Nobel Symposium on Nonlinear Effects in Plasmas

A Nobel Foundation Symposium on Nonlinear Effects in Plasmas was organized by Prof. Hans Wilhelmsson and his collaborators of the Institute for Electromagnetic Field Theory of the Chalmers University of Technology at Göteborg in the charming environment of Aspenäsgården at Lerum. It was attended by about 40 research workers from all over the world who had the opportunity of exchanging and discussing recent results and developments in the field.

Among the topics extensively discussed in the symposium was laser light interaction with plasmas. High fluxes of radiation ($> 10^{15}$ W/cm^2) are required for studies on laser-induced fusion, and their effect on high temperature matter raises interesting physical problems, most of which involve nonlinear properties of plasmas. Consider for instance a coherent EM wave impinging obliquely on a density gradient. There is no simple way of determining what are self-consistent field (standing waves) and density profiles while resonances at the critical or quarter critical density imply couplings with plasma modes which influence the particle distribution functions.

For the past ten years, many laboratories have been involved in experimental research on laser light interaction with solid surfaces. Most of it has been brute force experiments in which a high energy and power laser beam is focused on to the surface yielding a high temperature strongly inhomogeneous plasma flow. No satisfactory theoretical explanation has emerged so far of many of the observed facts. Theoreticians have instead been dealing with the action of EM waves on a plasma in idealized situations not always related to lasers.

According to the talks delivered at the symposium things are changing. Refined theoretical evaluations using extensive computer simulations are being devised and compared with experimental data (K. Brueckner, W. Kruer). Since many phenomena are dealt with at the same time, one gets only indirect evidence of explicit effects such as resonant absorption. This effect predicted long ago by Denisov for EM waves obliquely incident on a density gradient with the electric vector in the plane of incidence, has not so far been definitely identified. Normally in laser plasma interactions it appears among other processes, but the assumption that it is dominant is consistent with some observational results: polarization effects, measurements of absorbed energy, X-ray spectra. However, it seems improbable that this is a complete explanation particularly as very steep density gradients should be involved. So far they have not been identified, perhaps simply because diagnostics are not accurate enough. In dealing with focused high power laser experiments one has to compare in a complicated situation : theory, numerical simulations and measurements whose domains do not exactly overlap.

On the other hand, there is also a trend towards setting up simple experiments aimed at isolating a single process in EM wave plasma interactions. Such studies are not restricted to lasers and microwaves can be used to simulate laser problems. Such a technique has been applied to reflective instabilities and cavity formation.

Half-way between these two approaches is laser spectroscopy. The impinging laser light excites characteristic lines which contain information about well-defined mechanisms : harmonic and subharmonic lines, in connection with parametric decay and two plasmon resonance (R. Sigel, J.L. Bobin), forbidden lines in He plasmas, in connection with ion sound and Brillouin back scattering (F.F. Chen).

At all events, a better understanding of laser-plasma interaction is obviously being progressively acquired. It is one of the most fascinating applications of nonlinear plasma physics like the interpretation of recent experiments at Stanford. A 10.6 μm laser beam is amplified by the action of a relativistic electron beam passing through a corrugated magnetic field. In competition with stimulated Compton scattering, nonlinear coupling with plasma waves might account for the observed results (J. Dawson).

A great deal of interest came from the results concerning soliton formation. Theories originally devised to account for shallow water dynamics found new applications in nonlinear plasma physics as well as in other fields such as galactic density waves. Through filamentation cavity creations and density gradient steepening, the subject has a clear connection with laser plasmas.

An introductory review of the state of the art in this field was given by V.N. Tsytovich. Two questions were dealt with at length : the modulational instability which leads to soliton collapse when the number of dimensions is greater than unity, and the multiple soliton solution. Both are related to strong Langmuir turbulence. In a typical soliton, a large dip in density is associated with high intensity HF field : Combining fluid dynamical and Maxwell's equations yield partial differential equations of various types, Korteweg-De Vries, nonlinear Schroedinger, Sine Gordon, Boussinesq... which all admit soliton-like solutions : a solitary wave with specified conditions at infinity. Since the equation is nonlinear, the superposition principle does not apply. However, multiple soliton solutions can be found through the inverse scattering method which is basically a nonlinear generalization of the linear Fourier transform (C.S. Liu, R. Nakach).

Solutions are thought to be stable in one-dimensional situations only. Interaction between solitons is not a trivial problem, nor is the decay into ion sound waves. A discussion of these problems was presented by D. ter Haar.

The usefulness of using a Lagrangian description for investigating solitons in particular and nonlinear plasma dynamics in general was emphasized by L.M. Kovrizhnykh.

Most of the work dealing with solitons is theroy. However, experimental evidence of such a behaviour has been obtained although none of these experiments was presented at the symposium.

A review of the state of the art in the field of the interaction of intense relativistic electron beams with plasma of high density ($n = 10^{16} - 10^{18}$ cm^{-3}) was given by D.D. Ryutov (Novosibirsk). From a theoretical point of view the case of plasmas of β much larger than 1 and moderately strong beams such that only a weak turbulence is excited has been extensively studied. For stronger beams generating strong turbulence, and for plasmas in a strong magnetic field the picture is still very incomplete, and very little is done for situations where the electron temperature is much larger than the ion temperature, so that ion-acoustic turbulence comes into play. The turbulence excited by the relativistic beam may consist of Langmuir waves, whistlers, and electron cyclotron waves. The effect of plasma inhomogeneities has also been considered. Experiments are so far mostly done in the strongly turbulent regime, so that a reliable comparison with the theory cannot be made, yet.

Problems of turbulence in magnetically confined plasmas were not addressed systematically ; instead the communications in this field covered a certain number of specific topics. P.K. Kaw (Princeton) discussed the problem of disruptions in tokamaks. He considered, on the one hand, couplings between tearing modes and drift wave turbulence, and on the other, the effect of plasma flow towards the tearing-unstable layer, both effects resulting in an increase in the growth rate of the tearing instability. In another paper of the same author, non-linear effects in the lower-hybrid heating mechanism were discussed. H. Cotsaftis gave an account of a macroscopic approach to the non-linear dynamics of Joule-heated toroidal discharges which is based on the introduction of certain invariance properties. The theory of anomalous transport, one of the most important but still very rudimentary fields in magnetic plasma confinement, was represented by a contribution on the diffusion of a multi-species plasma due to drift waves, presented by K. Nishikawa, and by a review of the state of the art for high density pinches by R.C. Davidson.

Also as far as applications to astrophysical problems are concerned a few selected topics were treated by D. ter Haar, S. Ichimaru, and C. Montes. D. ter Haar showed how non-linear effects can stabilize density waves which explains the structure and the observed long life-time of galaxies. S. Ichimaru treated some problems of plasma dynamics relevant to the behaviour of pulsars, whereas C. Montes presented a kinetic theory of photons, showing that induced non-linear Compton scattering on electrons leads, at high photon intensities, to a soliton-like distribution of the photon frequency distribution.

Of course, there was a relatively large group of papers addressing various more fundamental aspects of non-linear plasma theory, like the dynamics of three-wave interactions and effects of non-linear interactions between waves and particles in different circumstances. As it would go too far to enter into a detailed discussion of all the contributions to this field, in which many interesting developments have been reported, let us just mention a paper by D.D. Ryutov here, who discussed linear and nonlinear Landau resonance mechanisms in various macroscopic systems from a unified viewpoint. Upon noting that Landau damping is a general phenomenon in systems where different degrees of freedom can be associated with different kinds of oscillators, being able to enter in resonance if certain selection rules are satisfied, he treated a number of examples (including the propagation of acoustic waves in a glass of champagne).

In conclusion, the Symposium has shown again that the research on nonlinear plasma phenomena is a very active field, into which a large effort is invested and where new results are produced at a high rate. However, the intrinsic difficulty of the topic is such that much more work will be needed to come to a satisfactory understanding of the experimental facts, in particular, those regarding strongly turbulent plasmas.

The success of the Symposium induced the hope that it might be possible to repeat encounters of this kind regularly. Sincere thanks are due to the organizers and sponsor for having provided this first and very fruitful opportunity.

J.L. Bobin and F. Engelmann

Nuclear Orientation

A pleasantly intimate Europhysics study conference (about 60 participants) on nuclear orientation was organized from 12-16 July, principally by members of the Clarendon Laboratory where nuclear orientation (N.O.) of radioactive atoms was first detected in 1954, and where N.O. techniques have been actively practised ever since. The planning of the meeting was impeccable, and the timetable, consisting of a limited number of invited papers with lengthy discussions and numerous coffee breaks, deserves to be imitated by anyone organizing a meeting on this scale in the future.

Topics ranged over all aspects of low temperature N.O. detected by nuclear radiation. The technique as applied to impurities in ferromagnetic metals by measuring γ ray anisotropies is well established, and a large number of experiments have now been done on the destruction of the thermal orientation using NMR on the radio-active isotopes. Developments discussed included the possibilities offered by a lower range of temperatures (below 1 mk, compared with 3 to 10 mk for most present day work), the advantages and disadvantages of β detection, source preparation by implantation, recoil or on-line methods, and the use of pulsed NMR.

Recent applications in the nuclear physics field include the measurement of nuclear moments of isotopes with a few hours half-life thanks to top loading cryostats, and on-line measurements where oriented samples are bombarded with polarized neutrons or particle beams. In the solid state field, there was active discussion on the use of nuclear orientation as an absolute low temperature thermometer, and on experiments in nonferromagnetics — dilute magnetic or non-magnetic metals in high applied fields, and even non-conducting antiferromagnetic systems. In the ferromagnets, the relaxation time of the nuclei, adiabatic passage results and possible ferromagnetic Knight shifts continue to provide unsolved puzzles for N.O./NMR.

The N.O. technique now seems to have achieved adult status thanks to recent advances in low temperature technology and in nuclear electronics. It now appears possible for it to be a tool in any laboratory which needs it, instead of a rather mysterious art restricted to the initiated few. As a "standard" technique, N.O. would seem to have a rosy future before it.

Not the least of the pleasures of this meeting was the opportunity of tasting (or re-tasting) the joys of Oxford and its surroundings. The banquet took place on a boat going down the Thames from Folly Bridge to Godstow, following precisely in the path of Lewis Carroll who, on the fourth of July 1862, rowed the same stretch of water in the company of Alice Liddell. From "Through the Looking Glass" to parity non-conservation...

I. Campbell