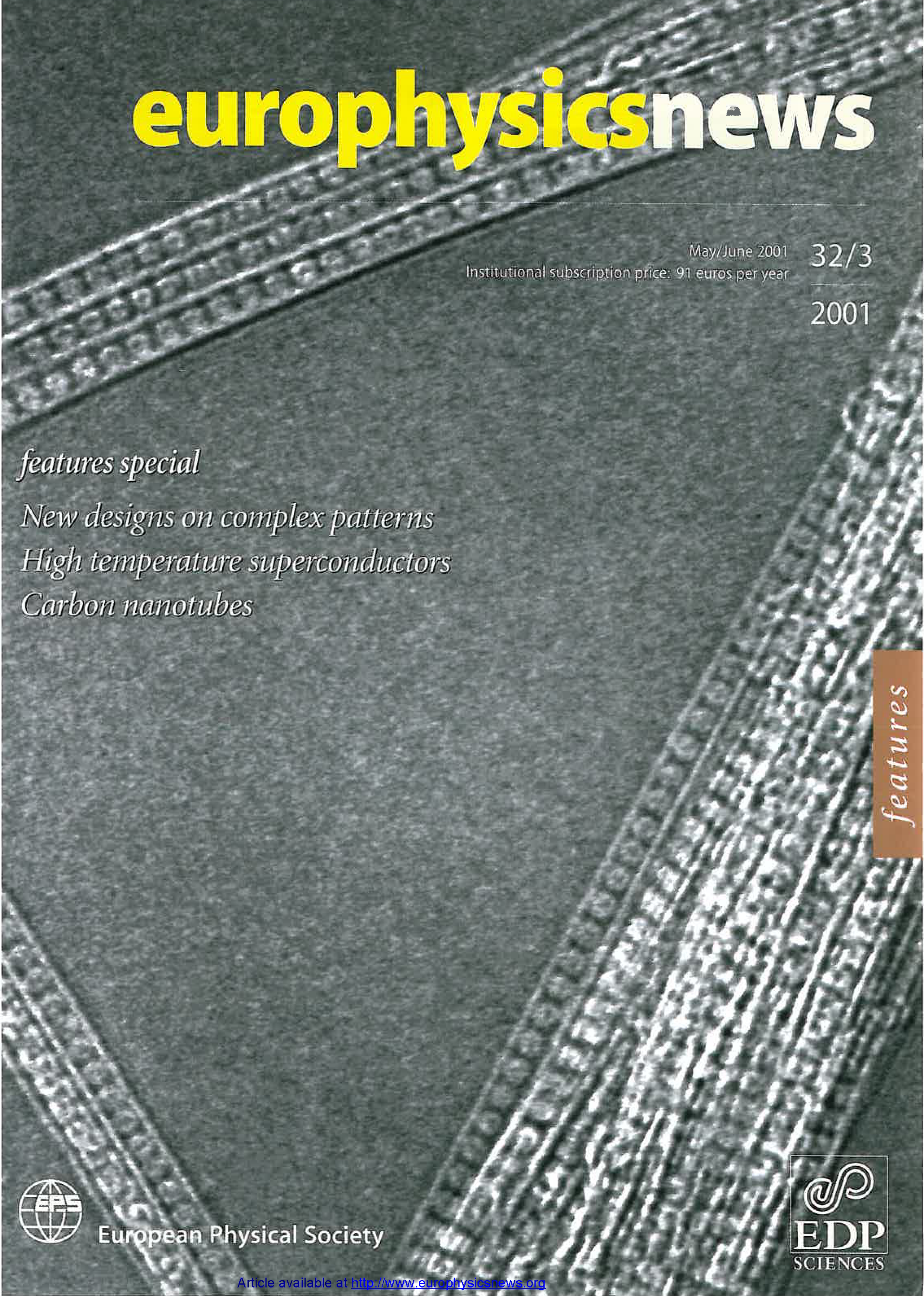

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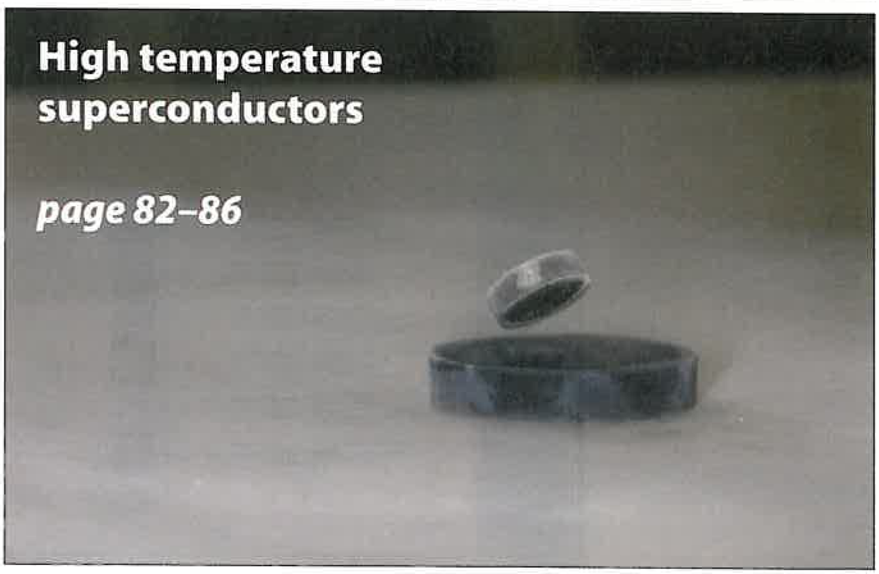

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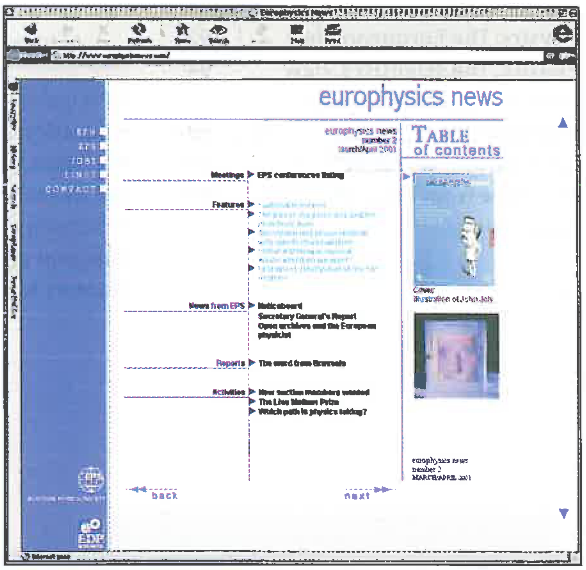

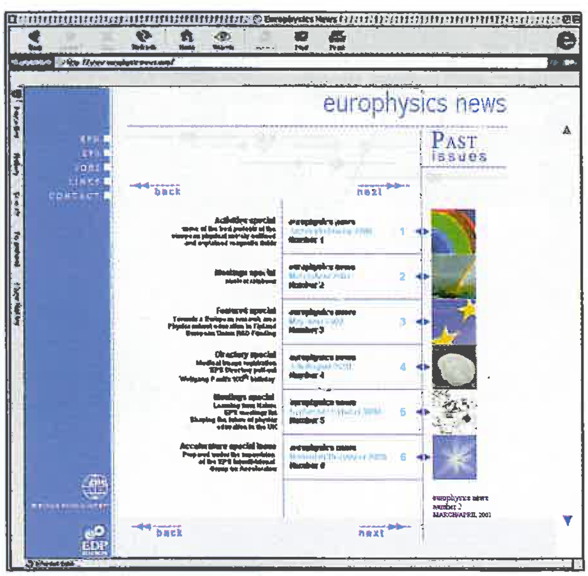

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Nonlinear analysis techniques that were originally developed to measure the structure of galaxies in the universe are now improving doctors' ability to diagnose skin cancer, tumours and detect serious heart problems

New designs on complex patterns

Greg Morfill and Wolfram Bunk, Max Planck Institut für Extraterrestrische Physik, Germany

In most areas of everyday life we are faced with growing levels of information. When we have to make decisions we are often confronted by huge amounts of data that need to be understood. Usually we have to reduce the data to a few characteristics in order to understand those aspects that have the greatest influence. It is then easier for us to make a decision based on these "reduced measures".

At the same time, man-made systems are becoming more and more complex, particularly those in finance, economics and technology. And we are only just beginning to learn of the complexities and interdependencies in natural systems throughout physics, biology and ecology.

The message is clear. In reducing many different measurements obtained from such systems to a few "characteristics", we must not cut across the inherent interdependencies. If we do so, we will not be able to monitor some of the essential aspects of the system, let alone understand them.

This is easily demonstrated with the well known "double pendulum", in which the second pendulum is suspended from the first. In the so-called linear regime, where the amplitudes of oscillation are very small, the system can be described approximately by the superposition of two independently moving pendulums. However, as soon as the amplitudes are "finite" – which is practically always the case – this simple description fails. Thus, reducing a coupled system to two independent pendulums, we clearly leave out some of the essential physics – a fact that becomes very clear from the measurements of the motion of a double pendulum.

Therefore as the complexity increases, we need a more sophisticated approach to reduce the system to its essential components, and to then derive the corresponding characteristics from measurements. The situation becomes more difficult if we cannot directly measure the system, and instead have to infer its components and interactions indirectly. In such situations – which are the rule, rather than the exception – a new data-analysis strategy is needed. Such a strategy must go far beyond the classical techniques and be able to characterize complex nonlinear behaviour.

About ten years ago at the Max Planck Institute for Extraterrestial Physics in Garching, near Munich we began developing nonlinear analysis methods to quantify the irregular and highly structured distribution of galaxies in the universe. The analysis technique allows us to differentiate between different theoretical models and to compare these with measurements of large-scale galactic surveys. More recently, we have applied the same techniques to a variety of industrial and medical applications, and in particular to the early detection of skin cancer and risk assessment of heart attacks.

Reductionism and fractals

One of the most widely used classical reduction techniques is Fourier analysis. In such an analysis, a series of measurements that has been made at regular time intervals is broken down into its different frequency components. Often the dominant spectral features are then used as indicators or "measures" of the system. As with all reduction techniques, Fourier analysis clearly involves removing some of the information – a fact that may be fatal, as is shown in figure 1.

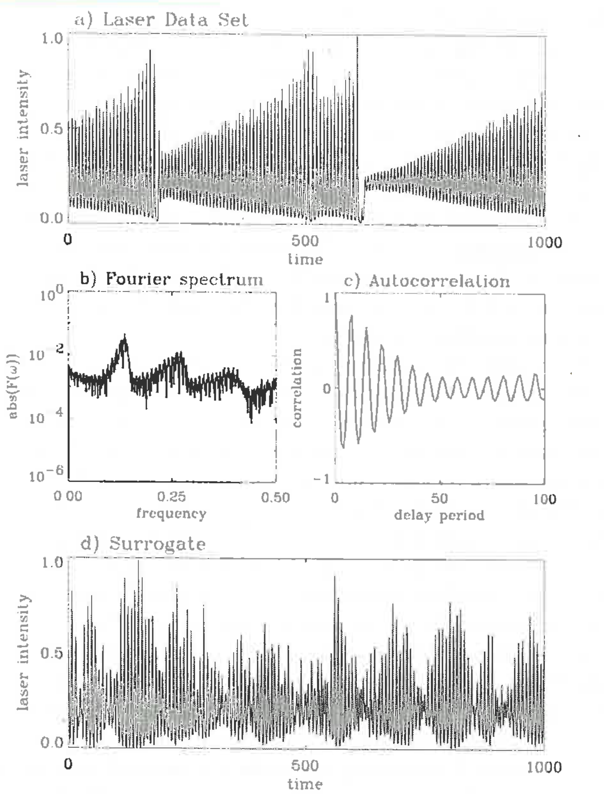

Fig. 1: Limitations of linear analysis
Example of the limitations of linear analysis techniques. The top panel (a) shows the time dependent variation of a laser intensity signal, which was analysed by Fourier (b) and autocorrelation techniques (c). The original data was then modified in such way that the linear properties remain, but the phase information was randomised. This "surrogate" data set is shown in the next panel (d). The Fourier spectrum and autocorrelation function that are derived from this signal are identical to those from the original data. This effect that two very different data sets may contain the same linear information highlights the limitations of linear analyses.

The problem is that Fourier analysis – together with power-spectral analysis, and wavelet and autocorrelation analyses – is a linear technique. As a result, it cannot describe the nonlinear aspects of the measurements obtained from complex systems. New techniques and methods have therefore been developed in recent years to overcome this shortfall, including neural networks and so-called nearest-neighbour, scaling-index and scaling-vector methods. In principle, they can provide "measures" for certain aspects of the nonlinearities contained in the measurements, thus allowing additional insights into the system under study.

The powerful nonlinear techniques we developed are based on the so-called scaling-index-method (SIM). Using this technique we can think of the "state" of a given system as a single point localized in an appropriate "state space". This state space is made up of the different "state variables". For example, each pixel in a static black and white image has three state variables – the x and y co-ordinates, and the greyscale – and hence a three-dimensional state space. Meanwhile a colour image has five state variables – x, y and the red, green and blue colour components. And a tomographic image of a solid body has four state variables – x, y, z and a greyscale.

A dynamic system may have many such variables that change with time. In this case, monitoring the trajectory of a system in state space can be an important tool, for example, in assessing how likely a person is to die from a sudden heart attack

In general the various states in a complex system do not occupy state space uniformly. The characteristics of the system usually mean that it will favour some regions in state space over others. In a colour image, for example, a local region with the same colour will lead to a sheet-like structure in state space, while a line will remain a line. Hence the complexity of a system may be measured by the structures found in the state space. The question then is how to quantify structure. The answer comes from "fractals" – geometric shapes that look similar at different scales. Many structures in nature can be quantified by their fractal geometry, including coastlines, mountains and clouds.

The scaling-index-method makes use of fractals to characterize the system. To calculate the local "fractal dimension" or the "scaling index", a(x), we first draw a sphere of radius r around a given state at position x in state space. Next, we count the number of other states, N(x,r), inside this sphere, and repeat the process for different values of r. The value of the scaling index, a(x), is then extracted from a graph of N(x,r) versus r using the scaling relation $N(x,r) \sim r\ a(x)$. We assume that this scaling law holds in the range of r chosen, which is usually the case. (For most applications, it is not a problem if the scaling law does not hold exactly.)

We are able to determine the type of structure from the measured value of a(x). For example, a point-like structure has $a \sim 0$; a line-like structure has $a \sim 1$; and a flat sheet has $a \sim 2$. Meanwhile curved lines or sheets have $1 \leq a \leq 2$ and $2 \leq a \leq 3$, respectively.

In addition, if the scaling law holds as r approaches zero, then we can regard the scaling index a(x) as a local property of the system at position x. We can thus define a nonlinear property for each observed system state.

More importantly, however, is the fact that a(x) is directly proportional to the gain in information we obtain by measuring this particular system state. For example, in a static system all the measured states occur at the same location in state space and $a(x) = 0$. A new measurement does not give us any new information about the system. On the other hand, in an evolving system each new observed state occupies a new location in state space and hence yields fresh information about the system.

Thus the scaling index is a very fundamental and independent property of each observed state because it retains information about the nonlinearity and complexity of the system. This makes it a prime candidate for the quantitative analysis of complex systems.

For specific applications there are a number of additional considerations, including the finite resolution, the scaling lengths and different sampling rates for different measurements.
(The Max Planck Society has patented the scaling-index-method and other associated analysis techniques.)

Diagnosing skin cancer

The occurrence of skin cancer has more than doubled in the last ten years. Minor surgery is almost always successful if the cancer is discovered early enough. However, the disease is invariably fatal if it is discovered too late. Reliable early detection is therefore a key issue. This is a formidable task as it involves detecting minute pigment changes on the skin and then differentiating between malignant and benign marks.

Currently dermatologists investigate pigment changes using magnified images of skin lesions. These images allow medical practitioners to identify sub-structures in the image with reasonable resolution. Experts can detect up to about 80% of early skin cancer signatures based on the structure and colour of a lesion. Less experienced practitioners, however, are not so successful.

Dermatologists have established four semi-quantitative risk indicators that can be used to analyse skin lesions based on the visual inspection of such images. These include the asymmetry of the skin lesion, the structure of its border, the colour variation across it and the differential structure inside it. These characteris-

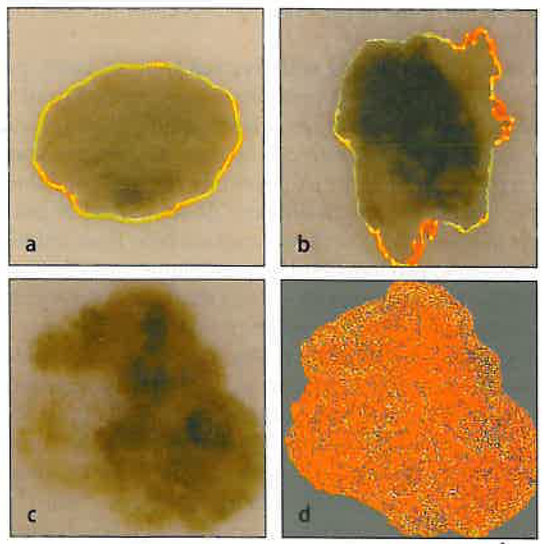

Fig. 2: Skin cancer signatures
Magnified images of benign (a) and malignant (b, c/d) skin lesions. The original size is ~ 11 mm x 11 mm. The border (a,b) is identified using the scaling index method (SIM) described in the text. It is colour-coded from red to blue, where "red" implies a diffuse (fuzzy) boundary (high a) and "blue" a sharp boundary (low a). It can be seen that the malignant skin lesion exhibits a large, connected fuzzy boundary region – a signature which is comparatively rare in benign lesions. Another example for the use of the structural "measure" to identify skin cancer is shown in the lower panels. The scaling index method enables a structural decomposition of the lesion. The colour-coded scaling indices (d) indicate the content of different structural elements of the skin lesion (c) and provide a powerful tool for diagnostic purposes.

tics are known as the "dermatoscopic ABCD rule". In co-operation with expert dermatologists, we have quantified the complex patterns in the images using the scaling-index-method. In these digital colour images, the state variables are the x and y position of each pixel, and the amount of red, green and blue it contains. The resulting structural measures can then be used to identify skin cancer at an early stage. For example, the border between pigmented and normal skin tends to be much more diffuse in harmful malignant skin lesions than in safe benign ones (see figure 2a and 2b) and characterising the structural details of the colour variations is a powerful tool for diagnostic purposes (see figure 2 c and d).

We have tested the scaling-index-method on over 740 images of malignant and benign skin lesions that were acquired by the dermatology centre at the University of Regensburg in Germany (figure 3). Each image was taken using a CCD camera combined with magnification optics and under the same lighting conditions. This assured that the sample was homogeneous from the point-of-view of data acquisition. Our method has improved the detection efficiency to over 90%, thus providing powerful "on site" diagnostic support to medical practitioners.

Such fast and accurate diagnostic support will be invaluable in screening tests or routine inspections. And the need for such support is likely to grow in the future as the trend towards "telemedicine" increases. Digital images of moles and freckles could be evaluated on site, while data from borderline candidates could be sent to an expert dermatology centre for further scrutiny and advice. This centre could double as a data archive that could be used for epidemiological studies and to develop new analysis techniques.

In this particular case, our scientific knowledge has been already transferred to industry and from there into everyday medical use. Since the middle of last year, Rodenstock Precisions has been marketing the digital imaging system, including the specialized software for the early detection of skin cancer.

Tumour diagnostics

In the previous example, we illustrated the power of general pattern-analysis techniques in identifying structures in colour images. More recently, we have extended the technique to tumour diagnostics. The aim is to provide doctors with better and faster methods to determine the volume and precise shape of tumours so that they can differentiate between live and dead tissue within a tumour, and can monitor how the tumour changes during treatment. Such information is invaluable, as it helps surgeons to plan operations according to a particular patient's needs. It can also be used, for example, to monitor the success of chemotherapy or radiation treatment, or to fine-tune the dose of drugs needed.

Currently experts base their decisions on 3-D data from X-ray or nuclear magnetic resonance tomography. However, it takes a trained expert over an hour to analyse these data by hand, which is far too long for routine use.

Our research aims to reduce this to a few minutes, and to provide experts with even more information about the tumour. First, we project the same 3-D tomography data – the x, y and z position of each pixel in the image, together with its greyscale – into a four-dimensional state space. We then perform the fractal analysis to identify the irregular border between the tumour and healthy tissue in 3-D, and to identify the substructure within the tumour.

We first tested our analysis method using computer tomography images of a cow's liver into which known samples of tissue had been implanted, and found that we could determine the volume of the implant to within 1%–3%. Since then, we have optimized the analysis strategy and techniques for all kinds of

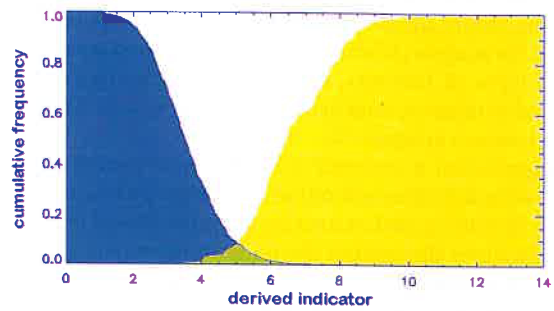

Fig. 3: Detection efficiency
Normalised distributions of benign (blue) and malignant (yellow) skin lesions plotted as a function of the quantitative "measure" (score) derived from the dermatoscopic ABCD-rule described in the text. The score is obtained using fractal dimensions (for the border B – as shown in figure 2a and 2b), entropy measures (for the colour variability – C) and local scaling properties (for an asymmetry feature – A, for the border – B, and for the differential structure – D, see figure 2c and 2d). The high level of discrimination between malignant and benign skin lesions is reproducible and has been tested on a sample of 749 skin lesions. The achieved overall accuracy is more than 90%.

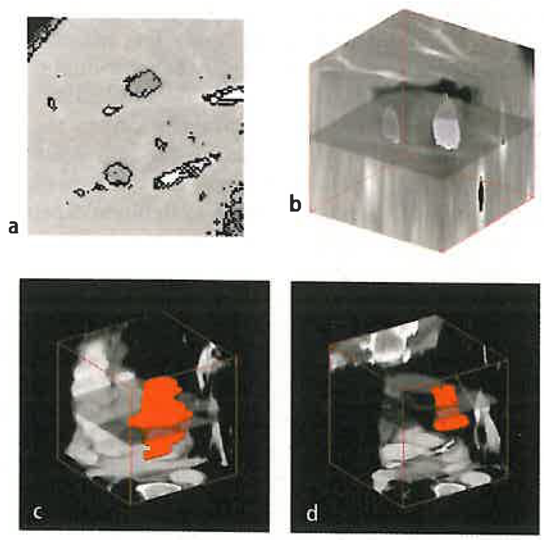

Fig. 4: Tumour diagnostics
The method is used to measure the volume of tumorous tissue. The upper left panel (a) shows one CT slice, with the identification of the boundary of two tumours (lines around the darker segments). The right panel (b) shows the 3D-reconstruction. The volume of the larger tumour was determined at 0.75 ml, the reconstruction "by hand" gave 0,77 ml – in good agreement with the computerised determination. Tumour volumetric analysis of the image data yields a very good method for a (noninvasive) quantitative monitoring of chemotherapeutic treatment. The 3D volume rendering of a segmented stomach cancer before (left) and after (right) chemotherapeutical treatment is shown (figure c and d). In this case it was found that the tumour volume has been reduced by 80 %.

tomography. This means that our software can, in principle, accompany future advances in technology and image resolution. However, the analysis technique has to be optimized separately for different types of tumours, for example in the liver or lungs, because of its inherent sensitivity to tissue structures. That this is possible is shown in figures 4a – d.

This application is currently still at an experimental stage. We need to perform further calibrations before we can be confident of routinely identifying and measuring the properties of tumours in various locations throughout the body, to determine growth or size reductions reliably and thus to contribute to a quantitative therapy. The first results, however, are very encouraging (figures 4c and d).

Dynamic pattern recognition

So far we have shown two different examples of image analysis for recognizing and quantifying complex, but stationary, patterns. The techniques can also be used to identify dynamical patterns in industrial systems or in the body's "biosignals", such as heart rate, brain waves, neural signals and variations in blood pressure.

These dynamical patterns need not be regular. For example, Morse code is based on a predetermined pattern of long and short signals that represent letters in the alphabet. A long chain of seemingly irregularly arranged "dots" and "dashes" can comprise a message, in the same way that a number of "symbols" can constitute a written text. In an analogous way, we believe that the dynamics of the biosignals provides information about the condition of a patient, ranging from normal states – such as when the patient is exercising or sleeping – to abnormal states, such as illness.

Our long-term aim is to decipher these "bio-messages" with sufficient accuracy so that we can identify any impending disorders before they become too serious. In the ideal situation, we would be able to "read" the information provided by the nerve traffic generated by the body's own sensors and the central nervous system. However, this is way beyond current technology in terms of both measurement and pattern recognition capabilities. We therefore have to restrict ourselves to what is possible and, preferably, use non-invasive or surface measurements. The available data fall basically into three categories – those that have a natural rhythm, those that are sampled continuously at a fixed rate, and those that occur in irregular bursts.

Risk assessment

Systems such as the heart have a natural rhythm or pacemaker. The heart pumps blood by contracting in response to electrical signals transferred between neighbouring cells in the cardiac muscle. This signal-transfer process, which involves a number of other electrophysiological processes, provides a complex signature of the "state" of the heart muscle. In this case, it makes sense to determine the variability in this rhythm very accurately, and to use the time between successive heartbeats as a measure for analysing the system. In principle, these timing data contain information about the pacemaker and signal transfer in the cardiac tissue.

Cardiologists can measure the electric signals using electrodes placed on the surface of the chest. They can identify various heart diseases from the resulting electrocardiogram (ECG) once the disease has developed, but not before. This is particularly true in the case of myocardial infarction, in which the blood supply to the heart is impeded by a blocked coronary artery. In addition, one of the major causes of death in the Western World is "sudden cardiac death", in which victims die suddenly from a seemingly stable situation. In both cases we assume that the heart has certain characteristics that can be detected sufficiently far in advance to allow preventive treatment.

If the processes involved are as complex as they appear, we have to use nonlinear analysis techniques to characterize the heart. In principle, one needs to typify the rich morphology of the ECG signals as accurately as possible, together with the levels of oxygen and carbon dioxide in a patient's blood and also the blood pressure. However, it is usually impractical to measure all of the quantities, and it may even be unnecessary for some purposes.

In practice it is sufficient to use the time between consecutive

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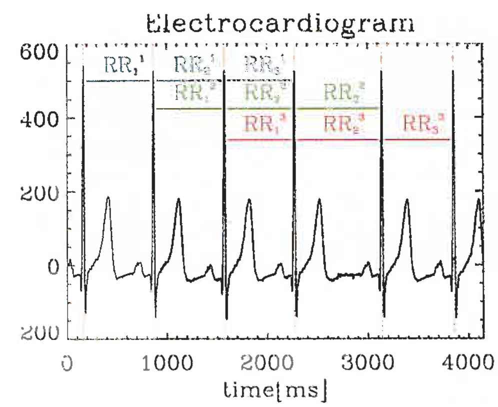

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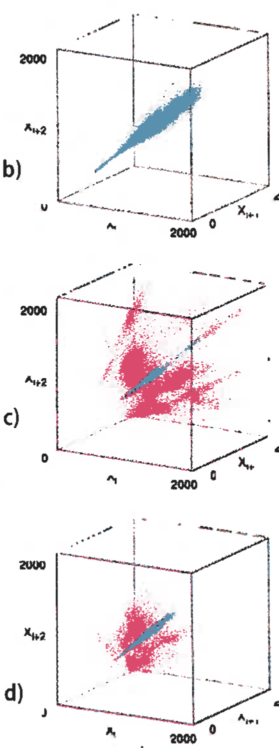

Fig. 5: Dynamic pattern recognition
a) The construction of an artificial 3-dimensional state-space representation of a single time series ECG measurement. One point in the state-space is given by three coordinates (xi = RR1i – the time between two heart beats, yi = RR2i – the time between the next two heart beats and zi = RR3i – the time between the next pair).
b) The state-space representation of a healthy heart containing 100000 measurements from an ECG taken over a period of 24 hours. The rapid heartbeats at the bottom-left were measured while the patient was jogging. The slow heartbeats at the top-right were measured as the patient slept. The homogeneity in structure suggests that we are dealing with a system that can be driven dynamically from one state to the next without major disruptions.
c) The state-space picture of the heartbeats of a patient who suffers from heart disease. The well-defined structure of the arrhythmias (red) appears to scale according to the healthy heart rate. This seems to be an inherently stable situation.
d) The state-space representation of the heartbeats of another patient with heart disease. The arrhythmias are not characterised by well-defined patterns and are much more irregular in structure than those of the previous patient (5c). A patient showing these signs is at risk from sudden cardiac death.

heartbeats. This is both the simplest measurement to make and the most accurate. Even this simple measurement contains a great deal of information. Its variability reflects the interplay between the central nervous system – which receives information from the various sensors in the body, processes them and then translates them into the optimum heart action – and the ability of the heart to comply. A rapid response indicates that the heart is healthy, while an impaired response signifies an unhealthy heart.

The most valuable data for identifying normal and abnormal behaviour patterns are from ECG measured over 24 hours. In this period, the heart experiences many different physical and psychological situations. In other words, the system has sampled a great many "states".

Our reduced analysis strategy involves investigating the pattern between heartbeats, and adding further information as and when required. We have found that by analysing the time interval between four consecutive heartbeats ("triplets"), we can accumulate a great deal of information that has powerful diagnostic and predictive value. We plot the ECG data in a 3-D state space, where each axis represents one of the consecutive beats. RR1, the time between the first two heartbeats, is plotted on the x axis; RR2, the time between the next two, is plotted on the y axis; and RR3, the time between the following pair, is shown on the z axis (see figure 5a).

If the heartbeat is perfectly regular over the time interval under consideration, the system will remain in an identical state and thus occupy exactly the same point in state-space. Over a period of 24 hours, however, the heart rate will change as a patient exercises or rests, for example, and the data will fill a volume in state space. Our analysis therefore concentrates on the occupation density and dynamics in state space (see figure 5b - d).

The characteristic state-space structure for a normal healthy heart is a club-shape structure that is centred along the diagonal. This structure shows that the rapid heartbeats join smoothly with the slow regular ones. This homogeneity in the structure suggests that we are dealing with a system that can be driven dynamically from one state to the next without major disruptions (figure 5b).

However, the state space structure looks very different for a patient suffering from a condition known as an arrhythmia, in which the electrical waves that drives the heart are impaired. The irregularity in the heartbeat is revealed clearly because these states occupy non-diagonal regions of state space. Surprisingly, we found that the arrhythmias appear to scale according to the healthy heart rate. In other words, the arrhythmias occur faster as the heart beats faster, thus creating the coherent off-diagonal structures.

Such structures signify that the electrical signals in the heart always travel along similar paths – for example, round a section of dead tissue in the heart wall – irrespective of the heart rate. This would appear to be an inherently stable situation, and indeed the patient was still well and in good shape 10 years after this particular ECG was taken.

The analysis can also be used to identify patients at serious risk from sudden cardiac death. In this case, the state space appears to have much less structure (figure 5d). And while the arrhythmias are identifiable, they do not scale with heart rate in the same way that they did in the previous patient. This suggests that the heartbeat irregularities do not correspond to constant, and hence stable, signal paths within the cardiac tissue. This patient died of a sudden cardiac arrest a few weeks after the ECG was taken.

Individual examples, such as those in figure 5, only illustrate the possibilities for new analysis techniques. In order to verify their usefulness in a clinical setting, we need to calibrate the technique using "training samples" – patients whose ECGs have been evaluated independently by experienced cardiologists. We then need to test the algorithms in blind studies where we do not know the clinical history of the patient.

Future outlook

The modern analysis methods that we have developed can identify and characterize complex spatial or temporal patterns in images or time-dependent signals. The techniques have a huge diagnostic potential in many applications, ranging from basic research through to engineering and medicine.

In the case of sudden cardiac death our preliminary studies have already shown encouraging results, improving the risk assessment by a factor of two. Such an improvement could potentially have a massive economic impact. It would ensure that only those patients at serious risk receive drug treatment or a defibrillator to regulate the electrical signals in the heart. Indeed, Karl Lauterbach, a health economist at the university of Cologne, has shown that even 20% improvement in risk assessment could save up to DM 3 billion a year in Germany alone.

We have also taken the first steps towards forming a series of industrial partnerships. BASF Pharma, for example, will use our methods to evaluate the effects that new drugs have on ECG measurements in pre-clinical drug trials. For a technique that was originally developed for basic research, nonlinear analysis has come a long way and has a bright future ahead.

Further reading

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Applications of high temperature superconductors

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Most of us are familiar with the basic idea of superconductivity, that a superconductor can carry a current indefinitely in a closed loop, without resistance and with no voltage appearing. In a normal metal, such as copper, the free electrons act independently. They will move under the influence of a voltage to form a current, but are scattered off defects and impurities in the metal. This scattering results in energy losses and constitutes resistance. In a superconducting metal, such as niobium, resistance does not occur, because under the right conditions the electrons no longer act as individuals, but merge into a collective entity that is too large to 'see' any imperfections. This collective entity, often described as a Bose condensate, can be described by a single macroscopic quantum mechanical wave function. Similar condensates are behind the peculiar behaviour seen in superfluid helium and in very cold gases of trapped rubidium atoms.

History of superconductivity

Superconductivity is not a new phenomenon. H. Kammerlingh-Onnes first demonstrated it in 1911 with his finding that resistance dropped to zero in a sample of mercury held at or below 4 K. This sudden drop in resistance, shown in Fig. 1, is characteristic of all superconductors. A number of metals besides mercury (including tin and lead, but not including magnetic metals or very good normal conductors such as copper and gold), as well as certain alloys and intermetallic compounds were also soon found to be superconducting at similar low temperatures. Above the transition or critical temperature T_c the metal or alloy behaved as a normal conductor. Even below the critical temperature, the material would revert to normal if a critical magnetic field or critical current were exceeded. The surface plotted in Fig. 2 defines the critical temperature, field and current for a bismuth-based superconductor. Until 1986 the record critical temperature was 23 K for Nb_3Ge. Two classes of superconductor were recognised. Type I, mostly the pure metals, had an abrupt transition from the superconducting to the normal state. Type II superconductors also allowed for a mixed state with normal and superconducting regions coexisting. Other important superconductor properties were discovered during the course of the last century, such as the exclusion of magnetic flux lines (the Meissner effect), which is responsible for magnetic levitation, as shown in Fig. 3, and quantum mechanical tunnelling over a narrow gap between two superconductors (the Josephson effect), which is used in extremely sensitive magnetometers.

The discovery of superconductivity soon generated interest in practical applications, mainly because of its potential to save energy. Indeed the replacement of copper or other normal conductors by superconducting materials avoids heat dissipation and other energy losses due to finite resisitance. In some types of equipment such as magnetic separators, these losses may account for most of the energy consumed in the device. Early prototypes for motors, transmission lines and energy storage magnets were developed, but they were never widely accepted. There were important reasons for this, apart from the tremendous investment in existing technology. In most superconducting metals and alloys the superconductivity tends to fail in self-generated magnetic fields when the current densities through them are increased to practical levels. A second problem was the cost and complexity of operating refrigeration equipment near liquid helium temperatures (4 K, -269°C). Removing one watt of heat generated at 4 K demands about 1000 W of refrigeration power at room temperature

While applications were stalled, progress was still being made in theoretical models. The London theory (1935) and the subsequent Ginzburg-Landau (GL) theory including quantum effects were phenomenological. These theories did not attempt to explain superconductivity on a microscopic level, but achieved good success in describing supercurrent behaviour. The BCS theory (1957) of Bardeen, Cooper and Schrieffer was a detailed microscopic theory that was quickly accepted as an explanation for the condensate in the superconductors that were known at the time. Such a condensate requires that the particles composing it be bosons, that is, have integral spin. Bosons obey Bose-Einstein statistics. Below the critical temperature the bosons in a superconductor can all gather together in the lowest possible energy state to form the condensate, and the greater the number that have accumulated, the harder it is for one of them to leave. Electrons are not bosons because they do not have integral spin. BCS theory

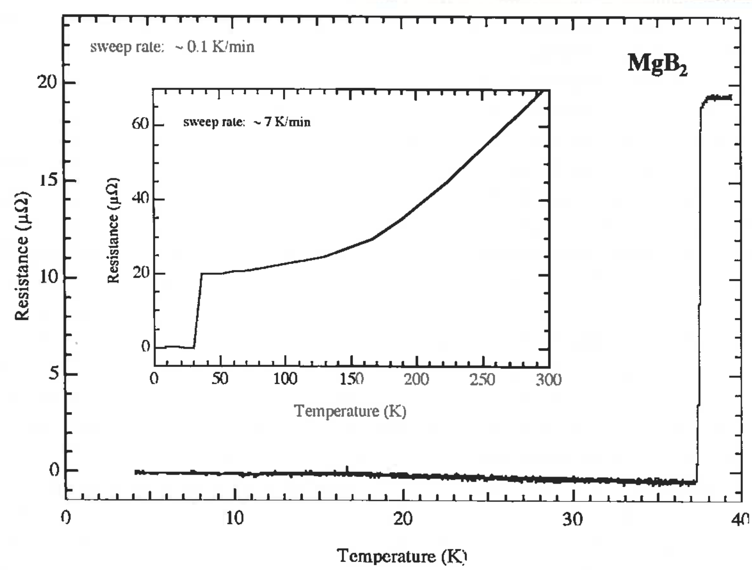

Fig. 1: A drop to zero resistance at the critical temperature is seen in all superconductors, including the newly discovered superconductor MgB_2. Figure courtesy of R.A. Lewis and A.D. Martin, ISEM.

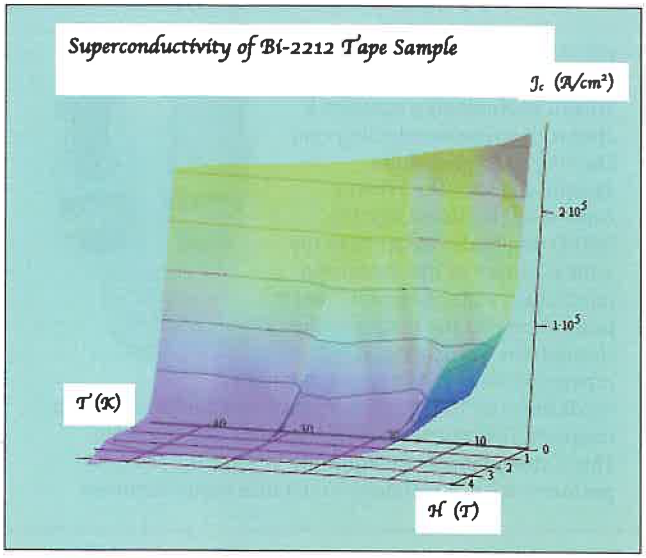

Fig. 2: The critical surface shown here defines the critical current (J_c) of a bismuth based superconducting tape for various values of magnetic field (H) and temperature (T). If the current is raised above the surface value at a particular field and temperature, superconductivity is lost, and the tape behaves as a normal conductor. Data courtesy of Mikhail Ionescu, ISEM.

Fig. 3: Superconductors exclude magnetic flux (the Meissner effect). A magnet lowered towards a superconductor will 'see' an identical magnet the same distance below the surface due to supercurrents induced on the superconductor surface. The resultant repulsive force levitates the magnet, provided that the force is greater than the magnet's weight. Magnetic levitation (Maglev) trains and frictionless superconductor bearings use this repulsive force. Here a neodymium-iron-boron magnet floats above a disk of lead-doped BSCCO superconductor, with a critical temperature T_c of 108 K. The superconductor has been cooled in liquid nitrogen, and the magnet falls when the superconductor is warmed above T_c.

explained how the interaction between the electrons and the phonons or lattice vibrations in the metal causes an electron-electron attraction. Some of the electrons form so-called Cooper pairs where the spins and momentum are opposite and therefore cancel out. Because the Cooper pairs have zero spin, they can participate in Bose condensation. It appeared that superconductivity was well explained and only possible at very low temperatures.

The first practical superconductors

In 1961 Kunzler *et al.* opened the "Type II" era by drawing a Nb tube filled with Nb_3Sn powder into a wire with a current density J_c of ~10^5 A/cm². The wire remained superconducting in fields up to 8.8 T. It was soon discovered that other highly cold worked type II alloys such as Nb-Ti and Nb-Zr were also able to carry high transport currents at high, technologically useful magnetic fields. In a type II superconductor there are two critical temperatures (or magnetic fields at a given temperature). The lower one indicates the onset of the mixed state as magnetic flux lines penetrate the material, with each accompanied by a vortex of supercurrent surrounding a normal state core. The higher one indicates the complete loss of superconductivity as the vortex cores overlap. In the cold-worked "hard" or "dirty" superconductors there are a wide range of defects and impurities that act as pinning centres to trap the flux lines and vortices and prevent further penetration and loss of superconductivity. The "dirty" superconductors had considerable potential for technological applications despite the continuing problems of working near liquid helium temperature. This was particularly true for magnet applications, because much stronger magnetic fields could be achieved as compared to conventional electromagnets. It was even possible to magnetise a superconducting magnet from a current source, then detach and short-circuit the winding, leaving what was effectively a giant permanent magnet that would hold its magnetic field constant for months.

There are a number of extra high field magnets, transmission cables and generators that have been designed and built using these low critical temperature (LTS) superconductors. Such superconductors are commonly used in the construction of the powerful magnets and electric resonators found in big particle accelerators such as CERN and Fermilab. The electric resonators produce very strong oscillating fields for accelerating the particles, while the magnets focus them and bend their path. The present commercial LTS superconductors for large-scale applications are typically NbTi or Nb_3Sn superconducting strands embedded in a copper matrix.

The high temperature superconductors

The high temperature superconductors (HTS) appeared on the scene in 1986 when Bednorz and Miller discovered a new oxide ceramic superconductor $(La,Ba)_2CuO_4$, with a critical temperature of 35 K. High temperature is relative. New HTS oxides were quickly discovered. The record HTS critical temperature is now ~133.5 K (160 K at high pressure) for $HgBa_2Ca_2Cu_3O_{8+x}$. Most current work is focussed on two families of materials, YBCO ($YBa_2Cu_3O_{7-x}$, T_c ~ 92 K) and BSCCO ($Bi_2Sr_2Ca_1Cu_2O_{8+x}$(Bi-2212), T_c ~ 85 K, and $Bi_2Sr_2Ca_2Cu_3O_{10+x}$ (Bi-2223), T_c ~ 110 K, shown in Fig. 3). The crystal structures of these materials can all be described as oxygen-deficient multiple perovskites with CuO_2 planes. There is always a strong anisotropy or direction sensitivity in the superconducting behaviour. Effectively the supercurrents flow along the CuO_2 planes, which are linked together by Josephson coupling. The HTS materials can be classed as type II superconductors. Their behaviour is well described by the London and GL theories, but there is still no generally accepted microscopic theory for high temperature superconductivity. The superconducting properties of MgB_2, a new high temperature superconductor that is not a copper oxide were just discovered this year by a team led by Jun Akimitsu at Aoyama-Gakuin University, Tokyo. The critical temperature is 39 K, but research on this compound has just begun, and it is not clear whether it is simply an LTS type II superconductor with an unusually high critical temperature or represents a whole new superconductor family.

The discovery of the HTS materials aroused tremendous excitement, because many of them are superconducting and carry significant current above the boiling point of liquid nitrogen at 77.4 K (-196 °C). It appeared as though a whole new age was opening up for practical applications, particularly large-scale applications. Because the mechanisms for the new type of superconductivity were not well understood, it seemed that room temperature superconductivity was just around the corner. Even at liquid nitrogen temperatures enormous savings are possible. Removing a watt of heat generated at 77 K requires 10 W or less at room temperature (as opposed to 1000 W at 4 K). The development of the cryocooler has allowed for refrigeration down to LTS temperatures without the use of cryogenic liquids, but if cryogenic liquids are used for cooling, a litre of liquid helium costs approximately $25, as opposed to 60¢ for a litre of liquid nitrogen. It was expected that aluminium and copper would be completely replaced by HTS materials in electromagnets, generators, power transmission lines, motors, and magnetic energy storage. Maglev trains would float above their tracks and flywheels above their superconducting bearings, while computing would depend on ultra-fast Josephson junctions.

These grandiose expectations inevitably led to disappointment. Room temperature superconductivity has remained a dream. Critical current densities in HTS materials also tend to be naturally too low for technological applications, while there are persistent problems with poor mechanical properties. These problems are both related to the ceramic, granular, anisotropic nature of the HTS materials (other than MgB_2, which behaves as a brittle metal). They need to be formed at high temperatures in the presence of oxygen. Like all ceramics, HTS materials are very brittle and very difficult to shape and handle, while long, flexible, superconducting wires are necessary for many large-scale applications. Large supercurrents can only flow along the CuO_2 planes, and only a small fraction of the material in a completed device is likely to be correctly oriented. The grain boundaries attract impurities, leading to weak links, which reduce the inter-grain current density and provide an easy path for flux vortices to enter the material. Flux creep or vortex penetration into HTS material is unusually rapid. The coherence length or diameter of a vortex core tends to be very small. This is a problem because pinning is most effective if the defect or impurity is of the same 'size' as the coherence length.

Fig. 4: A SQUID device, such as this HTS SQUID magnetometer from Tristan Technologies, contains a chip with a superconducting ring. The ring has one or more Josephson junctions. When a current is introduced into the SQUID ring that is larger than the critical current of the Josephson junctions, a voltage appears that is proportional to the magnetic flux through the SQUID ring. SQUID magnetometers can measure magnetic fields down to 10^{-14} T and are sensitive enough to pick up magnetic fields generated by the heart and the brain. This is three orders of magnitude better than the best performance of a standard inductance magnetometer.

Small-scale applications of HTS superconductors

Vast research efforts over the past 15 years have been aimed at overcoming these deficiencies. The most success has been achieved with HTS small-scale devices that rely on the special properties of superconductors, especially the Josephson quantum tunnelling effects. The materials for these devices have been largely perfected, although there are still problems in incorporating superconductors into integrated circuits. Progress is now largely limited by systems and refrigeration packages, not by materials, films or junctions. Some LTS and HTS small-scale devices, most notably SQUIDS, are now commercially available, with HTS devices, such as the one shown in Fig. 4, having the advantage of smaller size (due to the smaller refrigeration system required) and much smaller power consumption. YBCO is widely used for the HTS small-scale devices because it has a high critical temperature and can accommodate high current densities.

Perhaps the best-known small-scale device is the SQUID (Superconducting QUantum Interference Device) magnetometer. A SQUID contains a ring of superconductor with one or more Josephson junctions. When a current is introduced into the SQUID that is larger than the critical current of the Josephson junctions a voltage appears that is proportional to the magnetic flux through the SQUID ring. The SQUID is so exceedingly sensitive that it can detect magnetic fields 100 billion times smaller than the Earth's field, and it can also detect any other physical quantity that can be converted to a magnetic flux.

Other devices that have reached commercial availability are HTS passive RF and microwave filters for wide-band communications and radar. These are based on conventional microstrip and cavity designs with superconductors used for the microstrips or to line the metal cavity. Both types are shown in Figure 5. They have the advantages of very low noise and much higher selectivity and efficiency than conventional filters. This is offset by the disadvantage of the requirement for refrigeration, but for some applications they are still worthwhile. RSFQ (Rapid Single Flux Quantum) logic for integrated circuits and computers is still under development. The logic elements are composed of superconductor rings with a Josephson junction shunted by a resistor. The magnetic flux that can be contained in such a ring is quantised (i.e. comes in discrete packets). The logic functions are built around the very short voltage pulses that occur every time a flux quantum enters or leaves the ring. The pulses can be transmitted ballistically between gates over superconducting lines. Signals propagate virtually without dispersion. Because these elements dissipate hardly any power individual devices can be packed as close as 1 µm. RSFQ logic circuits are also have speeds of up to 100 times those of fast semiconductor ICs combined with great accuracy. Data rates of more than 750 Gb/s have already been experimentally demonstrated. The first RSFQ device to be mar-

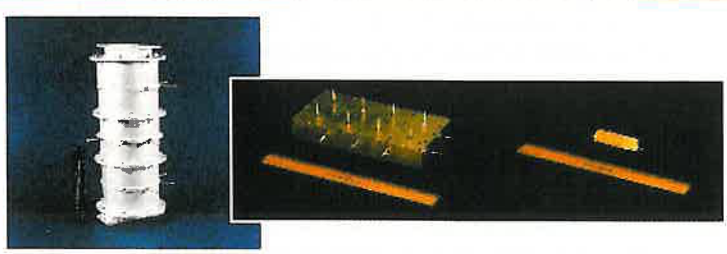

Fig. 5: Commercial HTS microwave filters from Conductus. The filter on the left is of a cavity type, while the others are microstrip filters.

keted is likely to be an A/D converter. Niobium LTS superconductors are most widely used for RSFQ logic, but research is continuing on the problems of constructing integrated circuits using HTS materials. These largely arise from grain boundary effects and the tendency for underlying layers to be degraded in growing multi-layer circuits.

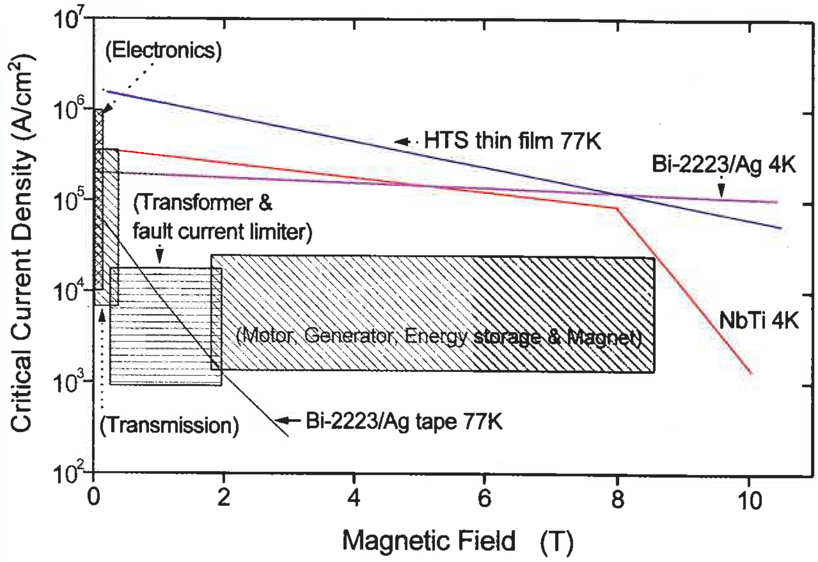

Fig. 6: Current and magnetic field demands for large-scale applications compared with the performance of existing HTS superconductors. NbTi, a commonly used LTS material is also included for comparison.

Large-scale applications

LTS superconductors are already in quite common use for large-scale applications, but still have stability problems and problems due to the complex and expensive refrigeration required. Large-scale applications for HTS materials present a major challenge to the materials scientist. Compared with the small-scale applications, a large-scale application generally means that much larger currents and lengths of superconductor are required in a working environment where the magnetic field may be several Teslas. The most important applications under consideration are magnets, power transmission cables, current leads, fault current limiters, transformers, generators, motors, and energy storage. In most of these applications, apart from fault current limiters, HTS superconductors would simply replace conventional conductors, e.g. a copper winding in an electromagnet is replaced by a BSCCO tape winding. Fault current limiters for electrical utilities depend on the fact that superconductivity is lost and resistance appears above a critical current. Under normal conditions the fault current limiter is superconducting and offers no impedance to the ordinary current. During a power surge the large fault current exceeds the critical current and is limited by the consequent resistance as the superconductor goes normal. The superconductivity returns after the current spike.

Applications related to magnet technology are probably among the most significant that are under research at the present time. These include magnetic energy storage, Maglev trains (relying on repulsion between magnets mounted on the train and the guideway) and magnets for MRI and other medical imaging applications. In all these cases the superconductor must not only carry a large current with zero resistance under a high magnetic field, but it must be possible to fabricate it in long lengths with high flexibility and a high packing density. This is because for large electromagnets it is necessary to build high current ampere-turn windings. For the large-scale applications the critical current density J_c must generally be greater than 10^4 A/cm^2, and the magnet must operate well in a magnetic field from about 0.2 T for a transmission cable to about 4 T for a generator. Figure 6 shows how some HTS superconductors meet the requirements of the different applications. The performance of the common LTS superconductor NbTi is also shown for comparison.

Research on HTS large-scale applications has focused on the BSCCO family because it is difficult to grow YBCO in bulk. Research has focused on processing methods, especially heat and pressure processing, to improve the phase and grain composition of precursor powders and to achieve greater density of the final product, thus reducing weak links. Selected defects and impurities are introduced to improve the flux pinning. While some applications such as current leads rely on bulk material, most

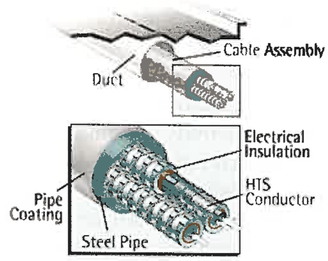

Figure 7(a)

Figure 7(b)

Fig. 7: American Superconductor is supplying the superconducting power cables for the Detroit Edison project. The current is carried by silver sheathed BSCCO tape. The construction of one type of cable is shown in (a). Liquid nitrogen flows through the core of the cable to provide the necessary cooling. (b) compares the BSCCO tape with copper cable. Three such tapes can carry as much current as the copper cable.

applications require very long, flexible tapes or wires. The powder in tube (PIT) method can achieve this. BSCCO powder is packed into a silver tube, which is drawn fine and goes through a sintering, rolling and annealing process. The individual BSCCO cored wires resulting from this process can be bundled together to create a multifilamentary tape. A number of large-scale prototype devices using BSCCO wire or tape have been constructed and shown to work satisfactorily. The tapes are cooled below 40 K when operation in high magnetic fields is required and to between 50 and 77 K for low field operation. The major remaining barrier to wider use is cost.

HTS underground power transmission cables carrying 3 to 5 times the current of a copper cable of the same diameter, as shown in Figure 7, are already coming into commercial use in cities such as Detroit. The extra cost of the HTS cable is justified because capacity can be upgraded using existing conduits and avoiding the cost and inconvenience of digging up the streets. Large (1000 hp) asynchronous ac motors with HTS armature windings are also very close to commercial viability. Their low losses and high magnetic fields allow for a much smaller and lighter motor in proportion to its output. Even after allowing for the energy required for refrigerating the HTS winding, such motors are approximately twice as efficient as the best conventional motors. BSCCO HTS current leads for LTS magnetic energy storage systems are also very close to viability. These have a current carrying capacity enormously greater than that of the copper leads they replace, so they not only eliminate losses due to resistance, but their small cross-section reduces heat transport into the LTS magnet. This allows for large energy savings on cooling.

Conclusion

The discovery of ceramic-type HTS materials in 1986, which exhibit superconductivity at liquid nitrogen temperature, has led to extensive research into materials formulation, characterisation and methods of fabrication. Many of the problems of fabrication into long lengths or thin films have been overcome, and more than 50 companies around the world have set out to commercialise HTS over the past 10 years. Small-scale devices have been commercially available for some time. The major problems for large-scale applications have been achieving high critical transport currents under high magnetic fields. The technical performance of long, state-of-the-art BSCCO wires have allowed prototypes to be constructed for large-scale applications, such as magnets and transmission cables, and HTS transmission cables have already come into commercial use where the advantages of high current density are crucial. It is expected that there will be further progress in bringing down the costs of these materials, leading to significant advantages in efficiency and energy saving.

Further Reading

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Carbon nanotubes, materials for the future

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The last decade of the last century in condensed matter physics has been marked by the revival of carbon-based materials. Besides the conventional forms of carbon, the graphite and the diamond, new forms of carbon have been discovered: fullerenes, carbon nanotubes, carbon onions. Although the parent compound of fullerenes, the C_{60} molecule was discovered in 1985 by Kroto, Smalley and co-workers [1], the full expansion of the activity concerning this material did not truly begin until the mass production of fullerenes was invented by Krätschmer and Huffman [2]. The great euphoria in the fullerene research started with the discovery of "high temperature superconductivity" in 1991, exceeding a critical temperature of 30 K [3] upon alkali metal doping. The search for new carbon nanostructures, higher mass fullerenes has strongly motivated chemists and physicists. Sumio Iijima discovered the multi-walled carbon nanotubes in the same year [4], which was considered at the beginning as a giant fullerene. In 1993 the single walled nanotubes were synthesized giving carbon structures of 1.4 nm in diameter and several microns in length [5]. At the beginning, while the production and purification of these structures were not sufficiently elaborated, the research mainly consisted of "photography", that is of spectacular images obtained by high-resolution transmission electron microscopy (HRTEM). Around 1994 some of these problems were solved, and the study of the physical properties began.

Today, carbon nanotubes are driving scientific research. This field has several important directions in basic research, including chemistry, electronic transport, mechanical and field emission properties. Furthermore, the perspectives for applications are very challenging and exciting. The main avenues of potential applications of carbon nanotubes are: ultimate reinforcement fibers for composites (high strength, high aspect ratio, high thermal and chemical stability);

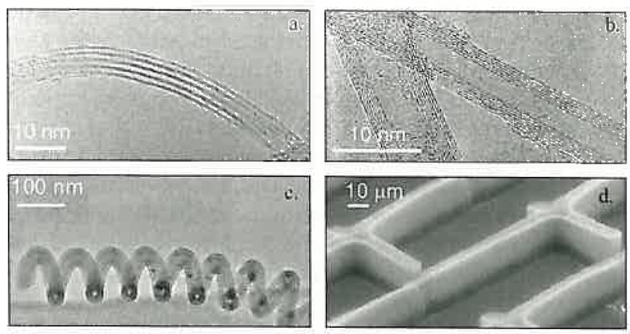


Fig. 1: Montage of electron microscope imags of various carbon nanotubes: a) SWNT rope prepared by laser ablation technique; b) MWNTs synthesized by the arc-discharge method; c) MWNT coil formed in the thermal decomposition of hydrocarbons in the presence of catalytic particles; d) patterns of oriented nanotube bundles grown on pre-structured deposits of catalytic particles by soft lithography.

conducting nanowires; field emitters (individual nanotube field emitters, large area flat panel displays,); nanotools (tips for Scanning Tunneling, Atomic Force, Magnetic Resonance Force and Scanning Nearfield Optical, Chemical/Biological Force Microscope tips, nanomanipulators, nanotweezers) [6].

In this short article we present these materials, which will certainly rule the condensed matter physics and nanotechnology at the beginning of the 21st century. We highlight a few spectacular results, and show what might be the new directions in this field and beyond.

Materials

There are several methods presently used to form carbon nanotubes. The first is a slightly modified version of the method used for fullerene production, an arc discharge between graphite electrodes, allowing a nanotube deposit to accumulate on the cathode. One can form nanotubes of a single rolled up graphene shell (SWNTs) of diameter in the 1 nm range; and multi-walled nanotubes consisting of several concentrically arranged single-wall carbon tubes nested into each other like a Russian doll. These multishell nanotubes have outer diameters typically in the range of 10-50 nm and are now referred to as multi-walled carbon nanotubes (MWNTs). Historically, SWNTs were discovered later, after an efficient production method was discovered by Smalley and colleagues, using laser ablation of graphite in the presence of catalytic particles. The SWNTs found in the resulting soot are organized into bundles of various diameters. The process of forming nanotubes by catalytic decomposition of a carbon containing reaction gas, like acetylene or methane, is extensively used because of two significant advantages. In the first place nanotubes are obtained in large quantity, and at much lower temperatures. This, however, is at the cost of lower perfection, the graphitisation of the tube walls being of poorer quality than in the case of the other two methods. Secondly, the catalyst (for example iron, cobalt or nickel) may be structured on the substrate prior to growth, thus enabling one to grow nanotubes selectively just where one wants to have them. This has enabled the growth of structured "nanobrushes" consisting of vertically aligned nanotubes at high density. Presently, nanotubes can be grown to a length exceeding 100 micrometers, yielding fibers with a very high-aspect ratio.

Nature forms carbon nanotubes in various forms, but our understanding of their microscopic growth mechanism is incomplete. For example, via thermal decomposition of hydrocarbons, one can magically grow nanotubes in the form of "telephone cords" or "nanosprings" (potentially suitable for nanomechanical applications), but the understanding of their synthesis is only at an empirical level. The montage of figure 1 illustrates the characteristic forms and shapes of various carbon nanotubes mentioned above.

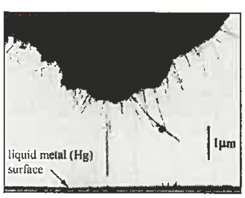
One has to mention that although these carbon nanostructures are very attractive and their production seems to be simple, they are never prepared in a pure form. The first step in their study is always technological: their purification. This is especially true for SWNTs, which are severely contaminated with magnetic particles from the catalyst. The purity of the arc-discharge fabricated MWNTs is much better, since magnetic materials are not used in their production. Nevertheless they have to be separated from graphitic flakes, polyhedral particles and amorphous carbon present in the raw soot.

Electronic properties

One can view carbon nanotubes as giant conjugated molecular wires with a conjugation length corresponding to the whole length of the tube. In order to understand their electronic structure, we have to start with graphene, a single sheet of graphite. Carbon has four valence electrons of which three are strongly bound to neighbor atoms giving graphene its very high in-plane rigidity. The fourth electron is delocalised and shared by all the atoms, thus allowing for electronic current transport. However, because of its particular structure graphene is electronically between a semiconductor and a metal. It is a semimetal or a "zero-gap" semiconductor.

This peculiarity renders the electronic states very sensitive to additional boundary conditions, such as that created by a single shell of a carbon nanotube. A stationary electron wave can only develop, if the circumference of the tube is a multiple of the electron wavelength. This condition removes the zero gap property of graphene and turns a nanotubes into either a true metal or a semiconductor, depending on how the graphene sheet is rolled up, in other words, depending on its helicity. (For MWNTs one expects a more complicated situation, because of a possible additional electronic coupling between adjacent shells). The helicity gives a fascinating richness for the engineering of electronic properties of SWNTs. However, for the time being, we cannot control neither the diameter nor nanotubes' helicity during the synthesis, and at the present this "richness" is rather a drawback than an advantage. For each nanotube one has to find out first its conduction characteristics. In order words, we do not study what we want, but what we get.

The electronic properties of one-dimensional (1d) conductors have generated much interest. The reason for this excitement lies in their very rich phase diagram and the prediction that in a 1d system the Coulomb interaction should lead to a strongly correlated electron gas, called a Luttinger liquid instead of the weakly interacting quasi-particles described as a Fermi-liquid in conventional metals. This issue is still controversial. There are experimental results both for SWNTs and MWNTs, which speak in favour of either exotic Luttinger-liquid or conventional Fermi-liquid behaviours.



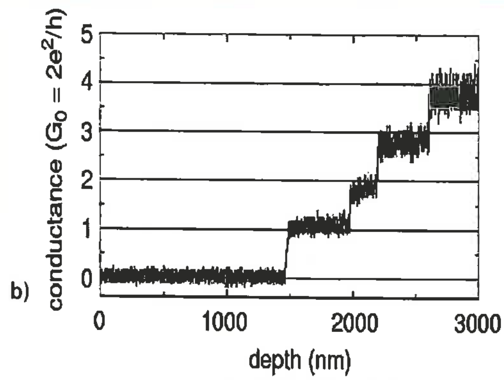


Fig. 2: a) Electron microscope image of an ensemble of MWNTs mounted on a motion stage realized by de Heer and coworkers at Georgia Tech. The MWNT sticking out most is progressively dipped into liquid mercury, which serves as a second electrode. As the individual nanotubes enter the metal, they contribute $G_0=2e^2/h$ to the overall quantum conductance, which appears to be ballistic, i.e. independent of length on each plateau.

A perfect metallic nanotube with uncorrelated electrons, is supposed to be a ballistic conductor, i.e. the best (normal electron) conductor an engineer can dream of, only surpassed by a superconductor. If an electron is injected from a contact into a ballistic wire with ideal contacts, the electron will emerge with certainty at the drain contact. There is no backscattering in the wire, which is the source of intrinsic electric resistance and leads to Ohm's law. For a perfect ballistic tube theory predicts not one, but the existence of two propagating eigenmodes independent of the diameter. The electric conductance (the inverse of the resistance) is then expected to be twice the fundamental conductance unit $G_0 = 2e^2/h = 1/13\ k\Omega$. Note, the resistance is not zero, as it would be for a superconductor but in contrast to classical resistors and to Ohm's law, the resistance is independent of the length of the wire. Data suggesting that MWNTs are indeed ballistic conductors even at room temperature are highlighted in fig. 2, although the observed conductance quantum appears to be G_0.

Our own investigations have proven that studying electric transport in MWNTs is somewhat similar to studying transport in a large diameter SWNT using lithographically deposited metal contacts in various configurations to connect electrical wires to the tubes (Figure 3). The current mainly flows on the external cylinder, the nanotube core solely acting as a mechanical support for the electrically active outermost shell. (Note, this were no longer true, if we could find a way to contact the core, or even to selectively address inner shells). MWNTs have certain specific advantages over SWNTs: their large diameter favors low-ohmic contacts, because of the larger contact area. Furthermore, the large diameter of MWNTs enables one to investigate quantum-interference phenomena in a magnetic field. The most profound quantum-interference effect is the Aharonov-Bohm (AB) effect that not only reveals that electrons are waves, but also demonstrates that the vector potential not the magnetic field plays a basic role. For the study of this phenomenon, a magnetic field of several Tesla is applied along the nanotube axis. Our electrical resistance

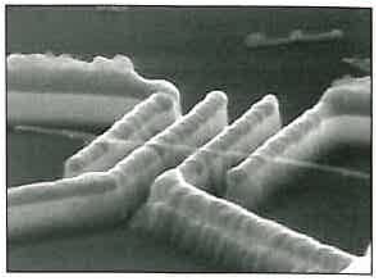


Fig. 3: Scanning Electron Microscopy image of an individual multiwalled carbon nanotube contacted by four electric leads for resistivity measurements. In order to check the influence of the substrate, the SiO_2 was etched away from below the nanotube.

measurements showed pronounced oscillations with a period of h/2e, h being Planck's constant, and e the electronic charge (Fig. 4). The oscillations are associated with the "weak localization", a quantum-mechanical manifestation of coherent backscattering of electrons, which arises from interference contributions adding up constructively in zero field. Backscattering is thereby enhanced, leading to a resistance larger than the classical Drude resistance. This observation has given compelling evidence that the phase coherence length, can exceed the circumference of the tube. But because the h/2e period (as opposed to h/e) requires backscattering on the scale of the diameter of the MWNT, this implies that these nanotubes are not ballistic, but rather diffusive. Nevertheless, most scattering processes are elastic, i.e. the coherence of electron waves is maintained over a large distance.

In our opinion contradictory results, ballistic contra diffusive transport, Luttinger contra Fermi liquid behavior, do not mean that one experiment is right and the other is wrong, but rather show us that we still do not have control of all experimental parameters, and that more decisive results are yet to come.

Elastic properties

The carbon atoms of a single sheet of graphite form a planar honeycomb lattice in which each atom is connected via a strong

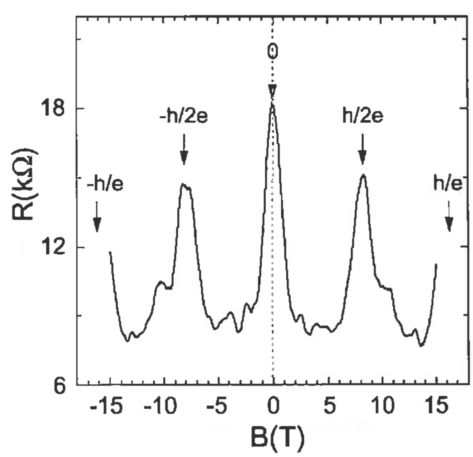


Fig. 4: Electrical resistance R as a function of magnetic field B of a MWNT aligned parallel to B. The resistance oscillation is due to the Aharonov-Bohm effect. Arrows denote the resistance maxima corresponding to multiples of h/2e of the magnetic flux through the nanotube *outer* perimeter, thus indicating that the current flows in the outer most shell.

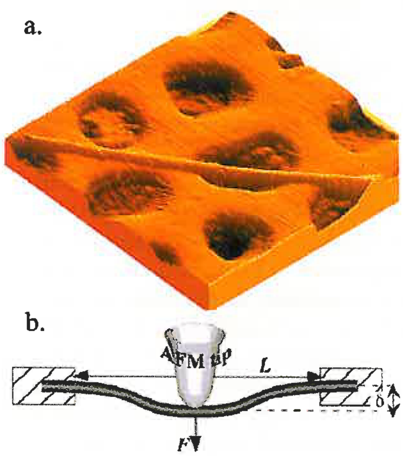


Fig. 5: (a) 3D rendering of an AFM image of a SWNT bundle (or a single MWNT), adhered to an alumina ultrafiltration membrane, leading to a clamped beam configuration for mechanical testing. (b) Schematic representation of the measurement: the AFM tip applies a load, *F*, to the portion with a suspended length of *L*, and the maximum deflection *d* at the center of the beam is directly recorded from the topographic image; d versus F is proportional to the Young's modulus of the nanotube.

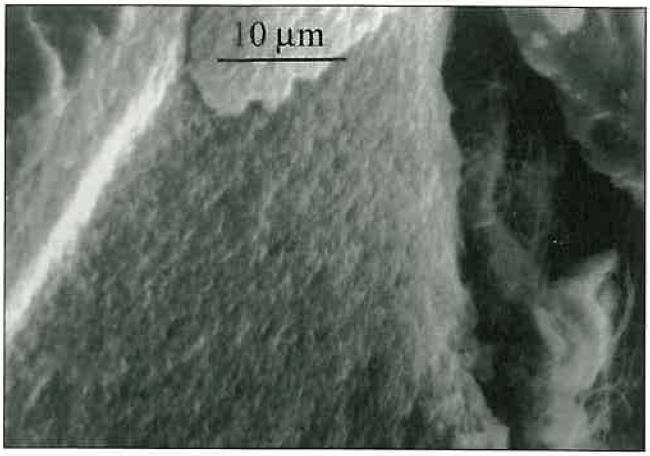


Fig. 6: SEM image of the surface of a fractured Aluminium/MWNT composite. The central part of the image shows a homogenously dispersed nanotubes in the Al matrix. (Courtesy of R. Schaller, EPFL).

Fig. 7: A prototype of a carbon nanotube based display (Samsung Display Technology, courtesy of Y. Choi).

chemical bond to three neighbour atoms. The basal-plane elastic modulus of graphite is one of the largest of any known material. For this reason, carbon nanotubes are expected to be the ultimate high-strength fibres. In our laboratory in Lausanne, we developed a simple method for measuring the mechanical properties of single nanotubes. The technique involves depositing nanotubes from a suspension in a suitable liquid onto well-polished alumina ultrafiltration membranes with a pore size of about 200 nm (See fig. 5). Carbon nanotubes strongly adhere to alumina, but occasionally span the pores by chance. The deflection of such a supported tube is then deduced from AFM images recorded at various normal loading forces. The measured deflection is inversely proportional to the Young's modulus. It is found to be approximately 0.8 TPa for arc-discharge grown nanotubes, while for the catalytically grown tubes a much lower – by one to two orders of magnitudes – modulus was found. This result demonstrates that only highly ordered and well graphitised nanotubes have stiffness comparable to graphite. In contrast, MWNTs grown by catalytic decomposition still contain many defects.

Besides their high strength nanotubes behave magically with respect to high loads. If the applied force exceeds the bending strength, a MWNT first bends over surprisingly large angles, start to ripple on the compressed side and eventually develops kinks, as well. The amazing thing is that all these deformations are elastic, i.e. disappear completely if the load is removed. If one would employ nanotubes as mechanical springs, these springs would be very stiff for small loads, but would turn into soft ones for larger loads allowing for longer extensions without breaking. One could then dream of making objects which after severe deformations relax into their initial form once the load is released.

All these features render nanotubes as very attractive reinforcement fibres for high strength composites. The technological impacts of light and strong structural materials would be enormous. There are reports on epoxy/nanotube, polymer/nanotube composites that have interesting mechanical properties, even though the problem of efficient load transfer to nanotubes has not been yet solved. In our laboratory in Lausanne, the main effort is the development of metal/nanotube composites (fig 6).

Carbon Nanotube Emitters

Field emission results from the tunneling of electrons from a metal tip into vacuum under application of a strong electric field. The small diameter and high aspect ratio of carbon nanotubes is very favorable for field emission. Even for moderate voltages, a strong electric field develops at the free end of supported nanotubes because of their sharpness. This was observed by de Heer and co-workers at EPFL in 1995. He also immediately realized that these field emitters must be superior to conventional sources and might find their way into all kind of applications, most importantly flat-panel displays. It is remarkable that after only five years Samsung actually realized a very bright colour display, which will be shortly commercialised using this technology (Figure 7).

Studying the field emission properties of MWNT, Bonard and co-workers at EPFL have noticed that together with electrons light is emitted, as well. This luminescence is induced by the electron field emission since it is not detected without applied potential. The typical experimental set-up for electron/light emission is shown in Fig. 8 for an individual nanotube. This light emission occurs in the visible part of the spectrum, and can sometimes be seen with the naked eye.

MWNTs in a configuration shown in fig 8, a single nanotube attached to a wire, also represents an excellent scanning probe tip for AFM and STM studies. Furthermore, due to the light emitting property, it can find application in Scanning Near-field Optical Microscopy, as well.

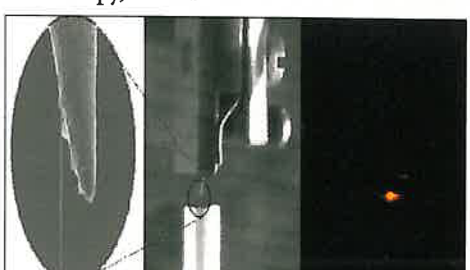


Fig. 8: SEM images a SWNT mounted on a gold wire and photograph of the experimental set-up for field/light emission studies. The emitted red light from the nanotube tip is visible with the naked eye.

Conclusions

The future for nanotube looks very bright: Nanotubes are interesting model systems for fundamental studies of one-dimensional systems, but they are equally well (or even more) attractive for applied researchers and industry due to the wide variety of their potential applications. They offer lot of creativity in material preparation. Besides the variety of different structures illustrated in fig. 1, one can fill the hollow core with semiconducting metallic, or ferromagnetic materials etc. Along these lines, the latest "breaking news" is a single wall nanotube filled with C_{60} molecules (fig. 9). When a few years ago David Luzzi from the University of Pennsylvania first reported such "peapods", one thought of an "exotic bird", very nice, but without any importance for future studies. Today, several laboratories have developed methods for complete filling SWNTs with fullerenes, raising the possibility of creating an almost one-dimensional superconducting wire of C_{60} inside of a nanotube. A further advantage of this method is that even endohedral fullerenes (containing an atom inside their cages) can be introduced into the nanotubes, e.g. La@C82.

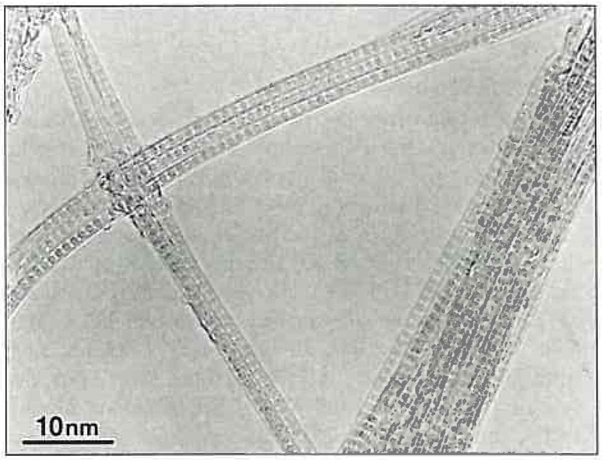


Fig. 8: SEM images a SWNT mounted on a gold wire and photograph of the experimental set-up for field/light emission studies. The emitted red light from the nanotube tip is visible with naked eyes.

Furthermore, since nanotubes are very user-friendly, very robust, they can also act as excellent model systems for learning manipulation at a nanometer scale, which is the scale of biological macromolecules like DNA, microtubules and proteins. For example, the method for measuring the Young's modulus of SWNT ropes was directly applied to measure the same property for individual microtubules in Lausanne, or the electronic conduction of DNA in Basel (group of C. Schönenberger), Delft (group of C. Dekker), and in Orsay (group of H. Bouchiat).

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Science makes waste less smelly

Every day, great quantities of domestic and industrial waste are put into landfill sites, covered over and left to rot. As this waste decomposes, it gives off a complicated mixture of gases, some of them poisonous and some of them smelly, often for several decades after a site is closed. As well as being unpleasant for near neighbours, landfill gas often poses a health hazard, particularly for those with respiratory problems.

Decomposition of some of the toxic materials placed in landfill sites results in the production of volatile organic compounds such as limonene and ethyl butunoate, halogenated compounds and the malodorous ("bad egg" smelling) sulphide compounds such as hydrogen sulphide, dimethyl sulphide and methanethiol. Current EU directives require that by 2010 there must be a 65% reduction in the amount of putrescibles placed in landfills.

Dr Imtiaz Ahmad and her colleagues at Manchester University are investigating how waste gases can be cleaned up with a plasma. The plasma is created by bombarding a gas with high frequency and high voltage electricity so that it becomes a soupy mixture of electrons, ions and highly charged particles. As Dr Ahmad will explain at the Institute of Physics Congress 2001 in Brighton on Monday 19 March, a noxious gas fed into this plasma reacts with it to produce new kinds of gases.

The aim is to create friendly "clean" gases that can be recycled and simply vented to the air, plus also perhaps gases that can be used as a fuel. By examining the gases coming out of the end of the plasma line using a Fourier Transform Infrared (FTIR) spectrometer, Dr Ahmad can see what compounds have been generated and decide what are the optimum conditions of the reaction needed to generate only desirable products.

If laboratory experiments are successful, field trials could be taking place by the end of the year. If the technique is found to be commercially viable, plasma reactors with big pipelines sunk deep into the ground could become common on landfill sites.

US support for NJP

In a move that reinforces academic support for innovative science publishing initiatives, the Utah Academic Library Consortium (UALC) has pledged to pay all author fees for faculty members at all Utah academic institutions who contribute research to the New Journal of Physics (www.njp.org). The New Journal of Physics is published by Institute of Physics Publishing (U.K.) and the German Physical Society (Bad Honnef, Germany). The New Journal of Physics, entering its second year, is an electronic journal that publishes original research in all areas of physics, and is available on the internet free of charge and supported by author fees. The NJP is a European initiative presenting an alternative approach to physics publishing, emphasizing a broad range of topics rather than a specific subdiscipline within physics.

EURESCO Conferences

A Programme of the European Science Foundation with the support of the European Commission

Particle – Solid Interactions:*

EuroConference on the Deposition of Atoms, Ions and Clusters at Surfaces

San Sebastian, Spain, 11-16 September 2001

Chairperson: Risto M. Nieminen (Helsinki, SF)
Vice-Chairperson: Archie Howie (Cambridge, UK)

SPEAKERS WILL INCLUDE

R. Averback (Urbana, USA); F. Banhart (Ulm, D); F. Besenbacher (Aarhus, DK); A. Borisov (Orsay, F); E. Campbell (Göteborg, S); L. Colombo (Cagliari, I); M. Di Ventra (Blacksburg, USA); K. Fichthorn (University Park, USA); T. Frauenheim (Paderborn, D); H. Häkkinen (Atlanta, USA); P. Hyldgaard (Göteborg, S); M. Manninen (Jyväskylä, SF); T. Michely (Aachen, D); M. Moseler (Freiburg, D); K. Nordlund (Helsinki, SF); R. Palmer (Birmingham, UK); M. Rauscher (Ithaca, USA); A. Rubio (San Sebastian, E); B. Svensson (Oslo, N); P.Z. van Emmichoven (Utrecht, NL)

SCOPE OF THE CONFERENCE

The programme will be built around a number of invited talks, with ample time for discussion and workshop sessions. A number of contributed papers will be included as posters. Topics wil include various aspects of particle-surface interactions, such as implantation, surface modification, morphology, atomic manipulation and imaging, cluster deposition, electronic excitations, charge transfer, and nanoscale structures. Experimental, theoretical and computational topics will be presented.

Deadline for Applications: 18 May 2001

Matter in Super-Intense Laser Fields:*

Short Pulse, Superstrong Laser-Plasma Interactions EuroConference

San Feliu, Spain, 29 September - 4 October 2001

Chairperson: Dimitri Batani (Milano, I)
Vice-Chairperson: Pierre Agostini (Saclay, F)

SPEAKERS WILL INCLUDE

P. Agostini (Saclay, F); S. Atzeni (Roma, I); A. Benuzzi-Mounaix (Palaiseau, F); M. Borghesi (Belfast, UK); C. Chesnais (Palaiseau, F); J.P. Chieze (Saclay, F); K. Eidmann (Garching, D); A. Giulietti (Pisa, I); T. Hall (Olchester, UK); J. Honrubia (Madrid, E); C. Joachain (Bruxelles, B); V. Malka (Palaiseau, F); P. Norreys (Oxon, UK); B. Remington (Livermore, USA); L. Roso (Salamanca, E)

SCOPE OF THE CONFERENCE

The recent development of high-energy short-pulse laser systems has led to the discovery of new phenomena in laser interactions with matter and in particular has opened new perspectives in plasma physics allowing completely new regimes to be investigated. Relativistic plasmas and strongly-coupled degenerate plasmas have become experimentally accessible. Numerical, theoretical and diagnostics improvements have also progressed at the same time. Applications like particle sources, X-rays and High harmonics generation, Fast ignition are foreseen. At the same time recently astrophysically relevant experiments and equation of state experiments in the Multimegabar regime have also been realised helping our comprehension of the universe.
The main topics of this conference will be: Astrophysics in the laboratory; Equation of state; Particle sources from high-intensity lasers; Numerical simulations; Advancement in ICF and fast ignition; Advanced plasma diagnostics including X-ray laser and high harmonics; Atomic physics in dense plasmas; Atomic physics in strong fields.

Deadline for Applications: 4 June 2001

Electromagnetic Interactions with Nucleons and Nuclei:*

EuroConference on Hadron Production with Electromagnetic Probes

Santorini, Greece, 2-7 October 2001

Chairperson: Klaus Rith (Erlangen, D)
Vice-Chairperson: Enzo De Sanctis (Frascati, I)

SPEAKERS WILL INCLUDE

V. Braun (Regensburg, D); V. Burkert (Newport News, USA); G. Chanfray (Lyon, F); E. Chudakov (Newport News, USA); D. De Florian (Zürich, CH); Y. Dokshitzer (Orsay, F); M. Guidal (Orsay, F); F. Maas (Mainz, D); N. Makins (Urbana, USA); V. Muccifora (Frascati, I); A. Müller (Columbia, USA); C. Papanicolas (Athens, GR); P. Rakow (Regensburg, D); M. Ripani (Genova, I); K. Rith (Erlangen, D); D. Ryckbosch (Gent, B); R. Schumacher (Carnegie Mellon, USA); P. Sphicas (MIT, USA); D. Von Harrach (Mainz, D)

SCOPE OF THE CONFERENCE

The ultimate goal of today's hadronic physics with electromagnetic probes (photons, electrons and muons) is to understand the strong interaction between quarks and gluons as described by the underlying field theory - Quantum Chromo Dynamics (QCD) - in the transition region where quarks and gluons become 'confined' into the observed subnuclear particles.
The main aim of this series of Euroconferences is to provide a forum where nuclear and particle physicists, especially those working with electromagnetic probes, will have the opportunity to present, summarise and discuss their actual results and to confront them with recent theoretical ideas and developments.
This year's conference, which is the 4th in the series, will be devoted mainly to the discussion of information about the internal quark-gluon structure of nucleons, baryons and mesons which can be obtained from the detailed study of the hadronic final state produced in the interaction of the electromagnetic probes with nucleons and nuclei.

Deadline for Applications: 29 June 2001

Quantum Optics:*

EuroConference 2001

San Feliu, Spain, 6-11 October 2001

Chairperson: Klaus Mølmer (Aarhus, DK)
Vice-Chairperson: Tilman Esslinger (München, D)

SPEAKERS WILL INCLUDE

E. Arimondo (Pisa, I); P. Bucksbaum (Ann Arbor, USA); I. Cirac (Innsbruck, A); C. Eberlein (Brighton, UK); C.A. Fuchs (Murray Hill, USA); V. Gomer (Bonn, D); P. Grangier (Orsay, F); C. Henkel (Potsdam, D); M. Holthaus (Oldenburg, D); S. Keiding (Aarhus, DK); D. Loss (Basel, CH); M. Ol'Shanii (Cambridge, USA); P. Pinkse (Garching, D); E.S. Polzik (Aarhus, DK); S. Popescu (Bristol, UK); T.C. Ralph (St Lucia, AUS); J. Rarity (St. Andrews, UK); C. Salomon (Paris, F); A. Sanpera (Hannover, D); F. Schmidt-Kaler (Innsbruck, A); J. Schmiedmayer (Heidelberg, D); A. Sinatra (Paris, F); T. Udem (Garching, D); D. Wineland (Boulder, USA); C. Wunderlich (Hamburg, D)

SCOPE OF THE CONFERENCE

This conference continues the annual series of meetings in Quantum Optics. It will include invited talks and contributed posters put together in a programme which will emphasize the common fundamental issues in quantum physics within a broad range of topics: emerging ideas and technologies for quantum control and measurements, quantum information, ions and matter waves, non-classical light.

Deadline for Applications: 30 June 2001

*Conferences are open to researchers world-wide, whether from industry or academia. Poster sessions are planned at all events above. Participation will be limited to 100. The registration fee covers full board and lodging. **Grants** are available, in particular for nationals from EU or Associated States under 35. (*EC support from the High Level Scientific Conferences Activity)*

For information & application forms contact: J. Hendekovic, EURESCO Office, ESF, 1 quai Lezay-Marnésia, 67080 Strasbourg cedex, France. Fax.(33) 388 36 69 87; E-mail: euresco@esf.org; http://www.esf.org/euresco

Physics: The European view

G. Morrison and D. Lee

Philippe Busquin, the European Commissioner for Research was interviewed by G. Morrison and D. Lee on 27 February 2001. Both interviewers were impressed by the Commissioner's enthusiasm and understanding of the issues facing European science. The General Directorates (Research, Education etc.) help develop and implement policy decided by the European Commission (i.e. representatives of the Member states). The DG Research is responsible for the operation of the Framework Programmes for Research and Technological Development, including the current proposal for FP6. Commissioner Busquin openly encourages debate and welcomes comments and new proposals for strengthening the European science base. The rules and procedures inherent in any decision concerning public funds, while often seen as bureaucratic, are designed to ensure an objective peer review process. The European Physical Society would like to express its thanks to P. Busquin and to A. Dahmen, his press officer.

Biography

P. Busquin was born in 1941 in Belgium. He went to University at the Free University in Brussels, where he majored in theoretical nuclear physics as a student of Prigogine. Demeure was his thesis director.

After university, P. Busquin became a science instructor at a teacher's training school, as well as lecturer at the university. At about this time, he became interested in politics, especially environment and science policy. He was president of the Institute of Radiology, a public utility company for production of radioisotopes, where he gained invaluable experience for the management of applications from science. He began a career in politics in 1977 as a representative for the province of Hanault and as a Deputy in the Chamber of Representatives in Belgium. Between 1980 and 1992 he held positions as minister for education, the interior, budget and energy, economy and social affairs. From 1992 he was Minister of State, President of the Belgian Socialist Party, from 1995 Mayor of Seneffe and Belgian Senator. He resigned from all mandates following his nomination as member of the European Commission and his appointment as Commissioner for Research in 1999 by President R. Prodi.

As European Commissioner for Research you proposed in early 2000 the establishment and co-ordination of research structure facilities as a key element in the development of the European Research Area. Would you expand on your proposal and how you see it advancing science in Europe. What is the relationship between maintaining and building a strong scientific research base and European construction?

In the budget proposal for the next Framework Programme, 900 million Euros have been reserved for infrastructure and research installations. They are important for Europe because they represent a major investment and should therefore be used by as many scientists as possible from as many countries as possible. It is also important no double financing and double work occurs in this area. Scientists and scientific research are necessary in fulfilling the EU's basic objectives because sound scientific advice is needed for politicians to make informed policy decisions.

Where do you see Europe's strengths in science and physics?

Europe is at the forefront of many areas of research, such as telecommunications, polymers, nanotechnologies, molecular biology, renewable energy resources, fusion, high energy particle research and aeronautics.

Are you satisfied with European research collaboration as it is now or do you think it should and can be improved?

Improving European collaboration is one of my priorities, and closely related to the creation of the European research Area. At present, the situation is not at all satisfactory. Much European research is fragmented, without sufficient sharing of research results. European scientists started, with very promising results, the project to decode the human genome. However, the project went finally to the US through a lack of co-ordination.

From your perspective, do you feel that research has, in general, become too applied? Has the development of EU Framework programmes that encourage target-oriented research been at the expense of the basic-research budget?

I think that it is difficult to differentiate between fundamental and applied research. At present, there is no real barrier and applications are developed more and more quickly from fundamental advances. The links between industry and research laboratories are growing, and industry is one of the major advocates of fundamental research. The European Commission is trying to identify strategic research areas, e.g. nano technology. The mandate of the European Commission is to strengthen the competitiveness of the European Union, because if the EU is too close to the market, it can be seen as favorizing one sector over another. The EU is not trying to concentrate on individual research initiatives, which is the role of private industry. Public funds should be used for projects with a mid to long term vision. As an example, the EU is looking at the aeroplane for 2020, which should be quieter, safer and more economical.

Are you satisfied with the way funds have been distributed under the Framework 5 programme?

To be funded under FP5, projects need European added value. This is difficult to assess and needs to be understood in terms broader than purely economic. What is needed is for Europe to develop the critical mass to be able to discuss with international partners on an equal footing. The overall idea is to create a European Research Area that will allow us to use more advantageously strengths that exist in Europe. Three specific axes have been defined to strengthen European Science. First, the EU will be looking to finance integrated projects on a wide scale on topics that are of interest to member states, e.g. genomics. This should allow us to pool our resources to create the critical mass, and allow for better management of the projects. The second is the identification and networking of centres of excellence. Finally, the EU will encourage the opening of national programmes to international collaboration. While the EU cannot impose this as an obligation, it should be obvious that it may be best to work on a European level when looking at issues such as aeronautics, oceanography, and the ozone layer.

Who determines what the criteria are used in choosing a centre of excellence?

This is a difficult question. It is necessary

to develop a series of objective criteria, and methodology for making the choice. Then the centres will be identified and the network established.

It is necessary for Europe to have centres of excellence. The best scientists want to work in the best labs. If these are in the US, then they will go to these labs. One encouraging project is Theseo, which is an international collaboration that studies the ozone layer. Europe has developed extremely sophisticated weather balloon technology, which the US does not have. At the same time, the project benefits from the expertise of the very high flying aeroplanes that the US has developed. Prior to this project, many European scientists left because the best work in the field was being done in the US. Now they are staying in Europe.

Should European research funding primarily concentrate on areas of strength or should all areas be considered on merit? Are you concerned that 'big' science may deprive 'small' science of its funding?

The principal criteria for funding of scientific research should remain scientific excellence. For the Commission, there is the additional factor of European added value, stemming from our mandate in the EU Treaty. Small science is often found in SMEs and in start ups, and we cannot afford to neglect them in future.

What ideas do you have for addressing the world-wide problem of the deep suspicion with which the general public regards scientists? Do scientists need to be more visible in public and political debate?

The problems as I see them are a poor image, and poor communication of the excellent results coming from scientific research. The scientific community is perceived as being too far from the general public. Certain areas, such as bioscience, generate tremendous concern and debate. Scientists need to address these issues. Citizens need a broader scientific education. Initiatives such as Physics on Stage are excellent starting points in seeing and sharing what can be done in this area.

The EPS has a position paper on the future of Nuclear Energy. What is the Commission's point of view?

The Commission has produced a Green paper on Nuclear Energy. It is a difficult question, and very delicate as Europe is not self sufficient for energy production. However, even without judging the merits of nuclear energy, the issue highlights one of the major problems facing Europe. There is currently a severe shortage of students studying physics. Whether nuclear energy programmes are continued or phased out, there will be a need for physicists to supervise their operation or their shutdown and dismantling as well as a safe deposit of nuclear waste.

Are there other areas where this shortage will be critical?

Generally, without a strong science base to develop new ideas there will be a decline in technological and industrial development. Europe needs to understand the relation between a strong science base and economic development. More science education is necessary, first to train more scientists, and second to provide some understanding of the issues involved to all citizens to make informed decisions about science policy.

What do you consider are the reasons for the attraction of the US to European scientists? How can European science stem the flow and successfully attract and compete for top-talent?

The main reasons are a lack of recognition for their work in Europe, lower taxes in the US, fewer mobility restrictions once in the country, a harmonized patent system and better conditions for start-up companies and university spin-offs. Europe needs to create and maintain centres of scientific excellence, which will attract excellent scientists. We also need a European patent and better access to risk capital for new innovative companies.

The EPS has recently floated the idea that the brain-drain of scientists from poorer countries will only be eased when the recipient countries reimburse (on a statistical basis) the donor countries. The poor donor countries would then be able to provide better conditions for their nationals. Comments, please.

I have seen the EPS position paper, which summarizes very well the problems caused by the brain-drain. The solutions are complex, and to focus only on the idea of a 'transfer tax' is insufficient. Another idea that could be explored would be to offer study grants for scientists including a return grant.

The EPS represents 38 countries and 80,000 physicists in Europe. What do you consider should be the role of the EPS in advancing European Science? Should it be more pro-active in developing its links with the EC in Brussels?

The EPS has a role to play in Europe. One specific example would be to propose criteria in defining centres of excellence. I am always open to proposals from interested organisations, and the EPS is well respected and represents a large portion of the physics community. Another would be in raising the public awareness of physics, and in trying to influence more students to study physics. When I was young, I was attracted to science because of its very positive image. I feel that at present, people find the issues difficult to understand, and concentrate more on the negative aspects and risks of scientific research.

Some say that the last century was one of Physics but that the present one will be the century of Biology. Do you agree?

To some extent, this is evident. But no one should forget that many of the tools that have made it possible for the biosciences to progress come from physics. And this does not mean that there are no exciting fields in physics research, such as nanotechnology and fusion.

You have recently been appointed EU commissioner for Research. Are you enjoying the experience so far?

I am quite enthusiastic about this important and challenging position. It is necessary to increase the interest in science studies. It is impossible for us to create the 'information society' without scientists, not only for generating new technology, but also increasing the knowledge base through fundamental research.

Physics: The scientist's view

G. Morrison

Sir Robert May is President of The Royal Society (2000-2005), and holds a Professorship jointly in the Department of Zoology, Oxford University, and at Imperial College, London. For the five year period ending September 2000, he was Chief Scientific Adviser to the UK Government, and Head of its Office of Science and Technology.

Initially enrolled in Chemical Engineering, May gained a BSc and PhD in Theoretical Physics from Sydney University and later became the holder, at age 33, of the University's first Personal Chair in Theoretical Physics. In the early 1970's he became interested in the dynamics of animal populations and in the relations between stability and complexity in natural communities. In 1973 he moved to Princeton University as Professor of Zoology and in 1988 he moved to Britain as a Royal Society Research Professor.

May's current research deals with factors influencing the diversity and abundance of plant and animal species, and with the rates, causes and consequences of extinction. May was the recipient of the Royal Swedish Academy of Science's Crafoord Prize in 1996, and of the 1998 Balzan Prize presented by the President of Italy. He was elected to The Royal Society in 1979 and is a Fellow of various other international learned societies. He holds honorary degrees from Uppsala, Yale, and Princeton Universities, The University of Sydney, and several UK universities.

For the last 5 years you were Chief Scientist to the UK Government. Is the position of CS seen by Government as primarily responsive or proactive? What would you consider you achieved? Did you enjoy the experience?

My five year stint as Chief Scientific Adviser to the UK Government and Head of its Office of Science and Technology ended in September 2000. During the tenure of my predecessor in that job the Office of Science and Technology was created, with the CSA being made its Head. Before that, the job was a somewhat less structured one, but with the creation of OST the job of CSA became defined within the formal structure of the civil service (at its top grade as "Permanent Secretary").

The job has always been a curious mixture of reaction and proaction. With its formal definition within the Civil Service, the holder of the job has to walk a delicate tightrope: on the one hand, as a Civil Servant one has certain constraints (the Civil Service exists, in principle, to implement Government policy); on the other hand, to do the job effectively one must both be, and be seen to be, a genuinely independent voice in Government. I think it helps to be an Australian in order to do this! Much of the job requires response – often at short notice – to science-based issues. But often the initiative comes from the CSA personally, recognising a need which may not be so obvious within the Civil Service. And often the two functions merge, with one being asked to do something, but with the definition of the task changing in the doing.

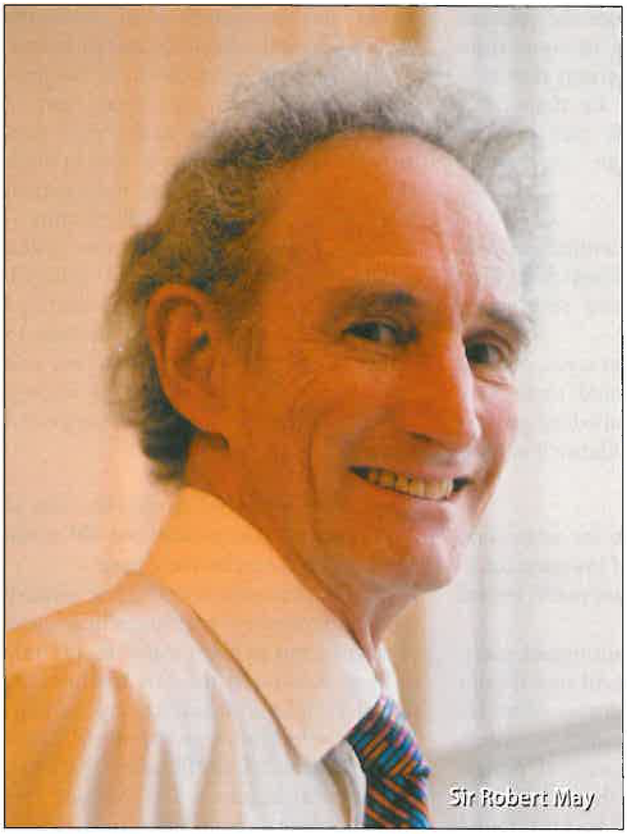
I think the achievements of the Office of Science and Technology over the past five years, which drew upon many efforts beyond that of the CSA personally, were: notable increases in the budget for basic science (the increases in the first, "comprehensive spending review", by the Blair Government for the science base were the biggest, proportionately, of any major budgetary unit; and in the second spending review again the science base was the biggest proportionate beneficiary, with 7% real terms increase year on year over the next thee years); a variety of other detailed initiatives which I will not spell out; and – not so evident a part of the job when I took it on – big changes in the engagement between science and society.

Possibly the most enduring change during my time as CSA was the drawing up of "Guidelines for Science Advice and Policy Making" under John Major's Government. These guidelines, motivated by experiences (particularly BSE) over the years before my taking on the job, spelled out basic principles of wide and varied consultation, and openness. Although perhaps "motherhood and apple pie", such wide consultation and openness represents a cultural change within the Civil Service. Under the Blair Government the guidelines were further embedded within Whitehall by a transdepartmental ministerial group (chaired by the Science Minister, Lord Sainsbury), and transdepartmental committee of officials to ensure oversight and coordination, and a thoroughgoing review of the guidelines in 2000 (resulting in a "Code of Conduct" for Science Advice in Policy Making). All these procedural things are now firmly fixed within the Civil Service, although the routine implementation will, as with all changes in human institutions, take time to be universally part of every day practice.

I found the experience of working in Whitehall very different from my previous life, spent in universities in Australia, the USA (20 years in total), and most recently in the UK. But it was thoroughly enjoyable. Civil Service life characteristically involves longer hours, and much more subjugation of the individual into collective effort. I found it – long hours and tight deadlines notwithstanding – less stressful than academic life, in the sense that one was always operating within a structure of collective effort. Academic research, with all its many pleasures and intellectual rewards, is more a "self employed" activity, which means the impetus to get things done – both enjoyable things and tedious things – comes much more from the individual. In short, for all the routinely longer hours, I found the structured work somewhat easier (and the weekends were usually free, rather than often taken up in catching up writing research work up, because there is too much distraction during the week!).

Do you consider that UK (and European) research funding should primarily concentrate on areas of strength or should all areas be considered on merit? Are you concerned that 'big' science may deprive 'small' science of its funding?

All research funding, whether UK, European or otherwise, should in my opinion be concentrated on the people who can demonstrate a capacity to use the money well. But there is no simple formula for achieving that easily-said thing! I believe that most basic research should be responsive to proposals put forward by individuals and groups, on their own initiative. But some of the work should be more directed, in the sense of calling for proposals in specific areas (without spelling out the nature of the proposals). Without this incentive – with the areas themselves suggested by groups of people with proven track records of creativity and judgement – one tends to have research funds concentrate unduly on yesterday's happy accidents, crystallised into today's fashions.



to harvest the fruits of their efforts in industry, is a rather separate matter. I think the UK "Foresight" programme has been of demonstrable benefit in this respect. In particular, a variety of measures suggest a rough doubling of interactions between basic researchers and business/industry over the last half dozen years or so (as measured by university ownership of patents; courses taught jointly; papers published jointly; and other things).

The EU Framework programmes are yet another question. It is my strong belief that framework spending should be concentrated on those programmes, and those areas, where for one reason or another the natural scale is European. Thus to have an aerospace industry which rivals that of the USA, for generic development one needs EU-scale activity. In other circumstances, it is the geographical sweep of the question at issue (for example, environmental questions) which suggests EU-level collaboration. But for individually initiated basic research, I believe funding best comes from the bottom up, and that the natural scale is within countries. I thus see only a limited role for general framework funding for basic research as such. For me, the litmus test is always "is there a European dimension, inherently, to this work".

The creation of networks of relationship among researchers, particularly younger researchers, is yet another distinct issue. Here I think the networks fostered by the European Science Foundation are greatly to be encouraged, and the postdoctoral funding under the Human Mobility programme, bringing bright young people into the best laboratories in Europe, should receive generous support.

I think quarrels between big science and smaller science are foolish. Both have their place. Some vital questions cannot be pursued outside the framework of "big science"; the only thing I would add is that the notion that big science means particle accelerators and telescopes is rapidly becoming a thing of the past, as big biology begins to rival big physics. Ultimately, however, the judgement must be based on how important the work is, and how much is its intrinsic cost. This means that both big and small science will both remain crucial.

From your perspective, do you feel that research, has in general, become too applied? Are you concerned about possible short-termism in the funding of research? How successful do you consider have been the links with industry through the 'Foresight' initiative in the UK and through the EU Framework programmes in Europe?

I am aware of the general feeling that research is becoming more applied. There is little evidence to support this feeling. Within the UK, the proportion of research council money spent on basic, as distinct from strategic or applied, research (by Frascati definitions) has increased, not decreased, in recent years.

The question of encouraging better networks of relationship among basic researchers in academia and those seeking

How important do you consider the European dimension in Science? Are you sympathetic to the role of the European Commission in attempting to develop 'the European Research Area'?

The previous question, I think, makes it clear the ways in which I think the European dimension in science is important, and should be recognised. As a good European, I am in favour of a "European Research Area". But with an appropriate definition! The last thing we want is a "one size fits all", foisted by ambitious bureaucrats upon the inherently diverse funding mechanisms of different – and highly successful in their differences – European countries.

The EPS has recently floated the idea that the brain-drain of scientists from poorer countries will only be eased when the recipient countries reimburse (on a statistical basis) the donor countries. The poor donor countries would then be able to provide better conditions for their nationals. Comments, please.

The idea you spell out under this question is a very interesting one, analogous to the transfer fees which works so well in major sports. I think it is a very clever idea, and I would be in favour of it. But the devil will lie in the details, and I have difficulty seeing it being implemented in practice.

As the new President of The Royal Society, Britain's foremost Science Academy, do you feel like a Gamekeeper - turned - poacher?

Do I, as President of the Royal Society, following my job as CSA, feel like a gamekeeper-turned-poacher? No!

What do you see as the role of The Royal Society in the UK, and in Europe?

In the office of science and technology, my primary concern was to make sure the best science was used, after wide and open consultation, in shaping government policy. And my aim was also to make sure that the science base in Britain was properly funded, repairing years of underinvestment in basic infrastructure. I was also concerned that the engagement between science and society was undertaken more deliberately, encouraging debate about how we wish to use the possibilities opened by our still accelerating understanding of how the world really works. These are exactly the aims I bring to The Royal Society.

The role of The Royal Society is spelled out very well in its summary of its objectives. These are to

- recognise excellence in science
- support leading-edge scientific research and its applications
- stimulate international interaction
- further the role of science, engineering and technology in society
- promote education and the public's understanding of science

- provide independent authoritative advice on matters relating to science, engineering and technology
- encourage research into the history of science

The objectives do not dwell specifically upon the role of The Royal Society in Europe, but I see it as being a good European citizen, engaging in dialogue with its sister institutions in the other fourteen EU countries. This we are, indeed, much engaged in at the moment, as we move toward creating some form of "European Science Council", which will aim to give top-level, independent advice on major scientific issues within Europe; such advice will be parallelled by the conventional bureaucratic machinery within Brussels, and will I hope helpfully supplement it.

Are you concerned by the widespread fall in student numbers entering physics (and chemistry) and would you attempt to arrest the decline or should the intake of students be left to market forces to determine? Should the latter view apply also to the intake of graduate students?

Within the UK, the number of students studying physics at universities has fluctuated quite a bit in recent years. But there is nothing as simple as a "widespread fall in student numbers", in absolute terms. On the other hand, as the total number of people going to university has greatly increased (so that, as a proportion of all 24 year olds, the UK has more university graduates than the USA this year), the fraction studying physics indeed has decreased (and the absolute number has also decreased in one or two recent years). I see this as something we should be very worried about. But I have no easy answer. Part of the answer has to be making it clear how exciting, and how hugely valuable, training in physics can be.

As a chemical engineer who ended up as a professor of theoretical physics at Sydney University, I consider that a training in theoretical physics is an absolutely superb training for any one of a variety of walks of life. In beginning the biological revolution, by unlocking the secret of DNA, Watson and Crick – a physicist and a chemist – brought the physical sciences tools to bear upon a biological problem. I believe this will happen again and again, as we learn more about the molecular machinery of life at every level. Make no mistake: sequencing the human and other genomes is only the end of the beginning, Tycho Brahe. The next phase, perceiving patterns (Kepler) and the possible perception of underlying rules that create the patterns (Newton) are likely again to come from the basic intellectual approach that is at the heart of physics. So we desperately need physicists, although not just for physics, exciting though its future remains.

Do you consider that scientists on 'soft money' should have more help from their research superiors to fund satisfactory longer term employment?

The answer to this question is yes, yes, and yes. And universities should make sure that there is more of an embedded process to make sure that such guidance is conscientiously delivered.

What new ideas have you for addressing the world-wide problem of the deep suspicion with which the general public regard scientists?

The general public does not regard scientists with deep suspicion. All recent polls in the UK, and a large number of others more generally, suggest that scientists come near the top of esteemed professions. More specifically, the MORI poll commissioned in the UK by OST found that more than 80% of people surveyed in depth believed that science has made their lives better, and that scientists are motivated to do exactly that. Two thirds of the people polled even went so far as to say that a life as a scientist must be most rewarding. Where their worries lay was that (more than half of those surveyed) they believed the pace of modern scientific advance is so fast that governments cannot keep up; more than half the respondents worried about the problem of effective regulation of the application of new knowledge. But this has always been the case. There were riots in the streets about smallpox vaccination, and in yet earlier ages people expressed their distrust of the new by burning the harbingers.

To put it yet another way, it is those countries whose citizen score best on quizzes about their knowledge of science whose inhabitants at the same time worry most about the consequences of scientific advance. And I think this is as it should be. When you really understand things, you understand better the possibility of unintended adverse consequences. I have no easy answer to all this. But certainly part of it is wide and open discussion of issues. As, for example, in the recent discussion of embryonic stem cell use in research in the UK, the right way to go about things is first to have wide consultation (involving a range of view points, including ethicists, jurists and lay-people along with the experts) carried out openly and with plenty of time for the discussion to be aired and digested. When, after three years of such discussion, the issue was then brought to Parliament, we saw in both Houses an overwhelming indorsement that – ethical pangs notwithstanding – research towards capturing the health benefits of this work should proceed, albeit under strict provisions. In short, as I have just said and as I said in response to earlier questions, wide consultation and open discussion have to be the key in these issues at the interface between science and society.

Some say that the last century was one of physics but that the present one will be the century of biology. Do you agree?

I agree in the sense that the last century saw a high number of advances in all areas of science, but perhaps most importantly in basic physics. In the 21st Century, the fractal frontiers of science are perhaps going to be longer (by an appropriate measure of fractals!) in the life sciences than in the physical sciences. But not for one instant does this diminish the huge importance of the vast range of problems on the frontiers of physics. Nor does it make as clear as it should that many of the people pushing forward the envelope of the known in the life sciences will be likely to have a background in physics!

For more information:

Philippe Busquin web links:

Home page:
http://europa.eu.int/comm/commissioners/busquin/

FP6:
http://www.cordis.lu/rtd2002/home.html

Sir Robert May web links:

Home page:
http://mathbiol.zoo.ox.ac.uk/bob/bob.html

The Royal Society:
http://www.royalsoc.ac.uk/

EPSRC:
http://www.epsrc.ac.uk/

How to write a technology implementation plan

Sean McCarthy

In European Union R&D contracts two contractual documents must be presented at the end of a contract: a scientific report describing the scientific developments and a Technology Implementation Plan describing how the results of the research and development will be exploited. This article provides a brief overview of a Technology Implementation Plan, the background to the document and sources of information to complete the TIP. The article is based on a training course developed by the author.

Background to the Technology Implementation Plan

During 1995 the European Commission funded a range of studies to assess the impact of the European Union (EU) research and development (R&D) programmes. The results of these studies were published in the Green Paper on Innovation (http://europa.eu.int/en/record/green/gp9512/ind_inn.htm) The highlight of this document was known as the 'European Paradox'. The Green Paper found that European scientists were producing world class science BUT this was not reflected in European economic performance. It found that, while European scientists were publishing scientific papers, American and Japanese scientists were publishing papers, filing patents, launching products and launching companies.

This 'European Paradox' stimulated a major debate in Brussels. The EU politicians and EU officials agreed that, in future, better use would have to be made of the results of EU research and development. In 1997 the European Commission completed a 5-year assessment of their R&D programmes. The report, which was known as the Davignon Report (after its chairman Viscount E. Davignon) argued that " the next Framework Programme must be firmly based on the twin pillars of scientific excellence and economic and social relevance".

In the EU R&D contracts the 'scientific excellence' is described in the scientific report and the 'economic and social relevance' is described in the Technology Implementation Plan.

Overview of the technology implementation plan

The TIP can be found on www.cordis.lu/fp5/tip.htm The documentation consists of a set of guidelines to prepare the TIP and a set of data sheets which are standard for all contracts. Writing the TIP is quiet simple as it involves filling in a number of forms summarising the results of the project and the plans the partners have to exploit the results. The difficult tasks are to identify the useful result, to source information on potential applications and finally to identify the different routes for exploitation.

The TIP has four main parts:

Part 1: This is an overview of the work and it will be used by the European Commission to promote the results of the work. It is a public (non-confidential) document and is written in a journalistic style.

Part 2: In this section each partner will describe how they plan to exploit the results of the R&D. This part is confidential and partners can send this to the European Commission without showing it to the other partners.

Part 3: This will be used by the Innovation Relay Centres and other Commission Services to promote public results from the work and to find organisations who would be interested in further developing the results. This is a public document .

Part 4: This will be used by the European Commission itself to justify the investment in the EU R&D programme. Part 4 summarises the contribution of the work to EU legislation, EU policies and other EU issues.

The role of the TIP

To most researchers the TIP is seen as another bureaucratic document. To fully appreciate the document you must consider its role in the eyes of the European Commission, the researchers and private enterprises:

The role of the TIP: The European Commission

To the European Commission the TIP is a tool which can be used to measure the impact of their R&D programmes. The officials in charge of the EU R&D programmes are under considerable pressure to argue for increased R&D funding in future programmes. If researchers prepare high quality TIPs, the EU officials will have better arguments for future R&D funding. The second role of the TIP is to identify genuine exploitable results. Successful results are as important to the EU officials as they are to the researchers.

The role of the TIP: The researchers

The most important point is that the TIP IS A CONTRACTUAL DOCUMENT. The payments by the European Commission will be based on the completion of a TIP.

In the TIP researchers are asked to identify further research based on the work done in the project. In other words the TIP can be used to promote or identify future research projects.

The TIP also summarises the ownership of intellectual property. While the TIP is not a legal document the issue of intellectual property has to be discussed and agreed by the partners. (The model contact and the consortium agreement are the legal documents that define the ownership of the intellectual property)

The role of the TIP: Private enterprises

For private enterprises the TIP summarises the ownership of intellectual property.

The TIP can also be used as a link to other sources of public and private funding. Private enterprises can use to TIP to identify Structural Funds or special initiatives such as LIFT (Linking Innovation, Finance and Technology). This is a programme to help venture capitalists to assess the results of EU R&D projects.

Routes for exploitation and sources of information

The results of EU R&D projects can be exploited through a number of routes. These can be summarised as follows:

1. Commercial Exploitation
2. Input to EU and International Standards
3. Input to EU Policy
4. Further Research
5. Social Good

To help researchers identify the most appropriate routes to exploit the results of their projects the author has designed a training courses which covers each of the routes (www.hyperion.ie/tipcourse.htm). A web page has also been prepared summarising the main web sites which can be used to study each of the above routes. This web page can be found at www.hyperion.ie/tipwebsites.htm

How to write a TIP

The instructions in the TIP guidelines suggest that the co-ordinator of the project should write part 1, part 3 and part 4 and that each partner should write an individual part 2. It does not work !

The most practical approach is to include one partner in the project (known as the 'Exploitation Manager') and to give this person the full responsibility to prepare the TIP. The TIP should be designated as a separate workpackage in the project and it should be allocated resources (labour, travel etc) in the same way as the technical development.

During the project the TIP workpackage should be reported in the same format as the technical developments. The contact states that the TIP should be produced at the end of the project. However, most project officers also expect to see a draft (Version 1) at the mid-term review.

How to find the exploitable results

This is actually the difficult part. Most researchers concentrate on the main deliverables from the project i.e. the technical development, the data, the publication etc. However, exploitable results can also be found in the tools, components and non-contractual documents which are produced in projects.

The best way to find the exploitable results is in the following way:
Step 1: Examine the project for the following items:
Technical prototype, documents, data, software, workshops, methodologies, web sites, media (CD ROMS, videos), training material, demonstrations, pilot sites and models.
Step 2: Identify real individuals (e.g. product developer in an instrument company) who will be excited with each result. This will require an input from the user organisation.
Step 3: Select the best results and find out why the person is excited about the result (i.e. the relevance of the results)
Step 4: What does the user call the result ? This is actually what you will put in the TIP.

The above process can be done as a TIP clinic and is a very simple way of 'translating' the researcher's description of a result into a format which is relevant to a potential user.

Conclusion

The Technology Implementation Plan can be approached by researchers in two different ways. The simplest approach is to fill in the tables 'to meet their contractual requirement'. The second approach is to use the TIP as a strategic document to identify future research opportunities, to identify results which can be genuinely exploited and finally to make sure that the intellectual property of the researcher is protected.

The TIP is not going to disappear. In future EU R&D programmes, and indeed in some National R&D programmes, the TIP will become an important aspect of R&D projects.

The successful exploitation of R&D results will require individuals who are both commercially and politically aware, who are able to acquire 'competitive intelligence' and who are able to 'make innovation happen'. These are our future entrepreneurs. The preparation of a Technology Implementation Plan is an ideal tool to develop these rare skills.

Author
Sean McCarthy *(sean.mccarthy@hyperion.ie)* is Managing Director of Hyperion Ltd. Hyperion specialises in the development of training course for research managers. Full details of their training courses can be found on www.hyperion.ie. In 1998 he was invited by the Finnish Government to prepare a strategy to improve the commercial exploitation of the results of Finnish R&D. In 2000 he chaired an EU working group on 'Obstacles to Mobility between Academia and Industry'.

EU copyright directive

The European Commission has welcomed the adoption by the EU's Council of Ministers on 9 April of the Directive establishing pan-EU rules on copyright and related rights in the Information Society. Adoption of the Directive fulfils one of the priority objectives set by the Lisbon European Council as part of the process to preparing the transition to a competitive, dynamic and knowledge-based economy in the EU. The final balanced outcome is a result of over three years of thorough discussion and a fine example of co-decision making where the European Parliament, the Council and the Commission have all had a decisive input. The adoption by consensus demonstrates the extent to which the Directive achieves common ground in an area of diverse interests. It is an essential building block for the Information Society and until now, one that was missing. The Directive is due to be implemented by Member States in national law within 18 months of its publication in the EU's Official Journal.

Internal Market Commissioner Frits Bolkestein commented that "This is a very significant achievement. Not only is this Directive the most important easure ever to be adopted by Europe in the copyright field but it brings European copyright rules into the digital age. Europe's creators, artists and copyright industries can now look forward with renewed confidence to the challenges posed by electronic commerce. At the same time, the Directive secures the legitimate interests of users, consumers and society at large."

The text, as adopted, includes all nine of the compromise amendments voted by the European Parliament at its February 2001 plenary session. The Parliament's amendments had already been fully endorsed by the Commission especially as they reflected the delicate balance of the Council's Common Position.

The Directive will stimulate creativity and innovation by ensuring that all material protected by copyright including books, films, music are adequately protected by copyright. It provides a secure environment for cross-border trade in copyright protected goods and services, and will facilitate the development of electronic commerce in the field of new and multimedia products and services (both on-line and off-line via e.g. CDs).

The Directive harmonises the rights of reproduction, distribution, communication to the public, the legal protection of anti-copying devices and rights management systems. Particular novel features of the Directive include a mandatory exception for technical copies on the net for network operators in certain circumstances, an exhaustive, optional list of exceptions to copyright which includes private copying, the introduction of the concept of fair compensation for rightholders and finally a mechanism to secure the benefit for users for certain exceptions where anti-copying devices are in place.

The word from Brussels

Tom Elsworth

The development of Research and Technological Development Framework Programme 6 goes on in its stately fashion. It passes across the stage that is Brussels rather like a crinoline clad 18th Century lady on the dance floor- she moves in a gliding motion from one point to the next, but the moving feet are invisible. Perhaps that is rather too generous a simile; those ladies generally moved I would suppose, with far more certainty of direction and timing than ever did the development of any EU policy, especially the development of an R&TD Framework Programme if previous experience is anything to go by.

However that might be, we now have the Commission's proposal for a decision by the European Parliament and Council to establish both the EC and the EURATOM programmes for 2002 to 2006 (see COM (2000) 94 final of 21/02/01). The Council gave its initial consideration to the proposal on 3rd March. The European Parliament's committee for industry, external trade, research and energy has been asked to give an initial opinion in term for a draft work programme for delivery of the Framework programme to be prepared by mid May. The members have complained however, of the very tight timetable describing it as "deplorable" in relation to such a large and important budget item. It certainly seems strange when consideration is given to the very prolonged nature of the whole approval process (see below) and the very many months that the Commission have had already to get their proposals this far.

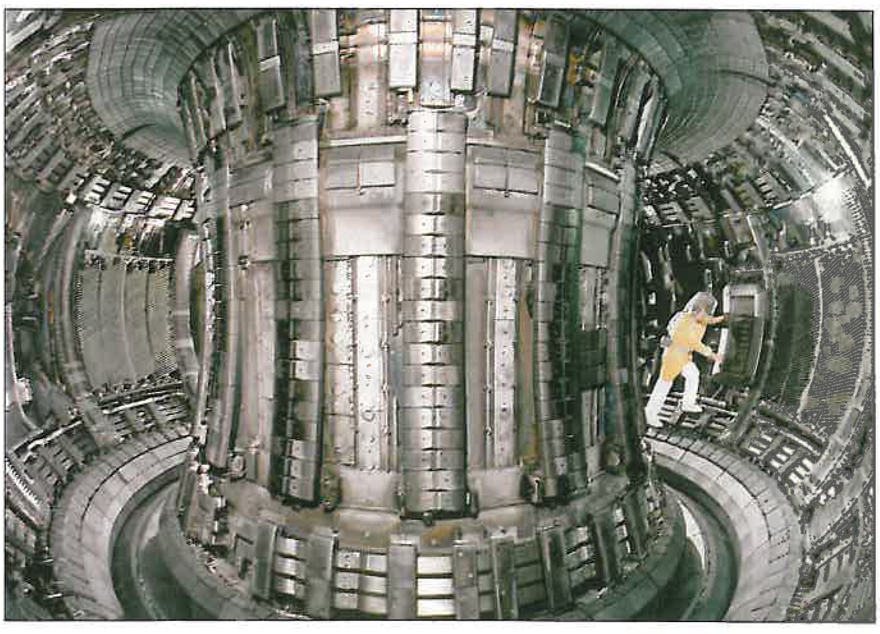
A second full Council discussion is expected at the end of June to be followed by a first formal reading by the Parliament (probably after the summer in September). By the end of the year there should in theory, be a common position amongst the Council members enabling the co-decision process to work its way through (it is generally a difficult birth) by the end of 2002. The present planning shows the common position being reached at the 1st October Research Council under the Belgian Presidency. This prolonged process gives all of us plenty of time to influence the final outcome. Let me encourage every EPS member to read the proposal and the various national position papers. Everyone should follow developments (as we will here) and make their voice heard by Governments, the Commission and the European Parliament.

The overall budget proposed is Euro 17.5 Billion for the two framework programmes together, (of which Euro 16.28B is for the EC programme). Commissioner Busquin says, "Europe has set out to become the most successful and competitive knowledge based economy in the world. Research and innovation are the keys to success in achieving this goal". His proposal highlights seven priority areas:

- information society technologies – Euro 3.6B
- sustainable development – Euro 1.7B
- Genomics and biotechnology – Euro 2.0B
- Nanotechnologies – Euro 1.3B
- Aeronautics and space – Euro 1.0B
- Ford safety and health – Euro 1.0B
- Citizens and governance in European Society – Euro 0.23B

In addition just over Euro 3B is slated to support the establishment of the European Research Area including nearly Euro 2B to promote development of Europe's R&TD human resources. The EURATOM proposals remain similar in shape to previous programmes.

The Commission proposal puts considerable emphasis on "empowering" participants in large integrated projects giving them the possibility to define and run their own detailed programmes even including issuing their own calls for proposals. The term "public/private" partnership has been used. A very Anglo-Saxon concept perhaps but appropriate to the needs of R&TD. It is certainly to be hoped that none of this gets watered down. It is not without challenge; the Greek Government for instance has expressed considerable reservations about both the proposed concentration on funding big integrated projects and the proposed "externalisation of management activities".



Left: Inspecting the interior of JET (Joint European Torus)

Below: Exterior of the JET experimental facility at Culham Science Centre

Photographs supplied courtesy of EFDA JET

It is interesting that these proposals have emerged from a Research Directorate under a Greek DG. Perhaps it is a case to use an English turn of phrase, of poacher turned gamekeeper? Does the DG recognise from his own experience the inadequacy of impact achieved by the penny packet funding approach of previous Framework Programmes? The press release from the Research Council on 3rd March clearly reveals a dichotomy of views between Ministers favouring big integrated projects and those working hard to avoid "marginalisation of the interest of smaller research actors".

This column is never afraid to voice its opinions, we and many others in Brussels and the leading research units around Europe have believed for many years that much money and good brains were being wasted in sub-critical mass activities in the smaller member states. The view has often been voiced that a management consultant from Mars with no political or national axe to grind would instantly close down many of the "smaller research actors". It is of course difficult for the Commission to act against any entity boasting a national flag.

Our notional interplanetary consultant would also give strong support to the "externalisation of management activities". The evidence is clear that successful science and innovation arises when flexibility and freedom from bureaucratic controls is granted. An example from our own recent European R & TD history is the massive and unparalleled success of the JET Project set up as a free standing entity entrusted to take a gigantic technological leap and which out-jumped the expectations of even its strongest proponents.

Indeed the French opinion paper on the EURATOM section of Framework Programme 6 goes so far as to say that the European Fusion research Programme as a whole is the sole example currently existing of a totally integrated big project. It is said to be comparable with the Commission's proposal for creation of a European Research Area and an exemplar therefore one might conclude, of what the ERA could achieve.

Calls for Proposal

Improving Human Research Potential and the Socio-economic Knowledge Base

- Raising Public Awareness of Science and Technology Thematic Networks and Accompanying Measures (IHP-RPA-01-1)
  Opening date: 07.04.2001
  Closing dates: 02.07.2001

Confirming the international role of Community research

- Calls for proposals for indirect RTD actions
  Opening dates: 15.03.2001
  Closing dates: See Call texts

Improving Human Research Potential and the Socio-economic Knowledge Base

- Stays at Marie Curie Training Sites Thematic Networks and Accompanying Measures (IHP-MCHT-01-1)
  Opening date: 15.02.2001
  Closing dates: See Call text

- Marie Curie Development Host Fellowships Thematic Networks and Accompanying Measures (IHP-MCHD-01-1)
  Opening date: 15.02.2001
  Closing dates: Sell Call text

- Industry Host Fellowships Thematic Networks and Accompanying Measures (IHP;MCHI-01-1)
  Opening date: 15.01-2001
  Closing dates: See Call text

Improving Human Research Potential and the Socio-economic Knowledge Base

- Open call for Strategic Analysis of Specific Political Issues Thematic Networks and Accompanying Measures (IHP-STRATA-2001-1)
  Open date: 01.02.2001
  Closing dates: See Call text

Promoting a User-Friendly Information Society

- 6th IST Call for proposals
  Opening date: 27.01.2001
  Closing dates: See Call text

Intelligent Manufacturing Systems

- Joint call for proposals –IST & GROWTH programmes – "Intelligent Manufacturing Systems" (IMS)
  Opening date: 27.01.2001
  Closing dates: See Call text

Improving Human Research Potential and the Socio-economic Knowledge Base

- Call for proposals for Common Basis for Science, Technology and Innovation Indicators (IHP_CBSTII.01.1)
  Opening date: 16.01.2001
  Closing dates: 17.04.2001, 15.10.2001

Statistics

A very interesting recent EUROSTAT report gives an overview of our R & TD at the start of a new century.

- Since 1993 our relative R & TD effort has decreased while in USA and Japan it has increased
- In Japan and USA the business sector accounts for the greatest part of their R & TD
- Germany, France, Italy and UK all reduced the R & TD spend as a proportion of GDP.

Worrying I should say! What do my readers think (I suppose there are some out there and would be glad to hear from them by e-mail to the address below).

Communiqué PR is a communications consulting firm specialising in supporting organisations in the science, engineering and technology sectors. Areas of work that can be tackled include media relations, event management, video and print promotional material, public awareness activities, lobbying in Brussels or in relation to EU linked activities and strategic planning and integration of internal and external corporate communications, Public Relations and Public Affairs.

Tom Elsworth, one of the partners in Communiqué PR, has prepared this article (it reflects his own opinions on matters in Brussels). Tom has experience working in the external relations of major science based organisation extending over 25 years and in locations including London, Brussels and Washington DC. Recent customers of Communiqué PR include EPS, UK Atomic Energy Authority and the Commission of the EU.

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noticeboard

New Sections approved

The Council approved the creation three new sections. If you are interested in learning more about them, please send an e-mail to the address indicated.

Division: Plasma Physics
New Section: Dusty Plasmas
Contact: J. Meyer-ter-Vehn: jxm@mpq.mpg.de

Division: the Joint Astrophysics Division of the EPS and the EAS
Gravitational Physics
Contact: G. Schaefer: schaefer@tpi.uni-jena.de

Division: Condensed Matter
New Section: Electronic and Optical Properties of Solids
Contact: J. Beeby: zjb@leicester.ac.uk

Physnet Charter

The Executive Committee approved the proposed Physnet Charter, which can be found at http://physnet.uni-oldenburg.de/PhysNet/charter.html. The PhysNet is an international effort to support the research, teaching and public understanding of physics to develop, establish, and maintain a high quality, relevant, global, coherent and synergetic communication and information set of services for physics. All member societies are encouraged to sign the Charter, as are all physics institutions

2005 as the World Year of Physics

M. Ducloy, EPS President obtained unanimous approval from the Council to work towards the international recognition of 2005 as the World Year of Physics. Using the 100th anniversary of A. Einstein's 2 papers published in1905 as a rallying point, the goal is to raise the pubic understanding of physics through a series of events organised around the world. The EPS will act as a catalyst to generate interest in organisations such as IUPAP and UNESCO.

Composition of the Executive Committee

Following the elections at Council below is the composition of the EPS Executive Committee

President	Martial Ducloy (France)
Treasurer	Peter Reineker (Germany)
Secretary	Christoph Rossel (Switzerland)
Members	Maria Allegrini (Italy)
	David Brown (UK)
	Gerardo Delgado Barrio (Spain)
	Karel Gaemers (Netherlands)
	Dalibor Krupa (Slovakia)
	Per-Anker Lindgard (Denmark)
	Ryszard Sosnowski (Poland)
	Christos Zerefos (Greece)

Outstanding Contributions

The Executive Committee designated two laureates for the 2001 Public Understanding of Physics Medal. A first medal will be awarded to Prof. L. A. Turski for his activities in popularising physics in Poland, including the Science Picnic. A second medal will be awarded to Prof. A. Bradshaw, for his public understanding of physics activities in Germany, particularly the events in "Year of Physics".

Summer School in Advanced Photonics

The first international NKT summer school in advanced photonics will be held in Copenhagen on August 19 - 26 2001. Optical communication is changing the world we know into a glassy bit world. This revolution is driven by a combination of exceptional technological skills, business opportunities and people exploring new ways of collaborating across borders be it in science, education or commerce. To be part of the school, please sign up at www.nkt.dk/summer

EPS QEO Prize

NKT, the leader in fibre optic manufacture and technological research and development will be the sponsor for the EPS Quantum Electronics Prize. The prize is awarded by the QEO Division on an annual basis to physicists who have made outstanding contributions to the field of quantum electronics and optics.

EPS Council highlights

Below are a few of the many highlights from this year's Council meeting (29-30 March)

European co-operation

In her opening address, the Deputy Mayo, Mrs Troxler Schmitt told the Council the story of Mulhouse: Mulhouse translates into the term "Miller's House". Throughout history, the region of Alsace has been the site of many wars and battles. One time, long ago, during one of the wars, a wounded soldier from the invading army sought refuge at the miller's house. The soldier and the miller's daughter fell in love and got married and founded Mulhouse. All children of Mulhouse, the legend says, are the fruit of this European co-operation.

Not a proper doctor

In reply to Mme Troxler Schmitt's use of the faux ami welcoming "Europe's physicians" (the French word for physicist), A. Wolfendale told the following anecdote: "In those in between years, after I received my PhD, and could use the title doctor, but before I became a professor, my son, like all of his class mates was asked "so what does your father do?", to which he replied "my father is a Doctor... but not a proper doctor".

Seed Money/Networks

H. Ferdinande told the Council of the importance of the contacts made and networks created through the EPS. "Some 5 or 6 years ago, I attended the Council meeting of the EPS in Lisbon. There, by pure coincidence I met the representative of the Macedonian Physical society, V. Urumov, while I was there as a representative of the EMSPS, and I was applying for my first EUPEN grant. We had never seen each other before, and after Council we went each our own way. We just had lunch together during the Council and this was all the seed money that was injected by the EPS.

However, in April 1999, Viktor approached me again and we submitted a project to the TEMPUS programme of the EU. We were successful and could start on 15 December 1999 the initiative. On 14 March 2001, we finished the project which received total EU funds of € 250 000. Most of the money (70%) was devoted to buying equipment and books to update the physics studies at the St Cyril and Methodius University of Skopje (Macedonia). On top that some 20 professors and assistants, as well as some 10 students visited universities in Belgium for one or two months, and up to three months for students.

Hence you see the very small seed money from EPS (just 2 lunches), was sufficient to trigger a budget of € 1/4 million from the EU!

Good News

C. Rossel reported on the plans for the new offices for the EPS Secretariat on the university campus in Mulhouse. The technical services of the university are currently studying the location of the building, which will be followed by an architect's drawing. Construction may begin as early as Spring 2002, with a move planned for the summer of 2003.

"Virtual EPS"
The proposed site for the new EPS Secretariat offices

In honour of Gero Thomas

P. Melville presented the IOP proposal to create a medal to honour Gero Thomas, Secretary General of the EPS for 25 years. The medal would be given on an annual basis for outstanding service to the EPS. There was unanimous approval from the Council.

Outgoing Members

The Council expressed its thanks to the outgoing (and outstanding) members of the Executive Committee: A. M. Eiro; D. Jerome and R. Klein.

Outgoing President

The Council expressed its thanks to Professor Sir Arnold Wolfendale the outgoing (and outspoken) President of the Society. Sir Arnold will be remembered for his energy and dedication to European science and for his remarkable wit. A new introduction has been added with which to begin an anecdote: "When I was President of the European Physical Society..."

Cheers Arnold.

Education Division action plan

A. Kleyn, Chairman

At its meeting in March the Education Division Board established the Division's action plan.

European conference on science education at the primary level

It was agreed that a European conference on science education at the primary level should be held during 2002. Aart Kleyn suggests to consider to have this meeting in conjunction with Physics on Stage 2, on 2-6 April 2002 at ESTEC, Noordwijkerhout, The Netherlands. Rosemary Feasey (who had chaired the Working Group on Science Education at the Primary Level at Physics-on-Stage 1) agreed to be the Chairman of the Planning Committee for such a conference and that she would produce a paper for consideration by the Committee.

European conference on teacher training

It was agreed that a conference on teacher training should be held in 2003; that it should be concerned with both pre-service training and in-service training. Brenda Jennison (UK) is willing to be chairperson of the planning committee for the conference. Prof. Harrie Eijkelhof (Utrecht NL) is willing to act as advisor. He has suggested to have a specific theme for the conference such as 'modern physics in the classroom'.

A survey of physics education in European schools

It was agreed that there was a need for a EUPEN-style survey of physics education throughout European schools. It was noted that Malvern College was willing to provide the necessary accommodation for the project and that T.D.R. Hickson would be willing to direct the survey. He was asked to produce a plan for the project in the hope that the necessary work could begin in 2003 and the funding for the project could be obtained.

Biographical posters

Warm approval was given to the series of posters already produced by EPS. A CD-ROM containing a preliminary form of most of the posters is available. These posters can be translated into national languages and then made available locally.

Posters on the relevance of physics to society

It was agreed that the production of a series of posters to promote better public understanding of physics and its relevance to society should be developed. It was agreed that the biographical posters were primarily aimed at 12-14 year olds, but these further posters should be aimed at 16-18 year old students, and the general public.

It had been suggested that different physical societies might be encouraged to produce posters on themes such as physics and the environment, physics and wealth creation, physics and sport, physics and music, etc. It was noted that the Institute of Physics was considering whether it might accept responsibility for a series on the theme physics and medicine, but in the first instance they hoped to produce three sample posters. It was hoped that the wording would be kept brief so that the posters could the more easily be translated into various languages and that there should be emphasis on bright and clear illustration.

Teacher exchange scheme

It was agreed that the teacher exchange scheme initiated by Alf Ölme should be given further publicity and that it should continue to be promoted and attempt should be made to start this up in several languages.

The International Young Physicists Tournament

It was agreed that the Section should continue to support the IYPT annual tournament to be held next in Finland. EPS has financially supported some participation from Eastern Europe. It was noted with pleasure that Professor Tibell had become President of the Tournament.

EUPEN

The EUPEN network was associated to a new EC pilot project 'Tuning of education structures in Europe' (supported by DG EAC to the amount of 500 kEUR). This activity tries to converge higher education in the field of Mathematics, Geology, Educational Sciences, Business and Geology and five disciplines (among Physics) are associated with it. Particular attention is given to education credit systems used. Physicists from 14 EUPEN countries are active on this matter.

At its executive committee meeting the EUPEN network has selected the following topics for its actions:

1. Quality assurance and evaluation in physics curricula ('ascent of physics').
2. First and second cycle physics degrees in the context of the Bologna Declaration.
3. Networking opportunities for specialisation in physics.
4. Trends in physics student enrolment and destination ('a scent of physics and a scent for physics').
5. Innovations in physics (multimedia) teaching and learning.

The next meeting of the EUPEN network will be held on 7-8 September 2001 in Köln, Germany.

University section

Professor Titulaer has formed the committee of this section: I. Strzalkowski (Poland), H.-J. Jodl (D), Chr. van Weert (NL), M. Vollmer (D), R. Millar or B. Lambourne (UK). The activities of the section will be discussed soon by the committee in its first meeting.

Web development

Dr Eddy Lingeman has made the connections of the Divisional web site to the EPS-site. He is asking for more links to Physics Education related sites.

Membership of the division

The membership of the Division is open at no cost to all members of EPS and its affiliated societies. There will be no separate membership for the sections. All members of the Forum on Education will automatically be made members of the Division. At this point no special opportunities will be created for those, who are not (indirect) member of EPS. If there would appear to be such a need (many high school teachers are not member of EPS) this point will be reconsidered.

Articles for EPN

The editor of Europhysics News is soliciting articles for EPN. Both sections and the EUPEN network will consider seriously to provide articles for EPN. Any other input is appreciated.

Program of the Division at EPS12:
At the EPS-12 conference in Budapest a symposium at EPS-12 will be organised. It will be considered to run a physics education satellite meeting before EPS-12.

Physics on stage 2
Its was welcomed that CERN, ESA and ESO will organise a second 'Physics on Stage' at ESTEC, Noordwijkerhout, The Netherlands on 2-6 April 2002. The Education Division will solicit to be involved again in this round. Kleyn seems a good representative since he is close to ESTEC.

Dates of next Board meetings of the Education Division
As possible dates are mentioned Friday 7 September in Köln, Germany in connection with the EUPEN Forum. The meeting thereafter will be before the EPS-12 conference in Budapest on 26-30 August 2002.

Brighton to host Condensed Matter Congress

Eoin O'Reilly

Plans are now well advanced for the 19th General Conference of the EPS Condensed Matter Division, which will take place from 7-11 April 2002 in Brighton, U.K. This is one of the leading condensed matter conferences in Europe. The format of the Brighton meeting will be similar to the most recent EPS-CMMD conferences in Montreux, 1999 and Grenoble, 1998, each of which attracted about 1300 participants. The programme will be based on parallel mini-colloquia, covering the full spectrum of condensed matter and materials physics, and will also include a wide range of invited and plenary talks, covering novel and established areas. The 2002 meeting is being organised in conjunction with the annual IoP Condensed Matter and Materials Physics Conference, which typically attracts 650 participants. The combined conference will therefore provide an excellent opportunity for meeting with and presenting work to a wide international audience.

Brighton developed as a holiday resort in the 19th century and is a lively town on the south coast of England. The venue was chosen both for its facilities and because of its ease of access for European visitors. London Gatwick airport is just 30 minutes away by train, and Brighton is also within easy driving distance of Dover and the Channel Tunnel. The conference sessions will be held in the Metropole Hotel and in the neighbouring Brighton Centre. The venues are ideally located on the Seafront in Brighton, allowing visitors to take full advantage of the town and all its amenities. Restaurants, pubs, shops and local nightlife are all within easy walking distance of the hotel.

The Program Committee, chaired by Peter Littlewood (Cambridge), have been selecting about 60 mini-colloquia topics, which, along with plenary talks and posters, will form the core of the conference. Each mini-colloquium is being organised by two chair persons, preferably of complementary backgrounds and from different countries to ensure broad participation. Suggestions for invited speakers can be submitted by any member of the condensed matter community through the conference web page: http://physics.iop.org/IOP/Confs/CMD19/

"One of the principal aims of the meeting is to provide an opportunity for young researchers to present their work" said Eoin O'Reilly (Surrey), the conference chairman. "This will be strongly encouraged both through the mini-colloquia and the poster sessions, with prizes for the best student posters". In addition, the Conference will begin with a Student Day on Sunday 7 April. This will consist of a series of lectures by leading experts aimed at a general research student audience and designed to enhance appreciation of the key scientific issues of the meeting. A free sandwich lunch will even be provided for students that day, to encourage their active participation!

The conference will include a full social programme including a welcome drinks reception on 7th April, further receptions during the conference, and a range of visits and excursions. Overall, the meeting promises to maintain the high standard and spirit of the previous Montreux and Grenoble meetings.

DG Research News Centre

The Commission's Research DG has launched a News Centre for European Research on its web site to make developments in European science more accessible. Anyone interested in scientific research can browse hundreds of articles and case studies on EU research under various thematic headings such as energy, environment, medicine and health, new products and materials etc. This should prove particularly useful for journalists, students and researchers. The contents are written in a style that is easy to understand, without shying away from technical details where necessary. The Research News Centre is part of the Commission's efforts to bring science and society closer together. It also marks the beginning of a transition to a policy of publishing electronically first, making EU science news and articles will be available online much more quickly than in the past.

Other improvements
The News Centre is just one of several recent developments on the Commission's Research web site. Apart from a gradual redesign of the whole site to make it easier to use, recent additions include a Highlights section on the main page (http://europa.eu.int/comm/research/index_en.html) and European Research Headlines (http://europa.eu.int/comm/research/headlines.html). As the name suggests, Highlights list one or two of the most interesting items recently added to the site - a kind of best of the 'What's new?' section. Headlines, on the other hand, is a weekly feature giving summary details of three or four recent developments in European research. These are not restricted to EU-funded research, but cover the whole of the European Research Area.

Future developments include indexing press releases by topic, and better index and search facilities in general. In fact, the search facility on the redesigned pages already allows a user to limit their search to the Research pages only. In future, users will be able to restrict a search still further to those parts of the web site dealing with a particular topic or programme. Better indexing of information using a standard set of keywords will allow users to find information regardless of where they begin or how they look.

from europa.eu.int

Letters

Dear Sir,

R. Klapisch has published in the November/December issue of Europhysics News an interesting article on the so-called accelerator driven systems, i.e. subcritical nuclear reactors driven by a strong spallation source. Unfortunately there are a few significant misconceptions in the article regarding the safety of nuclear installations in general, that should be corrected.

The article identifies the reason for all accidents leading to core damage as "critical power excursions", arising as a result of positive reactivity. It is argued that because of larger margins to prompt criticality (due to operating in a subcritical regime) an ADS is inherently much safer than a traditional reactor. The fact is, that reactivity type accidents are not the only, and in fact the least probable, class of accidents. In the case when the reactivity quantitatively exceeds the fraction of delayed neutrons, also called prompt criticality, the power excursion can be exceptionally fast, leading to prompt core damage with possible chemical explosions that enhance the chance of release the radioactivity to the environment. This is only the case when inherent physical feedback effects, decreasing the reactivity when temperature rises, are absent. This is roughly what happened in Chernobyl, where the reactor design even implied a positive reactivity feedback, thereby enhancing the power excursion. However,a more likely scenario is that the nuclear reaction is stopped, but the so-called rest heat, arising from the decay of the radioactive products, is not cooled away. This is called cooling-type accidents. They can also lead to core melt-down, as was the case in the Three Mile Island accident.

In reactors operating in the Western world, reactivity type incidents are very improbable because of conservative design including negative power feedback coefficients. And for this reason it is misleading to claim that an accelerator driven system is much safer than a traditional reactor. There has indeed never been a reactivity type accident in a Western nuclear power plant. Three Mile Island was not a reactivity accident, but a cooling-type accident.

Accelerator-driven systems are just as vulnerable for cooling type accidents as traditional reactors. This fact is not even mentioned in the article. So while it is clear that accelerator driven systems have definite advantages compared to recent reactors what regards fuel utilisation, waste production etc., the safety aspect, as presented in the cited paper, is irrelevant or at least unreasonably exaggerated.

Interested readers may find more material on this subject in a recent article of one of the undersigned, H. van Dam, in the January-February issue of Nuclear Europe Worldscan.

Yours sincerely

Professor Hugo van Dam
Interfacultair Reactor Instituut, Delft University of Technology, Mekelweg 15, 2629JB Delft, The Netherlands

Professor Imre Pázsit
Chalmers University of Technology, Department of Reactor Physics, SE-412 96 Göteborg, Sweden

The author replies:

Professors van Dam and Pászit are correct in saying that reactivity type accidents are not the only type accident that can happen with reactors and that Western type reactors are much less prone to these than the Soviet designed ones.

The fact however remains that it was post-Chernobyl that many countries initiated moratoria of various sorts. Apparently, public opinion in Sweden, Austria, Italy etc. was not convinced by the (reasonable) arguments given by specialists such as Professors van Dam and Pászit. If one hopes some day to resurrect nuclear power (say to answer concerns about global warming), I believe that all concerns of the public – even those deemed improbable – should be answered.

To give an example, I for one would deem as very unlikely that any harm could be done by low frequency magnetic fields arising from computer displays. Yet when this was raised (mostly in Sweden I believe) the wise answer by the computer industry was not to argue about implausibility but to quietly move to make shielded displays in order to satisfy the popular demand. I wish the specialists in nuclear power would meditate about that example.

The special issue of Europhysics News aimed at reviewing applications of **accelerators**, hence the emphasis given to Accelerator Driven Systems the main impact of which is to provide an additional degree of freedom to the amount of naturally occurring "delayed neutrons" that allow critical reactors to be controlled.

It so happens that U235 (the only fissionable element occurring in nature) is also the one that gives the highest proportion (0.6%) of delayed neutrons. This figure rapidly decreases when going to heavier systems such as Plutonium (0.3%) and the so-called minor actinides. An actinide burner such as the Japanese designed Jaeri would have to deal with a fraction as low as 0.1%, making its control a much more tricky (hence costly) business. Again the issue of destroying nuclear waste is crucial to the survival of nuclear power – as well as to its orderly phasing-out– and therefore one has to think of all the advantages that ADS can offer.

It is absolutely correct that, when a reactor (even a subcritical one) is stopped, one has to deal with the heat coming from radioactive decay of the fission products. For that purpose, we incorporated in the Rubbia design a spontaneous cooling by radiation and air convection, (borrowed from the American liquid metal design) called the RVACS. Another cause of accident is the TLOP (Total Loss of Power): if there is a power breakdown in the plant, pumps will stop and lack of cooling will cause core meltdown. This is completely avoided in our design because there are no pumps: the heat is evacuated to the heat exchangers in a completely passive way by convection inside the molten Lead coolant. That feature is described in § 4 of the paper. Because of space limitations (there is only so much that you can say in 2000 words and 8 figures), I did not mention the RVACS, which I am sure is well known to Professors van Dam and Pászit.

Robert Klapisch
CERN, 1211 Geneva 23, Switzerland

In the recent feature article by Renée Lucas in Europhysics News 32/1, the fascinating variety of nuclear shapes is discussed. But the view brought by the author focussed on the achievements of one particular technique in nuclear structure research, namely in-beam spectroscopy, and therefore bypasses the important results from other techniques such as particle transfer reactions and decay studies. With the advent of powerful instruments such as recoil separators, decay spectroscopy and in-beam spectroscopy are growing towards each other as the large γ-ray detectors, placed near the target, are triggered by the subsequent decay of the radioactive nucleus many meters away at the focus of the recoil separators, which separates within μs the radioactive products of interest from the beam and unwanted background.

Especially when discussing shape transitions and shape coexistence in the lead region, this narrowed view leads to imprecise, even wrong information. The observation of shape coexistence in the Pb nuclei through the detection of excited 0^+ states does not come from the recent in-beam studies as mentioned in the article but from extended α- and β-decay studies conducted by our group at different Isotope Separator On Line (ISOL) and In-Flight (IF) facilities all over the world. Furthermore, the article mentions the confirmation of two low-lying excited 0^+ states in ^{208}Pb (without giving the reference) but probably the author alludes to the recent observation of two extremely low-lying 0^+ states in ^{186}Pb, one of oblate deformation and one of prolate deformation, forming together with the spherical groundstate a shape triplet. This result was obtained by an international collaboration using the SHIP velocity filter of GSI, Darmstadt and was published as a letter to Nature (A. Andreyev *et al.*, Nature 405, (2000),430 – 433). In fact the observed states form the first three states in ^{186}Pb, thus below the first excited 2^+ state. This is unique in nuclear physics and maybe also in other fields as for this quantum system it is easier to change its shape from spherical through oblate to prolate than to built up excitation energy through vibrations or rotations. And maybe the most intriguing aspect of this study is the fact that it is possible to relate this macroscopic shape-change to the action of only a small and specific number of particles thus linking macroscopic phenomena to their microscopic origin.

The atomic nucleus with its finite but elevated number of particles (< 300) and with its rich variety of possible configurations as two kind of particles (protons and neutrons) are interacting, is a fascinating mesoscopic system. Not all nuclei have been identified and the new field of radioactive ion beams, where unstable nuclei are accelerated and used in secondary reactions, will explore the unknown regions. Surprises will certainly come and, as the author states, it is by using the complete repertoire of available spectroscopy that a deep insight can be gained.

Mark Huyse and Piet Van Duppen*
Instituut voor Kern- en Stralingsfysica, University of Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium
* *on leave at CERN, Switzerland (Mark.Huyse@cern.ch)*

The author replies:

As I said in the introduction "this cannot be an exhaustive presentation of the recent results etc..". Of course, I recognize that in-beam spectroscopy is not the only way to study nuclear shapes and a lot of work has been done using alpha spectroscopy but also with lasers which are not described in my paper. I apologize for my typographical mistake in paragraph "Shape transitions and shape coexistence" where one has to read ^{188}Pb instead of ^{208}Pb at the end of the paragraph. The information given in this sentence was related to the work of Yves Le Coz (Eur. Phys. J. Direct A3 1-6 1999) that you mention also as a reference in your letter to Nature.

The aim of this article was only to draw the attention of non-specialists of the domain to the variety of nuclear shapes. I fully agree with the fact that it is indeed by a collaborative effort that eventually a full picture of the nuclear shape will emerge.
With best regards.

Renée Lucas
DAPNIA/SPhN CEA Saclay 91191 Gif-sur-Yvette France

Thermodynamics of Hell

The following is an actual question given on a University of Washington chemistry mid term. The answer by one student was so "profound" that the Professor shared it with colleagues, via the Internet.

Bonus Question: Is Hell exothermic (gives off heat) or endothermic (absorbs heat)?
Most of the students wrote proofs of their beliefs using Boyle's Law, (gas cools off when it expands and heats up when it is compressed) or some variant.
One student, however, wrote the following:
'First, we need to know how the mass of Hell is changing over time. So we need to know the rate that souls are moving into Hell and the rate they are leaving, I think that we can safely assume that once a soul gets to Hell, it will not leave.Therefore, no souls are leaving. As for how many souls are entering Hell, lets look at the different religions that exist in the world today.

Most of these religions state that if you are not a member of their religion, you will go to Hell. Since there are more than one of these religions and since people do not belong to more than one religion, we can project that all souls go to Hell.With birth and death rates as they are, we can expect the number of souls in Hell to increase exponentially. Now, we look at the rate of change of the volume in Hell because Boyle's Law states that in order for the temperature and pressure in Hell to stay the same, the volume of Hell has to expand proportionately as souls are added.
This gives two possibilities:
1. If Hell is expanding at a slower rate than the rate at which souls enter Hell, then the temperature and pressure in Hell will increase until all Hell breaks loose.
2. Of course, if Hell is expanding at a rate faster than the increase of souls in Hell, then the temperature and pressure will drop until Hell freezes over.
So which is it? If we accept the postulation given to me by Karen during my first year at university, "...that it will be a cold day in Hell before I sleep with you.", and taking into account the fact that I still have not succeeded in having relations with her, then, #2 cannot be true, and thus I am sure that Hell is exothermic and will not freeze.'
It is reputed that the student was the only one to get an A.

Anonymous e-mail

Letters, opinions, comments... please send them to:
Europhysics News, 34 rue Marc Seguin, BP-2136,
68060 Mulhuose Cedex, France
email: epn@evhr.net

activities

A Strategy Plan for the Society

M. Ducloy - President, P. Reineker - Treasurer, A.M. Eiro - Former Vice-Treasurer

During the Council Meeting on March 30/31, 2001, a Strategy Plan for the development of the EPS in the coming years was discussed and approved. This plan has been first worked out by a sub-committee of the EPS Executive Committee and endorsed by the EC. A shortened version of this Strategy Plan is given below. The preamble describes general political lines for guiding the future activities of EPS. Subsequent sections propose a structuring framework for implementing those actions, and discuss the financial resources needed to develop them. To be successful, this Strategy Plan will need the active participation of all the members and components of the Society.

EPS Strategy Plan 2001+

Preamble

The European Physical Society has been established more than 30 years ago as a union of individual physicists and Physical Societies of European Nations. At the beginning of a new century and, indeed, a new millennium, it is time for EPS to draw up a balance sheet of its activities, and then to define its objectives for the coming years, taking into account the accelerating changes of political, social and economic conditions in the present world.

Since 1968, EPS has steadily increased its number of Scientific Divisions and Sections, to more and more assert its presence in European Physics. The last creations are the Division of Statistical and Nonlinear Physics (1998), and, last year, the Division of Education. To disseminate information about the Society and European Physics, EPS publishes Europhysics News. Europhysics News is now distributed to the members of nearly all National Physical Societies in Europe. A large learned society needs to manage scientific journals: it is the case of EPS with Europhysics Letters (created in 1986) and the more education-oriented European Journal of Physics. However, it can be considered that the influence of EPS in Europe and in European Physics has not yet reached the level to be expected for a Society regrouping 36 National Physical Societies and 80000 physicists.

Five years ago, in March 1996, the EPS Council approved a Strategy plan, elaborated by Herwig Schopper, who was president at the time. It proposed action lines assembled along four headlines: Issues of Professional Physics, Care for the Next Generation of Physicists, East-West Co-operation, and Public Awareness and Information Dissemination. The issues presented in that plan have undergone developments with variable success. These themes should still be kept as important issues, but after five years, most of them need to be reconsidered and actualised.

The main objective of EPS in the coming years should be to turn it into a major policy-making professional organisation in Europe – in a way complementary to the goals pursued by National Physical Societies. This should be carried out by increasing the European presence of EPS and its visibility in the European Union, through its Executive Officers, Divisions, Committees, and its Secretariat. Obviously, it implies that EPS fully assumes its role in public awareness of physics, demonstrating the dynamical character of physics, and its exemplary nature as a scientific discipline with rigorous theoretical and experimental methods, as well as its "incubator" role in generating new disciplines (e.g., Astrophysics, Biophysics, Physics in Medical Sciences, Material Science, Information and Communication Technologies).

This major objective of EPS should be reached via the following actions:

1. Improving the visibility of EPS among European Physicists

EPS is the only European body in Physics, and, as such, should bring together – and represent – all European physicists. The visibility of EPS inside the community of European physicists has to be improved by increasing the presence of EPS in (i) the organisation of international conferences, workshops and physics schools, (ii) the control of leading European scientific journals (iii) the awarding of prizes, etc. A particular effort has to be made

- towards young physicists, in order to offer them all the services that an international learned society should provide, and also
- towards physicists in industry and professional physics (as was developed in the 1996 strategy plan).

To reach these goals, the role of EPS Divisions, which are in close contact with European physicists in their sub-disciplines, is essential and should not be underestimated. Each EPS Division has also to assume a leading role in its field, and should contribute its own share to these general objectives.

2. Improving the visibility of EPS outside the physics community: public awareness of physical sciences

The global visibility of EPS outside its community, which goes along with the promotion of physical sciences and the public understanding of physics, represents a major goal. Projects to be developed should include common actions with Learned European Societies in other scientific disciplines, an increase of the policy-making character of EPS, in particular by strengthening relations with other European bodies, e.g., the European Commission, or the European Science Foundation.

The promotion of physics should be performed at all levels of education (school, pre-university, university) and aim at emphasising the role of physics as an "incubator" of new emerging disciplines in Engineering and Technology. In this respect, an important initiative has been started by the EPS Executive Committee in December 2000: to make year 2005, "The World Year of Physics" – in reference to the 100 years jubilee of the famous papers of Einstein on relativity and photons – and to obtain its endorsement by international organisations. In the coming years, this project should summon up EPS strengths and bodies, as well as National Societies throughout Europe and worldwide. Obviously all these activities for promoting Physics should be devised in a geostrategic approach, developed through East-West relations, via the corresponding Action Committee (the East West Task Force), in the Divisions, as well as via North-South cooperation (in particular with Africa and South America).

Areas of Strategic Importance

For the EPS the following fields of strategic interest are identified:

1. Scientific Issues in Physics
2. Physics in Profession

3. Physics Education
4. East-West Cooperation and Physics for Development
5. Public Awareness and Information Dissemination

Core Business, Programmes, Projects

Each of these fields of strategic interest should be associated with specific members of the Executive Committee, the number of which will depend on the width of the field. The activities will usually consist of Core Business, Programmes, and Projects.

Core Business is that part of the activities, which continuously runs over the years and for which there might be no possibility of raising outside funding. In some areas, the Core Business part can be handled by the corresponding member(s) of the Executive Committee together with the EPS Secretariat.

A Programme is an ongoing activity that should normally be run by a Committee. Each Committee should regularly report to a member of the Executive Committee and preferably this person should also be a member of the committee that runs the Programme. Programmes reflect general policy of the EPS, and are established by the Executive and the Council. (An example of a Programme is the European Mobility Scheme for Physics Students/EMSPS.)

A Project should describe a specific action or series of actions to attain a defined goal within a given time. The major difference to a Programme is that Projects will end once they have achieved their goal, or reached their allotted time. Requests for project funding should be made to the Executive Committee. A member of the Executive Committee should be appointed to follow its progress. A final report should also be presented. (Examples of projects are the Malvern Seminar, and the Biographies Project.)

Programmes and projects are suggested by the Council, Divisions, Interdivisional Groups or individual members of the EPS. With the purpose of encouraging the suggestion of new activities, every year a meeting with divisional committee, interdivisional group and committee chairmen should be organised, preferably scheduled around the Council meeting. This will also provide the Executive Committee with the necessary input to draft the Society's budget.

Financial Resources

On the basis of the topical and organisational framework discussed above, the Executive Committee can structure, motivate and direct the development of the EPS, and establish the needs for financial support. Having the limited resources of EPS in mind, priorities should be chosen with respect to the essential goals of the Society. An important aspect is therefore to check whether EPS has the adequate funds to increase the services for the members, and also find a prescription of how to distribute and how to increase the income of the EPS.

Income has remained stable since the increase of the unit fee in 1996. However, more funds have become available for activities since that time, due principally to the move of the Secretariat to Mulhouse and reduced production costs of EPN.

Current sources for EPS income are membership fees, participation in publications, and the sale of Europhysics conference abstracts. In 2000, about 8% of EPS income came from conference services. The EPS needs to continue the development of these services. This requires the help of the Divisions that organise conferences. It was on the initiative of the Quantum Electronics and Optics Division that the EPS was able to obtain the contract for the CLEO Europe/EQEC conferences. EPS conference services can only be developed if similar arrangements can be made with other divisional conferences.

Generating more income is very important for expanding the role of EPS in Europe. The most obvious source is increasing the number of members. To that end, specific campaigns should be organised with the help of existing members, in particular to attract new Associate Members. The Interdivisional Technology Group should play a leading role in close collaboration with the Divisions.

There is scope for further involvement of the EPS in European publications. The EPS needs information about creation of new journals or the expansion of existing journals. The members of the EPS should take an active role in providing this information.

In addition to the suggestion to install programmes and projects, also possibilities for their financing have to be discussed. The initial financing of these activities by the EPS should be considered as seed money. In this connection, fund raising, e.g. from European programmes, must be considered seriously.

Finally, in connection with specific activities or to compensate for inflation, it might also be necessary to propose an increase of the Unit Fee in the near future.

The goal of the EPS

Highlights from M. Ducloy's presentation at Council. "The document is the result of numerous iterations for more than a year. The final version was prepared by A. M. Eiro, P. Reinecker and myself, and finalised by the Executive Committee. Its purpose is to state the policy of the EPS, define the areas of strategic importance, catalogue activities into define and attribute responsibility to monitor and implement, and establish a method for allocating resources. The EPS can proudly claim many successes since it was created 30 years ago. But there is still more to do. Comprised of national physical societies, the EPS needs to ask the question what it can do that does not double their efforts. The EPS must concentrate on issues with a European dimension.

Thanks to the foresight of H. Schopper, the EPS developed its first strategy plan in 1996 identifying important themes of Issues of Professional Physics, the Next Generation of Physicists, Public Awareness of Physics, and East West Co-operation. Looking at the budget allocations, it is clear that the EPS is successful in all areas except professional physics, even though it is identified as a priority.

What is the goal of the EPS? To raise the profile of physics at the European level. To do this effectively, we need to raise the profile of the EPS, in and outside of Europe and in and outside physics. Initiatives such as the position papers help, but we still have to work on this. The EPS needs to be the foremost learned society in physics in Europe, and must fulfil all of the main tasks, including the organisation of conferences directly from the secretariat, and the scientific management of high quality scientific journals. The EPS has a role to play in convincing European physicists to publish their best results in European journals.

The goals and activities of the EPS need to be interesting to attract younger physicists, not only as members but also as participants. Along the same lines, new divisions and sections are needed to keep in touch with the new developing fields of physics to safeguard the place f physics as the central scientific discipline.

Once we have shown that we represent all of the physics community in Europe, then we can go to other European bodies and assume a major policy making role.

Hannes Alfvén prize 2001

The name Shafranov caught for the first time international attention at the 2nd United Nations International Conference on the Peaceful Uses of Atomic Energy at Geneva in 1958 where, together with Leontovich, he presented the theoretical proof that a strong longitudinal magnetic field conferred to a toroidal plasma column not only the expected adequate thermal insulation but also its much needed stability. Of course, this particular work was just one, albeit important, manifestation of the pioneering studies undertaken by the young student Shafranov on the equilibrium and the stability of toroidal discharges.

On the topic of equilibrium, he had formulated in 1957, working in parallel with Lust and Schlüter and Grad, what is now known as the Grad-Shafranov equation. It was shown that the equilibrium equation for an axisymmetric system can be written as a differential equation for the poloidal flux function which comprises two arbitrary surface functions (the pressure profile $p(\Psi)$ and the current flux function $f(\Psi)$) that must be specified. This G-S equation proved to be an essential ingredient for designing the magnetic geometry and topology of high-temperature plasma confinement systems, not only tokamaks but also helical systems. In the latter case, a similar equation can indeed be obtained where all quantities remain fixed along a helix formed on a cylinder of radius r, but depend on the pitch of the helix and on r. Solving the Grad-Shafranov equation also reveals that all the centres of the magnetic surfaces are displaced with respect to the centre of the bounding surface, the highest displacement being achieved by the magnetic axis. This effect is known as the Shafranov shift (1962). It is easy to imagine why tokamak diagnosticians do not like this effect, even when they have long since learned to distinguish between the message and the messenger. As a positive side effect, the shift tailors the amount of magnetic shear in a discharge and can lead to what is known as α-stabilisation of turbulence. His insight into and fascination for magnetic geometry lead also to him proposing in 1972, together with L. Artsimovitch, to use plasma elongation as a means to improve tokamak confinement.

Professor Shafranov has also contributed tremendously to the theory of plasma stability. He initiated the theory of the kink modes, potentially the strongest of the ideal MHD instabilities, which lead to kinking of the magnetic surfaces and of the plasma boundary. One prominent case is the internal kink, characterised by the azimuthal mode number $m = 1$ and the toroidal mode number $n = 1$. In 1958, V. Shafranov showed that a sufficient condition for stability is that the minimum value of the safety factor q be greater than one: the Kruskal-Shafranov criterium. Experimentally, this instability manifests itself as a relaxation oscillation of the plasma parameters, which, on account of its most characteristic signature, became known as the sawtooth oscillation.

Besides through these many original contributions to plasma physics, Vitaly Shafranov has gained the esteem and gratitude of countless fusion plasma physicists by inscribing himself in the best tradition of Russian teaching. They particularly appreciate his many contributions to the series *Reviews of Plasma Physics* (Ed. by M.A. Leontovich, Gosatomizdat, Moscow; English translation: Consultants Bureau, New York), more than seven hundred pages : *"Plasma equilibrium in a magnetic field"* (Vol. 2, 1963), *"Electromagnetic waves in a plasma"* (Vol. 3, 1963), *"Plasma confinement in closed magnetic systems"* (Vol. 5, 1967, with L.S. Solov'ev), *"Equilibrium of current carrying plasmas in toroidal configurations"* (Vol. 11, 1982, with L.E. Zakharov), *"Equilibrium and stability of plasmas in stellarators"* (Vol. 15, 1984, with V.D. Pustovitov).

It is also fitting to mention in the context of the Alfvén prize some important contributions of Prof. Shafranov to space plasmas: on the structure of shock waves in plasmas (1957) and, together with R. Sagdeev, on the velocity space instability of plasmas with an anisotropic distribution function. The latter work describes the pitch angle instability that controls precipitation of particles from the Van Allen belts; it is considered as the first example of an Alfvén wave instability and is now used to explain the Alfvén Maser action set up in the ionospheric Alfvén resonator.

Professor Shafranov

The breadth and depth of his work make Prof. Shafranov an obvious choice as recipient of the Alfvén prize. It is however his emphatic wish that this prize also be regarded as a recognition of the collaborative contributions to the fusion endeavour of a score of Russian scientists and in particular of his good friend B. Kadomtsev, whose too early demise predated the establishment of the Alfvén prize. This attitude honours the recipient and is a testimony of the warm and generous personality of a truly great scientist.

Hannes Alfvén won the 1970 Nobel Prize in Physics for "his contributions and fundamental discoveries in magneto-hydrodynamics and their fruitful applications in different areas of plasma physics".
For more information, please see Europhysics News 31/4, 2000, page 32.

Book Review

R. Helsham: Lectures on Natural Philosophy. Reprint. Eds. D. Weaire, P. Kelly and D.A. Attis, P18 + x + 404 pp. + 11 plates. ISBN 1 898 706 17 4. Published 1999.

The physical tourist, while travelling in Ireland, should not forget to visit Trinity College Dublin with a large campus in the heart of the city. The west end of the campus includes many buildings from the 18th century, notably the Old Library – home of the priceless 8th century manuscript The Book of Kells. The Long Room of the Old Library is one of the most spectacular architectural spaces in Ireland.

Richard Helsham, physician and physicist (~1680–1738), entered Trinity College Dublin in 1698. After finishing his MA degree in 1705, he earned the degree of doctor of medicine in 1709/10. In 1711, as Trinity had established a new medical school, Helsham started lecturing to medical students on natural philosophy. In 1724, Trinity appointed him as a holder of a professorship, and with his new position he could continue to deliver the lectures on natural philosophy as he had for over a decade. He, like many of his colleagues at Trinity, had little interest in publishing his work, following the tradition of Trinity being the "silent sister" of Oxford and Cambridge. After Helsham's death, his pupil Bryan Robinson took up the task of editing Helsham's lectures on natural philosophy for publication. The *Course of Lectures in Natural Philosophy by the late Richard Helsham* went through seven identical editions 1739–1802. Selected parts continued to be published in three editions 1818–1834. Thus, Helsham's *Course* remained in use for well over a century.

Newton published his celebrated treatises *Philosophiae naturalis prinicipia mathematica* (usually called the *Principia*) and *Opticks* in 1687 and 1704, respectively. On the European continent Newtonian physics made but slow progress. In Great Britain, however, the abandonment of Descartes in favour of the Newtonian philosophy was much more rapid. Helsham, in any case, was a great admirer of Newton who, according to Helsham, had brought natural philosophy "out of the greatest darkness and obscurity into the clearest light."

Consequently, Helsham's *Course* is a thoroughly Newtonian text. A major reason for its success is that it presents Newton's original work in a simple and straightforward way. It is in fact one of the first purpose-written student textbooks on natural philosophy in the vernacular. As Helsham puts it, natural philosophy is "entertaining and delightful", contributing to the "ease and convenience of life." The *Course of Lectures* begins with a preface by Robinson laying out Newton's method and rules of philosophy as defined in *Opticks* and the *Prinicipia*. The first part of the *Course* deals with mechanics, and here the text looks surprisingly familiar to any modern student of physics (Helsham's *Course* is, one might say, the 18th century counterpart of Sears and Zemansky's *College Physics*). Topics include the composition of motion, elastic and inelastic collisions, simple devices such as the balance, lever and pulley, friction, motion on an inclined plane and projectile motion. All is explained with a minimum of mathematics. Helsham then moves on to hydrostatics, pneumatics and the theory of sound. The last part of the *Course* is devoted to light and optics, including the properties of lenses (dioptrics) and plain and curved mirrors (catoptrics). The "subtile fluid of light" is of course explained in terms of Newton's corpuscular theory. Finally, Robinson has added a few problems by way of appendix.

Helsham relies heavily on the treatments by Newton, but other scientists are occasionally mentioned in the text, *e.g.* Galileo, Descartes, Torricelli, Huygens and Roemer (who mistakenly is labelled Professor of astronomy to the late King of France instead of Denmark). Unintentionally, Helsham also delivers interesting pieces of information about daily life in the first half of the 18th century. Thus, in the lecture on friction, he discusses at length the construction of wheel carriages and the state of the roads in those days. When treating the pendulum, he gives some details on mechanical clockwork. In one of the numerical problems it is told that a Paris foot is to an English foot as 1142 to 1070 (the well-known British system of units, known as the imperial units, was not established until 1824).

In conclusion, Helsham's *Course of Lectures* – an early and popular Newtonian university text – offers interesting insights into the development of classical physics during a period of crucial changes. A sketch of Helsham's career, supplied by the editors, further illuminates the context into which Newtonian physics was received.

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Books for review

Nuclear Structure from a Simple Perspective
Richard F. Casten
Oxford University Press, 463 pp.

The Physics of Particle Accelerators
Klaus Wille
Oxford University Press, 315 pp.

The Genius of Science
Abraham Pais
Oxford University Press, 356 pp.

In Situ Real-Time Characterization of Thin Films
Orlando Auciello and Alan R. Krauss
Wiley-Interscience, 263 pp.

Genesis of the Big Bang
Ralph A. Alpher and Robert Herman
Oxford University Press, 214 pp.

Laser-Aided Diagnostics of Plasmas and Gases
K. Muraoka and M. Maeda
IOP Publishing Ltd, 295 pp.

Reaction-Diffusion Problems in the Physics of Hot Plasmas
H. Wilhelmsson and E. Lazzaro
IOP Publishing Ltd, 165 pp.

Theory of Photon Acceleration
J T Mendonça
IOP Publishing Ltd, 222 pp.

Introduction to Quantum Field Theory
V.G. Kiselev, Ya.M. Shnir and A.Ya. Tregubovich
Gordon and Breach Science Publishers, 435 pp.

Statistical Thermodynamics and Properties of Matter
Lucienne Couture and Robert Zitoun
Gordon and Breach Science Publishers, 604 pp.

Chaos and Harmony
Trinh Xuan Thuan
Oxford University Press, 366 pp.

Theory of Fusion Plasmas
Paper from the International School of Plasma Physics
Societa Italiana di Fisica, 474 pp.

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Editors, Physical Review C and Physical Review E

APS

The American Physical Society is conducting international searches for successors to the current Editors of Physical Review C (PRC) and Physical Review E (PRE), both of whom are retiring. Each position is that of the senior Editor of the journal, responsible for editorial standards, policies and direction of the journal, and leadership of the staff of remote and in-house editors. The Editor reports to the Editor-in-Chief. It is expected that each Editor will maintain his/her present appointment and location and devote approximately 20% of his/her time to the position.

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Peter Bond, Chair, PRC Search Committee OR Herman Z. Cummins, Chair, PRE Search Committee, c/o American Physical Society, 1 Research Road, Box 9000, Ridge, NY 11961-9000; electronically to edsearch@aps.org, or fax to +1 631-591-4275.

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