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IRPS BULLETIN

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Main

FROM THE EDITOR

Dudley Creagh

Welcome to a new version of the IRPS Bulletin!! You will notice that there are a few changes in its staff and its format.

We welcome Dr Mic Farquharson to the Editorial Board. We regretfully say farewell to Dr David Bradley, who has served as Co-Editor for the past few editions. He will continue to serve the IRPS as Editor of its Conference Proceedings and as Programme Committee Chairman for the Prague Congress.

In this Bulletin I have set up a section for **Submitted Papers**. In the first instance these should be no longer than three pages, in Times New Roman 10 point, and be submitted by 3.5" disc, using Word 7. Figures should be embedded in the document. Electronic transmission should be by attachment to a document using Eudora. This is an ideal way of introducing students to the discipline of scientific writing.

There will also be a section: **Recent Conferences**. If you attend a conference you should write a one page report in which you can embed a photograph. I have written a specimen report for this issue to start the ball rolling. Mind you: it will not roll far unless YOU keep it rolling.

I have started a **Letters to the Editor Column**. These must be restricted to less that 500 words. Again: this will be empty unless you send me your letters. Letters on any topic may be submitted to me, or to Shirley by email. (d-creagh@adfa.edu.au , s-mckeown@adfa.edu.au)

Your input is essential to the health of our Society!!

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PRESIDENT'S COLUMN

Bikash Sinha

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LETTERS TO THE EDITOR

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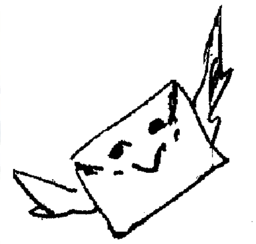

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Sir:

Just a note to tell you that I really enjoyed the April 98 issue of the IRPS Bulletin. You did a really nice job.

RT Perry, Los Alamos National Laboratory.

Ed: We are susceptible to all forms of congratulations, flattery, and the like. I'm pleased someone enjoyed it!!

Sir:

I write in response to your editorial to the last issue of the IRPS Bulletin. You wrote that governments do bad things sometimes in the name of their peoples. I am much concerned with nuclear explosions which have occurred recently in India and Pakistan. I beseech you to influence your readers to intercede on behalf of ordinary peaceful people to prevent militaristic shows of force from happening again.

Name and address supplied.

Ed: The detonation of nuclear devices is indeed appalling especially at a time when moves are being made to dismantle nuclear arsenals. Perhaps other readers have a view they might care to express.

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! ! ! ! !
IDEAS ! ! ! ! !

Give us a job!!!

Do you need a Ph.D. student? Do you need a research assistant? Are you looking for a Postdoc position?

We are considering having a slot in the Bulletin for vacancies and posts wanted. It would be a way to advertise these positions, wanted or vacant, within the IRPS membership with no cost. If this idea interests you, contact the editorial members of the Bulletin and we can place your ‘advertisement’ in the next issue and put it on the web page.

E-mail Addresses

We would like to have a register of the e-mail addresses of members. This would facilitate our ability to communicate rapidly with you. Please send your e-mail address by e-mail to :

s-mckeown@adfa.edu.au

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The Free-Electron Laser.
The Next Generation of High-Brightness Synchrotron Radiation Sources

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Introduction

X-ray tubes have been used ever since Roentgen's discovery of the new kind of radiation in 1895, and they have been developed into remarkably reliable and useful devices. Surprisingly, the brightness of these X-ray sources have not shown any radical increase in the course of time, the main innovations being the hot filament tube, invented by William Coolidge in 1913, and the rotating anode tube, devised by R. E. Clark in 1934. A major break-through occurred in 1947, when F.R. Elder, A.M. Gurewitsch, R.V. Langmuir and H.C. Pollock first observed synchrotron radiation as visible light from the General Electric 70-MeV synchrotron.

Synchrotron X-radiation is emitted by electrons or positrons orbiting at high energies in synchrotrons or storage rings. The first sources were true synchrotrons utilized in a parasitic manner, the machines being built and run by the high-energy physicists. Second generation facilities were purpose built electron storage rings, dedicated as light sources. Present third generation sources are based mainly on insertion devices, called wigglers and undulators. Examples of such rings are the Advanced Light Source (ALS) in Berkeley and the Advanced Photon Source (APS) in Argonne, both in USA, the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, and the SPring-8 facility in Japan.

During the last three decades, synchrotron radiation has proved its usefulness in many different fields of science, ranging from physics, chemistry and biology to materials science and medical diagnostics. Advances in the creation, compression, transport and monitoring of bright electron beams have made it possible to base the next generation of synchrotron radiation sources on linear accelerators rather than on storage rings. This development has been spurred by the availability of advanced low-emittance electron guns, linear accelerators in the GeV energy range, and precise undulators based on new materials for permanent magnets, such as SmCo5. Therefore, the next big leap forward with high-power light sources will most probably be the introduction of free-electron lasers producing VUV and X-radiation with unprecedented brightness and coherence.

Undulators

Synchrotron radiation is produced by electrons or positrons travelling along a curved trajectory with a velocity close to that of light. The radiation is emitted in the forward direction, tangentially to the orbit and confined within a narrow cone, having an opening angle y given by

$$\psi = \frac{1}{\gamma} \qquad (1)$$

where the relativistic factor is being the electron mass and rest mass, respectively, E the electron energy and c the velocity of light. Thus, for electron energies in the GeV range, the angular divergence y of the emitted radiation is less than 1 mrad.

The traditional device for producing synchrotron radiation in the first and second generation machines is the bending magnet. In the third generation facilities, the most important sources are devices inserted in the alternating polarity, causing the electrons to oscillate straight sections of the electron storage ring. The insertion devices are arrays of dipole magnets with around their linear trajectory (Fig. 1). In the following it is assumed that the symmetry axis of the insertion device is the z-axis, and that the magnetic field is directed along the x-axis. The magnetic flux density Bx is assumed to vary sinusoidally with the distance z along the undulator:

$$B_x = B_0 \sin \frac{2\pi z}{\lambda_0} \qquad (2)$$

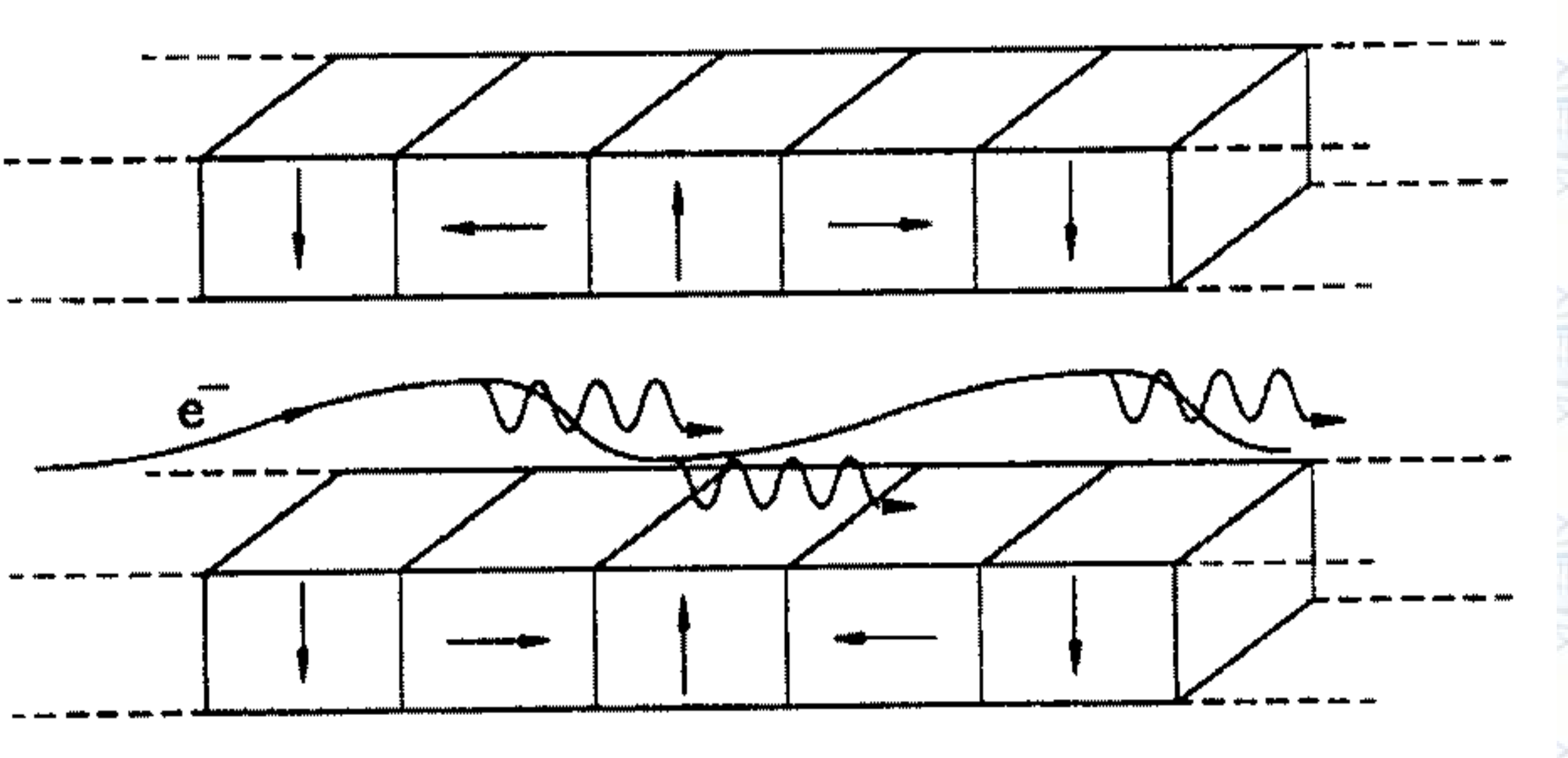

Figure 1 : Multipole undulator or wiggler

where B0 is the amplitude of the magnetic field, and l0 is the magnetic period. From the equation of motion of an electron in a periodic magnetic field, it can be shown that the maximum deflection angle a (Fig. 2) is given by

$$\chi = \frac{eB_0\lambda_0}{2\pi\gamma m_0 c} \qquad (3)$$

where e is the electron charge. The so called undulator parameter K is defined as

$$K = \frac{\alpha}{\psi} = \alpha\gamma = \frac{eB_0\lambda_0}{2\pi m_0 c} \qquad (4)$$

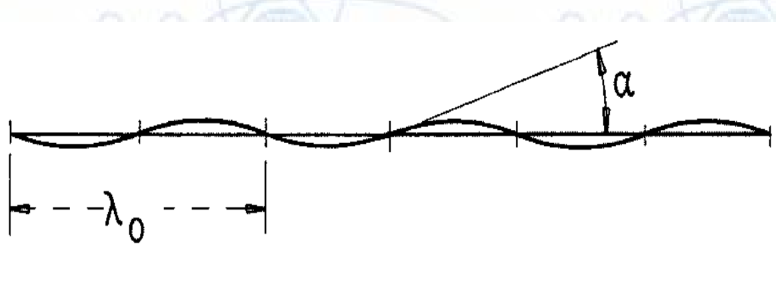

Figure 2 : Trajectory of an electron in a multipole or undulator or wiggler

For an undulator, K is of the order of one or less, i.e. the electron beam is kept within the angular emission of the synchrotron radiation from each wiggle. Thus, the radiation from different points within the undulator can interfere constructively, giving rise to a series of monochromatic spectral lines. When K >> 1 (typically > 20), there are no coherence effects, and the insertion device is called a wiggler.

The interaction between the speeding electrons and the electromagnetic field of the emitted radiation has to be calculated using advanced quantum mechanics [1]. Fortunately, the resonance condition can be understood from a simple model. While the radiation emitted by the electron in the forward direction propagates along the z-axis with the speed of light, the electron moves at an average velocity determined by its energy and its path length per magnetic period. After one period, the electron lags behind the radiation emitted at the corresponding point in the preceding period by a distance corresponding to one wavelength of the radiation. This condition can be formulated in the following way:

$$\frac{\lambda_0}{v_z} = \frac{\lambda_0 + \lambda}{c} \qquad (5)$$

where l is the wavelength of the emitted radiation, and vz is the velocity of the electron along the z-axis. The total velocity of the electron is

$$v = \sqrt{v_z^2 + v_y^2} \qquad (6)$$

where vy is the y-axis velocity component caused by the periodic magnetic field. A relativistic calculation using equations (5) and (6) shows that the resonance wavelength l is given by

$$\lambda = \frac{\lambda_0}{2\gamma^2}\left(1 + \frac{K^2}{2}\right) \qquad (7)$$

The wavelength is determined by the electron energy through g in equation (7). Tuning is then possible by varying the undulator parameter K. This is most easily done by varying the gap of the magnets, thereby changing the magnetic flux density B0. Higher harmonics are obtained by substituting nl (n = 1, 3, 5, …) for l in equation (7). Only odd harmonics appear on axis. The free-electron laser

A free-electron laser (FEL) can be realized by having an undulator situated in an optical cavity defined by mirrors
(Fig. 3). The periodic magnetic field causes the electrons to undergo transverse oscillations. Thus the electrons will have a velocity component in the direction of the electric field vector of the light in the cavity, and there will be an interaction between the electron beam and the light. The interaction induces a density modulation of the electrons (microbunching) with a periodicity equal to the wavelength of the light. When this occurs, the electrons will emit synchrotron radiation coherently, i.e. the intensity of the radiation is proportional to the square of the number of electrons participating, rather than proportional to the number of electrons as is the case with normal synchrotron radiation. In addition, the intensity of the light interacting with the electron beam stimulates the emission of synchrotron radiation, leading to a further increase of light intensity and a lasing action of the device.

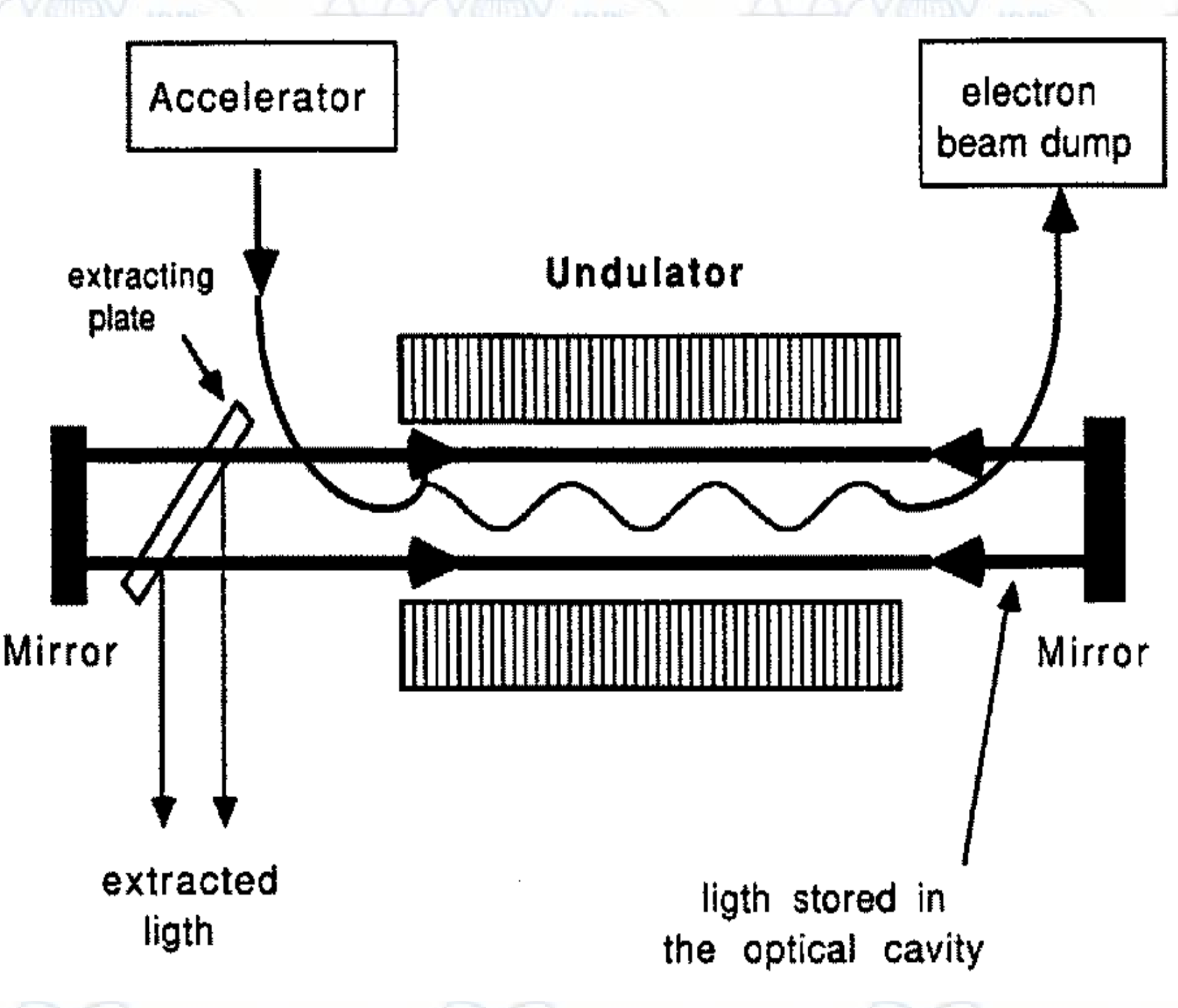

Figure 3 : Free-electron laser in an optical cavity (from Ref. [2])

In most present free-electron lasers the light from several passes of the electron beam through the undulator is stored in the optical cavity. Free-electron lasers using optical cavities are successfully operating at wavelengths l ³ 200 nm. Extending these devices to shorter wavelengths poses problems, however, because of the lack of high-reflecting mirrors for VUV and X-rays. Recently, it has become possible to consider another mode of operation, based on a single pass of a high-brightness electron bunch through a long undulator. No optical cavity is needed, and lasing action is achieved by a self-organizing process called Self-Amplified Spontaneous Emission (SASE) [3].

In the SASE mode, the laser has to start up from noise. In the first part of the undulator the electrons radiate incoherently, the power growing linearly with distance. Later, the interaction between the radiation and the electron beam leads to an amplification of the spontaneous emission, giving rise to coherent radiation. The power will then grow exponentially with distance until saturation is reached (Fig. 4).

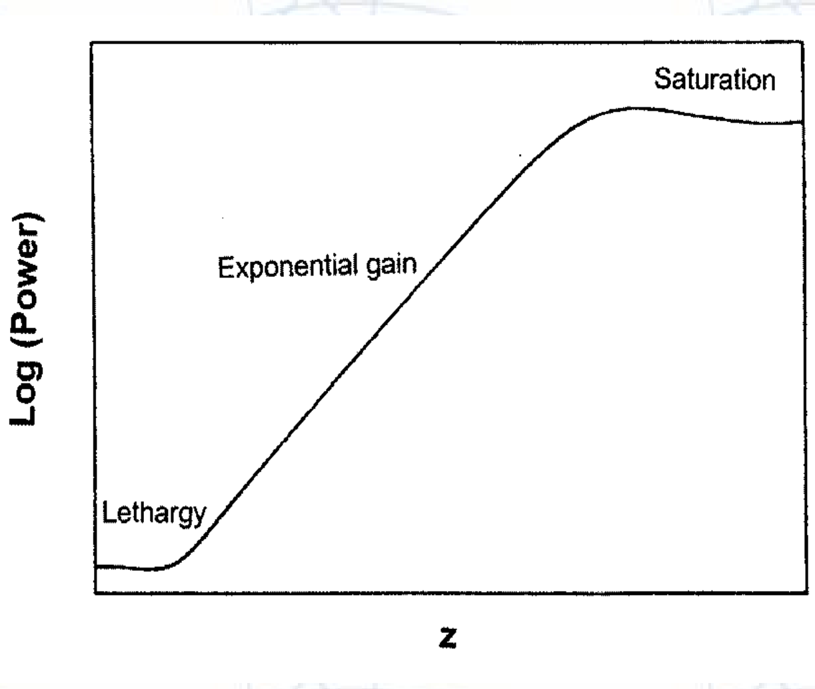

Figure 4 : Free-electron laser power growth vs. interaction length (from Ref. [3])

The basic concept of SASE has been demonstrated experimentally in the microwave region. An experimental verification in the short-wavelength range has been slow due to the tight requirements on the electron beam characteristics. With the development of new low-emittance electron guns, linear electron accelerators have become an attractive option for short-wavelength SASE. Serious considerations on the realization of VUV and/or X-ray free-electron lasers are now carried out at the Stanford Linear Accelerator Center (SLAC) in the USA, and the electron synchrotron DESY in Hamburg, Germany. In both places a number of workshops on this topic has been held [4-7].

The Stanford machine would utilize part of the existing 50 GeV linear accelerator. In the near future, the first 2/3 of the 3 km linac will be used to inject electrons and positrons in the soon to be completed PEB-IIB-Factory. The last 1/3 of the linac will then be available for the production of an up to 15 GeV electron beam that could be used to create a hard X-ray free-electron laser. A collaboration of American and Japanese scientists is investigating the technical issues and the potential scientific applications of the radiation produced. Single-pass free-electron laser projects are also planned at UCLA and BNL, utilizing 20 and 230 MeV linacs to reach wavelengths of 10 mm and 10 nm, respectively.

At DESY it is proposed to make use of the unique electron beam properties of the TESLA Test Facility (TTF) to construct a VUV free-electron laser based on the SASE principle. The project will proceed in two phases. In the first phase, a 390 MeV superconducting linear accelerator will be used to drive a free-electron laser operating at a wavelength of 42 nm. This facility is intended to test various components and, last but not least, to prove the SASE principle for the first time at short wavelengths. The phase I free-electron laser is under construction. The first cryomodule has been successfully tested, and first tests with the electron gun will take place in 1998. In the same year, two additional cryomodules will be mounted. After the installation of the undulator, the first experiments are expected to be carried out in the spring of 1999. In the second phase, the electron energy will be raised to 1 GeV and the undulator will be extended, producing radiation of 6.4 nm wavelength. An experimental hall completes the construction, and the facility will be available to external users as well. In a more distant future the DESY team is planning a hard X-ray free-electron laser for wavelengths in the 0.1 nm (1 Å) range. The latter facility would be integrated into a 500 GeV e+e- linear collider.

The scientific case

VUV and X-ray free-electron lasers would produce coherent radiation orders of magnitudes greater in power and brightness than present 3rd generation synchrotron radiation sources. The large increase in brightness, coupled with spatial coherence and the very short pulse duration, will certainly open new and interesting research possibilities in physics, chemistry, biology and allied sciences.

The high brightness of the free-electron laser source would facilitate the study of diluted systems and other weak scattering systems, such as atom clusters, magnetic scattering, surface atoms and biological materials. The spatial coherence would be beneficial to all kinds of imaging techniques, such as X-ray microscopy, holography and interferometry. The high brightness per pulse is certainly the most outstanding feature of the free-electron laser light. It will permit scattering and spectroscopic measurements based on a single pulse, having a duration of less than 1 ps. Thus, time resolved experiments would be possible in the sub-picosecond range. While the coherent radiation is monochromatic, the free-electron laser also produces a broadband pulse of radiation, incoherent but quite intense. This white radiation could be used for ultra-fast Laue crystallography, e.g. for the study of proteins.

In conclusion, a wide range of new and exciting experimental possibilites would be opened up by VUV/X-ray free-electron lasers. Such devices should lead to the same sort of revolutionary developments in VUV/X-ray studies of matter that was produced in optical studies by the introduction of lasers for visible light.

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In vivo trace element analysis: Applying radiation physics to find a needle in a haystack

Joanne M. O'Meara
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McMaster University, Hamilton, ON, Canada L8S 4M1

An obstetrician friend bumps into you at a party and starts recounting a recent challenging case. One of her patients reported suffering from lethargy and abdominal pain. This in itself was not immediately alarming, however, given the patient's history of two early mid-trimester miscarriages and several probable 1st-trimester miscarriages, the cause of this abdominal pain was investigated. The patient was found to be suffering from lead poisoning, as indicated by numerous factors, the most telling of which being elevated blood-lead levels. Given the possible health risks to the foetus and subsequently a nursing child, the source of this lead exposure was sought. However, therein lay the mystery. Thorough analysis of the family environment revealed no source of lead contamination, and her husband and two other children had normal blood-lead levels. It was revealed that the patient had suffered acute lead encephalopathy when she was 18 months old but has since had no known lead exposure.

Your friend speculated that with calcium turnover greatly increased during pregnancy, the patient was suffering from lead poisoning due to the mobilisation of lead stores from her bone. The obvious choice of treatment was chelation therapy, but without concrete evidence of high bone-lead levels it was a difficult decision to treat due to the potential harm to the foetus from chelation. In this case, a means for assessing bone-lead levels non-invasively, in vivo, would have provided an invaluable tool for your friend in helping the patient as soon as the problem was identified, rather than waiting until after childbirth during which time the child may have been lost. This is precisely the type of motivation for ongoing research at McMaster University and elsewhere in the field of in vivo trace element analysis.

For the past 20 years, the application of x-ray fluorescence (XRF), a standard elemental analysis technique, has been investigated for the purposes of measuring many toxic elements in vivo. In some cases, the source of exposure may be environmental. However, in the majority of cases, the development of measurement systems is driven by the need for better monitoring and health care for individuals exposed to toxic elements in occupational settings, e.g. Pb, Cd, U, and Hg. In addition, the need for measuring the in vivo concentrations of such elements as gold and platinum has arisen due to exposure to these toxic metals through medical procedures; gold salts are used in treating rheumatoid arthritis and platinum-based drugs are a common choice in chemotherapy. Research has focussed on developing systems to measure these elements generally in one of two sites, the bone matrix or the kidneys. The bone matrix represents the site of long term retention for elements such as lead and uranium. Therefore, measurements in this site give insight into the history of exposure of a given individual to these toxic metals. Other elements, such as Pt, Cd, Hg and Au, are better measured in the kidneys, as this organ can be a major retention site as well as often the organ to suffer damage due to metal accumulation.

XRF makes use of the unique electron energy levels to identify the elemental composition of an unknown sample. The sample is irradiated with x-rays or g-rays that interact through scatter and photoelectric absorption. When the incident radiation has energy greater than the K edge of an element, there is a significant probability that the element will absorb the photon and eject a K shell electron. With the element in an excited state, it can return to the ground state through emitting an Auger electron or an x-ray, with an energy corresponding to the difference between the K shell binding energy and that of an outer electron shell. Since the energy levels are unique to each element, the x-ray series emitted by an element has a characteristic energy signature that enables its identification. Furthermore, through careful calibration, the quantity of these x-rays detected can be used to determine the absolute amount of an element present in the sample.

In vivo XRF-based systems have been successful in measuring toxic elements of interest with high atomic numbers, e.g. Pb, Au, Hg, U, Pt, and to some extent Cd. This is because three critical parameters increase with increasing Z; fluorescence yield, K edge energy and characteristic x-ray energy. The higher fluorescence yield, as the name suggests, means that there is a greater probability of characteristic x-ray emission with every shell vacancy created instead of de-excitation through Auger electron emission. Therefore, there is an increased signal produced per unit irradiating flux. Higher K edge energies imply that a higher energy photon can be used to irradiate the subject. This results in the use of more penetrating radiation. Similarly, higher characteristic x-ray energies with higher Z elements result in greater penetrating capability of the outgoing signal. This is important in non-invasive measurements as the site of metal retention, bone, kidney, or liver, is shielded by a significant thickness of attenuating material.

Given that the element of interest has sufficiently high Z for XRF to be feasible, typically greater than 50, the optimisation of this in vivo probe must be undertaken for each element. There are a number of parameters that must be selected with a firm understanding of the underlying radiation physics principles. The first choice is whether the subject will be irradiated by g-rays from a radionuclide source or polarised x-rays produced by an x-ray tube. Polarised x-rays have been used in the development of systems to measure Cd, Hg, Pt, and Au primarily. The major difficulty in all XRF systems is that the element of interest is present in trace quantities within a low Z matrix. Therefore, the vast majority of detected photons are scatter events that only give rise to spectral background and increase the count rate in the detector. Polarised photons can be used to minimise the number of scattered events detected, as there is a much-reduced probability of scatter along the direction of polarisation. The isotropic characteristic x-rays are detected with a suppressed background when the detector is positioned along this axis, thereby enhancing the signal to noise ratio.

The pros and cons of these two classes of XRF systems can be looked at in parallel. A successful radionuclide-based system uses a g-ray source with an energy that is just above the K edge of the element under investigation, as this corresponds to the greatest photoelectric cross section. Once a source has been chosen with an appropriate g-ray energy, a sufficient half-life such that the source does not require frequent replacement, and minimal additional radiation emissions that merely give rise to subject dose, the irradiation geometry must be optimised. The source-sample-detector geometry is set such that the angle of scatter from source to detector gives rise to the Compton scatter distribution in the spectrum as far removed in energy from the characteristic x-rays as possible in order to reduce the background under the signal. These are essentially all the variables that can be optimised in a source-based system and therefore the sensitivity of the system is largely dependent on the availability of an appropriate radionuclide. This is the main reason for the outstanding performance of the 109Cd lead measurement system – with a g-ray that is only 30 eV above the K edge of lead, a reasonably long half-life of 462 days, and a lower energy photon emission that is readily shielded to reduce subject dose, 109Cd is the ideal radionuclide for measuring lead. Furthermore, the energy difference between the 88 keV g-ray scattered through ~ 160o and the lead x-rays is such that the signal is located in a reasonably low background portion of the detected spectrum, see fig. 1.

With polarised systems, the energy of the incident radiation is also a variable to optimise. However, a 90o source-sample-detector geometry must be chosen as this corresponds to the direction of initial polarisation and therefore minimal scatter. This limits the flexibility with which a fluorescing source can be designed since the energy dependence of the background spectrum now can only be altered by changing the energy dependence of the incident spectrum. Therefore, appropriate tube voltage, polarising material, and beam filters must be selected such that the incident energy distribution corresponds to high photoelectric absorption in the target element and results in the appropriate positioning of the characteristic x-rays in the background spectrum detected at the 90o scatter angle. The coupling of these factors in the polarised systems is the reason for the poor performance in polarised uranium measurements.

XRF measurements of lead concentrations in bone have been taking place clinically for many years now. This tool has become extremely useful in monitoring occupational exposure in workers at risk as it provides a measure of their long-term lead exposure and a means to ensure that their job is not putting their health at risk. In vivo XRF has allowed researchers to demonstrate that bone-lead levels are a direct measure of cumulative lead exposure and repeat studies of the same populations over many years are beginning to shed new light on physiological parameters such as the biological half-life of lead in bone. Furthermore, it has been demonstrated through these measurements that bone lead can be a source of endogenous lead exposure, just as your obstetrics friend speculated in her challenging case. It is hoped that with continued research this tool may become readily available to aid in occupational monitoring, optimising therapeutic procedures making use of gold (chrysotherapy for rheumatoid arthritis) or platinum (chemotherapy with cisplatin), as well as potentially monitoring environmental exposure to a wide range of toxic heavy metals.

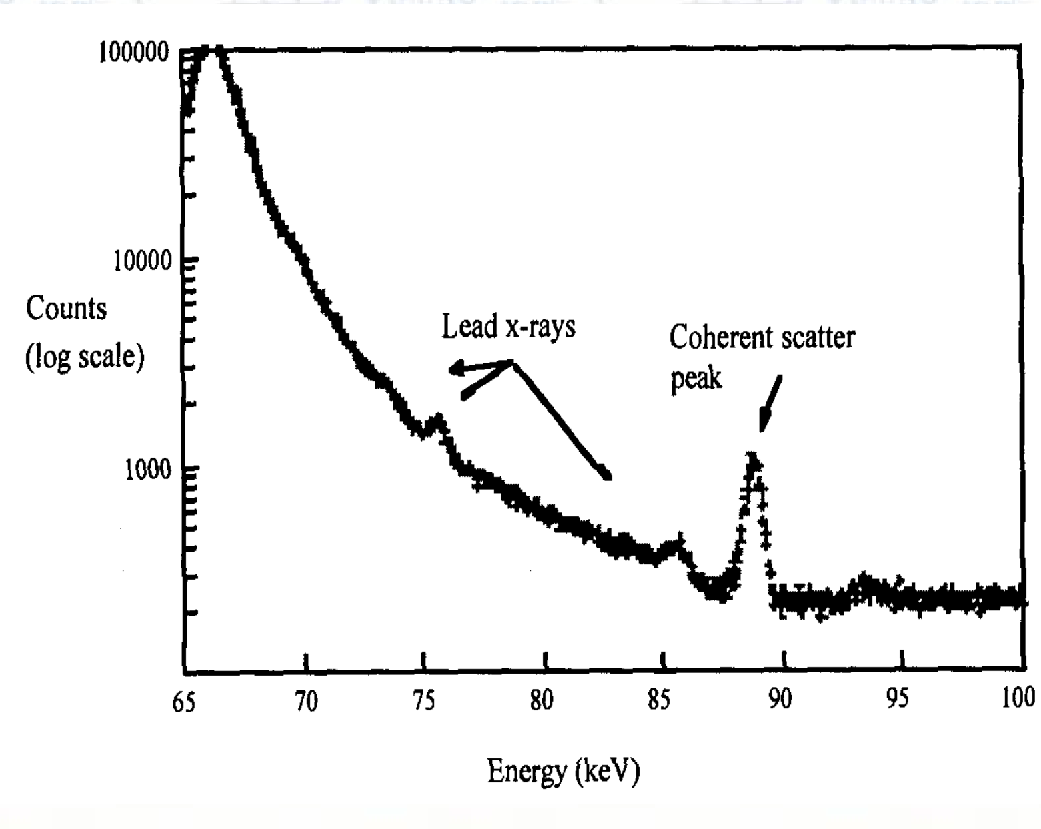

Figure 1: Spectrum acquired with a 140 ppm lead phantom with the 109Cd system. The lead x-rays are located in a reasonably low background region of the spectrum. The coherent scatter peak arises from the scatter of incident photons from the bone matrix, or in this case, from the phantom material, plaster of Paris.

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The European Conference on Energy Dispersive X-Ray Spectrometry, 1998

Dudley Creagh

EDXRS 98 was held in Bologna, Italy, from 7 to 12 June 1998. The venue for the conference was the University of Bologna, which has its Meeting rooms in the basilica of San Giovanni in Monte. The university is in the process of building modern facilities within the shell of the church complex. Lectures were held in a theatre constructed within a partially apse of the church. In the photograph you will see John Hubbell delivering the introductory address on "Compilation of Photon Cross Sections: some Historical Remarks and Current Status" in the Prodi Hall, which was originally part of the monastery.

Close examination of the photograph shows a fresco on the wall in the background, depicting important people discussing the fate on an unfortunate fellow in the hands of the constabulary of the time about to apply scourges and other tribulations to the hapless victim. Perhaps the message was that, if you do not speak well, this lot might befall YOU. Whatever: I here report that John's lecture was received with considerable acclaim, and he did not receive the fate so graphically depicted in the fresco.

The Organizing Committee provided a scientific and social programme of considerable substance and interest. In the session on Interaction of X-rays with Matter and their Modelling Professor Beckhoff (Physikalische-Technische Bundesanstalt, Berlin). Discussed recent synchrotron radiation experiments for the determination of fluorescence yields below 1.5 keV, a region of the x ray spectrum which contains emissions from atoms of biological interest. C.Q. Tran described research of Dr. Chris Chantler's group9 University of Melbourne) into x ray production by electron bombardment.

The session on Data Handling and Instrumentation brought discussions of both theoretical and practical issues. Dr Supra Kash Roy (Bose Institute, Bombay) spoke on the theory of the elastic scattering of photons at energies greater than 50 keV. The study of aerosolsamples, using redundancy in multi element PIXE measurements was discussed by Dr. F. Chimiello Universita di Prodova).

The session on Microanalysis with Photon Sources contained lectures on microscopic x ray fluorescence analysis (Dr. K Janssens, University of Antwerp) and the proton microprobe analysis of geological samples (Dr. M.T. Ramos (LURE, Orsay).

Total reflection x ray fluorescence analysis (TXRF) is of particular interest to those working with small specimens, and the delivery of the x ray beam to the sample needs the construction of appropriate xc ray optics. Papers by Professor Peter Wobarushek and Dr Christina Streli (Atominstitut der Universitates

Austriches) and Dr M. Milazzo (Universita di Milano) showed the usefulness of TXRF in environmental monitoring and archaeometry.

Sessions on Instrumentation and Special Applications brought out the significance of xrayscattering and emission to our lives through papers on medical imaging, analysis of tissue, blood serum and bone. The uptake of environmentally occuring toxicological metals by bone and their investigation in vivo was diccussed by Drs David Bradley (University of Malaya) and Mic Farquharson (City University, London).

The conference was not without its lighter side. We attended an excellent concert by the Symfonia Perusina at the Hall of the Academia Filharmonica, where the young Wolfgang Mozart almost failed to be admitted. His fatther, Leopold wanted him admitted because the Academy was such a prestigious institution. Wolfgang failed the test but after some discussion between Leopold and the Academia he was grudgingly passed. The conference excursion was to Firenze and to the Uffizi Gallery, with dinner in a banquet hall used by the Borgias for entertaining. I here that no-one was poisoned

The Organizing Committee, and in particular its President Professor Jorge Fernandez, are to be congratulated for the work they did to make the conference the success that it was.

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BOOK
REVIEWS

Review by:
Leif Gerward
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Naked to the bone. Medical Imaging in the Twentieth Century

Bettyann Holtzmann Kevles

Rutgers University Press New Brunswick, New Jersey, USA (1997)
378 pp., 74 illustrations, $35.95
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In her interesting and comprehensive book, Bettyann Holtzmann Kevles tells the history of medical imaging from Roentgenís discovery in 1895 to the present. The X-rays, says the author, altered instantly and forever the way people looked at each other and at themselves. The earlier, opaque world dissolved in the light of the X-rays. The author provides an interesting slant on the impact that this new way of seeing had upon society at large. In particular, she postulates that the discovery of X-rays led to a revolution in art. This is amply demonstrated by many of the book’s illustrations, from Pablo Picasso’s Girl before a Mirror (1932) and Frida Kahlo’s The Broken Column (1944) to Tori Ellison’s X-Dress (1993) and Annie Leibovitz’s Laurie Anderson MRI (1994).

The book is divided into two parts, corresponding roughly in time with the two halves of the century. Part I "The X-Ray Years" traces the history of the single technology of X-ray imaging. By means of an intensifying screen, physicist Michael Pupin produced an amazingly sharp radiograph of a human hand in 1896 revealing pieces of buckshot. As technology improved, physicians could see sharper and deeper into the human body, revealing first the skeleton, then the stomach, intestines, gall bladder, lungs, heart and brain. Although, as pointed out in the book, women never crowded the field, there have been prominent women in the community of X-ray experts. Most well known is perhaps Marie Curie, Nobel laureate, discoverer of the radioactive elements polonium and radium, and famous for her mobile X-ray units during World War I, but the author also portrays female radiologists Elizabeth Fleischmann, Alice Ettinger and Sigrid Lauritsen.

Part I also tells a darker story of the unanticipated side effects of radiation. Careless and ignorant use of X-rays caused radiation injuries, and in the 1920s radiation protection directives were prepared in several countries. What is now called the International Commission on Radiological Protection (ICRP) was born at Stockholm in 1928, during the 2nd International Congress of Radiology. Its birth caused less interest, however, than the action of its sister Commission on Radiation Units (ICRU), which recommended the roentgen (r) unit of radiation exposure, based on the ionization of air.

Part II "Beyond the X-Rays" deals with the daughter technologies of X-rays: computerized tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET) and ultrasound. The author gives an authoritative and well-informed account of how the combination of X-rays, engineering know-how and computer technology brought about a revolution in medical imaging and diagnostic medicine. In 1971 London-based EMI, Electrical and Musical Industries Ltd., demonstrated the first computerized tomographic scanner and immediately got contracts to build five more machines. However, as we are told in this enthralling chapter, the ingredients of CT had been around for over a decade. The Nobel prizes for physiology or medicine in 1979 were granted to Godfrey Hounsfield, engineer of EMI, and Alan Cormack, a nuclear physicist, for developing the CT scanner, but it had been a difficult decision for the awarding committee. There were others in the hunt, notably William Oldendorf and David Kuhl, who came close to the prize.

Very interesting is the author’s unveiling of how the highly advanced technologies for medical imaging were shaped by the size and structure of the medical market, particularly in the USA. The appearance of the CT scanner set the pace for the development and marketing of all the methods that followed, and the medical community invested generously in new and increasingly expensive instruments. The courtroom represents another driving force. Throughout the book, numerous case studies demonstrate how lawyers have used medical images to convince juries. The courts, says the author, fix the instant at which each new technology is accepted or doubted, and codify the rules for its acceptance as a legitimate way to convey reality.

Altogether, Bettyann Holtzmann Kevles has produced a fascinating book with refreshingly new aspects on medical imaging, how it evolved and how it affected science, culture and the entire society. The book should be of interest to physicians and radiologists and indeed to anybody with a genuine interest in the subject.

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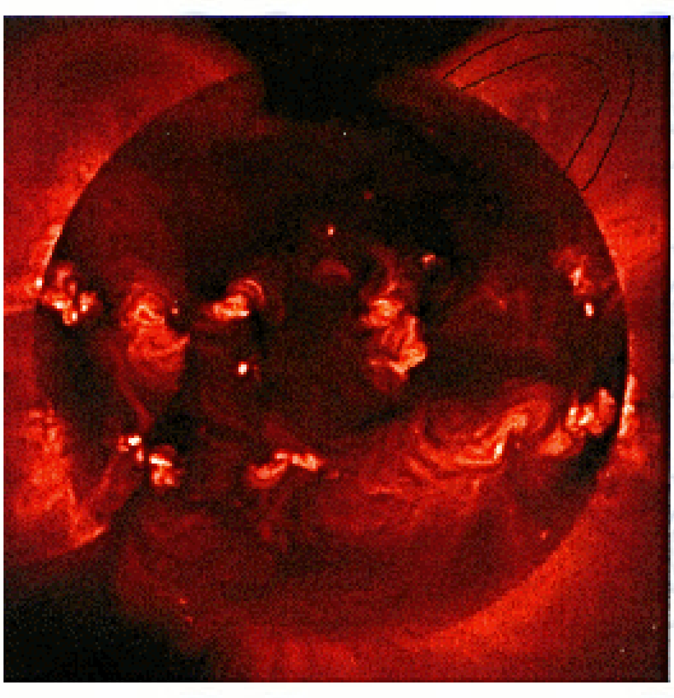
WORLD
NEWS

X-rays Resolve Solar Heat

(From "Post-Deadline", Physics World, Vol. 11, No. 7, 1998, p.5)

X-ray observations of the Sun have provided new insights into the heating of the solar corona. Scientists have known for over 50 years that the temperature of the Sun’s surface is about 6000 K, while the corona above is heated to several million kelvin. Much of the heat is carried in huge loops of material confined by magnetic fields, and the new observations have allowed astronomers to measure the temperature along a loop for the first time.

The measurements were taken with the Soft X-ray Telescope on-board the Yokhoh satellite, jointly funded by the UK, the US and Japan. Images from the satellite have revealed myriads of coronal loops that continually evolve and interact. The hottest loops change extremely quickly, leading to highly transient X-ray emissions, but cooler loops emit steady X-rays over many hours. A team of scientists from the UK, France and the US measured the X-ray emission along one particular loop (E Priest et al. 1998, Nature 393, 545). The measured emissions were corrected for radiation scattered from other parts of the Sun, and then translated into a temperature profile. The observations show that the temperature increases from around 1.7 million kelvin at the foot of the loop to around 2.2 million kelvin at the summit –- the part furthest from the Sun.



Solar power – coronal loops can extend to 0.8 solar radii above the Sun’s surface

The scientists compared the temperature profiles with predictions from the three main theoretical models for coronal heating. One of these models suggests that the heat is deposited at the foot of the loop, while another assumes that the heat source is located at the summit. But the observations are most consistent with the third model, which suggests that heating is uniform along the length of the loop.

Such uniform heating is most likely caused by the breaking and reconnection of magnetic field lines in many small regions of intense electric current. Such magnetic turbulence leads to energy dissipation and heating, and has recently been modelled in numerical experiments.

The scientists believe that other coronal structures could be studied by comparing theoretical predictions with observed temperatures. To help with such comparisons, they suggest that theorists should describe the type of heating produced by their models in detail, and that observers should refine their diagnostics so that temperatures can be derived as accurately as possible.

India Backs Renewables

Ganapati Mudur New Delhi, India

(From Physics World, Vol. 11, No. 7, 1998, p.7)

The Indian government is to more than double its spending on renewable energy research next year to Rs 4.2bn (about £60m). The sector was the biggest winner in India’s 1998/99 science budget, which rises by a total of 28% to Rs 48.3bn. The budget also includes Rs 13.7bn for space technology, up 62%, and Rs 13.9bn for atomic energy, up 68%.

India launched its renewable energy programme in the early 1980’s, and the country is now the world’s third-largest generator of wind energy after the US and Germany, with a capacity of some 925 MW. India also generates 25 MW of electricity from solar photovoltaic systems. The budget for renewable energy will include subsidies for solar-power stations and solar-powered home appliances, such as cookers and lighting systems. The government is also supporting projects to develop indigenous technologies in hydrogen energy, fuel cells and geothermal energy.

For scientists working in renewable energy, the new budget is a very good and positive signal after a long time," says Onkar Nath Srivastava, a physicist at the Banaras Hindu University (BHU) at Varanasi. His university has already developed a hydrogen-powered motorbike that uses a novel metallic hydride hydrogen-storage system. Srivastava says he has been waiting for funds to demonstrate the economic viability of such vehicles in India. A new Rs 252m fund will also be set up to support laboratory equipment in universities, which currently suffer from a lack of investment. "While industry-oriented research in government laboratories is important, India’s universities have to become major players in fundamental research," says Murli Manohar Joshi, India’s science minister and a former physicist.

Cuts Undermine Neutrino Breakthrough

Frederick Shaw Myers, Tokyo

(From Physics World, Vol. 11, No. 7, 1998, p.9)

The SuperKamiokande experiment in Japan – which last month announced the first "firm evidence" that the neutrino has mass – has had its budget for the next year cut by 15%. The cut will force SuperKamiokande to shut down for two months later this year and for four months in 1999. "This would be devastating at this critical time," says Yoichiro Suzuki, principal investigator on the collaboration. The evidence for neutrino mass, if confirmed, has immense significance for particle physics and cosmology.

Budget blow – the SuperKamiokande experiment

SuperKamiokande is a vast, other-worldly facility, located 1000 m below ground in a disused mine. It consists of a 50,000 tonne tank of highly purified water, surrounded by 13,000 very large photomultiplier tubes. The experiment, which opened in April 1996, measures neutrinos produced in the atmosphere by cosmic rays.

Neutrinos come in three types - electron, tau and muon. SuperKamiokande detects electron and muon neutrinos, which enter both from above the detector after travelling through the atmosphere, and from below, after travelling through the Earth. The researchers found that only half as many muon neutrinos entered the detector from below as from above, but that the number of electron neutrinos detected was the same in both cases. They attributed the discrepancy to the fact that muon neutrinos from below change, or "oscillate", into tau neutrinos, which cannot be detected by the experiment. The only explanation for this, they concluded, was that the neutrino must have masse.

But just as the 120-strong team of researchers from 23 institutions in Japan and the US was preparing to collect more data to verify the initial results, the Japanese Ministry of Education, Science, Sports and Culture (Monbusho) – a key supporter of the project – decided to cut the budgets of all of its research projects by 15%. The SuperKamiokande team will now not be able to carry out continuous, long-term sensitive experiments.

Suzuki and other researchers complain that Monbusho has, as usual, made an across-the-board cut of all research projects without distinguishing between dead wood and those that are doing outstanding work. "Not only will this greatly hamper our ability to follow up on the new results, it will also damage the international collaboration,." Says Suzuki. This could also prevent the team from measuring neutrinos produced by supernovae in our galaxy, he argues. The US collaborators on the team are requesting that the University of Tokyo’s Institute for Cosmic Ray Research, which leads the project, should make every effort not to interrupt the experiment.

Brookhaven Lab Faces Review

(From "News in Brief", Physics World, Vol. 11, No. 7, 1998, p.11)

Nuclear regulators in the US are to undertake a comprehensive review of the High Flux beam reactor at the Brookhaven National Laboratory in the US. The reactor has been shut since December 1996, when investigators found that water contaminated with tritium had leaked from the reactor’s spent-water pool. The Department of Energy, which oversees the Brookhaven Laboratory, will use the review to decide the fate of the reactor. John Marburger, director of the laboratory, told Physics World that the review will assess the safety of the reactor’s operations over a range of power levels. "The Nuclear Regulatory Commission will rely on our employees to provide the information for the work, and we will be active participants," he says. A final decision on the fate of the reactor will be made next May.

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