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Main

FROM THE EDITOR

Dudley Creagh

The IRPS Bulletin is at a crisis point. There are a number of reasons for this, but two essentially dominate: one is concerned with a lack of apparent interest by the members in its content and aspirations, and the second is related to the way we distribute the Bulletin.

I might assume, because I am not swamped by letters of complaint, that all is well, and I am doing a good job. I fear, however that is NOT the case, and all too few people read the Bulletin cover-to-cover. And I am not exactly overwhelmed by copy from the membership. I am willing to publish anything which might be of interest to the members, be it scientific papers, conference reports, letters to the editor, opinion, and so on. It would be good to feel that there IS, actually, a readership out there!! The distribution problem is also a significant problem. It costs money to make a hard copy of the Bulletin and send it out by post. It is true that we do have this web page, and on this web page we have a copy of the Bulletin.

However, we would like to send some of the copies by email. To that end we require an accurate set of email addresses and the computer platform, network software and word-processor used by members. It would help us considerably if each member could send us this information. This way we can start to reduce costs, and stop wasting your money.
Information should be sent to:

s-mckeown@adfa.edu.au

M.J.Farquharson@City.ac.uk

DO IT NOW!! **Make my day!!!**

PRESIDENT'S COLUMN

Bikash Sinha

Not available at this point in time

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LETTERS TO THE EDITOR

Unfortunately, none for this issue.

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REPORTS FROM MEMBERS

ESRF Users Meeting Report

Malcolm Cooper

on behalf of the ESRF Users Organisation

Department of Physics, University of Warwick, Coventry, U.K.

The history books show that this was the ninth meeting of ESRF users, although the first few took place at times when there was little to use, but lots to talk about. Now there are so many results that a one day meeting can do little more than highlight a few areas and offer a market place for the vast majority to display their results on posters for all to see.

This year 474 people registered for the meeting, which is a record, or near record. They were doubtless drawn to Grenoble by the associated workshop programme, which is described elsewhere. Suffice it to say that the three workshops were all over subscribed and the auditoria were full to their legal capacity. Of course we hoped that many would also be drawn by the opportunity to refine their beam time applications with just a fortnight to go before the submission deadline. We also suspected that several would seize the opportunity to take to the hills at the earliest opportunity. Whatever the reason they all came and Mother Nature took a hand in deciding to confine us all to Grenoble by dumping an unreasonably large amount of snow on top of the meeting!

The meeting began with reports from the ESRF Directors covering the operation of the machine (good and getting better), the completion of beam lines (almost done), the competition for beam time (higher ever higher) and some examples of the scientific activity. (where is that Nobel Prize?).

Jean Laissue (Berne) gave the first of the highlight talks on the MicroBeam therapy pre-clinical studies on ID17. Both Bill Thomlinson, who introduced the talk and Jean paid tribute to Per Spanne whose death in the Swissair crash was a tragic loss to the Medical Beamline. The very encouraging results for the "sparing" of benign tissue obtained with the use of a microslit / mulitslit collimator was described.

After coffee the focus moved to the work of the Scientific Advisory Committee (SAC) which advises the ESRF Council. Roger Fourme, the SAC Chairman, discussed its work and described its guiding role in the facility's development. He ended with some thoughtful points about the iniquities of short term contracts for young scientists on whose unstinting effort institutions like ESRF rely. We reported on the users' perception of ESRF as revealed by questionnaires, floor tours etc. and were happy to confirm that there are few complaints and plenty of compliments. Winfried Schulke (Dortmund) then described the selection process for the Young Scientist Award and announced the winner: Peter Cloetens who works on the topography beamline. Peter came to Grenoble in 1994 after graduating in Engineering from the Vrije Universiteit Brussels. During experiments on BM5 he observed that objects with negligible absorption can be imaged in a monochromatic beam. Over the following three years he explored this phenomenon both experimentally and theoretically and exploited it to study a number of problems in materials science. He also began developing, with an Italian team, a wave guide to produce a submicron coherent divergent source and hence the first magnified phase contrast images. Peter received the award (5, 000 French Francs -next year 762 Euros?) And gave an excellent account of his work.

The afternoon's highlights came from Physics, Biology and Chemistry. Firstly Luigi Paolasini (ESRF) described the heroic resonant scattering experiments carried out at ID20 which provide the first direct evidence for orbital ordering in addition to the more familiar magnetic ordering (in VxCr1-x)2O3. He made light work of describing this truly complex piece of physics despite a power cut to the overhead projectors! The true extent of his work was revealed by an innocent question about getting "more data". Luigi calmly explained just how much sweat and tears were involved in putting those vital few points on the curve!

Elsa Garcin (IBS, Grenoble) then described the characterisation of metal sites in hydrogenases using anomalous dispersion methods on BM14 and BM2. These materials are the metallogenzymes that are involved in hydrogen biocatalysis: they are "vital" materials. The beautiful experiments she described were able to pinpoint all the metal sites and their ligands.

The final highlight talk was given by a physicist - Eric Isaacs (Lucent Technologies New York) talking about chemistry: the covalency of the hydrogen bond in ice, which was first discussed by Pauling. The experiment that at last validated this concept was incoherent Compton scattering, rather than coherent diffraction. The study was carried out at ID15 and Eric showed how a simple analysis of the broadened Compton profile provided evidence - the first direct evidence - for substantial covalent character to the bond.

The session at Atria continued with a well attended poster session that amply filled the space and time available. Indeed at the end of the afternoon it was difficult to persuade everyone to brave the snow and drift back to the ESRF. Over 300 managed this in time to partake in an excellent dinner. Those of us who had been involved in choosing the food and the wines made every attempt to ensure that all our choices were excellent and indeed they were. On behalf of the Organising Committee would like to thank everyone for their help in making this such a successful meeting. Especial thanks are due to the speakers who clearly had made an effort to tailor their talks to the "SR family" audience and to the ESRF staff who helped to ensure that everything went smoothly. The USER Office staff, who bear the brunt of the organisation were devastated by 'flu in the two previous weeks, nonetheless they worked so hard that you would have never known it. Thank you.

Now what do we do to make next year even better? It will be our 10th so it must be special. What ideas do you have? The date will be Thursday, February 10th, 2000, by which time you will have recovered from millennium parties and millennium bugs. Suggestions for workshops, prayers for a little less snow and innoculations against 'flu should start now.

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MEMBERS' PAPERS

Tables of Elastic Scattering Cross Sections of Photons in the Energy Range 50 – 1500 keV for all Elements in the Range 13 < Z < 104

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Journal of Physical and Chemical Reference Data, Vol 27, 1998, 1011-1215
Table contains 205 printed journal pages containing 185 pages of tables.

A Brief Description

Tables of differential and total elastic scattering cross sections for 93 elements in the range Z=13 to Z=104 and for selected photon energies in the range 50 to 1500 keV have been published. The values of the cross sections have been obtained by accurate interpolation from the published cross section values available for ten elements and seven photon energies obtained using the state-of-the-art precise S-matrix method. The S-matrix method is known to produce Rayleigh scattering amplitudes in most cases accurate to the order of 1%. The elastic scattering cross sections presented in this table includes all elastic scattering processes, namely Rayleigh scattering by bound electrons, nuclear Thomson scattering and Delbruck scattering. This table contains elastic scattering cross section values for all elements for 14 photon energies (50.0, 59.54, 145.4, 316.5, 411.8, 468.1, 661.6, 778.9, 964.0, 1004.8, 1112.1, 1274.5, 1408.0, 1500 keV) for 55 different scattering angles in the range 0<theta<180 degrees. Angles were chosen judiciously, very close angular grids (namely, 14 angles between 0 and 1 degree) due to the sharp variation of cross sections at forward angles and at relatively coarser grids with increasing scattering angles. The energies are chosen to cover the commonly used photon energies and in a suitable grid so as to enable one to use the usual interpolation methods to determine the cross sections at other energies. We will also be happy to comply with any request from scientists to provide cross section values at any customized scattering angles and energies. Angle integrated total elastic scattering cross sections at all energies and elements are also presented in the table.

Comparison of experimental cross sections with the tabulated values is also made and presented graphically. Comparison shows that the predicted cross sections are, in general, in good agreement with the measurements. Although this comparison is not exhaustive, it gives a representative example about its suitability for use by experimentalists and radiation physicists. The paper also contains a table depicting the number of experimental measurements performed at each energy and element. This table along with the figures indicates the region of photon energy and elements for which further measurements are needed.

Elastic scattering is an important mode of interaction of photons with matter. The tables of precise elastic scattering cross sections for any element and for varying photon energies have long been needed, not only from the point of view of fundamental science, but also from the point of view of their applications in various fields such as material study, health physics, biology, medicine, etc. The authors will be happy if the radiation physicists find this table useful.

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The use of Energy Dispersive X-ray Diffraction (EDXRD) for the Determination of Bone Mineral Density

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Introduction

The increased porosity of bone, as a consequence of the reduction of bone mineral density (BMD), is known generally as osteoporosis. BMD loss may be localised to certain bones (or areas of bone), perhaps resulting from the disuse of a limb, or it may involve the entire skeleton due to the manifestation of a metabolic bone disease. Although the whole skeleton may be affected, osteoporosis manifests itself in certain regions to a greater extent than others, especially in regions with a greater surface area of bone.

Bone may be classified as either cortical bone or trabecular bone. The surrounding structure of bone is a hard, dense shell, known as cortical bone. Regions of bone that are filled with marrow are hollow except for a series of bony struts known as trabecular bone. These trabeculae enclose the bone marrow area and form a strengthening structure.

Bone is continuously being broken down and remodelled by dedicated cells called osteoclasts and osteoblasts. Trabecular regions of bone have a far greater surface area for a given BMD when compared to that of cortical bone, leading to a more active remodelling metabolism. As such, the internal trabecular regions of bones like the vertebral bodies or the femur are far more likely to show a significant manifestation of osteoporosis, becoming less dense and more porous. The measurement of bone mineral density with a view to detecting the onset of osteoporosis might therefore be improved if the density of trabecular bone were measured in isolation.

Measuring Bone Mineral Density

There are numerous techniques that have been used to measure the density of bone. The many various techniques are based on a diversity of different aspects of radiation physics. The key methods are noted briefly. A detailed introduction to BMD measurement may be found in a review article by Speller *et al* (1989).

A series of radiographs, usually of the hands, are taken over a period of time for the BMD measurement techniques of radiogrammetry and photodensitometry. For radiogrammetry, the thickness of the cortical bone is measured from each radiograph. Subsequent radiographs may show a decreasing thickness of cortical bone, indicating a loss in bone mass. With the photodensitometry method, optical densities are measured from the radiographs to determine mineral density, via a calibration phantom.

A measure of BMD may be obtained by employing photon absorptiometry methods, in which a collimated photon beam from an isotope source of radiation is directed through the site of interest. The subsequently measured photon attenuation is related to BMD. The site to be measured must be immersed in water to eliminate the effects of the soft tissue surrounding the bone. A variation of this method has led to the development of dual energy x-ray absorptiometry (DEXA). The isotope is replaced with an x-ray source, which is used to generate beams of two different energies. The use of two energies removes the necessity for water immersion.

Other BMD measurement techniques include neutron activation and ultrasonic attenuation. Neutron activation can be used to determine the quantity of a particular element within the site of interest by measuring the quantity of g-rays generated from n, g reactions. Alternatively, since ultrasound waves are attenuated when directed through tissue, the tissue composition may be determined by the degree of attenuation. Bone with a lower mineral density will attenuate the ultrasonic waves to a lesser degree than healthy bone, providing the necessary BMD information.

Data from quantitative computerised tomography (QCT) images (reconstructed from x-ray profiles of the site of interest) can be related directly to bone mineral. It is thought that this ability to isolate the QCT response of trabecular bone offers an improvement in accuracy over the previous techniques that measure total bone mass (trabecular and cortical bone). As previously noted, osteoporosis manifests itself more readily in trabecular bone, so removing the effect of cortical bone will increase the sensitivity of the detection.

A New Method for Bone Mineral Density Measurement

Research is being conducted into a method that isolates BMD measurement to trabecular regions of bone only. It utilises the coherent scattering of x-ray photons and is known as energy dispersive x-ray diffraction (EDXRD).

The EDXRD technique allows a scatter angle to be defined. A solid scatter angle produces a scatter which may be accurately positioned to fall within a volume of interest. For the purposes of EDXRD BMD measurement for osteoporosis detection, the scatter volume is chosen to fall within a site of trabecular bone.

An EDXRD experimental system is shown schematically in *Figure 1.*
A polyenergetic source of x-ray photons is generated using an x-ray tube. These photons are collimated into a fan beam with primary lead slit collimators, which is set to be incident on a sample under investigation. Within the sample, some coherent scattering will occur, an optimum of which will take place at a fairly shallow experimental scatter angle f. Collimators are arranged at this angle (from the incident beam) so that only photons scattered at the chosen angle f will reach the detector. It is this arrangement that defines the scattering volume. The final beam generated with this geometry is detected with a high purity germanium detector and then processed, using a multichannel analyser.

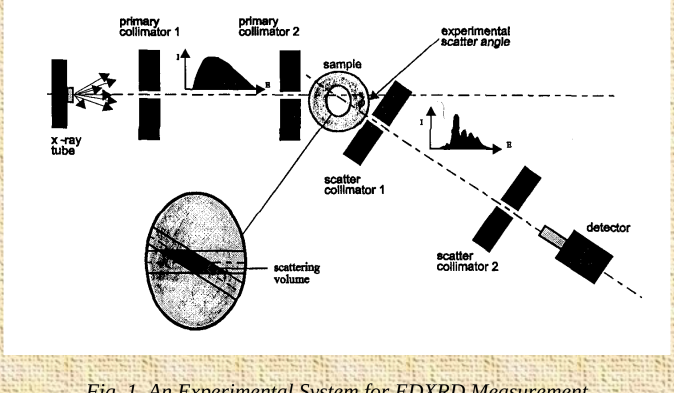

Fig. 1. An Experimental System for EDXRD Measurement

The optimum experimental scatter angle f will depend on the molecular structure of the sample material under investigation and the wavelength/energy of the incident photons. Since the bone mineral in the trabecular sample has a crystal-like structure, Bragg's Law will describe the conditions under which the constructive interference of x-ray photons occurs *(equation 1)* .

n*l = 2*d* sinn** ***(Equation 1)

l is the wavelength of the photons, *d* is the spacing between the scattering planes, q is the Bragg scatter angle (half the experimental scatter angle f) and *n* is the order of diffraction.

Constructive interference of the photons will occur when the wavelength is a whole multiple of 2*d* sin q.

Figure 2 shows when this condition is satisfied for a given Bragg scatter angle q and scatter plane spacing *d* . The paths of three photons are shown before scattering (x, y, z) and after scattering (x', y', z').

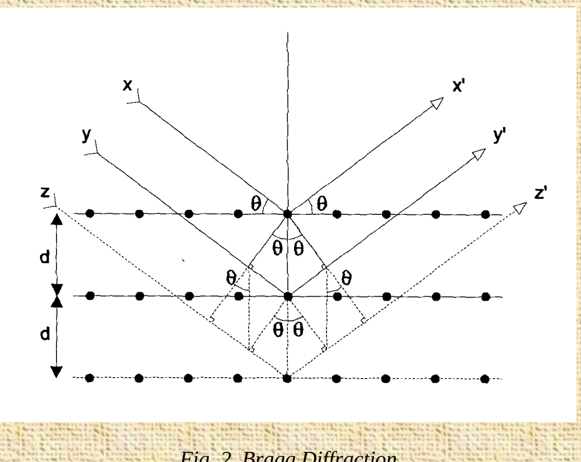

Fig. 2. Bragg Diffraction

There may be many scattering planes within a given material, presenting a range of plane spacings *d* . Some wavelengths from the energy range of the incident spectrum will satisfy Bragg's Law for constructive interference (for a particular value of *d*). This leads to the detection of a spectrum of photon energies that will have a unique 'signature' related to the material under investigation, in this case trabecular bone (predominantly formed from hydroxylapitite). This signature spectrum will change for a different material because the spacings *d* will change. Peaks within the signature spectrum will be at energies that correspond with materials present within the scattering volume. The intensity of each peak can be related to the quantity of each material.

An EDXRD spectrum for a bone phantom is shown in *Figure 3.* The phantom consists of a mixture of cleaned, ground bone and fat, which together simulate in vivo bone and marrow. The spectrum was produced using the experiment illustrated by Figure 1. In this example, the peak at 27.5 keV predominantly represents the scatter contribution from the fat content of the phantom. The small peak at 33 kVp and the large peak at 40 kVp predominantly represent the scatter contribution from the hydroxylapitite content of the bone.

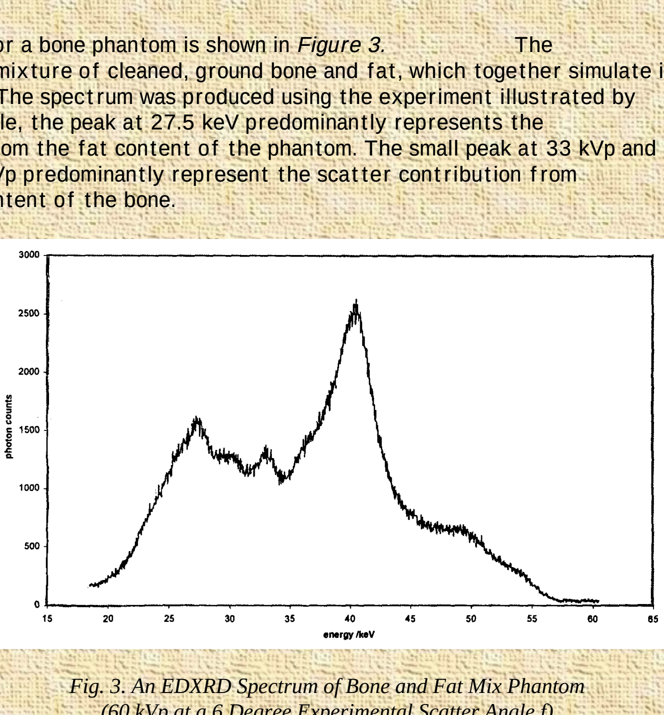

Fig. 3. An EDXRD Spectrum of Bone and Fat Mix Phantom
(60 kVp at a 6 Degree Experimental Scatter Angle f)

It is the intensities of the peaks for bone material within the spectra that is thought may be analysed to provide an accurate measure of bone mineral density within the scatter volume. If the scatter volume is positioned within a region of trabecular bone, a value for trabecular BMD may be used to provide an accurate indication to the presence or severity of osteoporosis.

EDXRD research currently being implemented at the City University Radiation Laboratory is concentrating on finding the minimum detectable limits of the technique. This involves work with bone samples, taken from total hip replacement operations, to simulate very small amounts of uniform BMD loss and the design of an optimised EDXRD system which will be compared to currently used methods such as DEXA. An attempt will also be made to relate small BMD losses as well as trabecular architecture, to changes in trabecular bone strength.

It is hoped that the EDXRD method can be shown to be sufficiently accurate, and of sufficiently low radiation dose, to be ultimately accepted in the clinical environment for BMD detection. If it can be shown that EDXRD can be used to detect smaller BMD changes than methods currently in use, the onset of osteoporosis in a patient might be detected earlier. Thus a treatment programme could be started sooner, perhaps preventing debilitating fractures that are also expensive to treat..

Further information about these EDXRD methods may be obtained by e-mailing the authors at

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or by referring to the papers by Farquharson et al (1997) and Farquharson and Speller (1998).

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Speller, R. D., Royle, G. J. and Horrocks, J. A. 1989. Instrumentation and techniques in bone density measurement, *J. Phys.E: Sci. Instrum.* 22, 202-214.

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WORLD
NEWS

Nanotubes as test tubes

(From Post-Deadline, Physics World Vol 12 , No.4, 1999, p5)

Now that carbon nanotubes can be fabricated routinely in the laboratory, physicists are exploiting their remarkable electronic properties to test fundamental aspects of physics. A team from the US, for example, has recently used nanotubes to explore electron transport in I -D (M Bockrath et al. 1999, Nature, 397, 598).

The properties of electrons in conductors and semiconductors in 2-D and 3-D are well understood in terms of the so-called Fermiliquid theory. In 3-D metals, for instance, electrons close to the Fermi level behave as though there is no interaction among the charge carriers. The theory breaks down, however, when the electrons are confined to 1-D and weak Coulomb interactions can have a big effect on the electron transport properties This system, known as a Luttinger liquid, is predicted to be very different from its 2-D and 3-D counterparts. For instance, electron tunnelling into a Luttinger liquid near the Fermi level is predicted to be strongly suppressed and to depend on the temperature and bias voltage, unlike a Fermi liquid. However, it is difficult to test Lutinger-liquid theory in experiments.

Bockrath and colleagues measured the conductance of bundles of nanotubes as a function of temperature and bias voltage, and found that the response could be characterized by a power law, in good agreement with he predictions of Luttinger-liquid theory. Meanwhile, Swiss researchers have used nanotubes to test a fundamental prediction of quantum mechanics (A Bachtold et al. 999, Nature, 397, 5673). When electrons pass through a cylindrical conductor placed in an external magnetic field, their wave-like nature should cause the electrical resistance to oscillate as a function of the magnetic flux through the cylinder. This behaviour can be explained in terms of the Aharonov-Bohm effect and has been previously observed in metal cylinders with walls that are a few micrometres thick.

The Swiss team scaled down the experiment to the single-molecule level using "multi-wall" nanotubes made from several rolled-up sheets of graphite. Electrons can move relatively freely over the outside surface of the cylinder. The waves associated with these conduction electrons can encircle the conductor in opposite directions, leading to quantum interference effects that are modified by the magnetic field.

Bachtold and co-workers measured the magnetoresistance of the nanotubes as a function of the magnetic flux and found oscillations that were consistent with the Aharonov-Bohm predictions. The researchers were surprised to find other oscillations that could be attributed to electrons that revolve around the cylinder many times before interfering. It is thought that defects in the carbon-atom lattice might be responsible for these oscillations.

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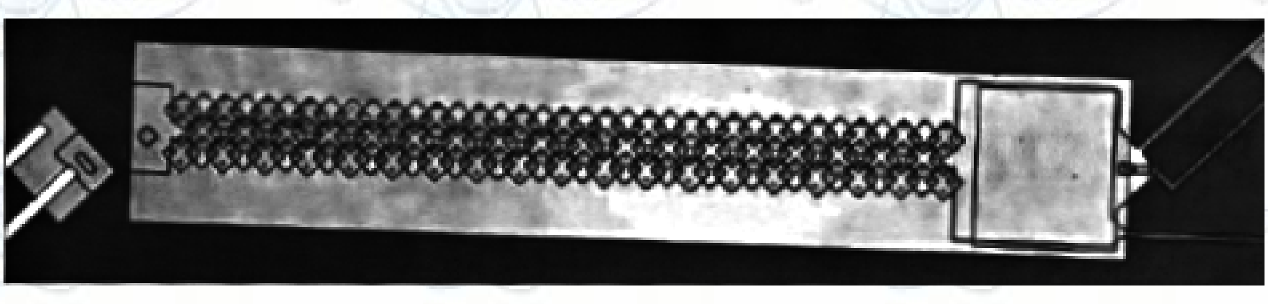
Superconducting lasers

(From Post-Deadline, Physics World Vol 12 , No.4, 1999, p5)



This 3 x 36 array of Josephson junctions can emit coherent microwaves when more than 14 junctions are switched on. The behaviour can be explained in terms of a laser.

Researchers at the University of Maryland in the US have discovered that arrays of superconducting devices can emit coherent radiation like a laser (P Barbara et al. 1999, Phys. Rev. Lett., 82, 1963). The devices, known as Josephson junctions, consist of two layers of superconductor separated by a narrow insulating gap. When a DC voltage is applied across the two superconducting layers, the devices can emit radiation as electrons tunnel through the junction.

Paola Barbara and co-workers found that coherent microwave radiation was only emitted when the number of activated junctions exceeded a threshold that depended on the length of the array. The frequency of the microwaves corresponded to the resonant frequency of the structure formed by the array itself and a "ground plane" that served as the return path for the electrical signals. The results suggest that quantum effects underlie the synchronized emission, analogous to the way laser light is produced.

Earlier work had shown that coherent radiation could be emitted by groups of Josephson junctions that were connected together like a classical electric circuit. However, the bonding itself was thought to have been responsible for the coherence. In contrast, the Maryland researchers studied the radiation from arrays that were not connected in this way. They used a rectangular array of 3 x 36 junctions fabricated from two layers of superconducting niobium separated by an insulating layer of aluminium and aluminium oxide (see figure).

Barbara and co-workers found that the radiation output by the array had a resonant frequency that was related to both the size of the array and its distance to the ground plane. When less than 14 rows of junctions were switched on, no detectable radiation was output by the "cavity". With more than 14 rows, however, the array produced radiation with a wavelength of a few millimetres. It is thought that this minimum number of junctions is needed to overcome losses in the cavity and the junctions. The power of the radiation increased according to the square of the number of active junctions, evidence that the radiation was coherent.

The arrays may eventually provide an alternative source of coherent microwave radiation. In the meantime, the results look set to provoke a debate on the quantum verus classical nature of Josephson arrays.

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UK digs deep in search of dark matter

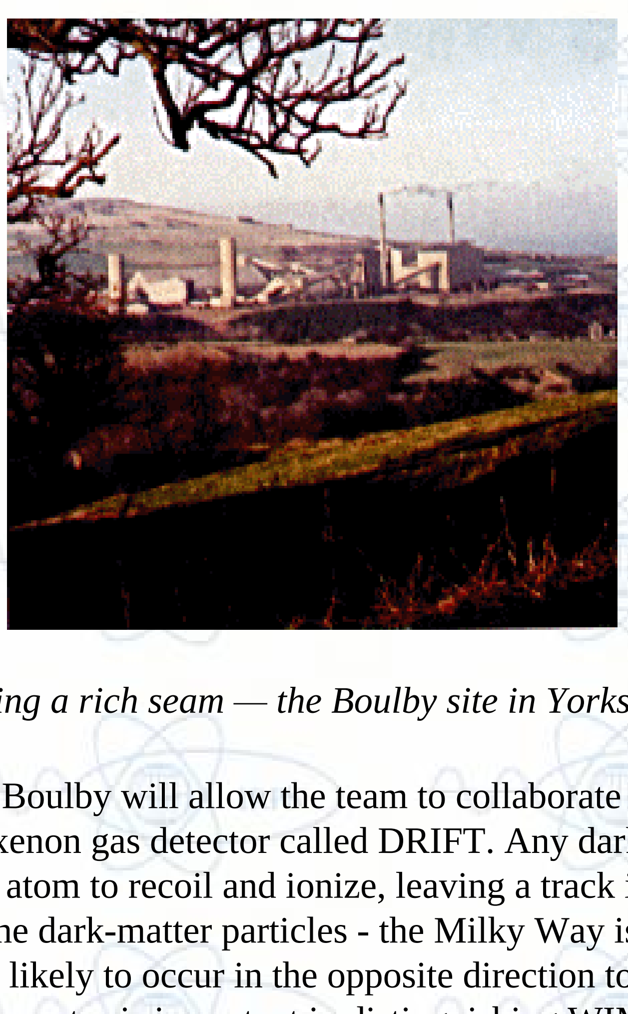
Edwin Cartlidge

(From Particle Physics, Physics World, Vol 12, No 4, 1999, p.8)

A potash mine in Yorkshire does not seem the natural place to solve one of the mysteries of the universe. But as part of a drive to boost innovative research, the UK is to increase spending on an experiment at the foot of the 1000 m shaft that should establish the mine's reputation as one of the world's leading centres for dark-matter research. The Particle Physics and Astronomy Research Council (PPARC) will spend £5.21m over the next four years on the project, an increase of 20% a year, enabling scientists working at the mine in Boulby to extend their ten-year search for weakly interacting massive particles (WIMPS).

Observations of stars and galaxies suggest that as much as 99% of the matter in the universe is invisible or "dark". Neil Spooner, spokesman for the Boulby experiment, says he hopes eventually to confirm or rule out WIMPS as a source of dark matter. But to try and detect these elusive particles, Spooner and his co-workers have to carry out experiments deep underground to prevent any data being swamped by interactions from cosmic rays.

Ian Halliday, chief executive of PPARC, which last month announced a new £3m scheme to foster innovative research projects (see page 45), says the investment in the Boulby mine undoubtedly increases the UK's chances of winning a Nobel prize. He admits the project is risky, since it offers no guaranteed results, but believes it is vital that the UK supports this kind of experiment. "If the UK doesn't spend money on innovative research projects it will lose its way," he comments.



Mining a rich seam — the Boulby site in Yorkshire

The increased funding for Boulby will allow the team to collaborate with several American groups on research into a xenon gas detector called DRIFT. Any dark-matter particle entering the gas will cause a xenon atom to recoil and ionize, leaving a track in its wake. And since the Earth moves through the dark-matter particles - the Milky Way is engulfed in a halo of WIMPS - recoils are more likely to occur in the opposite direction to the Earth's motion through the halo. This asymmetry is important in distinguishing WIMPS from the background of natural radioactivity in the surrounding rock.

The funding increase will also allow the group - a collaboration between Imperial College, the Rutherford Appleton Laboratory, and Shefffield University to upgrade its sodium iodide scintillator from 5 kg of detector material to about 50 kg, and to build a scintillator using 10-20 kg of liquid xenon. This second detector will be a collaboration with groups from the US, Italy and Russia. These upgraded detectors will improve the experiment's sensitivity and therefore the chances of capturing evidence of dark matter - one hundred fold.

This improved sensitivity will lie within the region that supersymmetry theory predicts will produce evidence for WIMPS. In supersymmetric theories that attempt to unify the strong and electroweak forces of nature, all particles have heavier "superpartners". The superpartners of fermions are bosons and vice versa.

"We already have some events in our detector that we have not yet ruled out as evidence for dark matter and we would like to investigate these further," says Spooner. "The new detectors will enable us to understand these events and to search for proof that WIMP dark matter really does exist."

A group at the Gran Sasso laboratory in Italy already has detectors with 100 kg of sodium iodide, and a group from Stanford and Berkeley in the US is about to start experiments using low-temperature detectors, which may allow greater sensitivity than is possible with sodium iodide. However, Spooner believes that, given the UK collaboration's advanced techniques for analysing particle interactions, the new money will keep the UK at the leading edge of the search for WIMPS. "If we'd had level funding it would have been impossible to compete with the groups abroad," he says, adding that if the collaboration had received the entire 60% annual increase that it had asked for, they would have been able to actually build DRIFT. "Getting DRIFT to work as envisaged would have put us indisputably number one in the world."

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