MPORU NEWSLETTER

Medical Physics Organised Research Unit

Physics Department, Carleton University

Editor: Alex F Bielajew (Also on: http://www.physics.carleton.ca/research/MPORU/) Number 8, June 1996

Contents

The MPORU

In the fall of 1989, an Organized Research Unit (ORU) was formed at Carleton University to encourage communication among those working in medical physics within the Ottawa area and to help coordinate the graduate studies program in medical physics at Carleton. The ORU was named the Medical Physics Organized Research Unit, or MPORU, and eight objectives were defined. They were:

1. To promote basic and applied research in those fields of medical physics in which there is local strength, in conformity with the research objectives of the institutions involved.
2. To advise the Carleton University Physics Department and the Ottawa-Carleton Institute of Physics on matters of medical physics.
3. To develop collaborative research activity in these fields.
4. To promote graduate studies in medical physics.
5. To facilitate graduate student placement with a supervisor who is a member of the MPORU.
6. To develop laboratory facilities for medical physics.
7. To encourage funding from government and from private agencies.
8. To organize seminars, meetings and other forms of communication among the members.

Membership in the MPORU is by invitation of the Executive. Members are expected to be involved in teaching, research or the supervision of graduate students. The main method for the exchange of information among MPORU members is via the monthly seminar series, in which both graduate students in medical physics and MPORU members make presentations.

MPORU Executive

The Executive of the MPORU consists of a Director (Paul Johns, who replaced Ian Cameron 96/1/1), Secretary (Barry McKee, who replaced Alex Bielajew 96/4/18), Academic Officer (Bog Jarosz), and a graduate student representative (Miller MacPherson). Members are elected for two year terms. The Executive meets about once a month and other MPORU members (Barry McKee, Ian Cameron (past Director), Joanna Cygler (who also coordinates the MPORU seminars), and Pavel Dvorak) have attended Executive meetings as observers in the past year. For the 95/96 academic year, Giles Santyr will coordinate the MPORU seminars.

A Note from the Director

The MPORU has had another good year! In fact, this Newsletter marks the end of 7 academic years of operation since the MPORU was accepted by the Faculty of Graduate Studies and Research in the fall of 1989. We have grown from 7 founding members to 26 members today.

There have been a number of developments this academic year. First of all, we welcome four new members:

- Allen Li is a medical physicist at the ORCC. Allen is well-known to many of our members since he was previously a physics resident at the ORCC, and prior to that a post-doc working with EGS4 at NRC IRS. Allen is accredited in clinical medical physics via Membership in the CCPM.

- Jan Seuntjens has joined the NRC IRS group to work on a project to evaluate ion chamber calibration characteristics in accelerator beams and to develop a primary standard for ^{192}Ir high dose rate afterloading sources. He is a recognized expert in water calorimetry after developing a standard for the Belgian standards laboratory where he worked and studied.

- Giles Santyr is the new faculty member at Carleton, filling the position that was advertised in early 1995. He is an mri physicist, and is returning to Canada after 5 years spent in Wisconsin. Giles is setting up clinical collaborations in Ottawa and Kingston, and a basic mr imaging science laboratory at Carleton (the Carleton Magnetic Resonance Facility, or CMRF). There is an article elsewhere in this Newsletter on the CMRF.

- Rob deKemp is associated with the new cardiac PET scanner at the Heart Institute. This is the only PET facility in eastern Ontario/western Quebec. Rob is a recent graduate of McMaster University where there is an active PET program, and his hiring brings considerable PET expertise to Ottawa.

You will find brief CV's of our new members near the end of the Newsletter.

Turning to graduate students, a record number of six physics graduate degrees in the area of medical physics were completed this academic year. Dennis Akyürekli completed his PhD in June 1995 and is now a physics resident at the ORCC. Bilal Shahine completed his MSc in Sept 1995 and enrolled in our PhD program. At this time, unfortunately, it appears that for family reasons he will be relocating to Vancouver at the end of this summer. He hopes to complete his PhD at UBC. Ria Corsten also completed her MSc in Sept 1995 and is now at the cancer clinic in St John's Newfoundland. Julia Wallace defended her PhD April 1996. For the immediate future she is concentrating on the next arrival in their family. Pat Rapley completed his PhD May 1996, having already been employed for some time at the Thunder Bay Regional Cancer Centre. For the last several months his PhD studies have been part-time. Finally, Cathy MacGillivray defended her MSc thesis just four days later. Her plans for the future are not yet finalized. We wish all of our graduates the best as they go on to new endeavours. They are our best ambassadors.

Despite the uncertain times, medical physics is still a growing profession. The outlook for our graduates, while not as wide-open as in the past, is still better than for most other disciplines in science. Demographics and the overall importance that our society gives to health will continue to reinforce the demand for our graduates and the talents of our profession.

For evidence of this, one need look no further than our region. High technology medicine in our community continues to grow. In the last few years there has been a major expansion of the ORCC, a new PET facility set up by the Heart Institute, and a radiotherapy clinic opened in Gatineau. In the future we can expect at least one more clinical mri unit in the city. In addition the new CMRF basic magnetic resonance science lab is now being set up at Carleton.

One of the strengths of the Carleton graduate program in medical physics is the quality of the courses. This year four half courses were offered: Medical Radiation Physics, taught by Bog Jarosz; Radiobiology, by Peter Raaphorst; Physics of Medical Imaging, by P Johns and Giles Santyr; and Radiation Protection, by V Elaguppillai. Special thanks to Peter Raaphorst and Elagu for taking the time from their busy schedules at their own institutions to make their courses available at the university.

The 2nd annual Ottawa Life Sciences Conference was held at the Congress Centre in October 1995, and once again work done by MPORU members and graduate students was a significant component. The Life Sciences Conference is a good venue for making contacts with other research groups in the national capital region. I would encourage further participation this fall.

Throughout this year we again had a successful MPORU seminar series of monthly presentations by graduate students and MPORU members. For maximum exposure, the venue rotates amongst different sites. In addition to this series, invited speakers from outside our region were hosted by Carleton on roughly a monthly basis. Suggestions for speakers to be invited to Carleton are always welcome. There were also a number of invited talks hosted by other institutions. Members aware of talks of general interest are encouraged to advertise them through the MPORU e-mail burster.

The funded chair in medical physics is still on the books as a component of the next fundraising campaign of the university. This campaign has not yet been officially announced, and awaits the installation of the new university President, Richard Van Loon, this summer. The President is one of the key players in fundraising. Meanwhile, this winter the MPORU membership was canvassed as to the strategy we should follow in trying to secure the $500k required for the funded chair. A consensus was reached that we should leave the options open, and not try to target any particular research area within medical physics. We will carry the fundraising efforts forward on this basis in the next academic year.

Finally, there have been a number of changes on the MPORU Executive. I replaced Ian Cameron as Director in December, with Ian consequently replacing Peter Raaphorst as Past-Director. Thank you, Ian, for the conscientious, balanced, and consultative manner in which you conducted MPORU business during your term. Thank you also, Peter, for providing input and guidance as Past-Director, after weathering five years as Director yourself.

Previously my role in the MPORU was that of Academic Officer. This is an enjoyable position because of the student contact, but after a number of years it is personally refreshing for me to move over to the Directorship. This is made possible by Bog Jarosz kindly agreeing to continue as Academic Officer for the near future, in which position he is serving the MPORU well.

At the close of this year Alex Bielajew steps down from the position of Secretary, having served since the end of 1993. Besides producing the last two Newsletters and his other duties, Alex and graduate student rep

Miller MacPherson have kept the MPORU current by putting the Newsletter on the world wide web. We welcome Barry McKee as incoming Secretary. Joanna Cygler is also stepping down as Seminar Organizer after two successful years. Giles Santyr will run the seminars starting this fall.

The MPORU is an example of how collaboration pays off. The Ottawa medical physics community has a strong presence in the medical physics universe, with both depth and diversity. Thank you to all MPORU members and graduate students for your support this past year. With our continued joint efforts we can look forward to another good year.

Paul Johns, Director of the MPORU

MPORU Membership Profile including Recent Research

In order that the Newsletter may serve as an annual report to the Dean of Graduate Studies and Research of Carleton University, this section describes briefly the research activities, recent publications and sources of funding of the MPORU members. The editor has attempted to reduce all the contributions to a standard[1] format.

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Recent Research: Using analytic and Monte Carlo methods to improve the foundations of theoretical dosimetry. • Analytic models of ionisation chambers. • Theoretical development of multiple scattering theory. • Development of electron and photon transport physics for fundamental dosimetry and radiotherapy treatment planning. • Improving Monte Carlo methods in the therapeutic range (10 keV–50 MeV) by modeling the physics more accurately—with most of the emphasis on the EGS (Electron Gamma Shower) Monte Carlo code. • Development of geometry modeling techniques for accurate Monte Carlo transport.

Funding: Lawrence Livermore National Laboratory electron transport grant, 68k$.

Publications:

- A. F. Bielajew. EGS4 timing benchmark results: Why Monte Carlo is a viable option for radiotherapy treatment planning. In *"Proceedings of the International Conference on Mathematics and Computations, Reactor Physics, and Environmental Analyses" (American Nuclear Society Press, La Grange Park, Illinois, U.S.A.)*, pages 831 – 837, 1995.
- A. F. Bielajew. HOWFAR and HOWNEAR: Geometry Modeling for Monte Carlo Particle Transport. *National Research Council of Canada Report PIRS-0341*, 1995.
- A. F. Bielajew. Incorporating the Lawrence Livermore photon interaction data base into the electron-photon Monte Carlo transport code EGS4. In *"Canadian Organization of Medical Physicists Conference Proceedings" (Canadian Organization of Medical Physicists Secretariat, Edmonton, Canada)*, pages 31 – 32, 1995.
- A. F. Bielajew. A hybrid multiple-scattering theory for electron-transport Monte Carlo calculations. *Nucl. Inst. and Meth. (in press)*, 1995.
- A. F. Bielajew and D. E. Cullen. Incorporating the Lawrence Livermore photon interaction data base into the electron-photon Monte Carlo transport code EGS4. In *"Proceedings of the International Conference on Mathematics and Computations, Reactor Physics, and Environmental Analyses" (American Nuclear Society*

[1] Publications involving more than one MPORU member are listed only in the publication list of the MPORU author that appears first in the author list. Also, the publication lists from NRC MPORU members do not include published abstracts. This information can be obtained directly from the authors.

Press, La Grange Park, Illinois, U.S.A.), pages 154 – 161, 1995.
- K. R. Borg and A. F. Bielajew. QUADPLOT: A programme to plot quadric surfaces. *National Research Council of Canada Report PIRS-0491*, 1995.
- M. J. Corsten and A. F. Bielajew. Determination of point-source non-uniformity correction factors for cylindrical ion chambers in the vicinity of brachytherapy sources. In *"Canadian Organization of Medical Physicists Conference Proceedings" (Canadian Organization of Medical Physicists Secretariat, Edmonton, Canada)*, pages 119 – 120, 1995.
- B. B. Sorcini, P. Andreo, A. F. Bielajew, S. Hyödynmaa, and A. Brahme. An improved energy-range relationship for high energy electron beams based on multiple accurate experimental and Monte Carlo data sets. *Phys. Med. Biol.*, 40:1135 – 1159, 1995.
- H. Tölli, A. Bielajew, O. Mattsson, and G. Sernbo. Determination of non-uniformity correction factors for small ionization chambers close to Ir-192 sources. *Department of Radiation Physics, University of Göteborg, Sweden, Internal Report, GU-RADFYS 95:01*, 1995.
- A. F. Bielajew. Plural and multiple small-angle scattering from a screened Rutherford cross section. *Nucl. Inst. and Meth.*, B86:257 – 269, 1994.
- A. F. Bielajew. Monte Carlo Modeling in External Electron-Beam Radiotharapy — Why Leave it to Chance? In *"Proceedings of the XI'th Conference on the Use of Computers in Radiotherapy" (Medical Physics Publishing, Madison, Wisconsin)*, pages 2 – 5, 1994.
- A. F. Bielajew. Improvements of elastic-scattering models employed by the Monte Carlo method for high-accuracy dosimetry applications. In *"Proceedings of the XI'th Conference on the Use of Computers in Radiotherapy" (Medical Physics Publishing, Madison, Wisconsin)*, pages 148 – 149, 1994.
- A. F. Bielajew. Comments on "Calculation of absorbed dose ratios using correlated Monte Carlo sampling". *Med. Phys.*, 21:35, 1994.
- A. F. Bielajew, H. Hirayama, W. R. Nelson, and D. W. O. Rogers. History, overview and recent improvements of EGS4. *National Research Council of Canada Report PIRS-0436*, 1994.
- W. R. Nelson, A. F. Bielajew, D. W. O. Rogers, and H. Hirayama. EGS4 in '94: A decade of enhancements. *Stanford Linear Accelerator Report SLAC-PUB-6625 (Stanford, Calif)*, 1994.

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Recent Research: Magnetic Resonance Imaging (MRI) is used to study water diffusion in brain and muscle tissue as well as perfusion of blood in capillary beds. In order to better understand, at a basic level, the effects of water diffusion in MRI, the range over which the water molecules diffuse in a given time is measured for a variety of tissues and experimental conditions in human volunteers (completely non-invasively). This quantity is strongly dependent on the nature of the cell that the water is in. These results are then interpreted using a combination of analytical models and simulations based on Monte Carlo algorithms. We have also designed and built special gradient coils which allow us to study this process over a much larger range of values than is possible with the gradient coils provided with a clinical imager. • We have recently also begun studies to determine if diffusion and/or perfusion weighted imaging can be performed in the abdomen where physiological motions due to breathing and peristalsis (i.e. digestion) could overwhelm the minute motions associated with diffusion. Initial attempts at overcoming this problem appear to be quite promising! As a practical application of this we hope to be able to measure the slow perfusion of blood in the placenta as a monitor of intrauterine growth retardation. This may help physicians decide whether or not to induce labour prematurely when a fetus is unusually small.

Funding: NSERC operating grant, $15,000/year.

Publications:

- L. Gates and I.G. Cameron. "Diffusion Measurements at Very Short Diffusion Times in Human Muscle Using a Double Maxwell Gradient Coil", Proceedings of the International Society for Magnetic Resonance in Medicine Conference, Nice, France, 1995.
- L. Gates and I.G. Cameron. "Time Dependence of Water Diffusion in Human White Matter", Proceedings of the International Society for Magnetic Resonance in Medicine Conference, Nice, France, 1995.
- L. Gates and I.G. Cameron. "Using MRI to Measure Diffusion of Water in Human White Matter", Proceedings of the Canadian Organization of Medical Physicists Conference, Montreal, 1995.
- L. Gates and I.G. Cameron. "Restricted Diffusion in Human White Matter for Long Diffusion Times", Proceedings of the Society of Magnetic Resonance Conference, San Fransisco, 1994.

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Recent Research: Studying the use of highly focussed beams of ultrasound for the reduction or removal of benign and malignant lesions. The process of tissue destruction, consisting of energy deposition, diffusion and tissue response is being studied experimentally, theoretically and by computer modeling. Appropriate lens design and the dosimetry of high intensity ultrasound are also being investigated.

Publications:

- 1994 Vaughan M. G., ter Haar G. R., Hill C. R., Clarke R. L. and Hopewell J. W., "Minimally invasive cancer surgery using focused ultrasound: a pre-clinical, normal tissue study", Brit J Radiology 67, 267-274
- 1994 Clarke R. L., ter Haar G. R., Hill C. R. and Ueno E., "Tissue heating with strongly focussed ultrasound", Ultrasound Med Biol, paper accepted for publication
- 1995 Clarke R. L. "Modification of intensity distributions from large aperture ultrasound sources", Ultrasound in Med. & Biol. 21 (3), 353-363
- 1996 Rivens I.H., Clarke R.L., ter Haar G.R. "Design of focused ultrasound surgery transducers", accepted Trans. IEEE - UFC
- 1994 ter Haar G. R., Clarke R. L. and Hill C. R. "Physical characterisation of ultrasonically induced ablative lesions", European J Ultrasound, 1 (Supp.1), 80
- 1994 ter Haar G. R., Hill C. R., Chen L. and Clarke R. L., "The art of successful ultrasound surgery", Ultrasound Med Biol, 20: S95

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Recent Research: The response of human malignant cell lines to ionizing radiation at various dose rates has been studied under oxic and anoxic conditions. • The mechanism of radiation induced cell death has been investigated as a function of dose and oxygen for rat thymocytes. Apoptosis appears to be the main mechanism of cell death in the range of low to medium doses. For higher radiation doses thymocytes die via necrosis. This study has been carried on in close collaboration with the NRC scientists from Physics and Biology Divisions and the pathologist from the Ottawa Civic Hospital. • Clinical verification of a new

dosimetry system based on Dual Bias Dual MOSFET detectors is on-going. Further work is needed to implement such a detector in routine clinical use. A collaboration with Canadian industry is ongoing on this subject. • A project on dosimetry of clinical electron beams is carried on in collaboration with the NRC scientists within the Omega project. New treatment technique with a high-Z mesh surface dose modifier has been implemented. Monte Carlo calculations for realistic clinical beams are used to optimize electron beam modifiers. • High dose-rate brachytherapy is also being evaluated and a clinical program is ongoing.

Publications:

- J. Cygler, N. V. Klassen, C. K. Ross, T. J. Bichay, and G. P. Raaphorst. The Survival of Aerobic and Anoxic Human Glioma and Melanoma Cells after Irradiation at Ultrahigh and Clinical Dose Rates. *Rad. Res.*, 140:79 – 84, 1994.
- C. M. Wells, T. R. Mackie, M. B. Podgorsak, M. A. Holmes, N. Papanikoloau, P. J. Reckwerdt, J. Cygler, D. W. O. Rogers, A. F. Bielajew, D. G. Schmidt, and J. K. Muehlenkamp. Measurements of electron dose distribution near inhomogeneities using a plastic scintillator detector. *Int. J. Radiat. Oncol. Biol. Phys.*, 29:1157 – 1165, 1994.
- Soubra, M. Cygler, J. and MacKay, G. Evaluation of a dual bias dual MOSFET detector as radiation dosimeter. Med. Phys. **21** 567–572, 1994.

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Recent Research: Development of three-dimensional attenuation and scatter corrections for positron emission tomography, automated 3D cardiac image interpretation, and development of an automated isotope delivery system for the short-lived blood flow tracer Rb-82.

Publications:

- R.A. deKemp, W.F. Jones, C. Nahmias, R.S. Beanlands (1996) "Design and Performance of 3D Single Photon Transmission Measurement on a Positron Tomograph with Continuously Rotating Detectors", In: Serie Computational Imaging and Vision, P. Grangeat, J.L. Amans (eds), Kluwer Academic Publishers (in press)
- R.A. deKemp, C. Nahmias (1996) "Automated Determination of the Myocardial Long Axis in Cardiac Positron Emission Tomography", Physiol. Meas. (in press)
- R.S.B. Beanlands, T.D.Ruddy, R.A. deKemp, E. Harmsen, J. Veinot, N.G. Hartman (1996) "Myocardial Kinetics of Tc-99m Teboroxime in the Presence of Post-Ischemic Injury, Necrosis and Low Flow Reperfusion", J. Am. Coll. Cardiol. (in press)
- C.C. Watson, D. Newport, M.E. Casey, R.A. deKemp, R.S.Beanlands (1995) "Evaluation of Simulation Based Scatter Correction for 3D PET Cardiac Imaging", IEEE NSS & MIC Conf.Rec. (in press)
- R. deKemp, C. Nahmias (1994) "Attenuation Correction in PET using Single Photon Transmission Measurement", Medical Physics, 21: 771-778 (1994)

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X-Ray Research: Studies of patient doses from x-ray procedures, computer simulations of x-ray procedures, development of testing and measuring techniques, both in medical and non-medical x-ray applications.

Facilities: Three phase and single phase radiographic/fluoroscopic, mammographic, dental and industrial x-ray machines, assorted phantoms, measuring equipment and automatic film processor.
Non-Ionizing Radiation Research: Interactions of RF fields with human body and possible association between electromagnetic fields and cancer; sound power from noisy machinery and biological effects of aircraft noise; interactions of ultrasound with human body; biological effects of solar radiation.
Facilities: RF anechoic chamber (13 m x 7 m x 6 m), with test equipment and signal generators from 5 Hz to 22 GHz; acoustic anechoic chamber (13 m x 9 m x 8 m) and laboratory, equipped to test and generate acoustic noise (includes aircraft noise simulation) and ultrasound; electro-optics laboratories with 25 W argon laser, 900 mW dye laser, 11 W excimer laser, incoherent light sources, cultured cells UV exposure laboratory, measuring equipment.

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Recent Research: Quantification of the risk to health (cancer, genetic and teratogenic effects) and environmental effects of exposure to low dose and low dose-rate of low and high LET ionising radiation, reduction of uncertainties in risk estimates, design and improvement of radiation practices at work places (hospital, research, power reactor, uranium mine, mill and refinery, radioactive waste disposal facilities) are the areas of main research interest.

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Recent Research: The Patient Position Monitoring System is being developed as a tool for the computer-controlled radiation therapy program. The design criteria are that this system will provide an independent means of measuring patient position in real time. Position can be reported in either absolute or relative terms and will provide both rotational in three planes and translational motions updating every five seconds. This is a joint project spearheaded by the ORCC and being done in conjunction with the National Research Council and Siemens Medical Laboratories. • There is a well-defined need for the development and implementation of a stereotactic radiation surgery and radiation therapy program at the ORCC. The principal difference between radiation surgery and radiation therapy is that radiation surgery delivers a very high dose in a single fraction whereas radiation therapy has all the same requirements except the dose must be delivered in a fractionated manner. The program includes the development of special radiation therapy cones to provide a very well-defined, well collimated x-ray beam, patient immobilization devices specifically for the radiation therapy component, localization devices which can be correlated to the patient immobilization devices and treatment planning and dosimetry for the verification of dose distributions. It is hoped that the stereotactic radiation therapy program will be implemented fully by May of 1993, although preliminary patient work has been done as early as November of 1992.

Publications:

- Asymmetric Arc Technique for Posterior Pharyngeal Wall and Retropharyngeal Space Tumors, Grimard, L, Szanto, J., Girard, A., Howard, M., Eapen, L., and Gerig, L. Int. Journal of Radiation Oncology Biol. Phys.

31(3), Feb. 1995.

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Recent Research: Studying radiation-induced conformational changes to the human genome in living cells using time-resolved and immunofluorescence spectroscopies. Using electron spin resonance (ESR) bio-dosimetry of human samples or tissue-equivalent surrogate samples. Developing an automated multiwell cell survival assay using a redox dye as a vital stain for quantitative studies of biological response modification and the radioprotective action of antioxidants. Measuring radiation damage to the lymphocyte immunosurveillance system. Fluorescent monoclonal antibody binding to specific cell surface receptors is used to monitor an early-warning response to radiation, cancer-proneness, cell signalling and adaptation mechanisms. An immunoassay technique (ELISA) has been set up to measure antioxidant enzyme levels in cells, and to explore their role in inducible and constitutive radiation protection mechanisms.

Funding: Candu Owners Group (COG), R&D support, $150k • AECB contract for organically bound tritium dosimetry, $62k • Faulding(Canada) contract to study catalase action in cancer therapy, $20k • COG graduate student scholarship support, $10k/year

Publications:

- A.Trivedi and C.L. Greenstock, Trends in biodosimetry. In "Biological Concepts in Radiotherapy" (B.B. Singh and D. Bhattacharjee, eds.) Narosa Publishing House, New Delhi, India, 62-71, 1995.
- C.L. Greenstock, A. Trivedi and R.E.J. Mitchel, Cellular response to stress and risk modulation, Proc. Amer. Assoc. Cancer Res., 36, 182, 1995.
- A. Trivedi and C.L. Greenstock, Recent developments in biodosimetry. Atomic Energy Control Board(AECB) Report, INFO-0597, Ottawa, 1-85, 1995.
- Y.Xu, C.L. Greenstock, M.V. O'Shaughnessy and B. Conway, The effects of low doses of gamma irradiation on HIV-replication in human peripheral blood mononuclear cells. Second National Conference on Human Retroviruses and Related Infections, II, 29, 1995.
- C.L. Greenstock, From Szechuan to Saskatchewan: A Profile of H.E. Johns and the Cobalt Bomb. In "A New Kind of Ray: The Radiological Sciences in Canada 1895-1995"(J.E. Aldrich and B.C. Lentle, eds.) The Canadian Association of Radiologists, Montreal, 247–251 and 428-429, 1995.
- C.L. Greenstock and A.Trivedi, ESR dosimetry using surrogate biosamples, Health Phys. 68, Suppl. 1, S23, 1995.
- C.L. Greenstock and S.R. Maves, Fluorescence lifetime studies of DNA structure in gamma-irradiated lymphocytes. In "Radiation Research 1895-1995". Congress Proceedings, Vol. 1(U. Hagen, H.Germany, 422, 1995.
- D.P. Heller and C.L. Greenstock, Fluorescence lifetime analysis of DNA intercalated ethidium bromide and quenching by free dye, Biophys. Chem. 50, 305-312, 1994.
- C.L. Greenstock and A Trivedi, Biological and biophysical techniques to assess radiation exposure: A perspective. In "Progress in Biophysics and Molecular Biology, Vol. 61(D. Noble and T.L. Blundell, eds.) Elsevier Science Ltd., London, 81-134, 1994.
- A. Trivedi, R.E.J. Mitchel, Y. Xu and C.L. Greenstock, Interleukin-2 receptors as biomarkers for occupational levels of radiation exposure. In "Proceedings of the 16th International Cancer Congress"(R.S. Rao, M.G. Deo, L.D. Sanghvi and I. Mittal, eds.) Monduzzi Editore S.p.A.-Bologna, Italy, 2719-2724, 1994.
- A. Trivedi, C.L. Greenstock and R.E.J. Mitchel, Is there a common stress modulating system(COSMOS) for transient cellular response to radiation? In "Proceedings of the International Symposium on Gene Regulation and Cellular Response to Radiation", Kyoto, Japan, 21, 303, 1994.
- C.L. Greenstock and A. Trivedi, The application of ESR spectrometry to retrospective and accident dosimetry: An assessment, AECL Report 10474(COG-94-02), 1994.

- A. Trivedi and C.L. Greenstock, ESR dosimetry using surrogate biosamples. In "4th International Conference on Radiation Protection and Dosimetry" Orlando, Florida, 15, 2, 1994.
- Y. Xu, C.L. Greenstock and B. Conway, Effects of low dose gamma irradiation on cytokine production and HIV replication in peripheral blood mononuclear cells. In "Conference on Gene Induction and Adaptive Response in Irradiated Cells: Mechanisms and Clinical Implications", Montreal, 3- 07, 1994.
- S.R. Maves and C.L. Greenstock, Time-resolved fluorimetric probing of DNA structure in irradiated cells. In "18th L.H. Gray Conference", Bath, U.K., 4-04, 1994.

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Recent Research: Therapeutic applications of ultrasound for hyperthermia of deeply localized tumours. Current research concentrates on wide range of animal and phantom tests of the array of original interstitial ultrasonic waveguide hyperthermia applicators. Of paramount importance is understanding of interaction of sonic waves with tissue and mode conversion in tissues, projects that have been currently studied. The array has been intended for therapy of brain tumours, an undertaking started in collaboration with the Ottawa Civic Hospital, Department of Neurosurgery. FEA simulations of ultrasound hyperthermia using the array has been also initiated. Also, laser generated ultrasound for hyperthermia has been of interest.

Publications:

- D. Kaytar and B.J. Jarosz (1995) "Hyperthermic fields generated by an array of interstitial ultrasonic waveguide applicators", Proceedings, 1995 COMP/CCPM Conference, Montreal, PQ.
- B.J. Jarosz, Martin Werner (1994) "Effects of Tissue Microstructure on Ultrasonic Heating with Interstitial Applicator", Proceedings, 16'th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Baltimore MD, USA.
- B.J. Jarosz, Martin Werner (1994) "Role of Microstructure in Ultrasonic Hyperthermia by Interstitial Applicator", COMP/CCPM Ann. Sci. Meet., Toronto, Canada.
- B.J. Jarosz (1994) "Ultrasound Hyperthermia in Normal and Emulsified Tissue by Interstitial Waveguided Applicator", Proceedings, World Congress on Med. Phys. and Biomed. Eng., Rio de Janeiro, Brazil.
- Vasco da Silva, B.J. Jarosz (1994) "Ultrasonic Interstitial Applicator for Hyperthermia of Glioma", 62'nd Ann. Conf. Am. Ass. Neurological Surgeons, San Diego CA, USA.

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Recent Research: Studying iterative reconstruction techniques to reduce artefacts in computed tomography (CT) by accounting for the polyenergetic nature of the x-ray beam as well as scattered x rays. •Investigating means of obtaining diagnostic information using coherent scatter. Although coherent scatter has a small cross section compared with Compton scattering, it is a forward directed process, so that coherently-scattered photons have a high probability of reaching the image receptor. Furthermore, the differential coherent cross section varies with scattering angle and photon energy in a material-specific manner, even for amorphous materials; this is the diffraction signature of the material. This dependence on Z and chemical structure suggests that it can be used to obtain chemical information about tissues. We are in the process of a detailed

investigation of coherent scatter imaging to determine its sensitivity, i.e. the radiation dose to the patient required to detect the presence of a volume of tissue of specified dimensions against a background of some other tissue. • Member of collaboration at Carleton investigating the use of gas microstrip detectors for medical x-ray imaging. By operating in photon counting mode, these detectors can achieve higher DQE than do integrating detectors. The energy of each photon event can be measured, providing input for applications such as dual-energy radiography.

Funding: NSERC Operating Grant $15,000/y

Publications:

- M.S. Dixit, J.C. Armitage, D. Bouius, L. Diaconescu, J. Dubeau, M. Grabari, P.C. Johns, D. Karlen, and F.G. Oakham, "Digital X-Ray Imaging Using Gas Microstrip Detectors", Proceedings of IEEE Medical Imaging Conference, San Francisco (October 1995).
- P.C. Johns, J.C. Armitage, M.S. Dixit, J. Dubeau, D. Karlen, and F.G. Oakham, "Gas Microstrip Detectors for Digital X-Ray Imaging", Proceedings of 41st Annual Meeting of the Canadian Organization of Medical Physicists, 143-144 (1995) [Abstract: Medical Physics 22 675 (1995)].
- P.C. Johns and L. Renaud (1994) "Radiation Risk Associated with PTCA", Primary Cardiology 20(12), 27-31.
- P.C. Johns and R.M. Bureauregard (1994) "Incorporation of Scattered Radiation into Dual-Energy Radiologic Theory and Application to Mammography", Medical Physics 21, 1455-1462.

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Recent Research: Involved with work to establish absorbed dose standards based on water calorimetry. This has been done for 20 MV and ^{60}Co beams. The computer simulations of the chemical changes during the irradiations is tested by measuring the production/destruction of hydrogen peroxide in the aqueous solutions irradiated in the calorimeter.

Publications:

- N. V. Klassen, D. Marchington, and H. C. E. McGowan. H_2O_2 Analysis by the I_3^- Method and by $KMnO_4$ Titration. *Anal. Chem.*, 66:2921 – 2925, 1994.
- N. V. Klassen and C. K. Ross. Testing model calculations of the heat defect. *Proc. of NPL Water Calorimetry Workshop*, 1994.
- N. V. Klassen, C. K. Ross, and K. R. Shortt. Water calorimetry: Model and experiment. *Proc. of NPL Water Calorimetry Workshop*, 1994.

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Recent Research: Several approaches have been implemented recently in ORCC to improve dose calculation accuracy for megavoltage photon beams. Separating output factor into head scatter factor and phantom

scatter factor was used to consider the situations when the field size on phantom surface differs from the collimator setting. A special care was taken for field-size dependent wedge and tray factors. Calculation for asymmetric jaw setting and acquisition of peak scatter factor are being investigated. EGS4 Monte Carlo simulation and experimental measurement are being used in the study. • Orthovoltage x-ray beams are widely used for the treatment of superficial lesions. The effects of extended SSD on orthovoltage x-ray dosimetry are being studied experimentally. We are also interested in the choice of relative dosemeters and improvement of output calibration for these beam qualities. A endorectal irradiation technique is currently being developed on our orthovoltage x-ray unit. • Dose optimization is a deterministic approach to treatment planning which offers several advantages over the current conventional "trial and error" approach. Collaborated with Dr. D. Salhani, the algorithms have been developed and tested for brachytherapy with very promising results.

Publications:

- X.A. Li, M. Soubra, J. Szanto and L.H. Gerig, "Lateral electron equilibrium in measurements of head scatter factors using miniphantoms and brass caps", Med. Phys. 22:1167-1170 (1995).
- X. A. Li and D. W. O. Rogers. Electron mass scattering powers: Monte Carlo and analytical calculations. *Med. Phys.*, 22:531 – 541, 1995.
- X. A. Li and D. W. O. Rogers. Reducing Electron Contamination for Photon-Beam-Quality Specification. *Med. Phys.*, 21:791 – 798, 1994.

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Recent Research: Using Monte Carlo techniques to improve our understanding of cavity theory and dosimeter response for radiotherapy dosimetry. • Using the EGS4 Monte Carlo code system to calculate correction factors for Fricke dosimeters and ionization chambers in medium-energy x-ray beams and in high-energy photon and electron beams. • Working on the OMEGA project. This is a collaboration between the NRCC and the University of Wisconsin to develop a Monte Carlo code to calculate dose distributions in a patient irradiated by a high-energy electron beam.

Publications:

- C. M. Ma. The fluence-to-dose-equivalent conversion factors for 4-element ICRU tissue, water and PMMA slab phantoms irradiated by external electron beams. *NRC Report PIRS 490*, 1995.
- C. M. Ma and A. E. Nahum. Monte Carlo calculated stem effect corrections for NE2561 and NE2571 chambers in medium-energy x-ray beams. *Phys. Med. Biol.*, 40:63 – 72, 1995.
- C. M. Ma and A. E. Nahum. Calculations of ion chamber displacement effect corrections for medium-energy x-ray dosimetry. *Phys. Med. Biol.*, 40:45 – 62, 1995.
- C. M. Ma, P. Reckwerdt, M. Holmes, D. W. O. Rogers, and B. Geiser. DOSXYZ Users Manual. *NRC Report PIRS 509b*, 1995.
- C. M. Ma and D. W. O. Rogers. BEAMDP Users Manual. *NRC Report PIRS 509c*, 1995.
- C. M. Ma and D. W. O. Rogers. BEAMDP as a General-Purpose Utility. *NRC Report PIRS 509e*, 1995.
- C. M. Ma and D. W. O. Rogers. Beam characterization: a multiple-source model. *NRC Report PIRS 509d*, 1995.
- H. C. E. McGowan, B. A. Faddegon, and C-M Ma. STATDOSE for 3D dose distributions. *NRC Report PIRS 509f*, 1995.
- C. M. Ma. Implementation of a Monte Carlo radiation transport code on a parallel computer system. *Parallel Computing*, 20:991 – 1005, 1994.
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- C. M. Ma and A. E. Nahum. Monte Carlo calculated correction factors for a NE2571 chamber in medium-

energy photon beams. In *"Proceedings of the IAEA International Symposium on Measurement Assurance in Dosimetry" (Vienna: IAEA)*, pages 371 – 382, 1994.

- C. M. Ma and A. E. Nahum. Theoretical and experimental investigation of the prototype NPL design of plane-parallel chambers. In *"Proceedings of the IAEA International Symposium on measurement assurance in dosimetry" (Vienna: IAEA)*, pages 495 – 504, 1994.
- C. M. Ma and A. E. Nahum. Plane-parallel chambers in electron beams: Monte Carlo findings on perturbation correction factor. In *"Proceedings of the IAEA International Symposium on measurement assurance in dosimetry" (Vienna: IAEA)*, pages 481 – 493, 1994.
- C. M. Ma, D. W. O. Rogers, G. X. Ding, and T. R. Mackie. Electron beam characterization: Reconstruction models and dose distributions in a homogeneous phantom. *Med. Phys.*, 21:895, 1994.

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Recent Research: Developing a high-resolution pinhole SPECT camera that will achieve a resolution of about 3 mm over a limited field of view. This will be useful for clinical imaging of wrists, etc., and for research applications in radiopharmaceutical development. • Modeling and measuring the scatter background in SPECT systems to develop and test improved correction methods. This takes advantage of recent experience in developing scatter correction methods for 3D PET imaging.

Publications:

- B.T.A. McKee, M.J Chamberlain, K.Y.Gulenchyn, R.B. Jammal and B.T.A. McKee (1996) "Nuclear medicine goes filmless: Experience with a miniPACS," Proceedings of the 13th Conference on Computer Applications in Radiology, Denver, Co., 1996.
- B.T.A. McKee, M.J. Chamberlain, and R.B. Jammal (1995) "The feasibility of 511 keV SPECT imaging: the scattered background," J. Nucl. Medicine, 36, no.5, 174P (abst).
- B.T.A. McKee, R.B. Jammal and M.J. Chamberlain (1995) "The scatter background in high-resolution pinhole SPECT," Conference Record of the 1994 IEEE Medical Imaging Conference, Norfolk, Va, 1498-1501.
- B.T.A. McKee, L.G. Hiltz and P.J. Harvey (1994) "Signal-to-noise ratios for attenuation correction in PET imaging," IEEE Trans. Med. Imaging, **MI-13**, 711–715.
- B.T.A. McKee and L.G. Hiltz (1994) "Attenuation correction for three-dimensional PET using uncollimated flood-source transmission measurements," Phys. Med. Biol. **39**, 2043–2058.
- L.G. Hiltz and B.T.A. McKee (1994) "Scatter correction for three-dimensional PET based on an analytic model dependent on source and attenuating object," Phys. Med. Biol. **39**, 2059–2071.
- L.G. Hiltz and B.T.A. McKee (1994) "A source and object dependent scatter correction method for transmission and emission imaging," Conference Record of the 1993 IEEE Medical Imaging Conference, San Francisco, 1600–1604.
- B.T.A. McKee, A.W. Dickson and D.C. Howse (1994) "Performance of QPET, a high-resolution 3D PET imaging system for small volumes," IEEE Trans. Med. Imaging, **MI-13** 176–185.

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Recent Research: The ability of drugs to potentiate the response of human cancer cells to X-radiation and hyperthermia is being investigated. The aim of these experiments is to determine if the inhibition of cellular repair of X-radiation damage or the interaction of the drugs with hyperthermia can lead to selective killing of human tumor relative to normal cells. A selective killing of tumor over normal cells is necessary to treat tumors successfully in the clinic. In particular, two types of drugs, DNA topoisomerase poisons and cisplatin, are being emphasized. Both of these drugs are already in active use clinically; the DNA topoisomerase poisons in particular, are also in widespread use in cancer chemotherapy. Very recent work has also focussed on the role of p53 in the modulation of killing by the topoisomerase poisons.

Funding: Supported as a Career Scientist with the OCTRF • OCTRF research funds (2 years,$30,000/year) • Co-investigator on NCIC grant to study cellular radiosensitivity (three years,$101,000/year) • Co-investigator on NCIC grant to study interaction of cisplatin with hyperthermia and radiation (three years, $95,000/year)

Publications:

- Ng, C.E., Bussey, A.M. and Raaphorst, G.P. Inhibition of potentially lethal and sublethal damage repair by camptothecin and etoposide in human melanoma cell lines. Int. J. Rad. Biol., 66: 49-57, 1994.
- Aitken, N.R., McGovern, K.M., Ng, C.E., Wehrle, J.P. and Glickson, J.D. 31P NMR spectroscopic studies of the effects of cyclophosphamide on perfused RIF-1 tumor cells. Mag. Res. in Medicine, 31: 241-247, 1994.
- Chen, K., Ng, C.E., Zweier, J.L., Kuppusamy, P., Glickson, J.D. and Swartz, H.M. Measurement of the intracellular concentration of oxygen in a cell perfusion system by an EPR spectroscopic technique. Mag. Res. in Medicine, 31: 668-672, 1994.
- Ng, C.E., Yang, D.P., Bussey, A.M. and Raaphorst, G.P. Cultured Chinese Hamster Ovary cells lack a transferable X-radiation resistance factor. Oncol. Reports, 2: 439-442, 1995.
- Ng, C.E., Bussey, A.M., MacDonald, H.M., Heller, D.P. Wilkins, D.E. and Raaphorst, G.P. Cross sensitivity to X-radiation and type I and II DNA topoisomerase inhibitors in a range of human and rodent cell lines. Int. J. Oncol., 7: 1179-1184, 1995.
- Ng, C.E., Bussey, A.M. and Raaphorst, G.P. Reduction of etoposide induced cell killing by hyperthermia can occur without changes in etoposide transport or topoisomerase II activity. Int. J. Hyperthermia, in press, 1995.
- Ng, C.E., Bussey, A.M. and Raaphorst, G.P. Sequence of treatment is important in the modification of camptothecin induced cell killing by hyperthermia. Accepted, Int. J. Hyperthermia, 1995.

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Recent Research: In vitro studies of the role of repair in the radiation resistance of various human tumour cell lines are underway. Hyperthermia is used to cause radiosensitivity and to inhibit repair. Low dose rate measurements are underway, and they show large increases in survival as the dose rate is lowered. The effects

of hyperthermia at low dose rates is being evaluated. These data show a large enhancement of radiation sensitivity, which is primarily caused by the presence of hyperthermia during irradiation, blocking systems which repair radiation damage. The response of human glioma cells to very high dose rates is also being studied. • The effect of radiation resistance is also being evaluated. Cell lines expressing radiation sensitivity as well as radiation resistance are being tested for characteristics of this resistance such as increased repair of radiation damage and methods are being investigated to overcome this resistance such as combinations of hyperthermia drugs combined with radiation. In addition, mechanisms of resistance are also being explored and survival curve models are being developed to predict and assess resistance. • The evaluation of patients' radiation sensitivity before treatment is also being investigated. The determination of genetic variation of radiation response can lead to better prescription of dose to individual patients depending on their relative radiation sensitivity. • Hyperthermia in animal model and in the clinic is also being evaluated. To date we have treated 35 patients and have shown that hyperthermia in combination with radiation can provide benefit in superficial tumours. This clinical trial has been completed. In addition, we are evaluating the effect of hyperthermia on blood flow in pigs. The data show that hyperthermia can effect blood flow in muscles, brain and kidney. These data are being analyzed and will contribute to developing a hyperthermia model which can be used in treatment planning in a prediction of thermal dose. • Magnetic resonance spectroscopy is being used to study 1H and 31P in human ovarian carcinoma and rat glioma cells both in vitro and in vivo. It is shown that there are differences in the 1H spectra between cells expressing a normal response and a resistant response to chemotherapeutic agents. Results also show that the stress of cancer therapeutic agents causes changes in the high energy phosphorous metabolites within cells. The effects of hyperthermia, radiation and chemical agents are also being studied. • Various aspects of external beam radiotherapy are being studied. This includes the development and implementation of asymmetric arc therapy; the development of a radiosurgery program; the development of a patient position monitor; the evaluation of therapy using asymmetric collimator jaws; the development of dynamic wedges; the development of algorithms for fitting treatment unit data, and the inverse problem is being studied.

Funding: NCIC grant for the study of cellular radiosensitivity, three years - $101,000/year • NCIC grant for the study of cisplatin in combination with low dose rate irradiation, three years - $95,000/year • NIH Grant, Study of hyperthermic and low dose rate irradiation, three years- $128,000/year • Industrial funding for development of patient positioning monitor system, five years $500,000 • ORCC capital and operating fund - $16,000 • $16,000/year MRC graduate fellowship • $16,000/year, NSERC graduate fellowship.

Publications:

- Raaphorst, G.P., Heller, D.P., Bussey and Ng, C.E. Thermal radiosensitization by 41°C hyperthermia during low dose rate irradiation in human normal and tumor cell lines. Int. J. Hyperthermia, 10: 263-270, 1994.
- Raaphorst, G.P., Bussey, A.M., Heller, D.P. and Ng, C.E. Comparison of thermoradio-sensitization in two human melanoma and one normal fibroblast cell lines by mild hyperthermia under low dose rate conditions. Radiation Res., 137: 338-345, 1994.
- Raaphorst, G.P., Bichay, T.J. and Ng, C.E. Further on prediction of radiotherapy response using SF2: Is it methodology or mythology? Radiotherapy and Oncology, 31: 85-91, 1994.
- Raaphorst, G.P., Yang, D.P. and Ng, C.E. Effect of protracted mild hyperthermia on polymerase activity in a human melanoma cell line. Int. J. Hyperthermia, 10: 827-834, 1994.
- Raaphorst, G.P., Szanto, J., Cygler, J. and Laewen, A. (1994) A safe method of analysis for mechanical damage in spherical radioactive sources used in remote afterloading brachytherapy devices. Med. Phys. **20** 247–249.
- Raaphorst, G.P., Yang, D.P., Grewaal, D., Stewart, D., Goel, R. and Ng, C.E. Analysis of mechanisms of cisplatin resistance in three pairs of human tumor cell lines expressing normal and resistant responses to cisplatin. Oncol. Reports, 2: 1037-1043, 1995.
- Raaphorst, G.P., Wang, G. and Ng, C.E. Radiosensitization by cisplatin treatment in cisplatin resistant and sensitive human ovarian carcinoma cell lines. Int. J. Oncol., 7: 325-330, 1995.
- Raaphorst, G.P., Doja, S., Davis, L., Stewart, D.J. and Ng, C.E. A comparison of hyperthermia-cisplatin sensitization in human ovarian carcinoma and glioma cell lines sensitive and resistant to cisplatin treatment. Cancer Chemo. Pharmacol., in press, 1995.

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Recent Research: Monte Carlo techniques are used to calculate correction factors required for primary radiation standards. Recent examples are the calculation of wall correction factors for ionization chambers used for air kerma standards, and the calculation of the wall effect for Fricke dosimeter vials. These correction factors have a significant impact on several national standards. • Developing more accurate and easily used clinical dosimetry protocols. In this regard, the effect of beam size and beam quality on ionization chamber calibration factors is being calculated. Also, work is underway on a formalism which will use absorbed dose, rather than exposure, calibration factors. • Measuring fundamental data using the NRC linear accelerator. A recent project has accurately measured the bremsstrahlung yield from thick targets as a function of energy and angle and compared the results to Monte Carlo calculations. Another project is underway to measure electron stopping powers which play a fundamental role in radiation dosimetry but have never been measured with an accuracy of better than 5%. • Working on the OMEGA project. This is a collaboration with Rock Mackie's group at the University of Wisconsin to develop a Monte Carlo based code to calculate the dose in a patient undergoing electron beam radiotherapy. We are developing a general purpose code to model radiation beams from clinical accelerators.

Funding: NSERC - graduate student support of $10k/year • NIH - $130k/year (to Ottawa) for three years for the OMEGA project

Publications:

- P. R. Almond, F. H. Attix, S. Goetsch, L. J. Humphries, H. Kubo, R. Nath, and D. W. O. Rogers. The calibration and use of plane-parallel ionization chambers for dosimetry of electron beams: An extension of the 1983 AAPM protocol, Report of AAPM Radiation Therapy Committee Task Group 39. *Med. Phys.*, 21:1251 – 1260, 1994.
- A. Booth and D. W. O. Rogers. PROT: A General Purpose Utility for Calculating Quantities related to Dosimetry Protocols. Technical Report PIRS–529, NRC Canada, Ottawa, K1A OR6, 1996.
- M. Boutillon, B. M. Coursey, K. Hohlfeld, B. Owen, and D. W. O. Rogers. Comparison of primary water absorbed dose standards. *IAEA–SM–330/48, Proceedings of Symposium on Measurement Assurance in Dosimetry, (IAEA, Vienna)*, pages 95 – 111, 1994.
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- G. X. Ding and D. W. O. Rogers. Energy spectra, angular spread, and dose distributions of electron beams from various accelerators used in radiotherapy. *National Research Council of Canada Report PIRS-0439* (see http://www.irs.inms.nrc.ca/inms/irs/papers/PIRS439/pirs439.html), 1995.
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- B. Walters and D. W. O. Rogers. QA for the BEAM System; Component Modules, Variance Reduction Options and Source Routines. *NRC Report PIRS–509k*, 1995.
- G. Zhang and D. W. O. Rogers. BEAM Example: A 10 MeV electron beam. *NRC Report PIRS 509h*, 1995.

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Recent Research: The amount of ionizing radiation absorbed by a material generally is specified by the quantity absorbed dose. For purposes of radiation therapy, it is the absorbed dose to tissue which is of most interest. As a first step in determining the dose to tissue, the dose to water is established in some well-defined geometry. Field instruments used to determine the dose to water must be calibrated in terms of some reference standard, and one of the objectives of our group is to develop and maintain standards and calibration services for the absorbed dose to water. Our standard for the absorbed dose to water is based on water calorimetry, in which the energy deposited by the radiation field is determined by measuring the temperature rise in irradiated water. Our intention is to have a single standard which can be used for all photon beams from ^{60}Co γ-rays to 30 MV x-rays. • A quantity of considerable importance to radiation physics and medical physics is the electron stopping power. Stopping power data in use today is based mainly on calculations. In order to test the calculated values, we are measuring electron stopping powers in the energy range from 5 to 40 MeV for various materials. The technique uses a large NaI detector to measure the electron spectrum after the electron beam has passed through an absorber of known thickness. By comparing the measured spectrum to that calculated using Monte Carlo techniques we can extract the stopping power. Preliminary results indicate that the uncertainty on the measured stopping power should be about 0.5%.

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- C. K. Ross and N. V. Klassen. Water calorimetry for radiation dosimetry. *Phys. Med. Biol.*, 41:1 – 29,

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Recent Research: The general goal of our research is to develop new Magnetic Resonance (MR) imaging methods for improved patient care. Our primary clinical focus is breast cancer. Current research activities in our laboratory include: the use of spin locking and magnetization transfer contrast for improving detection of lesions in radiodense breasts, characterization of breast lesions (benign vs. malignant) using rapid imaging of gadolinium-based contrast agents, image display and development of an MR-based breast biopsy system. Clinical studies to evaluate the usefulness of these techniques are in progress. Other areas of interest include: in vivo measurement of kidney glomerular filtration rate (in collaboration with the University of Wisconsin), basic physics of MR image contrast, development of MR phantom materials and imaging of hyperpolarized gases (*i.e.* ^{129}Xe and ^{3}He) for biomedical applications and non-biological material testing.

Funding: National Cancer Institute (U.S.) FIRST award ($100k/yr).

Publications:
- Bronskill M.J., G.E. Santyr, B. Walters and R.M. Henkelman, "Analysis of discrete T2 components of NMR relaxation for aqueous solutions in hollow fibre capillaries", Magn. Reson. Med. 31, 611 (1994).
- Santyr G.E. , E.J. Fairbanks, F. Kelcz and J.A. Sorenson, "Off-resonance spin locking for MR imaging", Magn. Reson. Med. 32, 43 (1994).
- Santyr G.E. and R.V. Mulkern, "Magnetization transfer in MR imaging: A report from the relaxometry and biophysics committee of the SMRI", J. Magn. Reson. Imag. 5, 121 (1995).
- Kelcz F. and G.E. Santyr, "Gd-enhanced Breast MRI", in Critical Reviews of Diagnostic Imaging 36(4), 287-338, CRC press, Inc. Boca Raton,FL (1995).
- Fairbanks E.J., Santyr G.E. and J.A. Sorenson, "One-shot measurement of spin-lattice relaxation times in the off-resonance rotating frame using MR imaging, with application to breast", J. Magn. Reson. B, 106, 279 (1995).
- Santyr G.E., Kelcz F. and E. Schneider, "Pulsed Magnetization Transfer Contrast for MR imaging with application to breast", J. Magn. Reson. Imag., 6, 203 (1996).
- Niendorf E.R., G.E. Santyr, P.C. Brazy and T.M. Grist, "Measurement of Gd-DTPA Dialysis Clearance Rates Using a Look-Locker Imaging Technique", Magn. Reson. Med. (in press).
- Kelcz F., G.E. Santyr, G.O. Cron and S.J. Mongin, "Application of a Quantitative Model to Differentiate Benign from Malignant Breast Lesions Detected by Gd-enhanced MRI", J. Magn. Reson. Imag. (in press).
- Santyr G.E., F. Kelcz, E.J. Fairbanks, E. Schneider, "Magnetization transfer contrast for MR imaging of the breast", Society of Magnetic Resonance, Dallas 1994 (abstract).
- Kelcz F., G.E. Santyr, S.J. Mongin, E.J. Fairbanks, F.A. Quintanna, "Clinical Experience with a model for

distinguishing benign from malignant breast lesions detected with dynamic Gd-enhanced MRI", Society of Magnetic Resonance, Dallas 1994 (abstract).
- Niendorf E.R., G.E. Santyr, T.M. Grist, M.J. Kim, "In situ measurement of Gd-DTPA clearance by dialysis filters using a Lock-Locker technique", Society of Magnetic Resonance, San Francisco 1994 (abstract).
- Bishop J., I. Soutar, G.E. Santyr, F. Kelcz, D.B. Plewes, "Analysis of errors in dynamic imaging using keyhole imaging techniques", Society of Magnetic Resonance, San Francisco 1994 (abstract).
- Kelcz F., G.E. Santyr, F. Quintana, G.O. Cron, "Incorporation of Gd-enhanced breast MRI into a clinical mammography practice", Radiological Society of North America, Chicago 1994 (abstract).
- Kelcz F., G.E. Santyr, G.O. Cron, "An Algorithm for incorporating breast MRI into clinical practice", AUR Meeting, San Diego 1995 (abstract).
- Santyr G.E., G. Wilson, F. Kelcz, "Breast Tissue Characterization Using a Lorentzian/Gaussian Model of Magnetization Transfer", Society of Magnetic Resonance, Nice 1995 (abstract).
- Kelcz F., G.E. Santyr, G.O. Cron, "Incorporation of Washin and Washout Criteria for Improvement of Specificity in Dynamic Gadolinium-enhanced MRI of Breast Lesions", Society of Magnetic Resonance, Nice 1995 (abstract).
- Bishop J.E., G.E. Santyr, F. Kelcz, D.B. Plewes, "Accuracy of Keyhole Data Acquisition in Quantitative Analysis of Dynamic Contrast-Enhanced Breast MRI", Society of Magnetic Resonance, Nice 1995 (abstract).
- Niendorf E.R., G.E. Santyr, R. Frayne, T.M. Grist, "Measurement of Gd-DTPA Filtration Fraction in a Dialysis Filter using an EPI Look-Locker Technique", International Society of Magnetic Resonance in Medicine, New York 1996 (abstract).
- Kelcz F., G.E. Santyr, K. Groh, G.O. Cron, "Reduced Sensitivity of Gd-enhanced MRI for Cancer Manifest Soley by Mammographic Microcalcifications", International Society of Magnetic Resonance in Medicine, New York 1996 (abstract).

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Jan Seuntjens

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Recent Research: The AAPM task group 51 is preparing a new code of practice, which will be based on absorbed dose to water standards. In the "k_Q - project", for which funding has been requested from the NIH, we measure the necessary beam quality dependence factors (k_Q) of commonly used cylindrical ionization chambers in high energy photon beams. Special attention is given to problems in our current understanding of wall correction factors (P_{wall}) for photon dosimetry. • A second project is involved with the set-up, calibration and characterization of a sealed water calorimeter for direct dose measurements in photon, electron and proton beams. • Finally, we are developing a new standard for HDR ^{192}Ir brachytherapy sources based on a cavity ionization chamber. This project, which is also part of the requested NIH funding, involves fundamental Monte Carlo studies of ion chamber response, compared with measurements for low and medium energy photons.

Publications:
- H. Palmans and J. Seuntjens. Construction, Correction Factors and Relative Heat Defect of a high purity,

4 ^{o}C Water Calorimeter for Absorbed Dose Determinations in High Energy Photon Beams. *Proc. of NPL Water Calorimetry Workshop*, 1994.

- H. Palmans, J. Seuntjens, F. Verhaegen, J.-M. Denis, S. Vynckier, and H. Thierens. Water Calorimetry and Ionisation Chamber Dosimetry in a 85 MeV Clinical Proton Beam. *Med. Phys.*, 23:(in press), 1996.
- D. F. G. Reher, A. H. L. Aalbers, H. Bjerke, N. Drugge, T. Genka, M. J. Rossiter, D. Santry, J. P. Septhon, J. Seuntjens, G. Sibbens, H. Thierens, F. Verhaegen, T. T. Williams, and M. J. Woods. Second EUROMET comparison of air-kerma rate and activity measurements of ^{192}Ir brachytherapy wires. *Nucl Inst Meth*, A339:386 – 390, 1994.
- J. Seuntjens, A. V. der Plaetsen, K. V. Laere, and H. Thierens. Study of the relative heat defect and correction factors for a water calorimetric determination of absorbed dose to water. *Proceedings of the Int. Symp. on Measurement Assurance in Dosimetry, 24-27 May, Vienna, Austria, IAEA SM 330/6*, pages 45 – 59, 1994.
- J. Seuntjens, A. V. der Plaetsen, H. Thierens, and M. Piessens. Comparison of measured and calculated dose distributions in lung after electron beam treatment of the chest wall. *Med. Phys.*, 21:1959 – 1968, 1994.
- J. Seuntjens, H. Palmans, F. Verhaegen, J. M. Denis, S. Vynckier, and H. Thierens. Water Calorimetry in a clinical 85 MeV proton beam. *Proc. of NPL Water Calorimetry Workshop*, 1994.
- A. Van der Plaetsen, J. Seuntjens, H. Thierens, and S. Vynckier. Verification of absorbed doses determined with thimble and parallel-plate ionization chambers in clinical electron beams using ferrous sulphate dosimetry. *Medical Physics*, 21:37 – 44, 1994.
- F. Verhaegen and J. Seuntjens. Dose conversion factors and LET for irradiation of thin blood layers with low energy X-rays. *Radiat. Res.*, 137:11 – 17, 1994.
- F. Verhaegen and J. Seuntjens. Monte Carlo study of electron spectra and backscatter dose in the vicinity of media interfaces for monoenergetic photons of 50 - 1250 keV. *Radiation Research*, 143:334–342, 1995.
- F. Verhaegen, A. Vral, J. Seuntjens, N. W. Schipper, L. D. Ridder, and H. Thierens. Scoring of Radiation-Induced Micronuclei in Cytokinesis-blocked Human Lymphocytes by Automated Image Analysis. *in press Cytometry*, 1994.

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993-2715 (voice) 952-9865 (fax) kshortt@irs.phy.nrc.ca (e-mail)

Recent Research: Involved with the establishment of a primary standard of absorbed dose to water for high energy x-rays. The approach is to use a water-filled calorimeter whose heat defect can be calculated or measured to calibrate a Fricke chemical dosimeter solution. The calibrated solution is placed in small glass vials to determine the dose at a point. The Canadian dose standard has been compared to those of other countries using transfer ionization chambers. A number of perturbations, such as those caused by vial walls and water proofing sleeves are under investigation. The x-ray energy range is being extended to go from ^{60}Co to 25 MV.

Publications:

- G. Mackay, N. Whyte, K. Shortt, I. Thomson, C. K. Steeves, and A. Egan. Performance of a new direct-reading extremity dosimeter. *Health Phys. Suppl.*, 69:S37, 1994.
- K. R. Shortt, C. K. Ross, and I. Janowsky. The response of LiF TLDs to ^{137}Cs and ^{60}Co γ-rays. *NRC Report PIRS–0518 (Ottawa)*, 1996.

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Recent Research: The application of experimental microdosimetry in radiation protection mixed field dosimetry and monitoring with particular emphasis on the radiation environment within CANDU power plants. The development of low pressure tissue equivalent proportional counters with enhanced sensitivity and, neutron spectrometry based on moderating spheres. The development of experimental methods based on laser desorption and time-of-flight mass spectrometry for microdosimetric studies at the molecular level for the study of fundamental aspects of radiation quality.

Publications:

- A.J. Waker, Microdosimetric Radiation Field Characterization and Dosimetry in a Heavy Water Moderated Reactor Environment, Radiat. Prot. Dosim. 52, 415-518, 1994
- Surette and A.J. Waker, Workplace Monitoring of Swipes and Air Filters for Fe-55, R.A. IEEE Trans. Nucl. Sci. 41, 4, 1994
- J. C. Nunes and A. J. Waker, Multisphere Spectrometry and Analysis of TEPC And Remmeter Results Around a HeavyWater Moderated Reactor, Radiat. Prot. Dosim., 59, 4, 279-284, 1995
- R. Khaloo and A.J. Waker, An Evaluation of Hydrogen As a TEPC Counting Gas in Radiation Protection Microdosimetry, Radiat. Prot. Dosim. 58, 3, 185-191,1995
- A. Arneja and A. J. Waker, Wide-Range Neutron Dose Determination with CR-39, Radiat. Prot. Dosim. 58, 3, 201-204, 1995
- A. J. Waker and C. D. Sauer, Properties of an Air-Flow Ionization Chamber for the Measurement of Beta Contamination Radiat. Prot. Dosim. 61, 1-3, 73-76, 1995
- P. Kliauga, A. J. Waker and J. Barthe, Design of Tissue- Equivalent Proportional Counters, Radiat. Prot. Dosim. 61, 4, 297-308, 1995
- A. J. Waker, Principles of Experimental Microdosimetry, Radiat. Prot. Dosim. 61, 4, 297-308, 1995
- J. C.Nunes, A. J. Waker and A. Arneja, Neutron Spectrometry and Dosimetry In Specific Locations at Two Candu Power Plants, Radiat. Prot. Dosim. 63, No2, 87-104, 1996

Curricula Vitae of New Members

Robert deKemp

EDUCATION:

McMaster University	PhD	Electrical and Computer Engineering
McMaster University	MSc	Medical Physics
University of Waterloo	BASc	Systems Design Engineering

RESEARCH AND PROFESSIONAL EXPERIENCE:

Present	Physicist, Cardiac PET Centre, Ottawa Heart Institute
	Assistant Professor of Medicine, University of Ottawa

SAMPLE PUBLICATIONS:

- R.A. deKemp, W.F. Jones, C. Nahmias, R.S. Beanlands (1996) "Design and Performance of 3D Single Photon Transmission Measurement on a Positron Tomograph with Continuously Rotating Detectors", In: Serie Computational Imaging and Vision, P. Grangeat, J.L. Amans (eds), Kluwer Academic Publishers (in press)
- R.A. deKemp, C. Nahmias (1996) "Automated Determination of the Myocardial Long Axis in Cardiac Positron Emission Tomography", Physiol. Meas. (in press)
- C.C. Watson, D. Newport, M.E. Casey, R.A. deKemp, R.S. Beanlands (1995) "Evaluation of Simulation Based Scatter Correction for 3D PET Cardiac Imaging.", IEEE NSS & MIC Conf.Rec. (in press)
- R. deKemp, C. Nahmias (1994) "Attenuation Correction in PET using Single Photon Transmission Measurement", Medical Physics, 21: 771-778 (1994).

X. Allen Li

EDUCATION:

Concordia University	PhD
Yunnan University	MSc
Yunnan University	BSc

RESEARCH AND PROFESSIONAL EXPERIENCE:

Present	Medical Physicist, Ottawa Regional Cancer Centre
	Assistant Professor of Radiology, University of Ottawa
1992–1994	Physics Resident, Ottawa Regional Cancer Centre
1992–1993	PostDoc, National Research Council
1986–1989	Assistant Lecturer, Yunnan University

SAMPLE PUBLICATIONS:

- X.A. Li, M. Soubra, J. Szanto and L.H. Gerig, "Lateral electron equilibrium in measurements of head scatter factors using miniphantoms and brass caps", Med. Phys. 22: 1167-1170 (1995).
- X.A. Li and D.W.O. Rogers, "Electron mass scattering powers: Monte Carlo and analytical calculations", Med. Phys. 22: 531-541 (1995).
- X.A. Li and D.W.O. Rogers, "Reducing electron contamination for photon beam-quality specification", Med. Phys. 21: 791-797 (1994).

Giles Santyr

EDUCATION:

Queen's University, Kingston	BSc	1985	Physics (honours)
University of Toronto, Canada	PhD	1990	Medical Biophysics

RESEARCH AND PROFESSIONAL EXPERIENCE:

Present	Assistant Professor, Dept. of Physics, Carleton University
	Visiting Assistant Professor, University of Wisconsin, Department of Medical Physics
	Assistant Professor (Adjunct), Queen's University, Department of Radiology
1994–95	Assistant Professor, University of Wisconsin, Department of Medical Physics
1992–94	Assistant Scientist, University of Wisconsin, Department of Medical Physics

PROFESSIONAL ACTIVITIES:

Peer Reviewer for J. Magn. Reson. Imag., Magn. Reson. Med., Medical Physics, IEEE Trans. Biomed. Eng., Grant Reviewer for NIH, SBIR Grant Reviewer for NIH SIG program.

PROFESSIONAL AFFILIATIONS:

American Association of Physicists in Medicine
Canadian Organization of Medical Physicists
International Society of Magnetic Resonance in Medicine
Medical Physics Organized Research Unit (Ottawa)

AWARDS/HONOURS:

Queen's Tricolor Scholarship
NSERC Summer Research Award
NMR Summer School Education Stipend
Ontario Cancer Institute Studentship
University of Toronto Open Fellowship
Ontario Graduate Scholarship
Truman Brown Education Stipend
NCI Studentship
NCI FIRST Award

RESEARCH INTERESTS:

Magnetic Resonance Imaging: detection and characterization of breast cancer using spin locking, magnetization transfer and exogenous contrast agents. Basic physics of MRI contrast and relaxation in biological tissues.

SAMPLE PUBLICATIONS:

- Santyr G.E., R.M. Henkelman and M.J. Bronskill, "Spin locking for MR imaging with application to human breast", Magn. Reson. Med. 12, 25 (1989).
- Santyr G.E., I. Kay, R.M. Henkelman and M.J. Bronskill, "Diffusive exchange analysis of two-component T2 relaxation of red blood cell suspensions containing gadolinium", J. Magn. Reson., 90, 500 (1990).
- Santyr G.E., E.J. Fairbanks, F. Kelcz and J.A. Sorenson, "Off-resonance spin locking for MR imaging", Magn. Reson. Med. 32, 43 (1994).
- Santyr G.E., Kelcz F. and E. Schneider, "Pulsed Magnetization Transfer Contrast for MR imaging with application to breast", J. Magn. Reson. Imag., 6, 203 (1996).

Jan Seuntjens

EDUCATION:

University of Gent, Belgium	BSc	1984	Nuclear Physics (honours)
University of Gent, Belgium	PhD	1991	Radiation Dosimetry, Department of Biomedical Physics

RESEARCH AND PROFESSIONAL EXPERIENCE:

Present	Research Associate at Ionizing Radiation Standards, National Research Council
1991 – 1995	Assistant Scientist, University of Gent, Department of Biomedical Physics, Belgium
1985 – 1991	Assistant Scientist, University of Gent, Physics Laboratory, Belgium

PROFESSIONAL ACTIVITIES:

Reviewer for Medical Physics, Physica Medica
Member of subcommittee of the "Nederlandse Comissie voor Stralingsbescherming: Lage en Medium Energie X–stralen Dosimetrie" (Low and Medium Energy X-ray Dosimetry)
Member of AAPM Task Group 61: Kilovoltage X-ray Dosimetry

PROFESSIONAL AFFILIATIONS:

American Association of Physicists in Medicine
Canadian Organization of Medical Physicists
Medical Physics Organized Research Unit (Ottawa)

RESEARCH INTERESTS:

Low and Medium Energy X-ray radiotherapy dosimetry; Water calorimetry to measure absorbed dose for photon- electron and proton radiotherapy beams; Measuring beam quality dependence factors k_Q for cylindrical ionization chambers in high energy photon beams; Monte-Carlo calculations of ionization chamber response for low and medium energy photon beams for the basic dosimetry of brachytherapy sources.

SAMPLE PUBLICATIONS:

- J. Seuntjens, H. Thierens, A. Van der Plaetsen and O. Segaert, "Determination of absorbed dose to water with ionisation chambers calibrated in free air for medium energy X-rays," Phys. Med. Biol. **33**, 1171 – 1185 (1988).
- J. Seuntjens, H. Thierens and U. Schneider, "Correction factors for a cylindrical chamber used in medium energy x–ray beams," Phys. Med. Biol. **38**, 805 – 832 (1993).
- J. Seuntjens, A. Van der Plaetsen A, K. Van Laere and H. Thierens, "Study of correction factors and the relative heat defect of a water calorimetric determination of absorbed dose to water in high energy photon beams," IAEA-SM-330/6.In: Measurement Assurance in Dosimetry. Proceedings of a Symposium, Vienna 24–27 May, 1993 (Vienna: IAEA), 45 – 59 (1994).
- A. Van der Plaetsen, J. Seuntjens, H. Thierens and S. Vynckier, "Verification of absorbed doses determined with thimble and parallel-plate ionization chambers in clinical electron beams using ferrous sulphate dosimetry," Med. Phys. **21**, 37 – 44 (1994).
- J. Seuntjens, H. Palmans, F. Verhaegen, J.-M. Denis, S. Vynckier and H. Thierens, "Water Calorimetry in a clinical 85 MeV proton beam," Proc. of NPL Water Calorimetry Workshop, (1994).

Seminars

MPORU Seminars

One of the main vehicles of the MPORU for developing and maintaining contacts is through a seminar series in which all the members and the graduate students in medical physics are required to make a presentation.

Seminars are scheduled monthly, and this year were held at 3:30 p.m. on Thursdays. The seminar location was rotated among the major centres involved in medical physics.

The following is a list of MPORU seminars held in 1995-96. The first speaker listed is a graduate student.

September 21 at Carleton University

Miller MacPherson	Carleton	*Accurate measurements of electron collision stopping powers*
Allen Li	ORCC	*Improving clinical dose-calculation accuracy for external photon beams*

October 19 at the National Research Council of Canada

Ruth Brown	Carleton	*Prediction of patient response to radiation using normal tissue sensitivity measured in vitro*
Jan Seuntjens	NRC	*Measurement of absorbed dose to water in a clinical 85 MeV proton beam using a water calorimeter and comparison with ionization chambers*

November 16 at the Ottawa Regional Cancer Centre, Civic Division

Julia Wallace	Carleton	*Classification of proton magnetic resonance spectra from ovarian cancer using linear discriminant analysis*
Doug Salhani	ORCC	*Prostate motion during standard radiotherapy as assessed by fiducial markers*

December 14 at the Ottawa Regional Cancer Centre, General Division

Kevin Lenton	Carleton	*An antioxidant assay based on competition kinetics for hydroxyl free radicals*
Carl Ross	NRC	*LiF TLD's and the cobalt-cesium anomaly*

January 18 at Carleton University

Robert Leclair	Carleton	*Use of scattered photons in x-ray imaging of low and high contrast objects*
Ian Cameron	OGH	*MRI today*

February 15 at the Radiation Protection Bureau, Health Canada

David Gobbi	Carleton	*Using deuterium NMR to study lipids membranes in the skin*
Cheng Ng	ORCC	*Topoisomerase poisons in cancer therapy*

March 21 at the Ottawa Civic Hospital

Ge Zhang	Carleton	*Monte Carlo calculated electron beam output factors vs cut-out size*
Robert deKemp	Heart Inst	*3D Positron emission tomography - instrumentation and applications*

April 18 at the National Research Council of Canada

Daryoush Sheikh-Bagheri	Carleton	*Monte Carlo simulation of photon beams from medical linear accelerators using the BEAM/EGS4 code*
Giles Santyr	Carleton	*Recent advances in magnetic resonance imaging of the breast*

Carleton University Physics Department Seminars

Carleton University Physics Department runs a regular seminar series on Monday afternoons (with overflow to other days of the week) at 3:30 p.m. in the Herzberg Building. Information on upcoming seminars is posted on the web. (http://www.physics.carleton.ca/seminars.html). The following seminars of interest to medical physics were held in 1995-96:

September 18, Hans-Dieter Reidenbach, University of Cologne, Germany
The first experimental results on high-frequency interstitial thermotherapy
November 17—Fall Graduate Student Seminars
Cathy MacGillivray, *Effects of Motion in diffusion-weighted magnetic resonance imaging*
Pierre Laporte, *Estimates of aggregate equivalent doses in a clinic*
November 27 , Paul M. Meaney, Dartmouth College, Hanover NH, USA
Development of a 2-D microwave imaging system for biomedical applications
December 19, OCIP Christmas Symposium - Barry McKee, Ottawa Civic Hospital
Medical physics research in a clinical environment: nuclear medicine imaging

February 5, Ervin B. Podgorsak, Montreal General Hospital/McGill University
Radiotherapy - state of the art
February 26, Joseph McKeown, AECL Accelerators
Uses of accelerators - a physicist's journey
March 14 , Martin Yaffe, Sunnybrook Health Science Centre, Toronto
Digital breast imaging
April 3, Bruce G. Pike, Montreal Neurological Institute/McGill University
Functional MRI of the brain
April 8, John Rowlands, Sunnybrook Health Science Centre, Toronto
Is amorphous selenium the ideal detector for medical x-ray imaging?
May 15—Spring Graduate Student Seminars
Larry Gates, *A Study of Water Diffusion in Human Tissue Using MRI*
Miller MacPherson, *Accurate measurements of electron stopping powers*

Other Seminars of Interest to the MPORU

In addition to the seminars listed in the above Sections there are a variety of other seminars in the Ottawa area which are of interest to the MPORU. The ones which have been brought to our attention are noted below:
July 25 at the Ottawa Civic Hospital
Doug Arnold, Montreal Neurological Institute/McGill University
Integrated MRI and MRS examinations in clinical evaluation of patients with neurological diseases
October 23 at the National Research Council of Canada
Assen Kirov, Washington University, St. Louis
Contributions to the dosimetry of the ^{192}Ir HDR brachytherapy source
November 9 at the National Research Council of Canada
Andrew Williams, National Physical Laboratory, Teddington, UK
Measuring the beam energy of the NPL linear accelerator
November 28 at Carleton University (IEEE EMBS)
Paul M. Meaney, Dartmouth College, Hanover NH, USA
Microwave imaging
January 30 at the National Research Council of Canada
Peter Munro, London Regional Cancer Centre
Patient imaging during radiation therapy
May 9 at the Ottawa Civic Hospital
Piotr Slomka, London Health Sciences Centre, University of Western Ontario
Automated analysis of myocardial perfusion images

Medical Physics Graduate Courses

The Carleton medical physics program has three specializations: imaging, therapy and biophysics. Shown below is the menu of courses for each. Required course numbers are printed in **underlined bold font**; the others are recommended.

Depending on the thesis weighting, the MSc typically requires six half-courses in addition to the thesis; the PhD requires four. PhD students who lack any of the relevant courses (or their equivalents) required for the MSc must complete them in their PhD. MSc students may be permitted to take up to two fourth-year half-courses and credit them towards the degree. PhD students can credit only graduate courses.

When a student has covered material in a prior program, such as an MSc in medical physics elsewhere, then the equivalent courses at Carleton are of course not required. The courses to be taken by a given student will be decided on in consultation with the student and the supervisor.

Listed for each course is the course number, the campus where taught and the course name. Carleton courses are numbered with the prefix "75" indicating Physics, followed by a 400-series number if fourth year, or either a 500- or 600-series number for graduate courses.

SPECIALIZATION IN IMAGING

Fall Term	**75.523**	Carleton	Medical Radiation Physics
	75.423	Carleton	Physical Applications of Fourier Analysis[1]
	75.527	Carleton	Radiobiology
	75.529	Carleton	Medical Physics Practicum
Winter Term	**75.524**	Carleton	Physics of Medical Imaging
	75.526	Carleton	Medical Radiotherapy Physics
	75.528	Carleton	Radiation Protection
Fall & Winter	ANA 7301	Ottawa HSC[2]	Anatomy
(both terms)	PHS 5210	Ottawa HSC[2]	Physiology
Fall or Winter	**75.5xx/6xx**	Carleton or Ottawa	Half-course outside of medical physics[3]

SPECIALIZATION IN THERAPY

Fall Term	**75.523**	Carleton	Medical Radiation Physics
	75.527	Carleton	Radiobiology
	75.529	Carleton	Medical Physics Practicum
Winter Term	75.524	Carleton	Physics of Medical Imaging
	75.526	Carleton	Medical Radiotherapy Physics
	75.528	Carleton	Radiation Protection
Fall & Winter	ANA 7301	Ottawa HSC[2]	Anatomy
(both terms)	PHS 5210	Ottawa HSC[2]	Physiology
Fall or Winter	**75.5xx/6xx**	Carleton or Ottawa	Half-course outside of medical physics[3]

SPECIALIZATION IN BIOPHYSICS

Fall Term	**75.523**	Carleton	Medical Radiation Physics
	75.527	Carleton	Radiobiology[4]
	75.529	Carleton	Medical Physics Practicum
Winter Term	75.524	Carleton	Physics of Medical Imaging
	75.526	Carleton	Medical Radiotherapy Physics
	75.528	Carleton	Radiation Protection
Fall & Winter	**ANA 7301**	Ottawa HSC[2]	Anatomy[4]
(both terms)	**PHS 5210**	Ottawa HSC[2]	Physiology[4]
Fall or Winter	**75.5xx/6xx**	Carleton or Ottawa	Half-course outside of medical physics[3]

[1] Prerequisite to 75.524; additional to degree if PhD
[2] HSC = Health Sciences Centre, Smyth Road
[3] Subject to approval. Permission may be given for 75.4xx if MSc
[4] In the Biophysics specialization, one of Radiobiology, Anatomy or Physiology must be taken.

COURSE DESCRIPTIONS

75.523—Medical Radiation Physics (1/2 course, Fall) Basic interaction of electromagnetic radiation with matter. Sources: x ray, accelerators, nuclear. Charged particle interaction mechanisms, stopping powers, kerma, dose. Introduction to dosimetry. Units, measurements, dosimetry devices.
Reference: H.E. Johns and J.R. Cunningham, *The Physics of Radiology*, 4th ed., 1983.
Lecturer: B. J. Jarosz (1995/96)

75.524—Physics of Medical Imaging (1/2 course, Winter) Outline of the principles of transmission x-ray imaging, computerized tomography, nuclear medicine, magnetic resonance imaging and ultrasound. Physical descriptors of image quality, including contrast, resolution, signal-to-noise ratio and modulation transfer

function are covered and an introduction is given to image processing.
Prerequisites: 75.523 or equivalent and 75.423 or equivalent.
Reference: S. Webb, editor, *The Physics of Medical Imaging*, 1988.
Lecturers: P.C. Johns and G. E. Santyr.

75.526—Medical Radiotherapy Physics (1/2 course, Winter) Terminology and related physics concepts. Bragg-Gray, Spencer-Attix cavity theories, Fano's Theorem. Dosimetry protocols, dose distribution calculations. Radiotherapy devices, hyperthermia.
Prerequisite: 75.523 or equivalent.
References: F.H. Attix, *Introduction to Radiological Physics and Radiation Dosimetry*, 1986.
H.E. Johns and J.R. Cunningham, *The Physics of Radiology*, 4th ed., 1983.
Lecturers: J. Cygler, D.W.O. Rogers, K.R. Shortt and L.H. Gerig.

75.527—Radiobiology (1/2 course, Fall) Introduction to basic physics and chemistry of radiation interactions, free radicals, oxidation and reduction, G values. Subcellular and cellular effects: killing, repair, sensitization, protection. Measurement methods. Survival curve models. Tissue effects, genetic and carcinogenic effects, mutations, hazards. Cancer therapy. Radiation protection considerations.
Prerequisite: 75.523 or equivalent must have been taken, or be taken concurrently.
Reference: E.J. Hall, *Radiobiology for the Radiologist*, 3rd ed., 1988.
Lecturer: G.P. Raaphorst

75.528—Radiation Protection (1/2 course, Winter) Biophysics of radiation hazards, dosimetry and instrumentation. Monitoring of sources, planning of facilities, waste management, radiation safety, public protection. Regulatory agencies.
Prerequisite: 75.523 or equivalent.
Reference: Herman Cember, *Introduction to Health Physics*, 3rd ed., 1996.
Lecturer: V. Elaguppillai

75.529—Medical Physics Practicum (1/2 course, Fall) This course provides hands-on experience with current clinical medical imaging and cancer therapy equipment, and with biophysics instrumentation. The student is expected to complete a small number of practical experimental projects during the term on topics such as magnetic resonance imaging, computed tomographic scanning, radiotherapy dosimetry, hyperthermia, biophysics, and radiation protection. The projects will be conducted at hospitals, cancer treatment facilities, and NRC laboratories in Ottawa.
Prerequisites: 75.523 or equivalent. Also, as appropriate to the majority of projects undertaken, one of 75.524, 75.526, or 75.527 or other biophysics course, or permission of the Department.
Coordinator: B. J. Jarosz

ANA 7301—Anatomy for Medical Physics Graduate Students (1/2 course, extends through Fall + Winter) A basic course in anatomy for medical physics students utilizing the systemic approach to emphasize practical and clinical aspects of the gross structure of the human body. The course consists of lectures, laboratory demonstrations with dissected materials and a series of audio-visual presentations involving imaging techniques.

PHS 5210—Mammalian Physiology (full course, extends through Fall + Winter) - A comprehensive study of mammalian physiology with an emphasis on regulating mechanisms. The course includes the biophysical basis of excitable tissues and the physiology of the central nervous system, blood and cardiovascular system, respiratory system, endocrine system, G.I. tract and renal physiology. It is assumed that students have a basic knowledge of chemistry, physics and biology.

75.423—Physical Applications of Fourier Analysis (1/2 course, Fall) Laplace transform and its application to electrical circuits. Fourier transform, convolution. Sampling theorem. Applications to imaging: descriptors of spatial resolution, filtering. Correlation, noise power. Discrete Fourier transform, FFT. Filtering of noisy signals. Image reconstruction in computed tomography and magnetic resonance. Integral transforms

and their application to boundary-value problems.
Precludes additional credit for Physics 75.424
Prerequisite: Physics 75.387; or permission.

Half-course outside of medical physics A half-course in an area of physics outside of medical physics is required. Appropriate possibilities include nuclear, theoretical, quantum, particle, solid state and computational physics. Selection is subject to the approval of the Academic Officer.

Bog Jarosz, Academic Officer, MPORU

Students

Medical Physics Programme Graduate Students

Note: "Starting date" is the date first started taking courses or commenced lab work, not the official date of first registration into degree.

Ph.D. Students

Brown, Ruth
Ottawa Regional Cancer Centre, Department of Medical Physics
Civic Division, 190 Melrose Avenue, Ottawa K1Y 4K7
725-6210 (voice) 725-6395 (fax) ruth@physics.carleton.ca (e-mail)
Starting date: 9/91, Supervisor: Raaphorst, Specialization: Biophysics, PhD
Thesis topic: Biophysics of radiation damage and repair

Gates, Larry
MRI Unit, Department of Radiology, Ottawa General Hospital
501 Smyth Road, Ottawa K1H 8L6
737-8476 (voice) 737-8611 (fax) larry@physics.carleton.ca (e-mail)
Starting date: 9/91, Supervisor: Cameron, Specialization: Imaging, PhD
Thesis topic: MRI measurement of water diffusion

Leclair, Robert
Physics Department, Carleton University
1125 Colonel By Drive, Ottawa K1S 5B6
520-2600x1854 (voice) 520-4061 (fax) robert@physics.carleton.ca (e-mail)
Starting date: 9/94, Supervisor: Johns, Specialization: Imaging, PhD
Thesis topic: X-ray imaging using scattered radiation

Lenton, Kevin
Radiation Biology and Health Physics Branch, AECL Research
Chalk River Laboratories. Chalk River, Ontario K0J 1J0
584-8811x3523 (voice) 584-1713 (fax) lenton@physics.carleton.ca (e-mail)
Starting date: 9/92, Supervisor: Greenstock, Specialization: Biophysics, PhD
Thesis topic: Studies of radiosensitivity at cellular level

MacPherson, Miller
Ionizing Radiation Standards, Institute for National Measurement Standards
National Research Council of Canada, Ottawa K1A 0R6
993-2197 (voice) 952-9865 (fax) mmacpher@irs.phy.nrc.ca (e-mail)
Starting date: 2/93, Supervisor: Ross, Specialization: Therapy, PhD
Thesis topic: Measurement of electron stopping powers

Rapley, Patrick
Institute for Biodiagnostics, National Research Council of Canada
435 Ellice Avenue, Winnipeg, Manitoba R3B 1Y6
807-983-2528 (voice) prapley@octrf.on.ca (e-mail)
Starting date: 9/89, Supervisor: Saunders, Specialization: Imaging, PhD
Thesis topic: MR gradient coil design using numerical optimization

Shahine, Bilal
Ottawa Regional Cancer Centre, Department of Medical Physics
Civic Division, 190 Melrose Avenue, Ottawa K1Y 4K7
725-6210 (voice) 725-6320 (fax) bilal@physics.carleton.ca (e-mail)
Starting date: 9/95, Supervisor: Raaphorst, Specialization: Biophysics, PhD
Thesis topic: Biophysics of radiation damage and repair

Sheik-Bagheri, Daryoush
Ionizing Radiation Standards, Institute for National Measurement Standards
National Research Council of Canada, Ottawa K1A 0R6
993-2197 (voice) 952-9865 (fax) dbagheri@irs.phy.nrc.ca (e-mail)
Starting date: 9/93, Supervisor: Rogers, Specialization: Therapy, PhD
Thesis topic: OMEGA (online Monte Carlo radiotherapy planning)

Soubra, Mazen
Ottawa Regional Cancer Centre, Department of Medical Physics, General Division
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Starting date: 9/88, Supervisor: Gerig, Specialization: Therapy, PhD (part-time)
Thesis topic: Asymmetric linac fields for radiotherapy

Wallace, Julia
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Starting date: 9/89, Supervisor: Raaphorst, Specialization: Biophysics/Imaging, PhD
Thesis topic: Biophysics of tumour cellular & tissue response via MRS

Zhang, Geoffery
Ionizing Radiation Standards, Institute for National Measurement Standards
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993-2197 (voice) 952-9865 (fax) gzhang@irs.phy.nrc.ca (e-mail)
Starting date: 10/93, Supervisor: Rogers, Specialization: Therapy, PhD
Thesis topic: OMEGA (online Monte Carlo radiotherapy planning)

M.Sc. Students

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Starting date: 9/95, Supervisor: Raaphorst, Specialization: Biophysics, MSc
Thesis topic: Biophysics of radiation damage and repair

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993-2197 (voice) 952-9865 (fax) mcorsten@irs.phy.nrc.ca (e-mail)
Starting date: 9/93, Supervisor: Bielajew, Specialization: Therapy, MSc
Thesis topic: Theory of ion chamber response to brachytherapy sources

Gobbi, David
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Starting date: 9/95, Supervisor: Johns/Dixit Specialization: Imaging/GMD, MSc
Thesis topic: Gas Microstrip Detector

Laporte, Pierre
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Starting date: 9/93, Supervisor: Salhani/Gerig, Specialization: Therapy, MSc
Thesis topic: Dosimetry for radiotherapy

MacGillivray, Cathy — MRI Unit, Department of Radiology, Ottawa General Hospital
501 Smyth Road, Ottawa K1H 8L6
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Starting date: 9/93, Supervisor: Cameron, Specialization: Imaging, MSc
Thesis topic: Motion correction for diffusion-weighted MRI

Niedbala, Malgorzata — Ottawa Regional Cancer Centre, Department of Medical Physics
Civic Division, 190 Melrose Avenue, Ottawa K1Y 4K7
725-6210 (voice) 725-6320 (fax) niedbala@physics.carleton.ca (e-mail)
Starting date: 9/95, Supervisor: Raaphorst, Specialization: Biophysics, MSc/Q yr
Thesis topic: Biophysics of radiation damage and repair

Graduate Student Theses Completed in '95–96

Student's Name	Degree	Thesis Title
Akyürekli, Ufuk (Dennis)	PhD	"The effects of Hyperthermia on Tissue Blood Flow" Supervisor: Lee Gerig, Thesis Examination Date: August 29/95
Shahine, Bilal H.	MSc	"Model of Radiation Treatment Response after Continuous and Fractionated Irradiation with/without Mild Hyperthermia" Supervisor: Peter Raaphorst, Thesis Examination Date: September 1/95
Corsten, Maria J. (Ria)	MSc	"Ionization Chamber Response for Brachytherapy Sources" Supervisor: Alex Bielajew, Thesis Examination Date: September 28/95
Wallace, Julia C.	PhD	"Characterization of Human Ovarian Cancer by Magnetic Resonance Spectroscopy Using In Vivo and Ex Vivo Models" Supervisor: Peter Raaphorst, Thesis Examination Date: April 3/96
Rapley, Patrick L.	PhD	"Semi-cylindrical surface gradient coils. A novel approach to NMR gradient coil design" Supervisor: John Saunders, Thesis Examination Date: May 6/96
MacGillivray, Mary Catherine (Cathy)	MSc	"Diffusion-weighted MR Imaging of moving structure using a three echo navigator imaging technique" Supervisor: Ian Cameron, Thesis Examination Date: May 10/96

Honours Fourth-year Undergraduate Physics Projects Completed in '95–96

Student's Name	Course	Project Title
Malgorzata Niedbala	75.498	"Studies of pulsed simulated low-dose rate irradiation with human ovarian carcinoma cells", Supervisor: G. Peter Raaphorst

Scientific Societies of Relevance to Medical Physics

The following scientific societies are of interest to students and scientists in medical physics. For further information contact the individuals shown:

AAPM	American Association of Physicists in Medicine	Paul Johns, Dave Rogers
ANS	American Nuclear Society	Alex Bielajew
CAP	Canadian Association of Physicists	Bob Clarke, Paul Johns, Dave Rogers
COMP	Canadian Organization of Medical Physicists	Paul Johns, Ken Shortt
CRPA	Canadian Radiation Protection Association	Dave Rogers
EMBS	Engineering in Medicine and Biology Society of the IEEE	Bog Jarosz
HPS	Health Physics Society	Dave Rogers
IRPS	International Radiation Physics Society	Alex Bielajew, Paul Johns
RRS	Radiation Research Society	Peter Raaphorst
ISMRM	International Society for Magnetic Resonance in Medicine	Ian Cameron, Giles Santyr

Kudos

- Sheri Boyden and David Gobbi were awarded David and Rachel Epstein Foundation Scholarships. These provide a $1000 stipend for outstanding graduate students (in their first year in a program) at Carleton University.
- Bilal Shahine was awarded an NSERC scholarship for PhD studies.
- Paul Johns was elected Chair-Elect of the Canadian Organization of Medical Physicists in 1995 and will become Chair at the annual meeting in Vancouver, June 1996.

Carleton Magnetic Resonance Facility

The Department of Physics at Carleton University received an early Christmas present last December with the arrival of a Magnetic Resonance (MR) imaging system. Purchased from the University Hospital in London, Ontario, the MR system will form the basis of the Carleton Magnetic Resonance Facility (CMRF). The facility will be directed by Dr. Giles Santyr, Ph.D., who recently joined the Department of Physics in January as an Assistant Professor. Dr. Santyr received his Ph.D. in MRI from the University of Toronto in 1990 and spent six years as a research associate and assistant professor in Medical Physics at the University of Wisconsin in Madison before joining the faculty at Carleton. Dr. Santyr has been joined by graduate student Greg Cron who will fulfill his Ph.D. requirements for the University of Wisconsin while working as a research associate with Dr. Santyr.

The MR system is a Bruker Biospec with a 30 cm diameter horizontal bore super-conducting magnet operating at approximately 2 Tesla and is expected to be operational sometime this summer. Lab renovations to accommodate the CMRF are in progress at the Herzberg building, including the installation of a Faraday cage and sound-proof room to house the imaging system. When completed, the CMRF will be capable of imaging and spectroscopy of both in vitro and non-biological samples as well as small animals.

In addition to continuing his NIH-funded research in MRI of breast cancer, Dr. Santyr plans to launch several new initiatives using the CMRF. In particular, a collaboration with NRC and local hospitals involving imaging of hyperpolarized noble gases is planned. The CMRF will be operated as a shared resource for researchers located both within and outside Carleton University.

Carleton Physics Polaroid Slidemaker

In the summer of 1995 the Department of Physics purchased a Polaroid HR6000 slidemaker. Funds for this acquisition were provided by a GR-5 grant from the Faculty of Graduate Studies and Research to P. Johns and B. Jarosz, and by the Physics Department Computer Committee. The main interest in this device

came from MPORU members and their students. Support for the purchase proposal also came from some members of the Department of Chemistry.

The slidemaker will take graphs, drawings, and text from a program such as CorelDraw and print them directly onto 35 mm colour slides.

The need for the device arose from the fact that there is no central photographic service at Carleton. In view of this, the Graduate Studies and Research funds were awarded on the condition that the slidemaker would be made available to all interested people in the Faculty of Science at Carleton. A growing number of scientists and graduate students from outside of Physics now use the slidemaker.

The slidemaker is available for use by all MPORU members and graduate students in the Carleton medical physics program. One has a choice of using either Polaroid instant slide film and mounting the slides oneself, or standard ASA 100 speed film, which can be processed and mounted conventionally by any photographic services retailer. Standard film is somewhat cheaper and its processing is more environment friendly. Either of these types of film, and glass slidemounts, can be purchased at cost from Physics Stores (Scott Potvin or Gary Findlay).

The device is located in Herzberg 3315, where it is currently interfaced to a 486/33 PC clone running Windows 3.1. The principal method of printing material to the slides is via CorelDraw 5. This software is capable of importing files from a wide variety of sources (e.g. word processors, graphing software), after which they can be printed to the slidemaker. The most flexible route is via Postscript files. Note that the slidemaker throughput is at best about 4 minutes per slide, so that a roll of film does require a few hours. By queuing jobs, the process can be semi-automated.

It's best to experiment with the software ahead of time to work out the most efficient route for printing material from a particular source onto slides. If one has not produced slides before, some experimentation with colour combinations would also be in order.

For more information, contact Paul Johns or Bog Jarosz.

MPORU E-mail Bursters

In May 1996 the MPORU e-mail burster was moved from NRC Ionising Radiation Standards to Carleton Physics. Mail directed to the following addresses is broadcast to all users on the respective lists:

E-mail address	**Target recipients**
`mporu_members@physics.carleton.ca`	Members of MPORU
`mporu_students@physics.carleton.ca`	Students in the Carleton Physics medical physics graduate program
`mporu_seminars@physics.carleton.ca`	All who receive MPORU seminar announcements—everyone on the above two lists plus additional people
`mporu_exec@physics.carleton.ca`	Members of the MPORU Executive

Member and Student Directory

Members	**telephone**	**fax**	**e-mail address**
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Raaphorst, Peter	725-6228	725-6320	graaphorst@octrf.on.ca
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Students	**telephone**	**fax**	**e-mail address**
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Cron, Greg[2]	520-2600x1854	520-4061	gcron@physics.carleton.ca
Gates, Larry	737-8476	737-8611	larry@physics.carleton.ca
Gobbi, David	520-2600x1854	520-4061	dgobbi@physics.carleton.ca
Laporte, Pierre	737-6743	737-6745	plaporte@physics.carleton.ca
	725-6334		plaporte@octrf.on.ca
Leclair, Robert	520-2600x1854	520-4061	robert@physics.carleton.ca
Lenton, Kevin	584-8811x3523	584-1713	lenton@physics.carleton.ca
MacPherson, Miller	993-2197	952-9865	mmacpher@irs.phy.nrc.ca
Niedbala, Malgorzata	725-6210	725-6320	niedbala@physics.carleton.ca
Sheik-Bagheri, Daryoush	993-2197	952-9865	dbagheri@irs.phy.nrc.ca
Soubra, Mazen	737-6743	737-6745	soubra@physics.carleton.ca
Zhang, Geoffery	993-2197	952-9865	gzhang@irs.phy.nrc.ca
ALL STUDENTS			mporu_students@physics.carleton.ca

[2]University of Wisconsin at Madison student of Giles Santyr now located at Carleton