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IRPSBulletin

Newsletter of the International Radiation Physics Society


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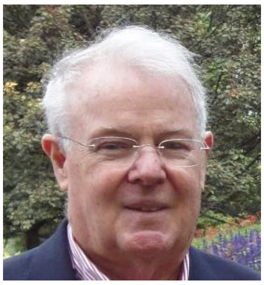
ELECTION EDITION

Who will be your next IRPS president?




25 years of IRPS Presidents

Clockwise from the top right:

John Hubbell. Bikash Sinha, Malcolm Cooper, Richard Pratt, Dudley Creagh, Odair Goncalves, Ladislav Musilek, Christopher Chantler, David Bradley

CURRENT IRPS COUNCIL MEMBERS 2018-2021

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From the Editor

Greetings from the new IRPS Bulletin editorial team. We wish all colleagues and their families well during the dire and difficult covid-19 pandemic which rages worldwide. As 2021 is an election year, this ISRP Bulletin focusses on the election of all the IRPS officers, from the President to the executive councillors. In this issue we will present the biographies members seeking election together with their biographies.

I have the honour to have been invited to be the editor of the IRPS Bulletin. My fields of research include the biomedical sciences, nuclear medicine, particle radiation, and I work at Sunway University, Malaysia. I am being assisted in my editorial task by Dudley Creagh and Shirley McKeown (University of Canberra). They have been associated with the IRPS Bulletin for 30 years as editors and publishers.

The Editorial Team wants the IRPS Bulletin to be both informative and vibrant. To achieve this we hope that you, the members, will send us items of news from your institutions and your countries which we can incorporate in a new section *News from the World*. Distributing news from IRPS members has been made all the more necessary in this covid-dominated world, in which the fragile links between people are easily broken, To place more emphasis on research we welcome the submission of short articles on their research from established scientists and their students. Details of the submission requirements for these articles are given laten in this issue. Research supervisors: this is an ideal platform for your students to describe their research results.

This issue contains invited articles by IRPS members, both on the application of radiation physics in practice: James Tickner writes on the use of a photonuclear technique for assaying gold in ores, and Bleddyn Jones writes on what essential work remains to be done in the field of proton therapy.

As well, this issue contains an Obituary for Leif Ingemar Gerward, remembering his life's work and his contributions to IRPS and to physics in general.

Ming Tsuey Chew mtchew@sunway.edu.my

From the President

It takes Perseverance: no kidding Sherlock

The Perseverance Rover touched down on the surface of Mars on 18th February of this year and is presently going about its business exploring the crater Jezero. A key instrument on the Perseverance Rover is PIXL (Planetary Instrument for X-ray Lithochemistry), a microfocus X-ray fluorescence instrument that can analyze the elemental chemistry. Customised polycapillary X-ray focusing optics applied to an X-ray beam (from a rhodium anode, grounded-cathode design X-ray tube) provides for micro-X-ray fluorescence analysis of rocks or soil at a spatial resolution of some 120 μm (suggestive of the use of MCVD doped silica fibres). The induced X-ray fluorescence information is returned to earth via telemetry. The effort is supported by SHERLOC, an instrument on the end of the rover's robotic arm that can hunt for sand-grain-sized clues in the rocks, working in tandem with WATSON, a camera that is intended to take close-up pictures of rock textures. The high X-ray flux of PIXL gives rise to high sensitivity and hence fast acquisition times, allowing rapid scanning of most of the detectable elements, 26+ in all, now detectable at lower concentrations than possible on previous landed payloads; several new elements can be detected that were not previously detectable on these missions. In particular, PIXL can measure a large number of major and minor elements at 0.5 wt% in 5 seconds, detecting important trace elements at the 10's of ppm level.

The Perseverance Rover has its antecedents, most recently the Curiosity Rover (functioning for more than 3000 days). Just as is now true of the Perseverance Rover, the Curiosity Rover (which landed on Aeolis Palus inside the Gale crater), was equipped with a radioisotope power system, electricity being generated by the heat given off via the radioactive decay, in these particular cases by plutonium (presumed to be ^{238}Pu, $t_{1/2}$ 87.7 years), such a system generally being referred to as a radioisotope thermoelectric generator (RTG) although for these space missions the power source is referred to as a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). Power production is suggested to be at the level of some few hundred watt. Although one is not privy to the particular inner workings, in principle the nuclear battery makes use of thermocouples, converting the decay heat into electricity via the Seebeck effect. Importantly, this type of generator has no moving parts. For the Curiosity mission, instead of use of an x-ray tube for fluorescence analysis, use was made of an Alpha Particle X-ray Spectrometer (APXS), an updated version of the spectrometers used on the Mars Exploration Rover (MER) and Mars Pathfinder missions. In these, the samples are bombarded with X-rays and alpha particles from a curium source, commonly ^{244}Cu, emitting alpha particles with an energy of 5.8 MeV, while x-rays of energy 14 and 18 keV are emitted via the decay of ^{240P}Pu. The APXS power has been provided by a thermoelectric generator, as previously discussed.

We the International Radiation Physics Society have been trying to play our part, seeking to progress research and education in radiation physics, having just run IFARP-3, the 3rd International Forum on Advances in Radiation Physics (24-25th February). This virtual platform meeting, co-hosted by Sunway University and the University of Melbourne, in collaboration with Putra University Malaysia (UPM), had contributions from Nigeria, Croatia, Italy, Turkey, Egypt, Saudi Arabia, the Yemen, Bahrain, Qatar, Kuwait, UAE, Pakistan, India, Bangladesh, Thailand, Malaysia, China, Malaysia, South Korea, and Australia, going from West to East. There was a great gender mix, a great age mix and considerable energy and enthusiasm, the themes including atomic physics effects in materials (solid-state effects), physico-chemical effects, human dose deposition studies, radiation sources and detectors, medical physics, environmental physics, and geophysics. Standing back from the particular, many of the radiation physics aspects surrounding the Perseverance Rover were implicit in our discussions. In the twelve-month period since the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) came to so overwhelmingly control our lives, such activities all point to the power of perseverance and of curiosity, even when confronted by difficulties and complexity. We press on regardless.

D A Bradley
1st March 2021

Invited Articles

Commercial Analysis of Gold Ores via Photonuclear Activation

James Tickner, Chrysos Corporation Ltd, Adelaide, Australia

Abstract

Measurement of gold in mineral ores is an important commercial problem that presents significant technical challenges due to low gold concentrations and sample heterogeneities. PhotonAssay, a novel approach based on photonuclear activation using high-energy X-rays, has been developed and commercialized. PhotonAssay provides analytical precision comparable to or better to existing methods. It significantly reduces sampling errors by measuring much larger sample volumes, and is also rapid, safe, and non-destructive.

Introduction

Accurate analysis of the concentration (grade) of commodity metals in ores underpins the entire minerals industry. From initial exploratory drilling and mapping of deposits through to management of mining, blending and ore processing, knowledge of ore grade is essential.

Gold is one of the world's most important commodities, with global production in 2020 valued at over $US180 billion. However, analysis of gold in mining applications presents unique challenges. First, gold usually occurs naturally at very low concentrations, often significantly less than one part-per-million (ppm). Second, gold ores are often very heterogeneous, with metal present as discrete nuggets in the host rocks. Large sample volumes are necessary to ensure good sampling of the underlying grade. Third, mines can produce thousands of samples per day so any analysis method must be fast and easy to use.

Commercial laboratories analyze gold using a variety of chemical methods, of which the most common is fire-assay (Hoffman, et al., 1999). Materials sent for analysis typically include drill-cores and reverse circulation drill chips (

Figure 1). Samples must be dried, crushed and then finely ground or pulverised to a maximum particle size of about 75 μm to allow a representative 30-50 g aliquot to be taken for assay.

Figure 1. Drill-core (left) and reverse-circulation drill-chip samples (right) prior to preparation for analysis. Photo credit: MinAnalytical Laboratory Services Ltd.

The aliquot is mixed with a flux and heated in a furnace until it melts; lead oxide in the flux is reduced to lead which dissolves any gold present. The sample is cooled and the glassy residue is separated from the lead button. The button is remelted in a porous cupel to form a tiny speck of gold metal; this is dissolved in acid and the concentration of the resulting solution measured. The whole process is labour intensive, requires careful quality control to deliver accurate results for different ore types and exposes operators to a range of health and safety hazards. Nonetheless, the commercial cost for a fire-assay analysis is relatively low (typically $US10-20 per sample).

Photonuclear activation analysis or gamma activation analysis provide an interesting alternative for direct measurement of large samples with particularly high sensitivity for gold (Burmistenko, 1981), (Řanda, et al., 2007), (Tickner, et al., 2017). In this paper we describe the design, development and application of a commercial gamma activation analysis approach that we call PhotonAssay. We present performance comparisons with existing assay methods on both reference materials and real gold ores.

Photonuclear excitation reactions

In addition to the familiar atomic processes, high-energy photons can undergo interactions directly with nuclei. For energies up to a few tens of MeV, the interaction cross-section is dominated by the giant dipole resonance (GDR) (Spicer, 1969).

The GDR corresponds to absorption of the incident photon resulting in a collective oscillation of the protons and neutrons. If the absorbed energy exceeds the neutron separation threshold deexcitation generally proceeds by emission of a neutron. Otherwise, the nucleus cascades down through intermediate energy levels mainly via emission of gamma-rays.

Normally the entire excitation and deexcitation process is almost instantaneous. Spectroscopic detection of instantaneous characteristic emissions from elements of interest at trace concentrations is complicated by high levels of background from both the radiation source and emissions from other elements in the sample.

There are two options for making delayed measurements with significantly lower background levels. First, if a target isotope emits a neutron and the resulting daughter nucleus is radioactive, its characteristic decay radiations can be measured after removing the sample from the vicinity of the source. Second, some naturally occurring isotopes have so-called isomeric states whose spin and parity retard their decays. The half-lives of these levels range from fractions of a second to many years. If the cascade from the GDR to the ground-state becomes 'stuck' in an isomeric state then any subsequent emissions from this level are delayed.

Naturally occurring gold consists entirely of the isotope ^{197}Au which has an isomeric state at 409 keV. *Figure 2* (left) illustrates the theoretical GDR excitation cross-section determined using parameters from (Capote, et al., 2009), and experimentally determined cross-sections for the reactions ^{197}Au(γ,n)^{196}Au and ^{197}Au(γ,γ)^{197m}Au (Vogt, et al., 2002) (Meyer-Schützmeister & Telegdi, 1956). Above the neutron separation energy, the excited nucleus almost always decays *via* neutron emission; below this energy, the isomeric state forms in approximately 10% of decays. *Figure 2* (right) illustrates the population mechanism for the 409 keV isomeric state and its subsequent gamma-ray emissions, the strongest of which is a 279 keV gamma-ray produced in 70.9% of decays. The 7.73 s half-life of the isomeric state means that these emissions are separated in time from the initial excitation.

Notwithstanding the much larger cross-section of the ^{197}Au(γ,n)^{196}Au reaction, the isomer-formation reaction is the preferred pathway for gold analysis for two reasons. First, the much shorter half-life of the isomer (7.73 s versus 6.17 days for ^{196}Au) leads to much shorter measurement times. Second, the excitation can be efficiently performed using relatively low-energy X-rays, for example those created *via* Bremsstrahlung from an electron accelerator operating at an energy of 6-9 MeV. The lower excitation energy simplifies the radiation shielding design and minimizes unwanted excitation of other elements in the sample.

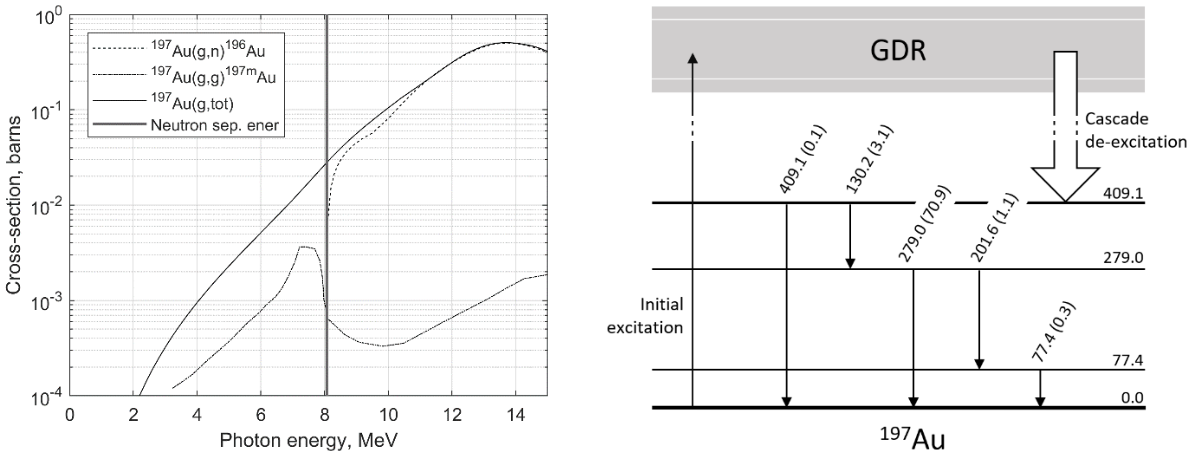

Figure 2. Left – cross-sections for photon-induced reactions of ^{197}Au; the neutron separation threshold is shown as a vertical line. Right – formation and decay of the 7.73 s, 409 keV isomeric state in ^{197}Au. Level and gamma-ray transition energies are shown in keV; gamma-ray emission intensities per 100 decays are shown in brackets.

Conceptually, the analysis of gold *via* photon excitation is then straightforward. An ore sample is exposed to intense high-energy X-rays for a short time and then rapidly transferred to a counting station where gamma-rays are measured. The relationship between the number of detected gamma-rays, N_γ, and the mass of gold in the sample, M, is given by

$$N_\gamma = \int \sigma(E)\varphi(E)dE \cdot \frac{M p_\gamma p_d}{m} \cdot \frac{1}{r} \cdot (1 - e^{-rt_i}) \cdot e^{-rt_c} \cdot (1 - e^{-rt_m}) \qquad (1)$$

where $\sigma(E)$ is the activation reaction cross-section as a function of photon energy E, $\varphi(E)$ is the energy-dependent average photon flux inside the sample, m is the mass of a gold atom, p_γ and p_d are respectively the probabilities of a gamma-ray being emitted in a decay and being detected, $r = ln(2)/t_{1/2}$ is the decay rate of an isomeric state with half-life $t_{1/2}$ and t_i, t_c and t_m are the irradiation, cooling and measurement times respectively.

The main practical challenges are then maximising the photon flux inside the sample to maximise sensitivity, correcting for variations in flux due to changes in the output power or energy of the X-ray source, and correcting for attenuation of both incident X-rays and emitted gamma-rays inside the sample volume.

PhotonAssay instrument design

In 2012-15 we conducted a series of experiments (Tickner, et al., 2017) using an electron accelerator fitted with a copper Bremsstrahlung convertor target. Designed and operated by Mevex Corp in their facility in Ottawa, Canada, the accelerator had a beam energy adjustable between 6.5 and 13 MeV and a maximum beam power of approximately 4.5 kW. The accelerator was used in a heavily shielded concrete bunker. Additional steel and lead shielding was used to allow high-purity germanium (HPGe) detectors to be situated in the bunker approximately 2 m away from the accelerator target. A pneumatic transfer system rapidly cycled samples between the irradiation and measurement.

Based on this test work, a concept design for an industrial photonuclear analysis system was developed which was closely followed in the first commercial PhotonAssay unit. Key elements of the design include:

- A high-power electron linear accelerator with Bremsstrahlung convertor target. Normally operated at 8.5 MeV, 8 kW beam power for gold analysis, energies up to 14 MeV at lower beam power can be produced.
- A compact engineered radiation shield with a footprint of approximately 2 × 5 m. Successive layers of material attenuate primary X-rays, photoneutrons produced in the target and gamma-rays resulting from neutron capture. A sliding ‘plug’ collects samples and presents them to the X-ray beam whilst simultaneously prevent radiation leakage.

- Sample presentation in custom-design cylindrical jars measuring approximate 100 mm in diameter. Jars are irradiated from the side whilst being rotated to ensure uniform sample activation.
- A high-efficiency radiation detection system comprising a pair of 90 mm diameter, 30 mm broad-energy germanium (BEGe) detectors. The detectors are electro-cooled to their operating temperature (typically -185°C) and can operate continuously without liquid nitrogen. The resolution at the gold gamma-ray energy of 279 keV is approximately 1 keV.
- An automated robotic sample handling system that accepts jars loaded onto an input conveyor, runs them through one or more activation/measurement cycles, and then places them on an output belt. By the time samples emerge from the unit, residual radioactivity is negligible, and materials can be safely handled or disposed of without special precautions.
- A fully containerised design housing the source, detectors, shielding, sampling handling equipment and ancillary components in 3 cabins with a total footprint of 6 × 7 m.

Figure 3. Photographs illustrating design of the commercial PhotonAssay Max system PA1408X. (Left) Overview of complete system, showing input and output sample conveyors, control console and cabins housing X-ray source, detector system and automation. (Right) Interior of automation cabin, showing reference discs and reference disc robot.

Indirect monitoring of the X-ray flux produced by the accelerator is performed using a 'reference disc' which is irradiated and measured simultaneously with the sample. The disc comprises a metal cassette containing a stable salt of bromine and is positioned by a robot in a pocket in the underside of the sample jar before irradiation and removed after the measurement is complete. Bromine undergoes a similar isomeric excitation reaction to gold leading to emission of 207 keV gamma-rays with a half-life of 4.84 s. The ratio of gold and bromine activation rates with electron energy varies less than 2% over the energy range 8 – 9 MeV, thereby correcting for both power and energy fluctuations in the LINAC output.

Attenuation of photons inside the sample is corrected for by performing detailed Monte Carlo simulations of both the activation and measurement processes. The EGSnrc (Kawrakov & Rogers, 2003) code is used (with modifications) to simulate photonuclear excitation (Bencardino, et al., 2010). A large suite of sample types is simulated and used to build a look-up correction table. Prior to measurement jars are weighed and their fill-level optically determined to enable the sample density to be calculated. The appropriate attenuation correction is then applied to convert the measured number of gamma-rays to the mass of gold in the sample and hence to gold concentration.

Assay performance on reference materials and real gold ores

Figure 4 compares certified gold grades (in parts-per-million, ppm) with grades measured via PhotonAssay for a suite of 94 commercial certified reference materials provided by four different manufacturers. Excellent agreement is observed for sample grades spanning nearly four orders of magnitude.

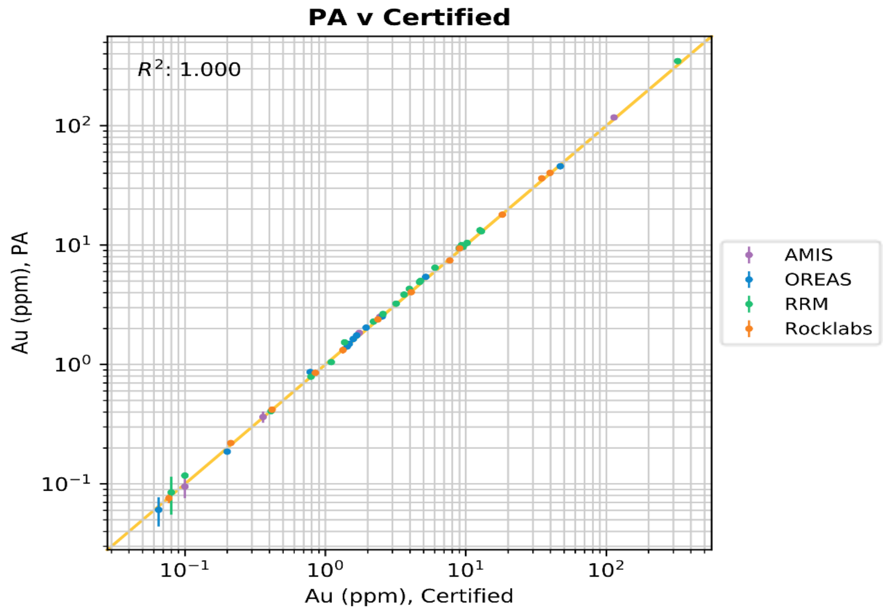

Figure 4. Comparison of gold grades measured using PhotonAssay (y-axis) and certified grades provided by manufacturers (x-axis) for a suite of 94 certified reference materials.

Table 1 compares the performance of PhotonAssay and fire-assay. At lower grades, the PhotonAssay precision is dominated by Poisson counting statistics associated with measurement of the gold gamma-ray photopeak. The detection limit depends mainly on concentrations of naturally occurring uranium and thorium, both of which undergo X-ray induced photofission giving rise to a broad gamma-ray background from short-lived fission products, and barium, which produces the ^{137m}Ba isomer (2.55 min half-life, 662 keV gamma-ray emission). Although fire-assay can offer a lower detection limit, the precision of PhotonAssay is comparable at commercially important concentrations.

Table 1. Comparison of detection limits and 1-standard deviation measurement precisions for PhotonAssay and fire-assay at different gold concentrations.

Gold assay performance	Value for fire-assay	Value for 2-cycle PhotonAssay
Detection limit (2σ)	0.001 ppm (ICP) 0.005-0.010 ppm (AAS)	0.008 ppm (blanks) 0.01-0.025 ppm (typical ore)
Repeatability @ 0.35 ppm	5-8%	7%
Repeatability @ 1 ppm	3-7%	4%
Repeatability @ >10 ppm	2.5-3.5%	2%

Demonstrating that PhotonAssay can be used effectively on samples of real gold ores is critical. A complicating factor is that the true grades of the samples are unknown and have to be measured using a method such as fire-assay with its own errors and potential biases. Sampling errors normally dominate the overall measurement precision. For example, a 50 g fire-assay aliquot with a mean grade of 1 ppm would only contain 5 particles of gold if the average gold nugget size is 100 µm, resulting in a 1-standard deviation sampling error of 0.45 ppm (45% relative). For a 500 g PhotonAssay aliquot of the same material the sampling error is 0.14 ppm.

Detailed sample preparation, the measurement of multiple aliquots and careful statistical analysis (Tickner, et al., 2021) is required to separate out the sampling and instrument errors of PhotonAssay and fire-assay.

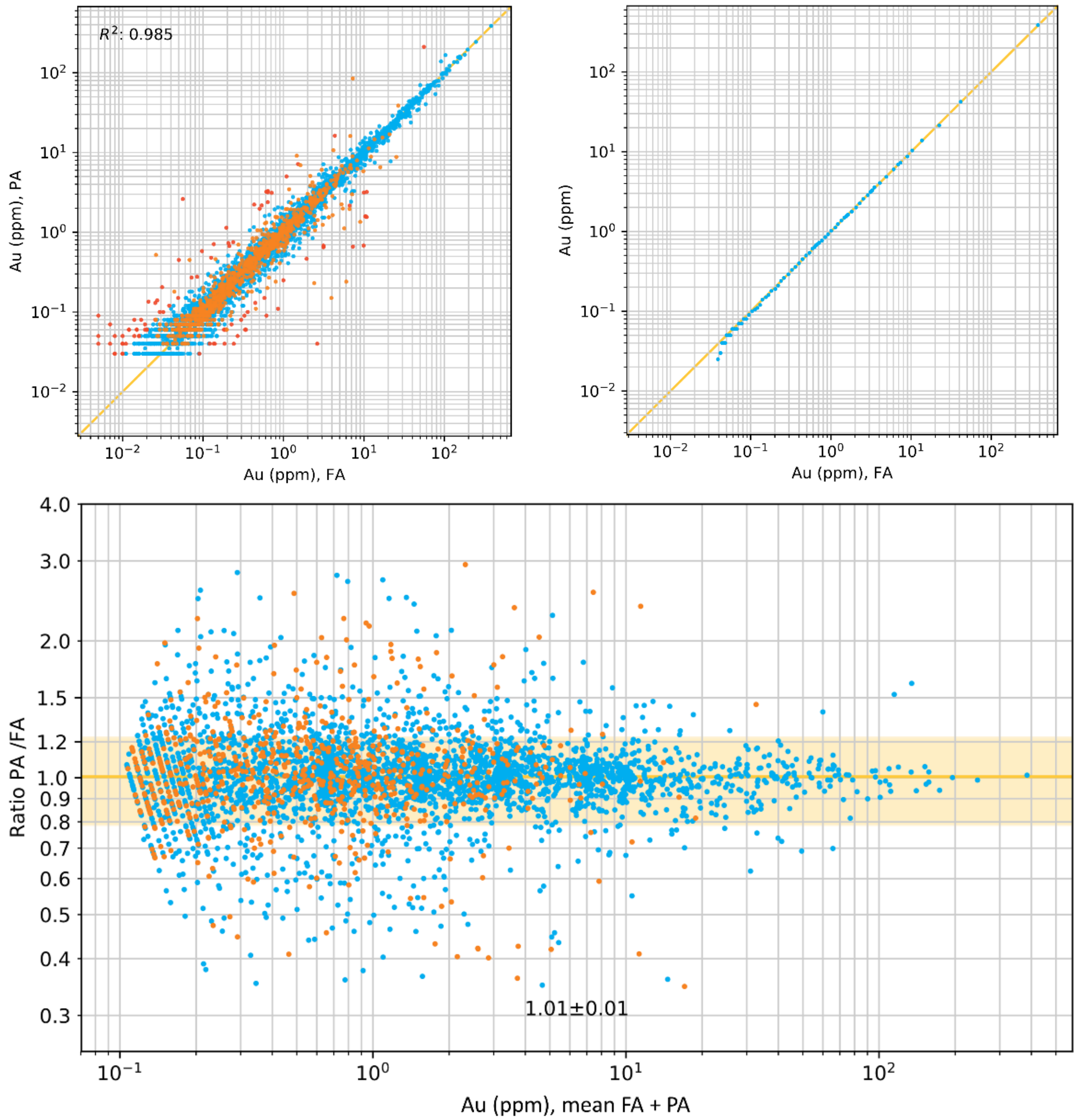

Figure 5. Top left: Scatter plot comparing measured gold grades using PhotonAssay (y-axis) and fire-assay (x-axis). Samples where the grades differ by more than a factor of 3 are coloured red. Blue and orange points indicate different sample chemistry. The R^2 value for a linear regression fit between the two analyses is also shown. Top right: quantile-quantile plot. Points represent the 1st, 2nd, 3rd … 99th quantile grades determined via PhotonAssay and fire-assay. Values below detection limit for either technique are set to a grade of zero. Bottom: Tukey mean-ratio plot, showing the gold grade ratio (PhotonAssay over fire-assay) plotted as a function of mean grade. The yellow band and gold line indicate the 1-SD grade-ratio spread and log-weighted mean grade ratio respectively.

To date we have performed more than 60 detailed studies comparing PhotonAssay and fire-assay performance on gold ores sources from mines on six continents. Study sizes range from a few dozens to tens of thousands of samples. Sampling errors vary significantly between deposits, depending on gold grade and dissemination. On ores containing coarsely distributed gold, the larger PhotonAssay sample mass results in total measurement errors 2-3 times smaller than those of fire-assay.

Results from one study involving several thousand samples are shown graphically in figure 5. The spread between PhotonAssay and fire-assay results on individual samples is 22% (1-SD), dominated by sampling. However, the distribution of gold grades measured using the two techniques is statistically consistent to within 1%.

Commercial pathway

Initial research into PhotonAssay was conducted at the CSIRO, Australia's national scientific agency. Commercial design and product development were carried out through the formation of a spin-out company, Chrysos Corporation. Engineering design and manufacture were performed in partnership with a major X-ray equipment manufacturer, with the first PhotonAssay product deployed approximately 16 months after Chrysos started operations.

PhotonAssay units are provided via a 'fee-for-service' lease model, where customers pay for each assay performed rather than purchase equipment. Currently four units are operational, with an additional five installations planned by the end of 2021.

Summary

Photonuclear activation provides a powerful alternative to conventional chemical assay methods for mineral ores due to its ability to rapidly and non-destructively measure large sample volumes. The method is particularly well-suited to the measurement of gold due to the convenient short-lived isomeric state of ^{197}Au. An integrated system for analysing gold in mineral ores has been developed and successfully deployed into several commercial assay laboratories, with more than 800,000 samples analysed to date.

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Invited Articles

What essential work remains to be done in proton therapy research? *A personal View*.

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Abstract

A considerable amount of research linking nuclear physics and radiobiology remains to be done in order to improve proton therapy of cancer. The conversion factor for dose between protons and photons (known as the RBE) is governed by the dose per treatment, the radio-sensitivities of the tissue or tumour being irradiated, and is especially influenced by the linear ionisation density (LET). The use of a constant RBE of 1.1 is presently applied to all tissue and tumours. This assumption, based on experiments that can be regarded as inappropriate, is probably incorrect.

A more flexible RBE with modelled values that exceed 1.1 especially in the radiobiological conditions of late reacting tissues could be used to reduce unintended toxicities in tissues such as the brain and spinal cord. The increasing use of magnetically scanned 'pencil' beams where particle inter-track distances (ITD) are closer and remain so with increasing tissue depth appear to maintain a high RBE in comparison with scattered beams where ITDs increase with depth and RBE values decrease. ITD are related to instantaneous fluence and dose rate.

Any shift to the use of larger treatment doses will require modification of the RBE values used with lower doses. For treatment optimisation purposes, further experimental approaches and detailed clinical research is required. Proton therapy requires greater radiobiological input.

Introduction

There is a steady increase in provision of high energy proton therapy for patients with specific rare tumours, or for some commonly-occurring cancers where anatomical considerations suggest that conventional x-ray based therapy dose distributions may be suboptimal [1]. The case for proton therapy is based on the fact that x-ray based treatments pass through the entire thickness of tissues, but proton beams 'stop' at positions determined by the beam energy. This occurs because of the formation of a sharp rise in dose (due to the Bragg peaks effect) at the end of range, beyond which there is no further energy release. Consequently, there can be considerable reductions in radiation dose to tissues beyond the standard treatment volumes that have to be irradiated to ensure loco-regional control or cure, and - in many instances – also in tissues proximal to the target volume. This significant change in dose distribution should allow better normal tissue growth and development in children, reduce both late vascular-related complications in vital organs, reduce bone marrow irradiation (with implications for cytotoxic chemotherapy tolerances), and the life-long risk of subsequent malignant induction [2-4].

As in most medical interventions, there may also be disadvantages. Within each Bragg peak, there is not only a higher dose, but also increasing proximity of ionizations which cause more clustered DNA damage than is the case with conventional radiotherapy [5]. Such clustering can increase to an extent that the inborn enzymatic repair systems are less effective, resulting in enhanced bio-effectiveness. Clustering is quantified by the linear energy transfer (LET) of a radiation which refers to the ionisation per unit length of radiation track. Bragg peaks have to be spread or scanned over the volume of a tumour and its surrounding margins that contain infiltrating cells. Figure 1 shows the differences between low and high LET radiation tracks, 3

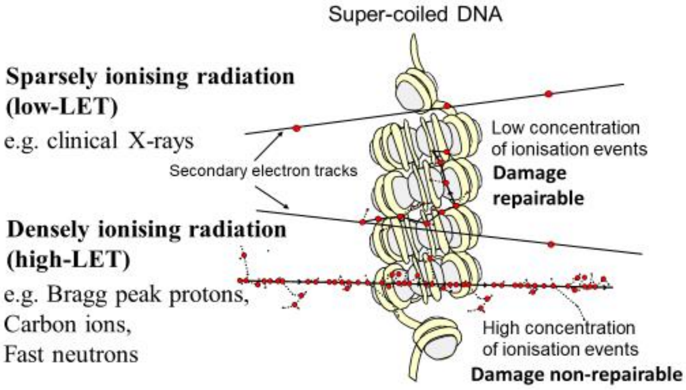

Figure 1. Features of low and high LET radiations superimposed on DNA. Courtesy of Dr Mark Hill, Oxford.

Because of the above physical and biological features, the two potential Achilles heels of particle therapy are:

- The accuracy of the complex placement and spread of proton Bragg peaks to form treatment volumes.
- The biological effects of protons vary with position in the beam, with dose itself, the LET, and also depend on the tissue being treated.

Clinicians about to enter proton therapy need to study the associated scientific base and the latest clinical results of proton therapy, although the latter continue to form a relatively small part of the medical literature, yet contain some reports of unexpected severe toxicities in over 10% of patients treated [6, 7]. Especially important is the longstanding controversy regarding the conversion of conventional photon dose to proton dose by the relative biological effectiveness (RBE) factor, which influences the dose prescription. The RBE is defined in Figure 2.

Essentially, the conventional photon dose for a specified medical end-point is divided by the RBE to provide the actual proton dose. If the RBE used is incorrect, the delivered proton dose will be incorrect. Presently, the prescribed proton dose includes an RBE of 1.1 regardless of tissue, tumour and dose given per treatment session. This longstanding practice can be criticized, since the experimental cellular and acute-reacting *in vivo* tissue RBE data sets used to determine this number will tend to underestimate the operative RBE for late reacting normal tissue effects (LNTE) at standard low clinical doses. Also, the data used only linear fitting methods, and many control experiments used kilo-voltage reference radiations with a higher LET than the protons [8].

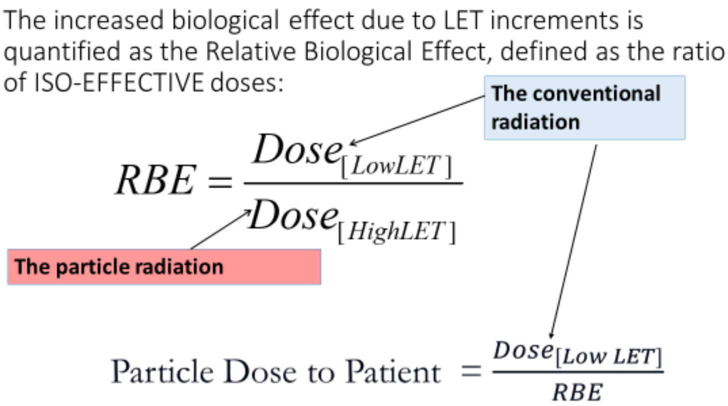

Figure 2. Formal definition of RBE

By definition, the RBE ratio numerator is the photon-based dose, which is highly dependent on dose per fraction (*d*) for LNTE, so RBE must vary with *d* in such tissues. The shape of cell survival curves

ensures that RBE will vary with dose, since with increasing dose curvature of the x-ray treated cells with incremental dose becomes greater than the less curved shape followed by the particle-treated cells [9]. Analysis of previous fast neutron radiobiology data show such effects very clearly and it is important to note that fast neutrons ionize biological systems mostly by the formation of recoil protons [10]. Thus, RBE values of up to 2 or more, typical of neutrons, may occur within proton Bragg peaks.
It is also of concern that experiments have shown that proton RBE values increase sharply with LET at much lower LET values than other ions, but to similar maximum RBE values [11], although the magnitude of the RBE depends on cellular DNA repair proficiency [12], Consequently, there should be no room for complacency regarding the RBE of protons.

Modelling systems, including the clinically useful biological effective dose (BED) concept [13] and based on cell survival experiments, which incorporate the phenomena described above, have been developed to estimate proton RBEs for different cellular radiosensitivities, dose and linear energy transfer (LET) values [14]. LNTE, such as severe brain damage, are predicted to have higher RBE values than 1.1 at low dose per fraction (1.2 - 2Gy) for typical treatment-volume LET values, with further increases in RBE towards the end of range (see Table 1): this could lead to unintended overdosage. This has been shown in in vitro studies [8, 15]. There is some recent evidence that this is the case in animal studies, using larger doses per treatment, with inevitable underestimation of the RBE at lower clinical doses [16]. Also, tumours with high intrinsic radiosensitivities to x-rays, such as lymphomas and most paediatric cancers, appear to have the lowest RBE values, below 1.11, and which may lead to clinical under-dosage [17, 18].

Another issue is that some experimental RBE reductions with tissue depth appear to depend on the beam delivery method [19]. Passively scattered beams were the previous norm, where the narrow beam emerging from the accelerator would be expanded in 3-D space by scattering foils before entering the patient. Over the past ten years there has been greater use of scanned beams (using magnetic deflection of the primary narrow 'pencil' beam so that the target is covered by a sequence of Bragg peak 'spots'), which can provide better dose conformity to a target [20]. A fall in RBE within the same sized target volume (containing cell lines) placed with increasing tissue depth has been found only with passively scattered beams (which diverge with inverse-square law effects), but not with actively scanned pencil beams (which do not diverge significantly until their end of range). These findings suggest that particle inter-track distances and changing radiation fluence (defined as the number of tracks per unit area) with increasing depth may cause such an effect. This has only been tested at two similar tissue depths by two different experimental groups [21, 22], so at present there is no information on intervening depths. If a smooth exponential fall-off of RBE is assumed to be caused by changes in inter-track distances, then the relationships plotted in Figure 3 are obtained. Further studies, over the full range of distances are now indicated. It is also important to note the converse: that scanned beams, with their much closer radiation tracks that remain stable until the end of range, can retain a higher RBE with depth and so might cause more toxicity compared with the past treatments that used passive scattering. This possibility needs to be investigated further, but detailed studies have already found surprisingly higher LET values (as high as 10 keV.μm^{-1}) outside target volumes in the case of scanned beams [23], which raises some concerns since the raised LET, but lower dose, in those regions will be associated with a higher RBE and so the bio-effectiveness could approach or even exceed standard tissue radiation tolerances.

It seems likely that the ratios of the instantaneous dose rates of the reference and proton beams will reflect the instantaneous fluences and their square roots the inter-track distances. It follows that some form of compensation as in

$$RBE_B = 1 + (RBE_A - 1).\frac{\sqrt{R_B}}{\sqrt{R_A}},$$

Where RBE_A and RBE_B refer to the RBE values of two different proton beams with dose rates R_A and R_B respectively. This equation can be further modified to include inverse square law dose rate changes with depth (d) relative to depth d_{ref} where the dose rates are equal, as

$$RBE_B = 1 + (RBE_A - 1).\sqrt{\frac{d_{ref}^2}{d^2}}$$

This last equation can simulate these processes, as shown in Figure 4.

In principle, this form of equation could be used to compare RBE`s with different dose rates for two scanned beams or for RBE determinations relative to any reference radiation.

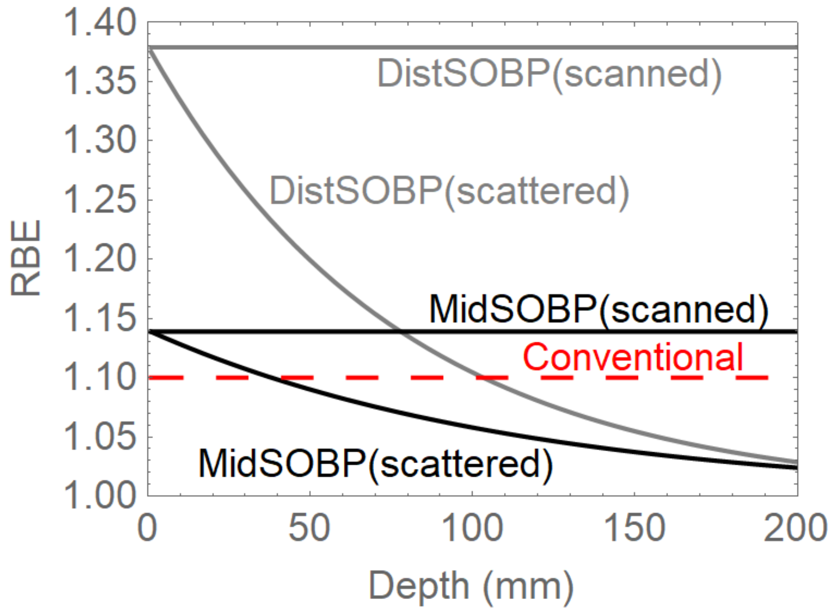

Figure 3. Modelled from cell survival assays at Bloomington, USA and Orsay, France. SOBP refers to spread out Bragg peaks which cover the same target volume but which is placed at different depths. DistSOBP refers to a more distal position in the target volume, further towards the end of proton range. MidSOBP refers to the middle of the target volume which is more proximally situated. The particle energies were the same over the target regardless of depth. The red hatched line shows the conventional RBE of 1.1.

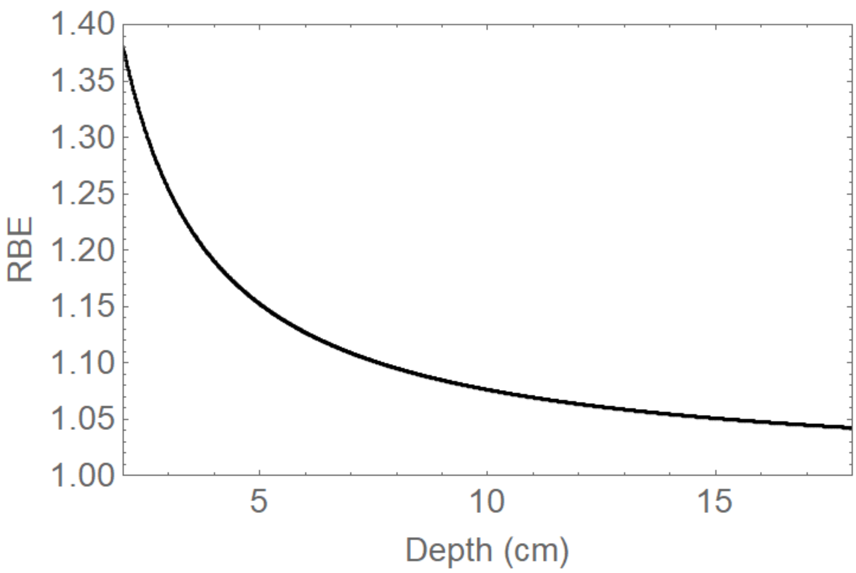

Figure 4 Simulation of loss of RBE from a depth of 2 cm in a scattered beam relative to a scanned beam (where the value will be stable with depth at 1.38 in this case), using the dose rate containing equation given in the text.

Table 1. Estimated RBE values compared with standard x-rays in different LET conditions for Central Nervous System late effects as in reference 13. The LET values are expressed in units of keV.μm^{-1}. Spread out Bragg peaks normally have values between 1-2 keV.μm^{-1}, but higher values within Bragg peaks and sometimes outside the target volume depending on the technique used.

Dose (Gy)	LET=1	LET=1.5	LET=2.0	LET=4.0	LET=8.0
1.25	1.10	1.15	1.21	1.42	1.80
1.8	1.08	1.13	1.17	1.35	1.66
2.5	1.06	1.10	1.14	1.29	1.54
10	1.02	1.04	1.05	1.11	1.22

To reduce unexpected severe clinical toxicity, the use of modelled RBE allocations, have been proposed [13]. Not only should tissue tolerances be adjusted to include a variable RBE, but the weighting of allowed dose from each Bragg peak should take such effects into account. A non-uniform dose distribution would be required in order to achieve a uniform biological dose across a target volume if the LET distribution and its linkage with RBE is taken into account. Optimisation programmes to ensure the highest LET is restricted to the gross tumour volume. Then, improvements in clinical safety and efficacy should follow. All modelling predictions show that RBE falls with increasing dose per treatment, with complete reversal of the rank order of RBE between low and high dose for late-reacting tissue endpoints when compared with acute reacting systems. For example, central nervous system tissues have the highest RBE at low dose, but the lowest RBE at high dose, when compared with estimates for a typical squamous cell carcinoma (see Table 2). This finding may encourage the use of fewer numbers of treatments (of larger dose than conventionally used) and so lead to cost-benefits. It is already the case that radiosurgery for small intracranial targets is practised in a single treatment session [24], an alternative to particle therapy in some indications.

Table 2. Modelled comparisons of estimated RBE values at different doses for SCC (squamous cell carcinoma) and CNS (central nervous system tissue), beyond mid spread-out Bragg peak region (LET=3 keV.μm^{-1}) and based on radiobiological parameters γ/β=2Gy (CNS) and 10 Gy (SCC).

Dose (Gy)	SCC	CNS
1.25	1.29	1.33
1.8	1.27	1.27
2.5	1.24	1.22
10	1.12	1.09
20	1.08	1.06

What research needs to be done?

The above exposition has implications as to what further research should be done to ensure optimal cost-benefit from expensive proton accelerators and delivery systems.

In terms of medical physics, present work to establish the location of Bragg peaks by remote imaging within tissues remains important, and increasing use of fast radiation transport (Monte Carlo) calculations of dose in heterogenous tissues remains a challenge, especially at the lowest energies (toward the ends of Bragg peaks) where our knowledge is incomplete. Improved access to LET (with some allowance for fluence) as well as dose treatment plans will be required; sophisticated 3-D dose plans alone will not be sufficient to warn the clinician of the risk of complications.

The following suggestions are intended to bring radiobiology quality assurance to the treatments. Firstly, and of the highest priority, the RBE issues described need to be addressed. Just as a linear accelerator dose outputs have to be carefully calibrated with respect to dose outputs at increasing tissue depths, so should proton dose distributions be further interpreted by RBE studies at varying depths with passively scattered and scanned beams. These need to be studied and analysed with prospective Monte Carlo simulations that also calculate LET and average inter-track distances, and matched with RBE such as the best predictive model is found. The information gained, in a representative panel of human cell lines, should be used within treatment planning computers to ensure that there is no substantial error in dose due to changes in LET and RBE. Such combined studies of beam ballistics and RBE can be undertaken during a commissioning phase. It is important that this should be done in at least one centre worldwide, but if possible at multiple centres that use different forms of hardware and software.

This especially important basic requirement, amongst other project aims, were planned within the proposed bio-medical research prospectus of CERN (European Centre for Nuclear Research, Geneva), where plans had been established for a dedicated ion beam bio-medical laboratory using extensive beam time on a semi-redundant synchrotron [25]. The envisaged facility could have taken further the need to determine the mathematical parameters that determine the relationship between LET and RBE for protons and other light ions with greater precision than the past experiments which were only designed to show interesting phenomena and they continue to be analysed although with limited statistical power. For example, it would be challenging to prove that RBE phenomenon for each ion species, determined by Z (the nuclear charge) have a unique turnover point for the LET-RBE relationship which determines the overall efficiency, since wasted dose/energy occurs beyond a certain saturation limit perhaps determined by particle velocity per unit charge [26] and where the maximum biological effectiveness occurs at a lower tissue depth than the actual true pristine Bragg peak [27]. A high throughput system, using representative panels of biologically well characterised cell lines in a dedicated international laboratory, would have improved bio-effect modelling considerably and reduced the uncertainties inherent in iso-effective dose predictions. This project foundered due to several reasons, including the appreciation of the Swiss currency, European economic conditions and the priorities set for research in high energy physics.

Perhaps it may be possible to revive this project by acquiring a dedicated small cyclotron in the first instance and solving the proton beam issues definitively, or perhaps such a national centre should be established in one country. It should be noted that the UK National Physical Laboratory (Teddington, UK) contains a modern linear accelerator for the purposes of national beam quality assurance, and perhaps a similar dedicated research cyclotron is also needed to do sophisticated proton beam studies, either in the UK or elsewhere.

In the absence of such a dedicated laboratory, there is a need for countries to do coordinated research using different accelerator systems but in a systematic way. This may be possible across Europe, or separately within the USA, or Japan at the present time. As a minimum requirement, the suggestions for combined particle ballistics and radiobiological research mentioned above should be pursued.

The time available for such essential pre-clinical research (as would be required by law for new drugs) is short, because of the present expansion in particle therapy facilities and increased patient recruitment. It would be unfortunate if standard (well-designed) randomised clinical trials, but which neglected the LET-RBE issues, were to find higher than expected complications and no clear advantage in local tumour control or cure. There are also ethical considerations, as mentioned below.

Facilities for experimental *in vivo* proton and ion beams are limited throughout Europe and there are natural ethical limitations.

More prospective studies of patients are indicated, where normal tissue effects are mapped and assessed by clinical, physiological, imaging and functional studies are compared with photon effects, although changes in treatment volumes will also complicate the estimation of RBE in such circumstances.

The well-coordinated systems for patient selection for proton therapy, based on dose distribution and predictive modelling of tumour control and LNTE in The Netherlands are exemplary and follows good recommendations in the photon-based literature [28], and will provide important capture of follow-up data for late normal tissue effects. However, the assumption has been made that the RBE is 1.1 in all tissues, so that the unexpected outcomes may yet occur. With careful prospective data collection, interventions for dose modifications may be necessary, although the interval between treatment and the development of late tissue damage may be as long as 5-10 years.

Questions such as should randomised clinical trials (RCT`s) be used, have not reached satisfactory conclusions [29, 30]. In the context of the present discussion it can be appreciated that there is considerable scope for large clinical research projects to optimise therapy. Even so, there may be risks in performing ‘definitive RCTs’ until the basic science is more completely understood, since a larger than anticipated yield of unwanted outcomes may have adverse consequences on the broader acceptance of a therapy that is so promising but needs to be given in the most correct way. A very pragmatic approach in childhood cancers might be to apply an RBE of 1 (to reduce the risk of under-dosage), while applying tougher constraints (RBE`s or 1.2 or above) to some normal tissues. Similar approaches could also be considered in adults. More sophisticated approaches would include the application of modelled RBEs after comparisons of what the best available model might be.

A summary of the required research prospectus is given in Table 3. These are the essential requirements needed before embarking on drug bio-modification and combination treatments with immunotherapy etc. Further work on ultra-high dose rates, referred to as FLASH proton therapy is underway in some institutes [31, 32], and this probably involves a combination of the concepts presented here and ultimately of radio-protective oxygen depletion in already existing hypoxic tissues [33]. It is often not realised that normal tissues include hypoxic areas due to cyclical variation in tissue perfusion, which is probably essential to life; but many tumours are chronically hypoxic. This subject is further complicated by the fact that increasing LET reduces oxygen modification of cell-killing efficiency by particle irradiation [34].
It must be concluded that a considerable amount of integrated basic and clinical research is necessary. This might be classified as being ‘essential preclinical research’ rather than ‘blue sky’, since many of the basic mechanisms are understood on a phenomenological basis, but have not been studied sufficiently to provide an overall framework for a high degree of treatment optimisation.

Table 3. Summary of the recommended minimum research prospectus that should essentially proceed proton therapy.

1. Perform comparative RBE measurements with depth for passively scattered and scanned beams with associated Monte Carlo studies, fluence and mean inter-track distances and study their relationships in cells of different radiobiological characteristics.
2. Determine as accurately as possible the turnover point position for the LET-RBE relationship, and LET-radiosensitivity slopes in cell lines with a relevant range of different radiobiological characteristics. These should be repeated for different ions to determine the uniqueness of each ion for radio-protective modelling purposes
3. Determine the best predictive model for the results obtained in the above experiments
4. Study late normal tissue effects in vivo (a) using selective experiments and/or (b) within carefully designed prospective clinical studies.
5. In the interim, test the use of RBE>1.1 in normal tissues, with RBE=1 within tumours in large prospective randomised trials.
6. The influence of instantaneous dose rate needs further detailed studies.

- 1-3 would probably require a dedicated cyclotron for research purposes as a large number of experiments would be required to provide the most accurate possible results, far greater than in normal biological research designed to demonstrate phenomena. Also, the physics and computing requirements are considerable.
- For 4 (a), any animal studies would require humane animal husbandry reasonably close to the experimental beam.
- For 4 (b), Hospital based treatment facilities are required.
- In all cases associated molecular characteristics may be studied simultaneously, although this is possible at remote locations from the beam facility.

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Declaration of Interests: none

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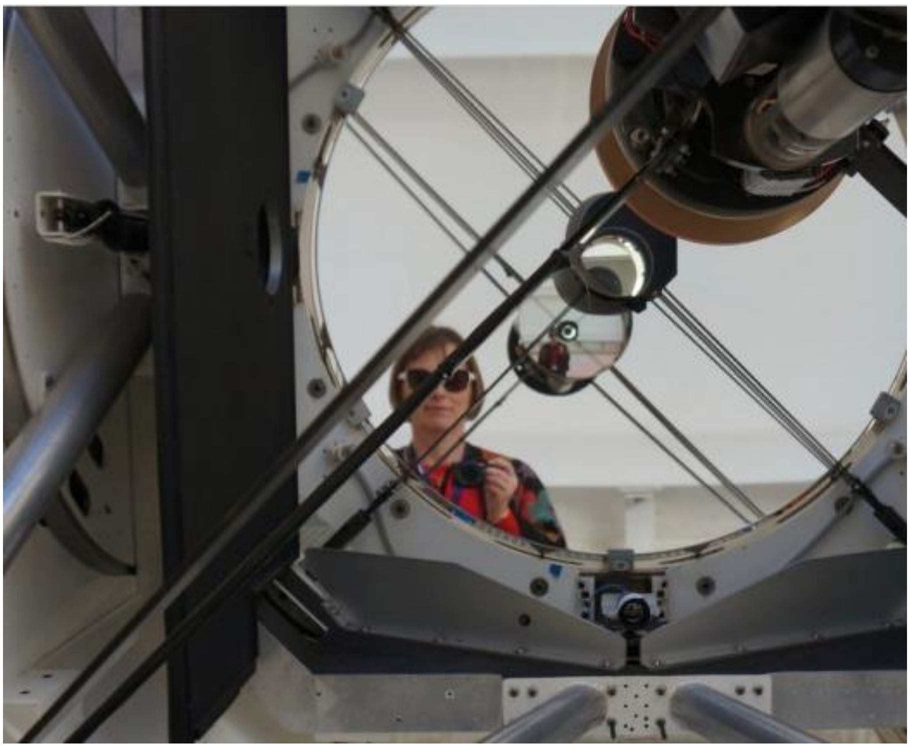
News from around the World



From an Australian National University Press Release April 2021

Researchers at The Australian National University (ANU) have harnessed a technique that helps telescopes see objects in the night sky more clearly to fight against dangerous and costly space debris.

> "Adaptive optics is like removing the twinkle from the stars"

The researchers' work on adaptive optics - which removes the haziness caused by turbulence in the atmosphere - has been applied to a new 'guide star' laser for better identifying, tracking and safely moving space debris.

Space debris is a major threat to the $US700 billion of space infrastructure delivering vital services around the globe each day. With laser guide star adaptive optics, this infrastructure now has a new line of defence.

The optics that focus and direct the guide star laser have been developed by the ANU researchers with colleagues from Electro Optic Systems (EOS), RMIT University, Japan and the USA as part of the Space Environment Research Centre (SERC).

EOS will now commercialise the new guide star laser technology, which could also be incorporated in tool kits to enable high-bandwidth ground to space satellite communications.

OBITUARY

Leif Ingemar Gerward

Born: 2 March 1939 ***Died: 13 November 2020***

Leif Gerward became a member of the International Radiation Physics Society in the early 1980s and served as a Councillor from 2004 until his retirement from the Technical University of Denmark (TUD) in 2015. He attended Council meetings and the IRPS Symposia whenever his other commitments allowed. He was a strong supporter of the IRPS Bulletin and submitted articles regularly for publication.

Quietly reserved but always helpful, Leif provided a role model to his students at the TUD from 1960 to 2015. I am pleased to have known him both as a friend and as person with whom I could converse on the several different scientific topics we had in common.

Leif's research was in the general field of the interaction of X-rays with matter. A number of members will be familiar with his work on metals, semi-conductors, superconductors and perhaps have cited him in their publications. Others might say "Leif…who?" because they have never consciously used his work. But hidden in software packages associated with many specialized X-ray systems produced by a number of manufacturers for research across a range of experimental fields is the XCOM tabulation of X-ray absorption coefficients. Leif contributed significantly to this tabulation.

The last list of citations of Leif's work in Semantic Scholar showed that his work had received 2358 citations from 102 publications. Of these, 51 were rated as significant.

Leif was born in Lund, Sweden, and attended the Chalmers University of Technology, Gothenburg, where he received the degrees of Master of Science (1963), Doctor of Philosophy (1970), and Doctor of Science (1974). From 1964 to 1966 he was a *stipendiary* at the Max Plank Institute in Stuttgart. From 1970 to 1972 he was an *amenuensis* at the Technical University of Denmark. Leif progressed to be a lecturer, then associate professor *docent* (1989 to 2015) at the TUD. Like all fit Swedish adults he served in the Swedish army for two years as part of his National Service, achieving the rank of Sergeant.

The 1970s saw the start of a revolution in X-ray scattering studies brought about by the development of Si- and Ge-solid state detectors. Created initially for measuring emissions from radioactive materials, these energy dispersive devices were recognized as being useful in X-ray Scattering experiments by staff of the TUD: Professor Bronislaw Buras, together with Leif, and others.

From this, a new experimental technique developed. In the next three decades the TUD group were to become leaders and innovators in many fields of X-ray diffraction. Initially used for X-ray powder diffraction (XRD) studies of metals, metallic compounds, and alloys the technique gave additional compositional information because of the fluorescence radiation created by the incident photon flux. At that time, sealed X-ray tubes with tungsten targets operating at high voltages and currents were used as sources of radiation, caused by the collision of the electrons with the target (Bremsstrahlung). This produced a continuous energy spectrum, so-called *white radiation*. This radiation was collimated onto the sample, and the scattered radiation was detected by an energy dispersive detector. Hence the technique was referred to as Energy Dispersive X-ray Diffraction (EDXRD). The intensity and brightness of the source, however, is low, and data acquisition times are therefore long.

Large particle accelerators produce radiation whenever the particle beam is deflected by a bending magnet. The energy spectrum is a continuum like that from a sealed X-ray tube. But it is many orders of magnitude brighter and is self-collimated so that beam formation is much simpler. The HASYLAB facility at DESY in Hamburg is not far from the TUD's laboratory ay Lyngby, Denmark. This proximity afforded the TUD researchers the opportunity to adapt their techniques to match the synchrotron radiation source. They were probably the first group to undertake EDXRD at a synchrotron radiation source.

The EDXRD technique was used for every kind of diffraction experiment one can imagine: strain broadening in materials due to particle size (important in the development of better sample preparation techniques for XRD and X-ray Fluorescence Spectroscopy (XRF)); lateral strain in ion-implanted silicon (important to the development of the then-new semiconductor devices); studies of preferred orientation in alloys (important in metal fabrication processes): and high pressure studies of a wide variety of materials using diamond anvil cells (important in studies as diverse as the effect of pressure on structure in the minerals of the earth's mantle; and influence of pressure on the shape of the Brillouin zones in semiconductor crystals). The TUD group investigated phase transitions of crystal structures under pressure for a wide range of materials. Of these a study of UX_2 (where X = Co, Fe, Mn, Al….) is of particular importance. As well, a study of the effect of temperature and pressure on Goethite (FeOOH) was a significant demonstration of the power and versatility of the EDXRD technique.

And Leif played a key role in the evolution of the technique.

But all this makes him sound like a "one-trick pony". He was not.

I knew him initially through his interest in the accurate measurement of the X-ray attenuation coefficients and the determination of the so-called anomalous dispersion corrections. We had much in common in this, because I was involved in that field from the early 1970s and later devised and directed a project for the Commission on Crystallographic Apparatus of the International Union of Crystallography: the *X-ray Absorption Project*. In 1992 I summarized my work in International Tables for Crystallography Volume C. At that time, in collaboration with the then US National Bureau of Standards (now NIST), Leif was involved in the development of a computer program for calculating X-ray attenuation coefficients which could run even in the sort of home computer available in 2000. This program, XCOM, is still used by equipment manufacturers, and can still be purchased on-line from NIST.

We had other interests in common. I had been using X-ray interferometry to measure the real part of the X-ray scattering amplitude: Leif was using an interferometric Moiré effect to measure lattice strains in "perfect" crystals.

In his later life Leif became interested in the foundations of modern physics, and wrote histories of the people who made the discoveries on which our present theories are based. Each of these was published in the year of the centenary of the discovery. He wrote histories on Becquerel, Roentgen, Villard, and Thomson. Some homework: what were these discoveries?

When Leif was proud of the small garden of his house in southern Sweden, where he cultivated organically grown vegetables, and grew the roses that he and his wife, Gullan, loved. When he retired he also became involved in Gullan's passion for genealogy. Gullan died in 2017. As far as I know he was continuing her work at the time of his death.

Leif is no longer with us. But the results of his research live on …..and will be used by generations of scientists.

***Vale* Leif Gerward.**

Written by Dudley Creagh

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Executive Councillors	Odair Gonçalves (Brazil) Esam Hussein (Canada) Avneet Sood (USA) Christopher Chantler (Australia)
Immediate Past President	David Bradley (Malaysia)
Executive Councillors (Continuing)	Richard P. Hugtenburg (UK) Mark Bailey (Denmark) Zdravko Siketić (Croatia) Pedro Vaz (Portugal)

Profiles of Election Candidates

Profile of member standing for President
Isabel Lopes

Isabel Lopes, Full Professor of Physics
Department of Physics, University of Coimbra,
Laboratory of Instrumentation and Experimental Particle Physics
3004-516 Coimbra, Portugal.
isabel@coimbra.lip.pt [isabel@coimbra.lip.pt]

I am Full Professor at the Physics Department of the University of Coimbra, Portugal, and researcher at the Laboratory of Instrumentation and Experimental Particle Physics (LIP). Since 2018, I have been a member of the Board of Directors of LIP. I have worked in the field of radiation physics for more than thirty years. After graduation, I studied under Armando Policarpo at Coimbra University, Portugal, Werner Schmidt at Hahn- Meitner Institut of Berlin, Germany, and Tadayoshi Doke at Waseda University of Tokyo, Japan. I was an invited researcher of the Hahn-Meitner Institute and I was awarded a one-year fellowship from the Japan Society for Promotion of Science (JSPS) as researcher at Waseda University, Tokyo.

My research has been focused on the R&D of liquid-rare-gas radiation detectors from the point of view of both the physics processes involved in the radiation detection and their applications to the search of dark matter, nuclear medical imaging and particle experiments. From 2002 onwards, I have concentrated on the direct detection of dark matter, first in the framework of ZEPLIN-III Project and since 2010 within the LUX and LUX-ZEPLIN (LZ) experiments. I am also very interested and engaged in science education, high education policies, scientific literacy and physics outreach.

I lead a research group presently counting with 14 members, including junior researchers, postdocs, graduate and undergraduate students. I have been a Principal Investigator of more than 20 funded research projects. I am author or co-author of about 200 publications with more than 7000 citations, including two papers with 500+ citations.
See http://www.researchgate.net/profile/M_Lopes/publications.

I have served as member of the Executive Councils of the LUX e LZ Collaborations and of evaluation panels of funding agencies. I have also participated in the Stakeholders Tune European Physics Studies Network, as I am also very interested in physics teaching and science education.

Statement: I have been a member of the International Radiation Physics Society (IRPS) since 1991. IRPS have two characteristics that strongly motivated me to serve the Society. Firstly , it provides an international forum of researchers engaged in a large variety of different topics, both fundamental and applied, under the broad umbrella of Radiation Physics. Personally, I find this diverse and interdisciplinary character very stimulating and invaluable. Secondly, it truly promotes international links, collaborations and exchange of knowledge, with particular attention to the inclusion of countries with economies in transition and developing economies. It is an inclusive society in which members from all nations are encouraged to be participants.

My intention as President, with the collaboration of the next Directorate and Council, is to strengthen those roles of IRSP. I will pay special attention to reinforcing the Society's appeal to young researchers from all around the world, giving them opportunity to present research results in our conferences and activities.

I count on you to join me in this task. It will be an honor to be President of the International Radiation Physics Society.

Profile of member standing for Secretary
Tomáš Trojek

Tomáš Trojek
Czech Technical University in Prague, Czech Republic
tomas.trojek@fjfi.cvut.cz

I am the head of the Department of Dosimetry and Application of Ionizing Radiation at the Czech Technical University (CTU) in Prague. I graduated in Nuclear Engineering in 2001 and defended my PhD thesis five years later at the CTU. My PhD thesis was done at the ISIB and UPV in Valencia.

In 2013 I became Associate Professor in Applied Physics.

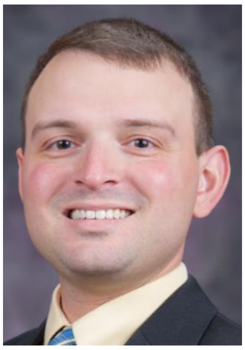
My research activities include the Monte Carlo calculation of radiation transport in matter; radionuclides in environment; high energy physics; and X-ray fluorescence analysis and its applications.

I joined the X-ray Spectrometry Laboratory at CTU in 2001, initially engaged with X-ray fluorescence analysis of art and archaeological objects. Also, I have been promoting the use of Monte Carlo simulation in quantitative XRF analysis. At present, I am engaged with confocal XRF and other depth-profiling XRF techniques. Apart from the X-ray techniques, Tomas was also involved with monitoring of radionuclides in environment. It included in-situ gamma spectrometry and laboratory analyses of samples.

Last but not least, he has taken part in the experiment DIRAC in the CERN laboratory in Switzerland since 2001. The main goal of this experiment is to measure the lifetime of atoms made of Pi and K mesons.

I am the author or co-author of more than 65 papers published in international journals and I was awarded the CTU Rector's Award for excellent scientific results in the year 2010.

I have been been a member of IRPS for more than 11 years and an Executive Councillor in the last 6-year period. He participated in organizing the conferences held in Prague, i.e. ISRP-8 (2000), IRRMA-7 (2008), and ICDA-1 (2013).



Profile of member standing for Treasurer
Amir Bahadori

Amir Bahadori
Radiation Engineering Analysis Laboratory
Kansas State University
bahadori@ksu.edu

I graduated with the degree of Bachelor of Science degrees in Mechanical Engineering with Nuclear Engineering Option and Mathematics from Kansas State University in 2008 sand attended graduate school at the University of Florida, graduating in 2010 with a Master of Science degree in Nuclear and Radiological Engineering, and in 2012, receiving a Doctor of Philosophy degree in Biomedical Engineering. I was then employed at the NASA Lyndon B. Johnson Space Center from 2010 to 2015, with work focused on astronaut radiation risk projection and assessment, space radiation dosimetry using active pixel detectors, and space radiation transport using deterministic and Monte Carlo-based codes.

I returned to Kansas State University as an assistant professor in December 2015, where I teach courses in nuclear and radiological engineering and conduct research with focus areas in space radiation protection, radiation transport applications, and semiconductor detector modelling and simulation. Since 2015, I have been certified in the comprehensive practice of health physics by the American Board of Health Physics., I am a member of the Health Physics Society, American Nuclear Society, and the IEEE Engineering in Medicine and Biology Society. I am, as well, an associate of the Committee on Space Research of the International Council for Science.

Profile of Member standing for Vice-President, Western Europe
Jorge Fernandez

Jorge Eduardo Fernandez
Laboratory of Montecuccolino
Department of Industrial Engineering (DIN)
Alma Mater Studiorum University of Bologna
via dei Colli, 16 - 40136 Bologna -ITALY
jorge.fernandez@unibo.it

After obtaining my M.Sc. in Physics (1977) and my Ph.D. in Physics from the University of Cordoba in Argentina (1985), I was affiliated to academic institutions in Cordoba and Buenos Aires. From 1994 on, I was affiliated with the Alma Mater Studiorum University of Bologna, Italy. I am an Associate Professor at the Industrial Engineering Department (DIN) of this University, and from 2016, Director of the hub for all Latin America of the Alma Mater Studiorum University of Bologna located in Buenos Aires. I am also affiliated to the Italian National Research Council (CNR) and the Italian Institute of Nuclear Physics (INFN).

My research interest is mainly focused on the fundamental physics of the interaction of x-rays with matter including polarisation effects and its implications for applications, and metrology problems of X-Ray Spectrometry. In particular: modelling of X-ray interactions; Transport Models (deterministic and Monte Carlo) for polarised and unpolarised photons, and for charged and neutral particles; coupled transport problems involving photons and charged particles; problems of multiple scattering of photons; characterization of the response function of radiation detectors; inverse problems in X-Ray Spectrometry (spectrum unfolding from detector influence and improvement of the detector resolution); spectroscopic techniques using X-rays (XRF, EDXRS, XANES, electron microprobe, computed tomography); applications of X- and gamma rays to industrial diagnostics, medical physics, environmental physics, and cultural heritage (non-destructive methods),

I am the author of over 120 articles in scientific journals, many as invited contributions, 3 books, 1 patent and several computer codes (SHAPE, MSXRF, MCSHAPE, etc) related to XRS, photon transport and the interactions of x-rays with matter.

I organised the European X-Ray Spectrometry Conferences (EXRS) in 1998 and 2014, the 5th International Topical Meeting on Industrial Radiation and Radioisotope Measurement Applications (IRRMA-5) in 2002, the first International Forum on Advances in Radiation Physics (FORUM BA-2017) in 2017, the Non-Destructive Techniques for Cultural Heritage (NDTCH-2018) in 2018, and the first Italy-Argentina Forum in 2019. In 2007 I acted as co-chair of, both, the Scientific Committee of the 10th International Symposium on Radiation Physics (ISRP-10) and the satellite Workshop on the Use of Monte Carlo Techniques for Design and Analysis of Radiation Detectors.

I am Editor of Applied Radiation and Isotopes (ARI) and Editorial Board Member of X-Ray Spectrometry (XRS). I am the current secretary of IRPS.

Statement: I have been a member of the International Society of Radiation Physics from its foundation in 1985. I fully endorse the objectives of the society of promoting the global exchange and integration of scientific information pertaining to the interdisciplinary subject of radiation physics. My intention as Vice President for Western Europe is to maintain and improve the high scientific level of the society symposia (ISRPs, IRRMAs, ICDAs, Forums), disseminating these conferences to countries interested to increase their activities and to attract young scientists to the subject.

Profile of Member Standing for Vice-President, Former Soviet Union (FSU) Sultan Dabagov

Professor Sultan Dabagov
Dir Ric INFN, Lab. Naz. di Frascati
Via E. Fermi 40, PO Box 13
I-00044 Frascati (RM), Italy and MEPhi, Russia
sultan.dabagov@lnf.infn.it

I began my research career in 1980, investigating surface effects in solids at the Kabardino-Balkarian State University, and completed my undergraduate work in the Dept. of Physics, Moscow State University and the I.V. Kurchatov Institute of Atomic Energy (KIAE), under the supervision of Prof. M.A. Kumakhov, head of the laboratory for Electromagnetic Interactions, KIAE.

My undergraduate and postgraduate research was mostly dedicated to the development of the quantum theory of coherent and incoherent scattering of relativistic electron beams in oriented crystals. During 1991-92 I performed studies at the Institute of Physics Astronomy (Aarhus University) at the invitation of Profs. J. Lindhard and J.U. Andersen. The joint research was devoted to the investigation of ion, neutron and electron beams scattering in high T superconductors (HTSC), especially channelling and channelling radiation of MeV- electrons in Y-Ba-Cu-O crystals, to be used as a novel technique for investigating characteristics of HTSC. In 1992 I was nominated as a Research Director at the International Institute for Roentgens (a former KIAE Laboratory), which aimed at the development of novel beams optics based on capillary/polycapillary systems.

From 1992 to 1995 I proposed and developed the wave theory for neutral particles passing through capillary structures (from micro/surface to nano/bulk channelling) that allowed new features of X-rays and thermal neutrons propagation in periodical structures to be predicted and observed successfully; within the project at the Hahn-Meitner Institute (by the invitation of Prof F. Mezei) together with Kumakhov, designed the first neutron capillary bender.

During 1994-1998 Dabagov led the project at the Laboratory for High Energy Electrons of P.N. Lebedev Physical Institute RAS by the invitation of Acads. O.N. Krokhin and V.L. Ginzburg that was dedicated to studying coherent phenomena in SR focussing by means of various capillary/polycapillary systems.

Since 1998 I have performed my research within the framework of the international projects on channelling of X-rays and neutrons in various capillary-based structures at the National Institute of Nuclear Physics (INFN) and led the group at the National Laboratories of Frascati (LNF).

I was a principal investigator of a number of projects at both INFN and CERN on the interaction of charged and neutral particles in strong external fields of various origins within the research program on the advanced techniques of particle acceleration and novel powerful sources of electromagnetic radiation.

Since 1990, I have participated in many Soviet Union, Russian, Former-Soviet States, European and USA conferences, workshops, and schools as a member of Advisory Boards, Program and Organizing Committees. He is the chairman of the International "Channelling" conference "Charged and Neutral Particles Channelling Phenomena" and the organizer of the international permanent seminar "Advanced Accelerator & Radiation Physics."

At present I am, *Dirigente di Ricerca*, INFN, the head of new LNF laboratory XLab Frascati, and Professor of National Research Nuclear University MEPhI.

Profile of Member Standing for Vice-President, North America
Ron Tosh

Ronald E. Tosh
Radiation Physics Laboratory
National Institute of Standards and Technology (USA)
ronald.tosh@nist.gov

I work as a physicist in the Radiation Physics Division at the National Institute of Standards and Technology (NIST), working in the Dosimetry Group on standards and instrumentation for absorbed dose. I joined NIST in 2004 after several years as a sales engineer for National Instruments (now NI). Prior to that, I did experimental research in molecular-beam scattering as a postdoctoral researcher in the Department of Chemistry and Biochemistry at the University of Delaware. I was awarded an M.S. and later a Ph.D. degree in physics from the Department of Physics and Astronomy at the University of Pittsburgh, studying atomic physics and gaseous electronics.

Current projects at NIST include development of calorimetry standards for absorbed dose in beams of gamma rays, x-rays, electrons and protons used in medicine and industry. Research activities are focused on uses of acoustic and optical methods and photonic sensors for dosimetry in radiation fields with large spatial gradients and high dose rates, with applications in radiotherapy, irradiation of surfaces, and radiosensitivity of semiconductor microdevices and biological systems.

Statement: I have been with the International Radiation Physics Society since 2005 and coedited the IRPS Bulletin for 13 years. The past two decades have brought big changes to IRPS and the radiation physics landscape, with new facilities and conferences and faces moving the spotlight among academic institutions, metrology institutes, private industry, and broader stakeholder communities (including the general public). The variety of perspectives has helped us in different ways to weather the impacts on research, education and outreach efforts wrought by economic booms and busts and shifting political sands. This variety is the source of our strength and so I would hope to contribute as an IRPS Vice President for North America to realizing and enhancing opportunities for collaboration in research, educational outreach and fellowship.
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Profile of Member Standing for Vice-President, South East Asia
M.Iqbal Saripan

M. Iqbal Saripan
Professor of Biological Engineering
Faculty of Engineering
Universiti Putra Malaysia
iqbal@upm.adu.my

I have served the International Radiation Physics Society as the Regional Vice President of South East Asia since 2018. My area of research is in nuclear medical imaging, especially in gamma camera, Single Photon Emission Computed Tomograhy (SPECT) and Positron Emission Tomography (PET).

I was appointed as the Deputy Vice Chancellor (Academic and International) at Universiti Putra Malaysia in 2017.

As well, I am the chairman of 15th International Symposium on Radiation Physics that will be held in Kuala Lumpur in late 2021.

Profile of Member Standing for Vice-President, South and Central America
Marcelo Rubio

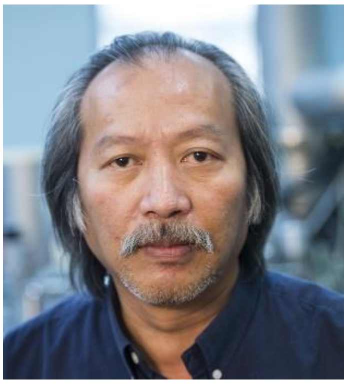
Marcelo Rubio
Associated Professor
SEU, National University of Cordoba
rubiocba@yahoo.com

Marcelo Rubio holds a doctorate in physics and lives with his wife in Huerta Grande, Córdoba, Argentina. I have two children in scientific and professional activities in Canada and Argentina. My present academic position is honorary and is related to the training of young students in processes of technological and productive innovation at SEU, National University of Córdoba.

In my academic and scientific career I have held the following positions:

- Professor at the Faculty of Mathematics, Astronomy and Physics (FAMAF) of the National University of Córdoba (UNC)
- Researcher at CONICET – Argentina
- Vice Dean of FAMAF (UNC)
- Secretary of Science and Technology of the Government of the Province of Córdoba, Córdoba, Argentina.
- Founder of the CEPROCOR Technological Center of Córdoba, Argentina.
- President of the National Agency for Scientific and Technological Promotion of the Argentine National Government.
- Member of the Board of Directors of the Argentine Military Aircraft Factory.

Profile of Member Standing for Vice-President, Australia and Oceania
Chanh Tran



Chanh Tran
Department of Chemistry and Physics
La Trobe University
Victoria Australia
CQ.Tran@latrobe.edu.au

I am a Lecturer of Physics at La Trobe University in Australia. My major research interests include interactions of X-rays with matter, complex anomalous fine structures, optical coherence and x-ray imaging. I received my PhD from the University of Melbourne in 2003 in the area of precision measurement of the imaginary component of the atomic form factor using the X-ray Extended Range Technique.

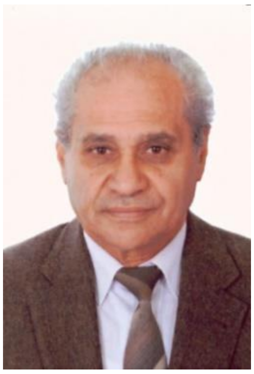
I won an Australian Synchrotron Research Fellowship and an Australian Research Fellowship in 2003 and 2006, respectively. Since 2007, I have been a lecturer at La Trobe University with ~70 refereed publications to date. My work in the field of radiation coherence led to the first complete reconstruction of the coherence function of a synchrotron beam.

I have extensive synchrotron experience and have conducted my research at major facilities around the world including the Australian Synchrotron (AUS), the Photon Factory (Japan), the Advanced Photon Source (US), the Stanford Synchrotron Radiation Lightsource (US), The European Synchrotron Radiation Facility (EU), and Diamond Light Source (UK).

Recently, I have combined my expertise in precision X-ray spectroscopy and imaging to develop a technique for determining both the amplitude and phase components of the complex anomalous fine structures. This is an analogue to X-ray Absorption Spectroscopy in the phase domain and promises exciting opportunities in probing structures of matter.

Profile of Member Standing for Vice-President, Afrika and Middle East

Mohamed Ahmed Mahmoud Gomaa



Mohamed Ahmed Mahmoud Gomaa
Emeritus Professor
Egyptian Atomic Energy Agency
mamgomaa@gmail.com

I was born in the middle eastern city of Alexandria, Egypt. I graduated from physics Department, Faculty of Science, Alexandria university. I granted PhD degree in Radiation Physics from London University. My PhD topic was Neutron Shielding.

Later I joined Atomic Energy Authority at Radiation Protection Department. And my interest was shifted to radiation detection and dosimetry, later my interest was directed to nuclear Safety and security. Currently, I am Emeritus Professor of Radiation Physics at the Egyptian Atomic Energy Authority.

It is nearly 40 years since I participated in the Proceedings of the Second International Radiation Physics Symposium (IRPS) held in Penang Malaysia. It was great change to meet in person John Hubbel and Prof Ghose and in this event the foundation of IRPS was established.

Consequently, ten years later and with the help of Egyptian Radiation physicists the first radiation physics was held in Qena (800 Km south of Cairo), Egypt in 1992. With the help of John Hubbel, the proceedings of the conference were published at Journal of Radiation Physics and Chemistry as special issue in 1994. Among the participants of the conference, was the late Prof Isabelle. In 1994 the second radiation physics conference was held in Sheeben El Kom, (100 Km north of Cairo), Egypt. And among the participants David Bradley (IRPS Chairman) and the proceedings was published at the same journal in 1996. In 2009, I attended the 9th IRPS symposium held in Melbourne.

Local Radiation physics conferences were regularly held every two years and in 2018 the 12th conference was held in Cairo.

Currently I represent Egypt at UNSCEAR (United Nation Scientific Committee on the Effects of Atomic Radiation).

Furthermore, I am chairman of the IRPA Egyptian Associate Society, which was founded in 1992. Among the activities of the local society was to organize the second regional radiation protection African congress which was held in Ismailia in 2007. International experts from IAEA staff, from Europe and US attended the congress.

Several radiation protection Workshops were held in Cairo. The last one was held in 2020.
I am actively participating in IAEA technical meetings leading to publications of its safety series and safety requirements.

Profile of Member Standing for Vice-President, North East Asia
Yu-hui Dong

Yu-hui Dong
Deputy Director
Institute of High Energy Physics
Chinese Academy of Sciences
dongyh@ihep.ac.cn

I am the Deputy Director of Institute of High Energy Physics, Chinese Academy of Sciences. I am the executive member Biophysics Society of China, the director of Photobiology Committee and also the member of Chinese Crystallography Society and Macro-molecular Crystallography committee.

In 1990, I obtained B.S. in Physics in Sun Yat-Sen University (Zhongshan University), Guangzhou, China. I earned my Ph.D. in Physics in Beijing Synchrotron Radiation Facility, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China, in 1995. During 1995-2000 I was Post-doctoral Research Associate at Institute of Physics, Chinese Academy of Sciences, Beijing, China and University of Trento, Italy.

In 2001 he became Professor of condensed matter physics in Institute of High Energy Physics, Chinese Academy of Sciences. Teaching activities have included lectures in MSc and PhD courses and supervising of MSc and PhD theses.

My research activities focus on the methodological research in structure determination of proteins and protein complexes based on synchrotron radiation. The main research fields are:

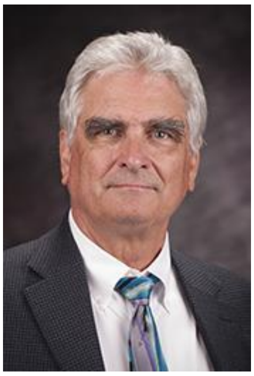
- The structure-function relationship of proteins and protein complexes by synergic method on synchrotron radiation, e.g., protein crystallography, SAXS, X-ray imaging;
- Methods in structure determination of proteins and complexes;
- The structures and functions of proteins involved in DNA repair and metabolism.

I have authored/co-authored: 3 chapters in books written by teams; about 160 scientific papers in journals and conferences.

I am a reviewer for *Nature, Nature Communication, Scientific Report, Nucleic Acid Research Acta Crystallographica Section A: Foundations of Crystallography, Acta Crystallographica Section D: Biological Crystallography, Acta Crystallographica Section F: Structural Biology and Crystallization Communications, Journal of Applied Crystallography, Journal of Physical Chemistry, Journal: Physica B, Solid State Sciences, Chinese Physics Letters*; also for proposals applied to National Natural Science Foundation of China; National Basic Research Program of China (973 Program), Ministry of Science and Technology; ECHO Grants - Chemistry in Relation to Biological and Medical Sciences, Netherland.

I am the Co-organizer of “Lecture Course on Structural and Biophysical Methods for Biological Macromolecules in Solution” (Sponsored by European Molecular Biology Organization), Beijing Synchrotron Radiation Facility, Beijing, April 28- May 5, 2011.

Profile of Member Standing for Vice-President, IRMMA/Industrial Applications
William Dunn



William Dunn
Professor and Teaching Scholar
Department of Mechanical and Nuclear Engineering
Kansas State University
dunn@ksu.edu

I have devoted my professional life to radiation measurement applications. Along the way, I have investigated techniques for modeling radiation responses from sensors and simulating radiation transport, primarily by Monte Carlo methods. I obtained my BS degree in Electrical Engineering from the University of Notre Dame and my MS and PhD degrees in Nuclear Engineering from North Carolina State University.

I spent my early career as an in-house nuclear engineering consultant for Carolina Power & Light Company, where I conducted radioactive and inert tracer studies at the H.B. Robinson nuclear power-plant. After a stint as Reactor Applications Engineer and Adjunct Assistant Professor at the Nuclear Engineering Department at North Carolina State University, I then entered into a long career in contract research. In 1988 I founded Quantum Research Services, Inc., a small-business contract research firm in Durham, North Carolina.

I spent fourteen years as President of Quantum, performing research primarily in radiation applications, such as nondestructive testing. My research often involved Monte Carlo modeling and inverse analysis. In the summer of 2002, I joined the Kansas State University (KSU) faculty as Associate Professor in the Department of Mechanical and Nuclear Engineering (MNE). I was Head of the MNE Department at KSU from 2013 to 2019.

I am now a Professor and the Don and Linda Glaser—Carl and Mary Ice Cornerstone Teaching Scholar in the MNE Department. I have received numerous awards, including the Fred Burgraff Award of the Highway Research Board, the North Carolina Entrepreneurial Excellence Award, and the Radiation Science and Technology Award from the American Nuclear Society.

I am author of over 100 scientific publications, including four patents. With Dr. Ken Shultis I am preparing the second edition of our book *Exploring Monte Carlo Methods*. I am the originator of the symbolic Monte Carlo (SMC) method and the X-ray backscatter scanning technique. I attended the third ISRP in Ferrara, Italy, and has been a member of IRPS for 46 years.

Profile of Member Standing for Executive Councillor
Avneet Sood

Avneet Sood, PhD.
Senior Scientist, Computational Physics (X) Division,
Weapons Physics Directorate,
Los Alamos National Laboratory,
sooda@lanl.gov

Dr. Avneet Sood has served in Los Alamos National Laboratory's nuclear weapons program since 2000 as a technical leader and organizational manager.

His last 10 years have been in a key leadership role responsible for approximately 50 technical staff, post docs, and graduate students involved with Monte Carlo radiation transport methods and code development (including MCNP) and variety of radiation transport applications.

These applications involve applying radiation transport principles supporting the US nuclear emergency response, nuclear counter-terrorism, and nuclear non-proliferation efforts. He has helped produce seven PhD students at five universities, post-doctoral student advisor for seven students, and is an adjunct professor of nuclear engineering.

He serves as an academic reviewer to nuclear engineering departments and professional societies.

Profile of Member Standing for Executive Councillor
Christopher Chantler

Christopher Chantler
Physics Department
University of Melbourne
chantler@unimelb.edu.au

I am Professor of Physics at the University of Melbourne where my major research interests include high-accuracy XAS in transmission and fluorescence, XERT and Hybrid techniques at synchrotrons, atomic and condensed matter theory and experiment, and tests of Quantum Electrodynamics [QED] at Electron Beam Ion Traps [EBITs]. I am a Fellow of the AIP and APS. I received my D Phil from Oxford in High-accuracy X-ray tests of Quantum Electrodynamics and following fellowships at Oxford and the National Institute for Standards and Technology, Maryland, USA I returned to Australia and the University of Melbourne some 27 years ago.

My research makes extensive use of synchrotron, X-ray and IR beamlines and in particular XAS. I have used BigDiff at Tsukuba extensively in collaboration with Australian and Japanese collaborators. I have published over 205 papers. My research work has been recognised with numerous awards including the international JARI Enterprise award, and the David Syme Prize.

I have chaired, co-chaired or been the scientific or proceedings chair on many conferences. I am Chair of the International Union of Crystallography Commission on XAS, am a member of the Society of Crystallographers in Australia and New Zealand, Immediate Past President of the International Radiation Physics Society, a member of the IUCr Commissions on International Tables, Editor-in-Chief of Radiation Physics and Chemistry, and Editor of the forthcoming International Tables for Crystallography, Volume I on X-ray Absorption Spectroscopy.

I have created several new fields of inquiry, including high-accuracy XAS and analysis with uncertainty, the popular FDMX codes, updates of GRASP atomic theory, the first measurements of low energy Inelastic Mean Free Paths at synchrotrons, and the new coupled plasmon theory of solid state transport. Recently I have applied this to understand such issues as Alzheimer’s disease using synchrotrons.

Profile of Member Standing for Executive Councillor

Esam Hussein

Esam Hussein, Ph.D., P.Eng.
Faculty of Engineering and Applied Science,
Education Building, Room 409
Regina SK S4S 0A2, Canada
Esam M.A. Hussein <esam.hussein@uregina.ca>

(http://www.uregina.ca/engineering/faculty-staff/faculty/hussein-esam.html)

I am currently the Dean of Engineering and Applied Science at the University of Regina. After completing my undergraduate studies and a master's degree in nuclear engineering at Alexandria University, Egypt, I earned a PhD also in nuclear engineering from McMaster University. I was then employed as a Nuclear Design Engineer at Ontario Hydro (now Ontario Power Generation). Subsequently, I joined the University of New Brunswick – Fredericton, where I taught subjects in Chemical then Mechanical Engineering, and served as Department Chair, Associate Dean and Vice-President and President of the Association of UNB Teachers.

I led a research program that focused on the industrial and medical uses of nuclear and atomic radiation for non-destructive testing and imaging and for the detection of threat materials. I have supervised many graduate students, published numerous scientific papers and industrial reports, am a holder of six patents, and the author of three books on I am a recipient of the 2019 Outstanding Achievement Award of the Association of Professional Engineers and Geoscientists of Saskatchewan, the Canadian Nuclear Innovation Achievement Award in June 2003, and the Sylvia Fedoruk Award in 1999. I am currently a receiving editor of Applied Radiation and Isotopes and Physics Open. My current research focus is on small modular reactors.

I am a registered professional engineer in the Provinces of Saskatchewan, New Brunswick and Ontario. As well I am a member of the Canadian Nuclear Society, American Nuclear Society, American Society of Mechanical Engineer, IEEE Nuclear IEEE Nuclear and Plasma Sciences Society, American Society for Non-destructive Testing and a Fellow of the Canadian Society of Senior Engineers. I currently serve as an executive councillor of the International Radiation Physics Society.

Profile of Member Standing for Executive Councillor
Odair Gonçalves

Odair Gonçalves
Instituto de Fisic
Universidade Federal do Rio de Janiero
odair@if.ufrj.br

I was awarded my Bachelor's degree in Physics from Universidade de São Paulo (1973), my Master's on Physic from the Universidade Federal do Rio de Janeiro (1978) and PhD on Physics from the Universidade Federal do Rio de Janeiro (1986).

I have been an Associated Professor at the Instituto de Física, Universidade Federal do Rio de Janeiro since 1979. My fields of expertise are: fundamental and applied research on interactions of photons with matter, mainly Rayleigh and Compton scattering, Medical Physics and Nuclear Energy (policies, safety and security). Between 2003 and 2011,I moved away temporarily from the university to be head of the Comissão Brasileira de Energia Nuclear (CNEN- Brazilian Nuclear Energy Commission), institution responsible for formulating the nuclear energy policies which is also the National Nuclear Regulatory Body; during this period was also president of the Executive Board of the nuclear companies NUCLEP and INB.

Between 2009. and 2012 I was President of the Radiation Physics Society (IRPS) and since then am a member of the IRPS Executive Council. In 2012 hosted the 12. International Symposium on Radiation Physics

In 2011, I returned to UFRJ assuming the coordination of the Medical Physics Under-graduation Program. As well I am responsible for the Laboratory of Gamma and X rays Physics.

I am the author of 63 papers with more than 400 citations.

Honors:

- 2010 - Grand Officer of the Order of Rio Branco, Ministry of Foreign Affairs - Federal Government;
- 2009- Member of the Order of Scientific Merit, Ministry of Science and Technology - Federal Government;
- 2008- Grand Officer of the Order of Merit Anhanguera - Government of Goiás, Goiás State; 2018 - Carneiro Felipe Medal, awarded by the CNEN Deliberative Commission to personalities who stood out for the development of peaceful applications of nuclear energy.

Profile of Member Standing for Membership Officer
Eric Shirley

Dr. Eric L. Shirley, Physicist
Sensor Science Division, NIST
100 Bureau Drive, MS 8441
Gaithersburg, MD 20899-8441 USA
Email: eric.shirley@nist.gov

Eric L, Shirley: Staff member, physicist, at the National Institute of Standards and Technology in Gaithersburg, Maryland, USA; PhD in Physics from the University of Illinois at Urbana Champaign, 1991.

I am currently serving as Membership Secretary for the Society. I work closely with the Treasurer to keep abreast of new memberships and membership renewals. At present I am overhauling the database for the membership roster and (as of March 2021) is undertaking another Society-wide renewal cycle.

By training I am a theoretical solid-state physicist, with experience in atomic-structure calculations, band-structure calculations, and many-body theory. I have been involved in calculations of the optical spectra of solids throughout the electromagnetic spectrum, from the far-infrared to the hard x-ray region, including the very important topic of calculating inelastic mean free paths for charged particles. My research interests lie in computational physics, which relies heavily on the use of extensive computational resources, as well as mathematical physics, which is limited only by the abilities of the practitioner. Beyond studying the main moving parts of solids, i.e., electrons, having a background in mathematical physics (of the applied, down-to-earth sort) has helped me and my colleagues study the wave propagation of photons in photonic crystals and practical optical systems such as collimators, radiometers, and telescopes. These research endeavours have led to successful understanding of problems pertinent to communities ranging from semiconductor manufacturing to astronomy.

Recently, I have also studied generation of synchrotron radiation, going beyond the conventional Schwinger formula, which is only approximate, and is presently considering effects of recoil as a correction to the calculated photon flux. This is in support of NIST's use of a synchrotron as a standard optical source in radiometry.

I am a member of the American Physical Society, the International Radiation Physics Society, and Sigma Xi. I have been actively involved in the Conference on Characterization and Radiometric Calibration from Remote Sensing (CALCON) since 1995, having contributed to short courses and session planning, and during 2001-2013 was on the International Advisory Board and Program Committee of the Vacuum Ultraviolet (VUV) International Conference, which has now merged with the X-ray and Inner-Shell Processes (X) International Conference.

A Hertz Fellow in graduate school, I began my postdoctoral research as a Miller Fellow at the University of California at Berkeley. I have also been honoured with the Presidential Early Career Award for Scientists and Engineers (1999), the Sigma Xi Award Young Researcher Award (2002), Fellowship of the American Physical Society (2006), and the Arthur S. Flemming Award in the area of Basic Science (2008). As well, I am a co-recipient of Department of Commerce Silver Medal (2002), Bronze Medals (2005 and 2020), and Gold Medal (2013) award.

Editor

The position of Editor of the IRPS Bulletin is usually decided at a Council Meeting. For this and future issues in 2021 the position of Editor has been decided by the President in consultation with relevant Council members. Ming Tsuey Chew has accepted the position, and this is her first IRPS Bulletin.

Ming Tsuey Chew
Sunway University
5, Jalan Universiti, Subang Jaya
Malaysia
mtchew@sunway.edu.my

My qualifications are: PhD (University of Surrey, UK), MSc (Uppsala University, Sweden), BSc Biomedical Sciences (University Malaya, Malaysia). I am a Senior Lecturer at the Centre for Applied Physics and Radiation Technologies, School of Engineering and Technology at Sunway University, Malaysia.

My particular research interests include the radiobiology of photons and heavy ions. Within the fields of radiation sciences more widely, my work has me engaging in efforts to improve the overall survival for cancer patients, and in nuclear medicine research for diagnosis & improving cancer patient care management. I am also involved in implementing preliminary screening for high incidence cancers such as colorectal cancer in the community. My other fields of interest include preventive medicine for non-communicable diseases such as hypertension, diabetes and cardiovascular diseases.

ELECTION BALLOT FORM

For all posts, except those of executive councillors, vote for one by marking the appropriate box. For executive councillors, you may vote for up to four candidates who are running for the full six-year term.
For all positions you may write in names of other members of the Society and cast your ballot for them.

President *(vote for one)*
Isobel Lopes (Portugal) __________ □
________________________________ □

Secretary *(vote for one)*
Tomáš Trojek (Czech Rep.) _______ □
________________________________ □

Treasurer *(vote for one)*
Amir Bahadori (USA) ____________ □
_________________________________ □

Vice Presidents:
Western Europe *(vote for one)*
Jorge Fernandez (Italy) ___________ □
________________________________ □

Central & Eastern Europe (*vote for one*)
Ladislav Musilek (Czech)__________ □
_________________________________ □

Former Soviet Union (FSU) (*vote for one*)
Sultan Dabagov (FSU)_____________ □
_________________________________ □

North America (*vote for me*)
Ron Tosh (USA)________________ □
________________________________ □

South & Central America (*vote for one*)
Marcelo Rubio (Argentina) ________ □
_________________________________ □

Vice Presidents (Continued)
South East Asia *(vote for one)*
Iqbal Saripan (Malaysia) ______________ □
_____________________________________ □

North East Asia (*vote for one)*
Yu-Hui Dong (People Rep. China) _______ □
_____________________________________ □

Africa and Middle East (*vote for one*)
Mohamed Gomaa (Egypt)______________ □
_____________________________________ □

Australasia & Oceania (*vote for one*)
Chanh Tran (Australia)________________ □
_____________________________________ □

IRMMA/Industrial Application
Bill Dunn (USA)______________________ □
_____________________________________ □

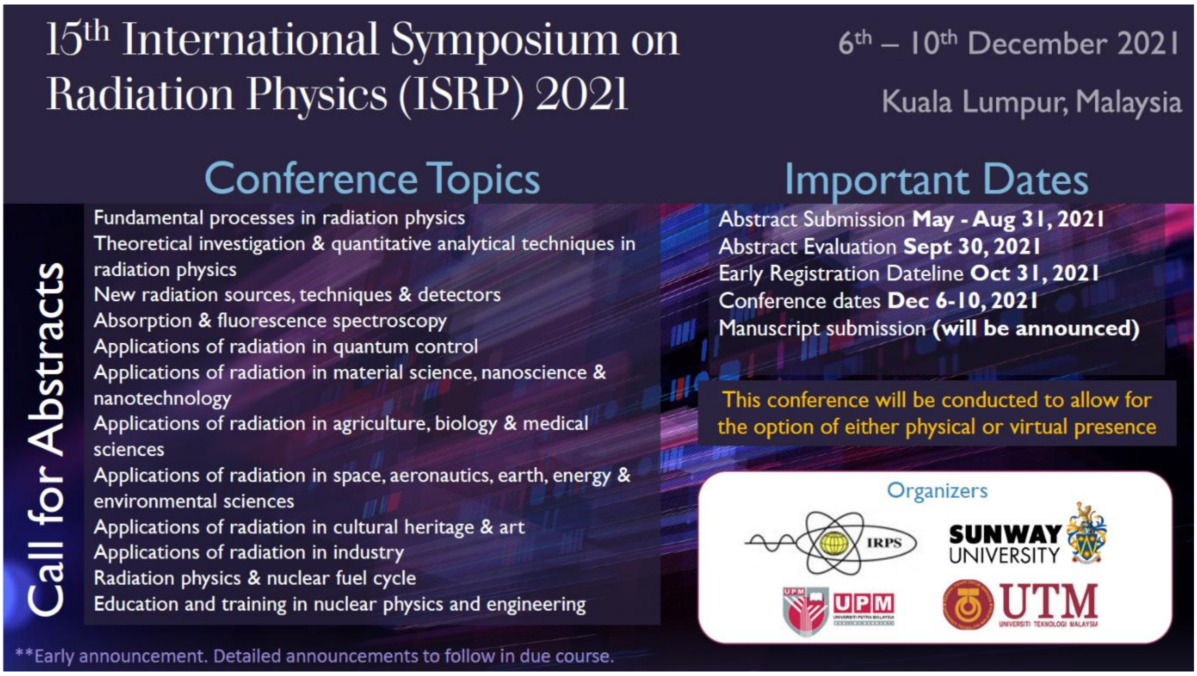
Membership Officer (*vote for one*)
Eric Shirley (USA)______________________ □
______________________________________ □

Executive Councillors: (*vote for four*)
Avneet Sood (USA)____________________ □
Christopher Chantler (Australia) __________ □
Esam Hussein (Canada) ________________ □
Odair Gonçalves (Brazil) ________________ □

Please use this ballot to vote. Instructions for return:
1) Electronic submission: Scan your completed ballot and email the image to Jorge Fernandez at **Jorge.Fernandez@unibo.it**
Ballots must be received by the Secretary by *30 September 2021*
The results will be announced at ISRP-15

Calendar

ISSSD 2021; International Symposium on Solid State Dosimetry (online), September 27 to October 1st. 2021. Organised by Mexican Society of Irradiation and Dosimetry. For details please contact: Professor Hector Rene VEGA-CARRILLO,Universidad Autonoma de Zacatecas, Unidad Académica de Estudios Nucleares, 98068 Zacatecas, Zac, Mexico.o Email: fermineutron@yahoo.com



IRRMA-2022, Moscow, 3-8 July 2022; https://agenda.infn.it/event/20271/ also http://www.lnf.infn.it/conference/irrma2021/ (showing delay of the meeting to 2022).

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International Radiation Physics Society

The primary objective of the International Radiation Physics Society (IRPS) is to promote the global exchange and integration of scientific information pertaining to the interdisciplinary subject of radiation physics, including the promotion of (i) theoretical and experimental research in radiation physics, (ii) investigation of physical aspects of interactions of radiations with living systems, (iii) education in radiation physics, and (iv) utilization of radiations for peaceful purposes.

The Constitution of the IRPS defines Radiation Physics as "the branch of science which deals with the physical aspects of interactions of radiations (both electromagnetic and particulate) with matter." It thus differs in emphasis both from atomic and nuclear physics and from radiation biology and medicine, instead focusing on the radiations.

The International Radiation Physics Society (IRPS) was founded in 1985 in Ferrara, Italy at the 3rd International Symposium on Radiation Physics (ISRP-3, 1985), following Symposia in Calcutta, India (ISRP-1, 1974) and in Penang, Malaysia (ISRP-2, 1982). Further Symposia have been held in Sao Paulo, Brazil (ISRP-4, 1988), Dubrovnik, Croatia (ISRP-5, 1991) Rabat, Morocco (1SRP-6, 1994), Jaipur, India (ISRP-7, 1997), Prague, Czech Republic (ISRP-8, 2000), Cape Town, South Africa (ISRP-9, 2003), Coimbra, Portugal (ISRP-10, 2006), Australia (ISRP-11, 2009), Rio de Janeiro, Brazil (ISRP-12, 2012), Beijing, P.R.China (ISRP-13, 2015), and Córdoba, Argentina (ISRP-14, 2018)

The **IRPS Bulletin** is published twice a year and sent to all IRPS members.

The IRPS Secretariat is: Jorge Fernandez (IRPS Secretary),
Address: Laboratory of Monte Cocclino, Department of Industrial Engineering Alma Mater Studiorum, University of
Bologna, via di Colli 16-40136 Italy*:*
Email*:* jorge.fernandez@unibo.it

The IRPS welcomes your participation in this "global radiation physics family”

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INTERNATIONAL RADIATION PHYSICS SOCIETY
Membership Registration Form

1. Name : ____-

(First) (Initial) (Last)

2. Academic rank (e.g., Dr., Prof., etc.), or preferred title (e.g. Mr./Mrs./Ms):___

3. Address : ____-

(Post Code) (Country)

Telephone:__________________ Email: ______________________________ Fax: ________________

4. Field(s) of interest in Radiation Physics (feel free to attach a list of your publications, if any, in the field:

____

5. (Optional) list any national or international organization(s) involved in one or more branches of Radiation Physics, of which you are a member:

____

6. The IRPS has triennial (3-year) membership dues. Dues periods are by calendar years. New members joining prior to July 1 are treated as joining in January 1 of that year. Otherwise, they are treated as joining January 1 of the following year. Acceptable modes of IRPS membership dues payment, to start or to continue IRPS membership, are listed below. Please check payment-mode used, enter amount (in currency-type used). All cheques should be made payable to the **International Radiation Physics Society**. There are four membership rates depending on student and country status:

Membership dues (stated in US dollars - circle equivalent amount sent):

Full Voting Member: 3 years		**Student Member: 3 years**	
Developed country	$75.00	Developed country	$25.00
Developing country	$30.00	Developing country	$10.00

For payments via credit card

- https://www.ph.unimelb.edu.au/~chantler/opticshome/irps/registrationirps.html

For payments by mail -

Send to Dr W.L. Dunn, Dept. Mechanical and Nuclear Engineering, Kansas State University, 3002 Rathbone Hall, Manhattan, KS, 66506-5205. U.S.A.

Amount paid, currency and US dollar equivalent : ___________________________________

7. To complete enrolment, send a copy of this Membership Registration Form and a copy of your bank transfer receipt (or copy of your cheque) to Eric Shirley

email:(preferred) : eric.shirley@nist.gov

Dr Eric L. Shirley
Sensor Science Division, NIST
100 Bureau Drive MS 8441
Gaithersburg, MD 20899-8441, U.S.A.

Signature _______________________________ *Date* ________________________