Nuclear Instruments and Methods

The Group is engaged in two different lines of activities: *Computational Physics*, and *Development of Nuclear Instruments and Methods and Technical Assistance*. The first line covers applied research on two domains: *Calculation of radiation fields* and *Modelling of cold plasmas for material processing*.

Calculation of radiation fields

The calculation of radiation fields has a broad range of applications, such as in medical physics, material processing, radiosterilisation, reactor irradiations and radiation transport in superconductors.

In diagnosis or therapy using radiation beams it is necessary to calculate the absorbed doses by patients. The work in this field consists on calculation of absorbed dose curves in phantoms, originated by radiation emitted by electron linear accelerators and by ^{192}Ir sources. The results will be applied in radiosurgery and brachytherapy.

Material processing by radiation and radiosterilisation in UTR, require the knowledge of isodose curves in the irradiator. This has been achieved by simulating the transport of gamma radiation emitted by the ^{60}Co sources. Absorbed dose determinations in products will be extended to dynamic processes; besides, a systematic study of different new arrangements for cobalt sources replacement in the irradiator will be initiated.

The knowledge of the epithermal self-shielding factor is useful in neutron spectrometry and for determination of the epithermal neutron flux, evaluation of the contribution of epithermal neutrons to the electrical current of self-powered neutron detectors and for activation analysis of samples. Resonance self-shielding factors of ^{60}Co and ^{197}Au are being calculated as a function of the wire diameter or foil thickness.

The radiation field associated to a nuclear reactor is a "mixed field" of neutrons and gamma radiation. The absorbed dose by a sample irradiated in a reactor is mainly due to gamma radiation. However, certain experiments may require high fast neutron doses compared to the gamma dose. The optimisation of fast neutron doses can be achieved by the reduction of the gamma dose and the enhancement of the fast neutron flux. The objective can be reached by irradiating the sample inside a hollow lead cylinder. Simulation studies were carried out to optimise the device thickness.

The neutron field at the end of a reactor beam tube has an energy spectrum extending from some meV to more than 10 MeV. In some experiments it is necessary to enhance the epithermal flux. This optimisation can be achieved by using a proper filter material arrangement. Monte Carlo methods are used to study the neutron transport in the filter arrangements in order to increase the epithermal flux.

Performed Monte Carlo simulations of the energy loss spectra of ^{187}Re beta decay and ^{55}Fe X-ray irradiations in micrometrically-thick rhenium strips enable to understand experimental measurements carried out on these detectors. The energy loss spectra will be extended to other superconductor materials.

Modelling of cold plasmas for material processing

Cold plasmas have a significant presence in surface modification and semiconductor processing. The main objective of the work has been the development of competence in low temperature gas discharges with special attention to applications in material processing. The first goal has been the establishment of a solid experience on numerical modelling:

a) Evaluation of new methods for basic problems – in cold discharges the *electron energy distribution function* is not Maxwellian and must be evaluated. This is a difficult task and it is important to compare several methods for solution of Boltzmann equation;

b) Development of software tools – a general chemical kinetics package for "bulk" and surface reactions;

c) Study and optimisation of discharges – study of electron kinetics in Ne-Cu mixtures for advanced lasers and magnetron discharges; study of constriction phenomena in glow discharges; simulation of glow discharges for CN_x film production.

The launching of an applied experimental and demonstration project is now being planned.

Development of Nuclear Instruments and Methods and Technical Assistance

The main objectives of the *Development of Nuclear Instruments and Methods and Technical Assistance* are the technological support for internal groups, including specific design for nuclear instrumentation, and assistance to industrial companies which takes the form of specialised consultant engineering advice, installation, calibration and repair of nuclear gauges, supply of locally produced ^{192}Ir sources.

ITN is the only Institute in the country with expertise in the field of nuclear instrumentation. There is no private company working on design, maintenance or repair of this instrumentation. There are several import firms, which are only dedicated to commercial purposes. For this reason, the group plays an irreplaceable role in providing technical assistance to companies and universities, which use nuclear equipment. Therefore, it is very important to maintain the expertise acquired in our Institute, in this domain.

To achieve the goals of the Group, three projects are presently running: *(1)* Modelling and simulation of radiation fields, *(2)* Numerical modelling of plasmas for materials processing and *(3)* Nuclear instrumentation.

Modelling and simulation of radiation fields

C. Oliveira, I. F. Gonçalves, J. Salgado

Objectives

Calculation of radiation fields in materials for different applications: dosimetry (industrial and medical), neutron irradiations and radiation transport in superconductors.

Results

Simulation studies were carried out with the MCNP code, with the following purposes:

(a) to enhance the fast neutron flux to gamma dose ratio in samples irradiated near the core of a pool type nuclear reactor, in order to maximise the absorbed dose due to fast neutrons [1];
(b) to calculate the resonance self-shielding factor, G_{res}. Resonance self-shielding factors of ^{60}Co and ^{197}Au are being calculated as a function of the wire diameter or foil thickness;
(c) to simulate an electron linear accelerator. The results will be applied to radiosurgery [2, 3, 4].
(d) to simulate water and acrylic phantoms with a ^{192}Ir gamma source, for determination of gamma and electron doses in a heterogeneous media, mainly near of the interface of different materials. The results will be applied to brachytherapy studies [5].
(e) to study the absorbed dose in products and to optimise the irradiation planning in the Radiation Technology Facility [6, 7].
(f) to calculate the energy loss spectra of ^{187}Re β rays and Fe X-rays in micro-thick rhenium strips [8, 9, 10].

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Further work

The applications to medical physics will be deepened. Concerning the radiotherapy studies, the work will be oriented to study narrow beams used in radiosurgery and originated by the interposition of additional collimating systems. In the field of brachytherapy, the work will consider heterogeneous media and dose calculations near the interfaces in order to compare the simulated results with experimental measurements. Absorbed dose determinations in products in UTR will be extended to dynamic processes; a systematic study of different new arrangements for cobalt sources in irradiator will be initiated. The energy loss spectra will be extended to other superconductor materials.

Another problem to be solved is the optimisation of the filter material arrangement for a beam tube of the RPI. At the same time, the calculation of self-shielding factors will be carried out.

Numerical Modelling of Plasmas for Materials Processing

N. R. Pinhão

Objectives

The main objective of this project is the development of competence in low temperature plasmas with special attention to applications in material processing. As research and development in this domain is heavily based on numerical modelling, the first goal has been the establishment of a solid experience on this field. The launching of an applied experimental and demonstration project is planned for the next year.

Results

- **Study of the electron kinetics in Ne-Cu mixtures: Comparison between Boltzmann equation methods and Monte Carlo simulation.**
  Ne-Cu plasmas are formed in several discharges, namely in He/Ne-Cu lasers and magnetron devices with copper cathodes. The characterisation of electron kinetics is essential to study these discharges. The first results of this collaboration work[1] have been published in a conference proceedings [1].
- **Experimental and theoretical investigation of discharge constriction in the cathode region of argon glow discharges.**
  Collaboration on a project conducted by SZFKI, Budapest and University of Antwerp, Belgium [2] [3] [4].
- **Development of a chemical kinetics software package for plasma physics**
  This library was developed to address common problems in a large range of plasma modelling problems. The library has been fully tested in several codes and resulted in significant reduction of code development time.

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Further work

- **Comparison between Boltzmann equation methods and Monte Carlo simulation.**
  The interest on the first published results, has conducted to the formation of a larger inter-comparison group[2] involving different Boltzmann equation algorithms. This group is coordinated by ITN and final results are expected in the first quarter of 2000.
- **Simulation of CN and CN_x thin films production in a N_2 glow discharge with a carbon cathode.**
  The synthesis of carbon nitride CN_x thin films is an active field of research due to the possibility of realisation of the "diamond-like" superhard β-C_3N_4 phase. The modelling of a glow discharge for CN production is in progress. Comparison with optical emission measurements will be used for model validation. Results are expected in the second quarter of 2000.
- **Development of a chemical kinetics software package for plasma physics**
  The user's manual and a publication to *Computer Physics Communications* are under preparation and are expected in the first quarter of 2000.
  The development of a new Boltzmann code and a code for self-consistent evaluation on the *vibrational distribution function* in molecular gases, based in that package, are in progress and expected also in the first quarter of 2000.

[1] Donkó Z, SZFKI, Budapest, Hungary; Pinhão N. ITN, Portugal; Pinheiro M., IST, Portugal.
[2] Initial group + Loffhagen, D, Institut fur Niedertemperatur – Plasmaphysick, Greifswald, Germany; and Richley E., Silva Court, EUA.

Nuclear instrumentation

J. Manteigas, J. Neves, C. Cruz, J. Salgado, F. G. Carvalho

Objectives

The main objectives are the technological support for internal groups, including specific design for nuclear instrumentation and assistance to industrial companies which takes the form of specialised consultant engineering advice, installation, calibration and repair of nuclear gauges, supply of locally produced ^{192}Ir sources.

Results

Works related with automation and robotics have been done involving Omron PLC and peripheral controllers. The PLC was programmed to replace an old panel with tenths of solenoids, contractors and starters to automate and make easy all operations for ventilation, cooling systems and safety related to the irradiator system of the UTR facility. Furthermore, some sensory and temperature system controllers modifications were done as well as diagnostics of pneumatics and air cooling equipment, to improve functionality and make easy the yearly maintenance.

Several prototypes of electronic instrumentation have been designed and constructed for the following facilities: Hot Bird, DIDE [1] and EPA (see **5. Patents and prototypes**).

Some software was written (using LabView) for remote control of the X Rays generator of the Hot Bird Diffractometer.

The technical assistance in the field of engineering applications of radiation and radioisotopes consists in the installation, calibration, maintenance and repair of nuclear instrumentation and supply of ^{192}Ir sources for industrial applications.

A RADIAC SYSTEM 22NRS, installed in a MEKO class ship of the Portuguese Navy was studied and debugged in order to perform the system calibration in collaboration with DPRSN.

A summary of the more relevant services is present in **12. Services**.

References

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Further work

In the near future the Group will be particularly involved in the conclusion of projects related to the neutron spectrometer and Hot Bird facilities, the upgrade of the development system for a Programmable Logic Controller, PLC, and a new control programme with better specifications for the UTR facility.

ITN is the only Institute in the country with expertise in the field of nuclear instrumentation. There is no private company working on design, maintenance or repair of this instrumentation. There are several import firms, which are only dedicated to commercial purposes. For this reason, the group plays an irreplaceable role in providing technical assistance to companies and universities, which use nuclear equipment.