# High-tech firms take to subtle quantum effects

One of the remarkable features of advanced technology is its close interplay with fundamental physics. Unlike traditional industry, modern high-tech firms can no longer afford to ignore quantum mechanics—the abstract theory of atomic and nuclear processes. Physicists, mathematicians and industrial researchers alike must now get together and discuss their dreams and problems. This new realization has been heightened by the success of Akira Tonomura, Chief Researcher of the Advanced Research Laboratory of Hitachi Ltd, Japan. Tonomura is the winner of the prestigious Nishina Medal of Japan.

Using electron holography and a toroidal magnet of the dimension of a micron (one ten-thousandth of a centimetre), Tonomura and his group have successfully demonstrated a very small but striking quantum effect (predicted by Aharonov and Bohm in 1959) on charged particles like electrons when they travel through force-free regions enclosing a magnetic field. This demonstrates the physical reality of the electromagnetic gauge field and bolsters our confidence in the unified gauge theories of the fundamental forces. They have also demonstrated the wave-like properties of single electrons, a near-impossible practical feat. Their success is prompting many high-tech companies like IBM to perform other 'thought experiments' conceived to demonstrate new facets of physical reality at the subatomic level. The hope is to be able to use these subtle effects in new types of high-speed switching devices called 'wave function' devices.

Tonomura recently visited the S. N. Bose National Centre for Basic Sciences in Calcutta from 20 to 26 January, 1990. The main purpose of his visit was to explore the possibility of collaborating with theoretical physicists in planning further electron experiments which could throw new light on certain longstanding problems of quantum theory highlighted by the famous debate between Einstein and Bohr.

One possible experiment that was mooted (with Partha Ghose and Dipankar Home) was a variant of the electron double-slit experiment to probe the distinction between the ensemble and single particle interpretations of the wave function championed respectively by Einstein and Bohr. The experiment will be able to demonstrate that the way an ensemble is built up (by passing either (a) one electron at a time or (b) a single bunch of the same number of electrons through the apparatus) has different observable consequences under time-varying conditions—the fringe patterns will be different in the two cases. The time variation can be achieved by introducing an electronic shutter which can periodically open slit 1 or slit 2 or both slits in a time short compared to the time between successive electrons in case (a) but long compared to the time of passage of the bunch through the apparatus in case (b). If the predicted distinction is actually observed, it will raise many interesting issues. First, it will show that the wave function of a single particle has a physical significance and cannot just be a 'figure of speech' or a purely mathematical construct. It would also raise a number of other sensitive issues like the significance of the Complementarity Principle in dynamic situations as well as the implications of 'partial' collapse of the wave function.

Another experiment that was discussed would involve passing one electron at a time through a small hole (of diameter $d$) in a perfect absorber. If the initial lateral spread $L$ of the incident wave function is larger compared to the diameter of the hole ($L > d$), there should be a 'collapse' in the lateral spread of the wave function to a smaller width $d$. This is because a passage through the hole is a measurement that reduces the uncertainty in the lateral spread of the electron's position (its wave function being related to the probability of finding it within this spread). If the incident wavelength $\lambda < < d$, diffraction will be negligible and the shrinkage in the lateral width can be clearly detected on a screen. If such a shrinkage is actually observed with single electrons passing through the hole one at a time, it would again demonstrate the physical reality of the wave function (it cannot merely represent our subjective 'knowledge' of the electron's whereabouts) and its 'collapse'. Since the electrons that pass through the hole do not interact locally with the absorber material, the collapse can only be due to a non-local quantum effect brought about by the spread of their wave function to regions blocked by the absorber.

Tonomura finds quantum mechanics so 'mysterious' that he would personally like to do these experiments in spite of pressures in an industrial laboratory to develop more products.

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# Upstart pulsar a non-starter

A year after they left astronomers baffled with what would have been a bizarre pulsar, and inspired a host of new equations and theories of pulsar formation and behaviour, the purported pulsar-like optical signals from supernova SN 1987A have been found to be spurious.

After SN 1987A burst on the astronomical scene, excitement ran high in anticipation of finding a newborn pulsar. Theory predicts that a supernova, which is the explosion that accompanies the collapse of a star too massive to support itself under its own gravitational force, must leave behind a rapidly spinning, highly condensed neutron star. At least some neutron stars are pulsars.

The long wait of astronomers seemed to have ended when, in January 1989, John Middleditch and colleagues, working at the Cerro Tololo observatory in Chile, recorded optical signals that looked like the signature of a pulsar. Only this one was spinning so fast, 1968.629 times a second, that it was a wonder it had not come apart. There was also a variation of the spin frequency that could only mean that the pulsar, if indeed there was one, was part of a binary system whose other component was an object the size of Jupiter. This led to speculation if the pulsar had indeed broken up and produced this companion. After that single observation in January 1989, no signals were detected again, which left many other astronomers in some doubt.

To explain the properties of this pulsar, astrophysicists came up with new equations of state of neutron star matter and even new theories of pulsar formation and behaviour. But bizarre properties or not, supernova 1987A had tantalized astronomers with the opportunity of observing a pulsar almost in the moment of its creation.

Now those hopes have been belied, at least as far as the observations of Middleditch *et al.* are concerned. In January this year, almost exactly a year after their first report, Middleditch *et al.*, now making their observations at Las Campanas in Chile, again detected the signals, but this time they had the impossible frequency of 7874, almost exactly four times the originally detected frequency of 1968.629! Middleditch *et al.* smelled a rat, and indeed the culprit was found — electrical interference from a TV camera used to record the images focused by the telescope. A similar camera had been used at Cerro Tololo when the observations of January 1989 were made.

The US journal *Science* quoted Middleditch as saying, 'I'm a little bit let down and a little bit disgusted.' It is, however, fortunate that the error was detected, and by the same observers. G. Srinivasan of the Raman Research Institute in Bangalore, who had earlier discussed the implications of the pulsar in SN 1987A (see *Current Science*, 1989, **58**, 280), voiced a similar sentiment. 'But this "pulsar" certainly generated new ideas. It's always useful to stand a theory on its head. After all, that is the way of science.' But what of SN 1987A? Srinivasan is hopeful. 'A pulsar is lurking there somewhere. It will be found eventually.'

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**RESEARCH NEWS**

# Interfaces: structure and properties

*K. A. Padmanabhan*

D. McLean's book *Grain Boundaries in Metals* published in 1957 (Clarendon) represented the coming of age of this topic as a subject of serious study. Yet in 1973, while commenting on Gleiter and Chalmers' review of 'High-angle grain boundaries'[1], R. W. K. Honeycombe lamented about the 'notorious gap' between fundamentals and practice[2]. In his review, Honeycombe lists segregation, diffusion, migration and sliding at grain boundaries as partially understood problems. To this day these problems have not been solved. What then, has been the recent progress in this area? Has the gap between fundamentals and practice reduced? Is the settled pattern of research in this area adequate or is there a need to adopt new strategies? These questions were uppermost in this author's mind when he decided to attend a workshop*.

The workshop was inaugurated by R. Krishnan, Chief Controller, R&D, Defence Research and Development Organization. The keynote lecture was delivered by F. E. Saalfeld, Director, Office of Naval Research, USA. In all there were twenty-four invited papers. Over 140 delegates including 25 foreign scientists participated. On display were interesting posters dealing with diverse topics in metallurgy and materials science. The deliberations, some of which are discussed here, will appear shortly as a book.

From the beginning one could discern two near-parallel streams of thought: One holding forth that understanding thoroughly the structure of an interface is the essential first step and another emphasizing understanding of the interface properties, if necessary by wilfully neglecting certain details (which may later be introduced as secondary effects). It was also evident that over the years the field has widened to cover both intercrystalline and interphase interfaces and 'materials' instead of 'metals'.

V. Vitek described the atomic structure of grain boundaries in ordered and disordered binary alloys using many-body empirical potentials to represent the interatomic forces. It then becomes possible to understand the differences in the intergranular strength and brittleness of alloys and metals. However, as the empirical potentials are generated in the first place using some specific macroproperties of the materials, the procedure can only be regarded as rationalization. Theoretical development of many-body potentials, which will eliminate the semi-empirical nature of the modelling process, very much remains a desirable goal.

S. Ranganathan 'revisited' the coincidence site lattice (CSL) model and went on to explore the relation between the CSL and quasi-lattices. L. A. Bendersky gave a new definition of special orientations (hypertwin) based on the reduction of the number of arithmetically independent lattice vectors. Both confined themselves to describing geometrical relationships obtainable at the grain boundary giving no clues as to the features that are important for understanding the properties of interfaces.

K. H. Westmacott and U. Dahmen acquainted participants with the interesting technique of combining high voltage electron microscopy with the hot stage and a video camera for directly observing boundary migration and the effect of twins on interface mobility. They also considered, among other matters, the significance of the role of microfaceting and the effect of strain, which were interesting in that they provided information of relevance to ledge growth, for example.

An unusual departure from the interatomic potentials and atomic configurational details was represented by the

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*The Indo-US Workshop on Interfaces: Structure and Properties was held in Bangalore, 30 November–2 December 1989.