Accelerator-Related Research Activities in Malaysia

S. P. Chia, S.P. Moo and D.A. Bradley
Department of Physics, University of Malaya, 50603 Kuala Lumpur, Malaysia

Abstract

This paper provides a review of accelerator facilities in Malaysia and their applications. Special attention is paid to plasma research activities at the University of Malaya, in particular the generation of pulsed neutron and soft x-ray beams, and to neutron physics capabilities within the country, including work made possible by a small angle neutron scattering facility. A short summary will also be provided of national efforts in studying theoretical aspects of particles and heavy-ions.

1 INTRODUCTION

In Malaysia few accelerator facilities have been used to support basic research. A z-pinch plasma focus device, designed and constructed at the University of Malaya (UM), has undergone extensive characterisation as a pulsed source of neutrons and soft x-rays. In addition, at the University of Science of Malaysia (USM) in Penang a conventional D-T fast neutron generator has been used for study of uniform moderation of fast neutrons. Facilities for thermal neutron activation analysis (TNAA), neutron radiography and small-angle neutron scattering (SANS) are available at the Malaysian Institute for Nuclear Technology and Research (MINT), using its 1MW TRIGA Mk II swimming-pool reactor. A purpose built electron beam (EB) facility, also sited at MINT, is finding applications in adding value to a range of industrial and medical products.

In terms of medical applications a relatively large number of electron linear accelerators have been installed in Malaysian radiotherapy institutions over the past fifteen years. In particular, the University of Malaya has acquired state-of-the art medical linear accelerators. These facilities are equipped with multileaf collimators that allow use of shaped fields. Research into the treatment of nasopharnygeal carcinoma (NPC), a malignant disease particularly prevalent among peoples of Chinese decent, is at an early stage.

2 A CHRONOLOGICAL ACCOUNT OF ACCELERATOR DEVELOPMENT

Accelerators first made their appearance in Malaysia in 1968. The first machines were installed in the newly established Radiotherapy Institute of the Kuala Lumpur Hospital and comprised two MEL-75 travelling wave linear accelerators providing 6MV photons and a Siemens betatron which could provide electrons in the range 5- to 43 MeV. The first generation of accelerators intended for research purposes made their appearance in the early to late 1970's; one of these, a machine of German origin, was capable of producing plasmas, while the other two machines were neutron generators, both of French origin. The acquisition of the three research machines reflected an early interest of Malaysian physicists in participating in detailed studies of atomic and low energy nuclear physics.

Since the early 1980's, growth in the acquisition of linear accelerators for medical purposes has been stimulated by the advent of compact machines of high reliability. Radiotherapy centres equipped with electron linear accelerators are now well distributed amongst the large population centres. Medical electron linacs now tend to be standing wave devices, driven by either klystrons or magnetrons.

The 1980's also saw growth in the radiation processing industry, there being considerable demand for the sterilisation of medical and health products. Large-activity ^{60}Co irradiators have been in operation for more than a decade; of the three facilities that are now in operation, two belong to private enterprise. In the early 1990's national radiation processing capabilities were extended with the advent of a dedicated high-output electron irradiator, which was constructed at the Malaysian Institute for Nuclear Technology and Research (MINT) with the aid of the Japanese International Co-operative Agency (JICA).

While the use of medical and industrial accelerators is in a period of growth there are no plans for construction of any large national accelerator facility. Machines such as the synchrotron has proven to be immensely useful in stimulating research in atomic physics, materials analysis and biomedical research. This is well recognised in Malaysia and the most probable scenario is that Malaysian scientists will begin to participate in international efforts at multinational research centres.

3 APPLICATIONS OF ACCELERATORS IN MALAYSIA

Basic Research

The University of Malaya was the first institution in Malaysia to have what could be described as a high-energy research facility, this being a z-pinch device devoted to research in plasma physics. A considerable amount of effort has been devoted to investigation of pulsed neutron production using devices whose construction was stimulated by this early machine. Two Malaysian universities (the University of Science of Malaysia, USM, and the National University of Malaysia, UKM) possess neutron generators (constructed by Sames, France). The operation of these devices depends on ionisation of deuterium gas, and the subsequent electrostatic acceleration of deuterons through 100kV to impinge on a tritium target. Neutrons of energy 14.1 MeV are produced. A fast neutron flux of some 10^7 over 4π is possible. The production of quasi monoenergetic neutrons in the energy range 8 - 12 MeV has been demonstrated using thin paraffin wax converters formed into a surface of revolution [1,2]. In real terms room scattering and fast neutron flux limitations have not allowed the USM neutron generator to become a practical source of 8 - 12 MeV neutrons. As such the study was viewed as an attempt to demonstrate use of neutron generators of higher flux capability in measuring cross-section of importance for nuclear fusion. Csikai [3] has reviewed the method in his Handbook of Fast Neutron Generators. Research using the neutron generator at USM has declined in more recent years.

Radiotherapy Physics

As mentioned earlier, electron therapy first became available in 1968, with the installation at Kuala Lumpur Hospital of two 6MV MEL-75 linacs and a Siemens betatron, the latter providing electrons in the energy range 5 to 43 MeV. Since 1985 some 16 or more medical electron accelerators have been installed in Malaysian hospitals. The highest photon energy currently available is 15MV; most of the other units in the country provide photons in the energy range 6 - 10 MV, it being the general experience that patients seen in Malaysia do not require more penetrating beams. A door incorporating polyethylene has been installed at the end of the maze of the 15MV facility, in order to take account of possible photonuclear production by photons in excess of 10MV. Neutron production on the treatment side of the door has been verified by measurements carried out by members of the MINT Secondary Standards Dosimetry Laboratory (SSDL); use was made of a BF_3 detector. In terms of electrons, present accelerator facilities in the country provide energies in the range 5 to 21 MeV.

A significant incidence of nasopharyngeal carcinoma (NPC) is apparent amongst Malaysians (in particular amongst the ethnic Chinese and Malays, although less so in the latter). Radical radiotherapy can be an effective mode of treatment (it being possible to produce cure rates of the order of 60%). A review of incidence, treatment, and survival rates of NPC in China has been provided by Hwang [4]. Side effects can occur, including fibrosis of jaw muscles and loss of mastication ability. Shaped fields, using multileaf collimators, and the ability to use mixed x- and electron fields offer some hope for improved treatment regimes and this is an important area of research that is now beginning.

Radiation Processing

MINT has developed a number of facilities for radiation processing; as an instance its large activity (~1 MCi) ^{60}Co irradiator is heavily utilised in support of radiation sterilisation of medical and health industry products intended for domestic and export markets. In addition a 3.0MV EB facility has been constructed which can be operated at beam currents of from 1- to 30mA, stable to within 2%. The scanning horn of the EB facility provides a beam of width 120-cm (with dose uniformity to within ± 5%) and materials can be irradiated on a conveyor belt driven at speeds of from 1- to 20m min^{-1}. The EB facility has been used to irradiate coatings of plywood, decorated tiles, glossy paper, printing ink, laminations etc., in addition to its use for research concerning radiation effects in various media.

4 THE PLASMA FOCUS AS A PULSED SOURCE OF NEUTRONS AND SOFT X-RAYS

The plasma focus (PF) device, developed independently by Filippov et al [5] and Mather [6], has stimulated a large amount of research at the University of Malaya. Many PF devices of the type first constructed by Mather have been built and studied, with voltages ranging from 10 to 200kV, energies from 1kJ to 1MJ and maximum anode currents from 100kA to 3MA. The mechanisms for the various processes occurring in the plasma focus are rather complex and much attention has been devoted to studying these processes.

In recent years there has been considerable interest in developing the PF as a compact pulsed source of soft x-rays for various applications including soft x-ray lithography and soft x-ray microscopy. Interest has also been shown in developing the PF as a source of pulsed neutrons for detection of explosives.

In the Plasma Research Laboratory, Physics Department of the University of Malaya (UM), work is being carried out with a 3kJ, 15kV PF. This Plasma Focus Fusion (PFF) device (designation UNU/ICTP PFF), powered by a single 30μF capacitor, was designed and developed at the laboratory as part of a training programme on plasma and laser technology, sponsored by the United Nations University [7]. Particular interest has been shown in the plasma focus (PF) device and its ability to produce rather high fluxes of fast neutrons and soft x-rays [7-11]. The UM effort has lead to a network of such devices, in China, Egypt, India, Indonesia, Italy, Nigeria, Pakistan, Sierra Leone, Singapore and Thailand [8]. Some of the research that has been carried out at the University of Malaya, includes half-life measurements [9], ion-beam and neutron production [10] and soft x-ray production [11,12].

5 THE MINT TRIGA RESEARCH REACTOR

In Malaysia only one research reactor has been constructed. No power reactors have been constructed in the country. The 1MW TRIGA (Training Research Isotope-production built by GA) Mk II swimming pool research facility is sited at MINT, some 20km south of Kuala Lumpur. This steady-state system, commissioned in July 1982, is now a centre for TNAA, neutron radiography and the SANS. Interest in SANS stems from the ability of neutrons to interact with nuclei, useful differential information being obtained for instance on isotopes of the same atom. Commissioning of the SANS instrument was completed towards the end of 1994. The system, described in detail by Sufi et al [13], comprises of a neutron source, a monochromator system, sample facility and a detector and data acquisition system. Sensing is provided by a position sensitive ^{3}He detector (PSD) of active area 59cm^2, manufactured at Risø, Denmark. Sufi et al [13] have reported first results for H_2O, SiO_2 particles and various forms of glass. These test results have assisted in characterisation of system performance, resolutions of between 5 and 80nm have been obtained. Use of the SANS facility for study of alloys, ceramics and polymers are indicated, while the relatively low source flux points to limited capability for weak scatterers such as dilute solutions of biological macromolecules.

6 THEORETICAL RESEARCH

Particle theory research began in Malaysia in the early 1970’s, study being made of Regge pole phenomenology, both at the University of Malaya [14-15] and at the University of Science of Malaysia. Later, the two groups changed their directions of research, perceiving the study of Regge pole phenomenology to be losing fashion. The group at University of Science of Malaysia headed by C.H. Oh shifted its emphasis to seeking classical solutions of gauge field theories. Research in particle theory came to an end at the University of Science of Malaysia with the departure of C.H. Oh to the University of Singapore. The group at the University of Malaya, headed by S.P. Chia, shifted its direction to CP violation and flavour-changing neutral transitions. Over the years, this group has investigated details of the flavour changing self-energy [16], the gluon-penguin [17], the photon-penguin [18], and the Z-penguin [19]. The group has also looked at the direct CP violation effect arising from the nonzero absorptive contribution of the various penguin vertices [20-22]. Some work has also been carried out to investigate the absorptive contributions of the box diagrams. Recent interest is directed to the investigation of the doubly emitted penguin vertex. Some initial results have been obtained for double-gluon vertex and gluon-photon vertex.

Since the mid-1970’s theoretical work on heavy ion scattering has also been carried out at the University of Malaya. A small group headed by K.S. Low has carried out investigations of various mechanisms for heavy ion induced nuclear reactions, using both quantum mechanical and semi-classical approaches [23-25].

7 CONCLUSION

Continuing interest is being shown in Malaysia in undertaking experimental studies of plasmas, neutron absorption and scattering. In addition, growing interest is also being seen in the use of electron linear accelerators for improving radical radiotherapy and in the favourable modification of a range of industrially important materials. Theoretical studies have focused on particle physics, with efforts being made in investigation of CP violation and flavour-changing neutral transitions. Formalisms for heavy ion induced nuclear reactions have also been developed. For the future, it is hoped that accelerator-related research in Malaysia can be stimulated by an increasing level of international collaboration.

REFERENCES

[1] D.A. Bradley, C.S. Chong and A.M. Ghose, ‘Production of monoenergetic neutrons by controlled moderation of D-T neutrons’, in *Proc. of Int. Symp. on Fast Neutrons in Science and Technology*, ed. S. Wiboolsake and T. Vilaithong (Univ. Chiangmai, 1985), pp. 19-21.

[2] D.A. Bradley, C.S. Chong and A.M. Ghose, ‘Studies on the production of monoenergetic neutrons by uniform moderation of D-T neutrons’, Nucl. Instr. Meth. Phys. Res., vol. A270, p. 537 (1988).

[3] J. Csikai, in *Handbook of Fast Neutron Generators*, vol. 2 (CRC Press, Boca Raton, Florida, 1987), pp. 27-28.

[4] H.N.Hwang, ‘Nasopharyngeal carcinoma in the People’s Republic of China: Incidence, treatment, and survival rates’, Radiology, vol. 149, p. 305 (1983).

[5] N.V. Filippov, T.J. Filippova and V.P. Vinogradov, 'Dense high temperature plasma in a non-cylindrical z-pinch compression', Nuclear Fusion Suppl., vol. 2, p. 577 (1962).

[6] J.W. Mather, 'Investigation of the high energy acceleration mode in the coaxial gun', Phys. Fluids Suppl., vol. 7, p. 28 (1964).

[7] S. Lee, T.Y. Tou, S.P. Moo, M.A. Eissa, A.V. Gholap, K.H. Kwek, S. Mulyodrono, A.J. Smith, Suryadi, W. Usada and M. Zakaullah, 'A simple facility for the teaching of plasma dynamics and plasma nuclear fusion', Am J. Phys., vol. 56, p. 62 (1988).

[8] S. Lee, L.K. Chen, T.C. Chia, S. Kumar, A. Serban, S.V. Springham, K.A. Toh, A.C. Chew, S.P. Moo and C.S. Wong, 'Collaborative research using the small plasma focus', in *Proc. IAEA Tech. Committee Meeting on Research Using Small Tokamaks* (Serra Negra, SP, Brazil, 1993), pp. 153-164.

[9] S.P. Moo, C.K. Chakrabarty and S. Lee, 'An evaluation of a 3.3kJ plasma focus for pulsed neutron activation', in *Proc. Symp. Small Plasma Physics Experiments II* (ICTP, Trieste, 1989), pp. 248-258.

[10] S.P. Moo, C.K. Chakrabarty and S. Lee, 'An investigation of the ion beam of a plasma focus using a metal obstacle and deuterated target', IEEE Trans. Plasma Sci., vol. 19, p. 515 (1991).

[11] C.S. Wong, S.P. Moo, J. Singh, P. Choi, C. Dumeitrescu-Zoita and C. Silawatshananai, 'Dynamics of x-ray emission from a small plasma focus', Malaysian J. Sci., vol. 17B, p. 109 (1996).

[12] C.S. Wong, 'Pulsed x-ray sources technology and applications', ASEAN J. on Science and Technology Development, vol. 11, p. 15 (1994).

[13] M.A.M. Sufi, S. Radiman, A. Wiedenmann and K. Mortensen, 'Performance of a new small-angle neutron scattering instrument at the Malaysian TRIGA reactor', J. Appl. Cryst, vol. 30, p. 884 (1997).

[14] S.P. Chia, 'Model of the pion-pomeranchon cut based on the Mandelstam diagram', Phys. Rev., vol. D7, p. 1496 (1973).

[15] S.P. Chia, 'A model for reggeon-Pomeranchon cuts', Phys. Rev., vol. D15, p. 290 (1977).

[16] S.P. Chia, 'Calculation of the s-d self-energy and its contribution to the K0barr to vacuum amplitude', Phys. Lett., vol. 147B, p. 361 (1984).

[17] S.P. Chia, 'An exact calculation of dsg vertex', Phys. Lett., vol. 130B, p. 315 (1983).

[18] S.P. Chia and G. Rajagopal, 'An exact calculation of the flavour-changing quark-photon vertex', Phys. Lett., vol. 156B, p. 405 (1985).

[19] S.P. Chia and N.K. Chong, 'The Z-penguin vertex', in Physics at the Frontiers of the Standard Model, ed. N.V. Hieu and J.T.T. Van (Editions Frontieres, Gif-sur-Yvette, 1996), pp. 532-535.

[20] S.P. Chia and P.C. Ch'ng, 'CP violation arising from penguin diagram in b to sg*', Malaysian J. Sci., vol. 15B, p. 73, (1994).

[21] S.P. Chia, 'CP violating decay asymmetry in $b \to s l^+ l^-$ and $s \to d l^+ l^-$', in *Proceedings of the Fifth Asia Pacific Physics Conference*, ed. S.P. Chia *et al*. (World Scientific, Singapore, 1994), pp. 349-360.

[22] S.P. Chia, N.K. Chong and T.L. Yoon, 'The electroweak penguins from the standard model', paper presented at Inauguration Conference of APCTP, Seoul, Korea, 4-10 June 1996.

[23] B.R. Wong and K.S. Low, 'An improved semi-classical method for heavy ion induced nuclear reactions', J. Phys. G, vol. 15, p. 1457 (1989).

[24] B.R. Wong and K.S. Low, 'Analytical formalism for heavy-ions induced nuclear reactions: Elastic and inelastic scattering', J. Phys. G, vol. 16, p. 841 (1990).

[25] B.R. Wong, 'Analytical expressions for the nuclear scattering phase shifts in heavy ion collisions', Malaysian J. Sci., vol. 16B, p. 3 (1995).