coherent sources, significant progress has been made with tunable near-infrared lasers. Two types are very promising: the colour centre laser (F_2^+) in alkali-halides, which now covers the entire range 0.8 μm - 2 μm, and the transition-metal-doped lasers using MgF_2 or MgO as matrix, and covering the 1 μm -2 μm range. Both types can sustain CW-action and operate at liquid nitrogen temperature. Recent work on NaF crystals however indicates that operation at room temperature may be possible. Note that F-centre lasers can be mode-locked and soliton propagation in an optical fibre has been observed at 1.55 μm using such a mode-locked laser.

An intense effort is being made to push coherent sources towards shorter wavelengths and laser action in the near UV from a YLF:Ce solid state laser has recently been observed. In gases, charge transfer lasers are being investigated (both in Europe: Hull University and MPI-Garching, and in the USA), and significant gain at the hydrogen Lyman-α line has been reported recently by a group at Cornell University. In another approach, the output frequencies of known lasers can be shifted toward the UV by frequency mixing in metal vapours or rare gases. Very short wavelength sources can be obtained in this way; for instance, third harmonic generaton of dye laser output can generate tunable radiation in the 1050 Å - 1470 Å range (Bielefeld University Germany) and that of KrF lasers between 823 Å and 833 Å.

On the other hand, work in the medium infrared (10 μm - 50 μm) seems to be less intense than a few years ago, with one exception — that of the free-electron laser. It was believed that in the Compton regime, only 1% of the kinetic energy of the electrons could be converted into radiation, but new concepts are being developed aimed at increasing the energy conversion and experiments are under way to verify their applicability.

Spectroscopic investigations on atoms and molecules form now well defined fields with their own specialized meetings and journals. The development of new methods for ultra-high resolution still sustains interest and new approaches such as utilizing the picosecond Raman gain or the inverse Raman effect (which is purely coherent) are being considered. The odd properties of Rydberg atoms can lead to interesting studies, not only for fundamental physics.

GENERAL TENDENCIES IN THE RESEARCH INTEREST

Volume	→	Surface
Crystalline	→	Disordered, Amorphous
Bulk semiconductors	→	Organics Low dimensionality
Statics	→	Dynamics Transient phenomena

They can be used as active media for new masers or detectors in the millimeter and submillimeter domain.

UNIVERSITY OF OXFORD
Research Officership in Nuclear Physics

The University proposes to appoint a Research Officer in the field of Experimental Nuclear Physics, with immediate effect.

The appointment is for a fixed period of three years in the first instance, and may be extended for a further and final period of two years. Salary according to age on the University Lecturer scale (under review), £ 5,505 to £ 12,370.

Applications (one typed copy), including a statement of qualifications and publications, and the names of two referees, should reach Professor K.W. Allen (from whom further particulars may be obtained), Department of Nuclear Physics, Keble Road, Oxford, OX1 3RH, by 20 March 1981.

Solid State Studies

In the realm of solids a large number of new results have appeared. Spectroscopic techniques which were developed with gases are now applied to solids and picosecond photon echoes have been observed in nitrogen doped GaP and in doped molecular crystals (Univ. of Groningen) whilst two-photon resonances have been used to probe solids high above their band gap for instance to study the formation of excitonic molecules (Strasbourg Univ. and CNET, France). Coherent-optics methods, such as laser hole burning, have been used to probe inhomogeneously broadened transitions in both rare earth doped insulating crystals and organic films and crystals.

The huge non-linear optical properties of organic compounds caused by the large electron delocalization and the possibility of charge transfer, are now under intense investigation. Organic compounds can form crystals orders of magnitude more efficient than mineral compounds. Systems that were first investigated in Europe (France and USSR), are now developed in a large number of laboratories. New concepts have appeared such as: molecules with vanishing dipole moment and large second order non-linearities, single crystal non-linear thin films, quasi one-dimensional semiconductor-like polymers. Details of their optical responses are studied by using multiphoton spectroscopy methods, which help reveal some most surprising features.

Surface Phenomena

Inelastic light scattering by molecules adsorbed on surfaces has received a lot of attention lately. The Raman cross section of molecules adsorbed on roughened metallic surfaces has been found to be 5 to 7 orders of magnitude larger than that of the free molecules. Several models have been put forward to explain this enhancement. Recent experimental investigations have shown that the effect extends beyond the first monolayer up to molecules not in direct contact with the solid, thus supporting classical models based on local field singularities due to plasma resonance. Further support for this interpretation has been obtained by using as substrate, silver particles with controlled shapes and spacing and by relating the enhancement factor to the particle shape and the dielectric constant which varies with wavelength and the surrounding medium. Applications of SERS (Surface Enhancement Raman Scattering) are very likely to be found in the diagnostics of catalytic chemical reactions near surfaces. It is interesting to note that the accuracy of the picosecond Raman gain technique is now such that non-enhanced Raman scattering from monolayers can be detected.

Another most promising observation on surfaces is multiphoton photoemission, which provides us with new means to study surface states. Photoemission involving up to four photons from a metal, such as tungsten, has been observed at Harvard whilst two-photon photoemission from a common semiconductor (silicon) has been studied at CNET. In both experiments, surfaces states have been shown to play a significant role. The observed spectra are very structured compared to one-photon spectra, showing that true multiphoton spectroscopy of photoemission can give new information on the energy levels of surfaces states, even in the case of well-known compounds.

Picosecond and Tunable Sources

Picosecond and tunable sources are well suited to probe the dynamics of excitations in condensed matter. They have been extensively used during the past decade to study electronic and vibrational molecular relaxations as well as fast photochemical processes. They are now applied to investigate ultra-fast relaxation in solids and solid state components. Studies on non-equilibrium transport in microstructures have revealed velocity overshoot in the carrier gas during its acceleration by a field. Infrared picosecond sources, which have been developed lately, have provided evidence of saturable absorption and dispersion of narrow gap semiconductors.

These experimental observations raise a number of questions about the underlying processes which are far from being identified at the present time. In the case of amorphous compounds, ultra-fast recovery times have been observed and are already used in optoelectronic devices to manipulate electronic signals. Electronic conduction seems to be governed by defect — associated extended states which rapidly relax to low mobility localized states. Along the same lines, the picosecond operation of semiconductor lasers is extensively studied. Passive mode-locking seems to be related to defect associated saturated absorption. Active mode-locking operation has been used by the Imperial College group to produce bandwidth limited picosecond pulses. Even shorter pulses (5 ps) can be obtained by fast gain switching through both optical or electrical pumping.

Phase Conjugation and Bistability

As mentioned in the introduction, the fascinating aspects of phase conjugation and optical bistability are currently attracting intense research effort. Phase conjugation is obtained by the non-linear interaction of three beams having the same frequency but different wavevectors. Two beams are propagated in opposite directions and their interaction creates a fourth which is the time reversed replica of the third. The effect can be used to correct optical aberration of arbitrary complexity and in high resolution spectroscopy. It can be viewed as a real time holography and should give rise to a number of applications. It has been observed in gases, liquids and solids.

Optical devices showing two states of transmission for the same incident light intensity are said to exhibit optical bistability, which can be viewed as the first step toward an all optical logic and signal processing (S.D. Smith, *Europhysics News,* **11** (1980) 10, p. 3). The non-linear transmission can be achieved through intrinsic or artificial non-linearities, while the basic elements can be Fabry-Perot resonators, coupled wave guides or interfaces between linear and non linear media. After the preliminary demonstrations, impressive improvements have been made through the discovery of giant non-linearities of semiconductors near the band edge (Bell Tel. USA, and Heriot-Watt University, Edinburgh). The switch on and off operations are so sudden that perturbative descriptions are doubtful. The puzzling aspects of this light driven change of state are quite similar to those of phase transitions and can be analysed in a similar way (Ecole Polytechnique, France).