PRESENT STATUS OF THE ACCELERATOR INDUSTRY IN ASIA

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Abstract

Different kinds of accelerators, such as rf electron linacs, DC high voltage accelerators, cyclotrons and synchrotrons, can be used in radiotherapy, Non-Destructive Test (NDT), irradiation and ion implantation. The accelerator industry in Asia almost covers all of the accelerators and application areas above. This paper will give some examples to illustrate the status of the accelerator industry in Asia. The collaboration of academia-industry will be also briefly mentioned here, with the situation of China as an example.

INTRODUCTION

The economy of Asia is developing fast during the past years, which also brings an opportunity for the accelerator industry of Asia. For example, more and more hospitals in Asia can afford very expensive medical equipments, such as PET, CT and radiotherapy accelerators. And the needs for irradiation and NDT accelerators, as essential tools for the other industries, are also increasing very fast.

The accelerator industry in Asia is quite different from country to country, and it depends on their accelerator education and technology. Most of the accelerator industry of Asia is in Japan, China, Russia, Korea and India. In Japan, the companies, such as Sumitomo, Mitsubishi, Hitachi, pay more attention on synchrotron and cyclotron technology for radioisotope medicine and heavy ion/proton therapy. In China, there are lots of companies can supply accelerators for different kinds of applications, and their main products are rf linacs and DC high voltage accelerators. Russia has ILU and ELV high power accelerators for radiation processing, and also developed cyclotrons for radioisotope medicine and linacs for NDT and electron or x-ray radiotherapy. Korea is developing L-band linac for irradiation, collaborated between companies and universities or institutes. RF linacs and DC high voltage accelerators have been developed for radiotherapy and radiation processing in India. Almost all of the countries of Asia are using accelerators in different areas. So Asia is developing and producing more and more accelerators, and on the other side the accelerator market in Asia is becoming larger and larger.

STATUS OF THE ACCELERATOR INDUSTRY IN ASIA

Table 1 gives the list of vendors supplying entire accelerators in Asia, which will be changing constantly. Their locations in Asia are given in Fig. 1. Some institutes or universities doing R&D and supplying parts of accelerators and the ion implantation accelerator vendors are not included in this list.

Table 1: Accelerator Industry in Asia

Vendors	Technology	Application
Mitsubishi (JAPAN)	Synchrotron	Proton & Ion Therapy
Sumitomo (JAPAN)	Cyclotron, Synchrotron, Linac	RI Production & Proton Therapy
IHI (JAPAN)	Linac	Inspection& Irradiation
NHV (JAPAN)	DC	Irradiation
HITACHI (JAPAN)	Synchrotron, Linac	Proton Therapy, ICT and radiotherapy
IHEP(CHINA)	Linac, DC	NDT and Irradiation
CIAE(CHINA)	Linac	NDT and Irradiation
TUB(CHINA)	Linac	NDT , Irradiation, Radiotherapy
NUCTECH (CHINA)	Linac	Cargo Inspection, Irradiation
RIAMB (CHINA)	Linac	NDT & Irradiation
HTA(CHINA)	Linac	Irradiation& NDT
Granpect(CHINA)	Linac	X-ray ICT and NDT
SHINVA(CHINA)	Linac	Radiotherapy
HaiMing(CHINA)	Linacs	Radiotherapy
EL Pont(CHINA)	DC, Linac	Irradiation
Ningbo (CHINA)	Linac	Irradiation
SPRI(CHINA)	Linac	ICT
FERES (CHINA)	DC	Irradiation
CJDS(CHINA)	DC	Irradiation
IMP (CHINA)	DC	Irradiation
SINAP(CHINA)	DC	Irradiation
NPKLUTS (RUSSIA)	Linac, Cyclotron	NDT, Radiotherapy and RI Production
BINP(RUSSIA)	ILU	Irradiation
EB-Tech (KOREA)	DC&RF	Irradiation
POSTECH(KOREA)	Linac	Irradiation
SamYoung Uintech (KOREA)	Cyclotron	RI Production
RRCAT(INDIA)	DC, Linac	Irradiation
BARC(INDIA)	DC, Linac	Irradiation
SAMEER(INDIA)	Linacs	Radiotherapy

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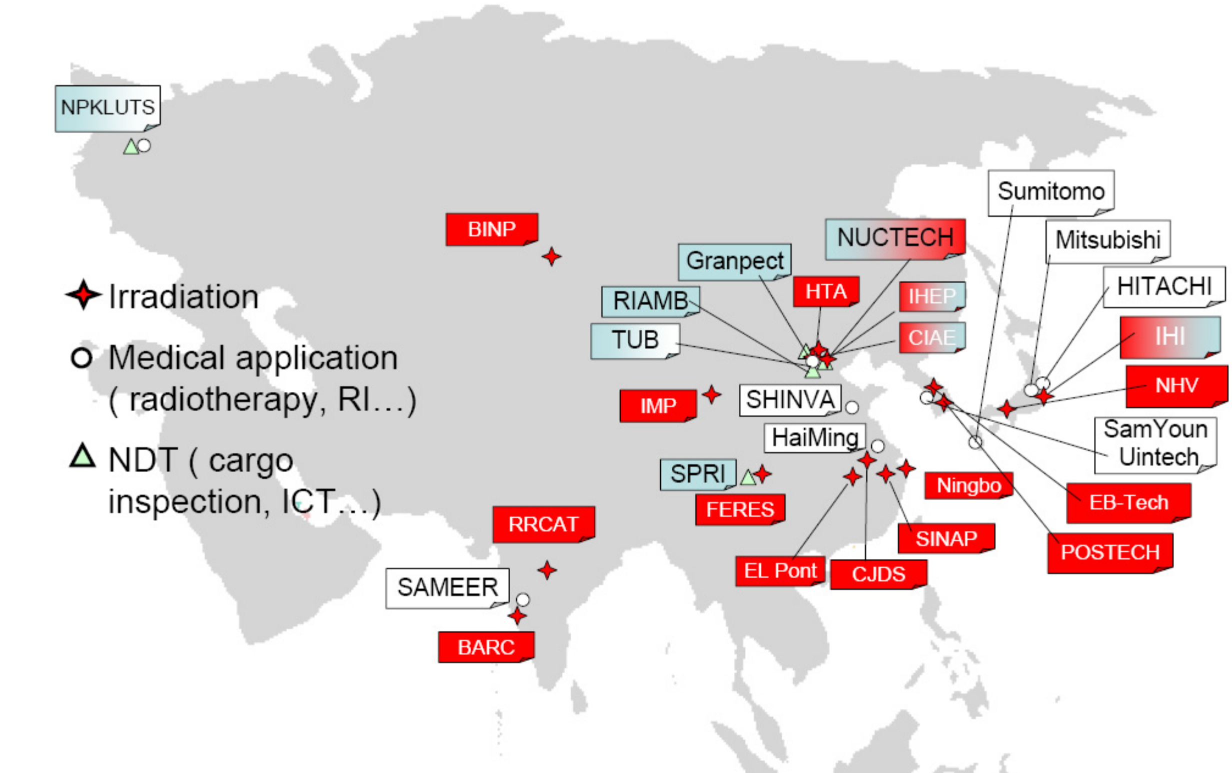

Figure 1: The vendors of accelerator in Asia.

Ion and Proton Therapy

From Table 1, we can see that the radio-therapy accelerators developed in Japan are mainly focusing on proton and heavy ion therapy. Since 1994, HIMAC has successfully treated more than 5,000 cancer patients with 290 MeV/n carbon beams [1] [2], which encouraged companies into this area. For example, Hitachi developed a 70-250MeV proton therapy synchrotron (see Fig. 2) for Proton Medical Research Centre (PMRC) and was designing a 60m circumference synchrotron which can deliver 480MeV/u carbon and 250MeV proton beams [3].

Sumitomo Heavy Industries manufactured the proton therapy system (see Fig. 3) based on 230MeV proton cyclotron for National Cancer Centre Hospital East in 1998. And a similar system with pencil beam scan has been ordered by the Chang Gung Memorial Hospital [4].

Figure 3: The cyclotron proton therapy system manufactured by Sumitomo, 230MeV cyclotron (left) and gantry (right).

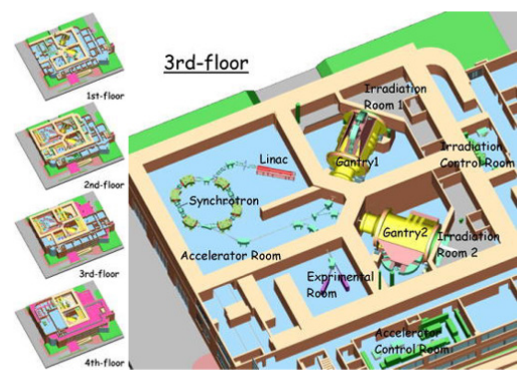

Figure 2: Layout of the proton therapy synchrotron by Hitachi for PMRC.

Mitsubishi Electric can supply proton type (70 - 250 MeV) and proton (70 - 250 MeV) /carbon (70 - 380 MeV/u) type synchrotron therapy systems (see Fig. 4). From 1994, four systems manufactured by Mitsubishi have been installed and another three systems under construction [5].

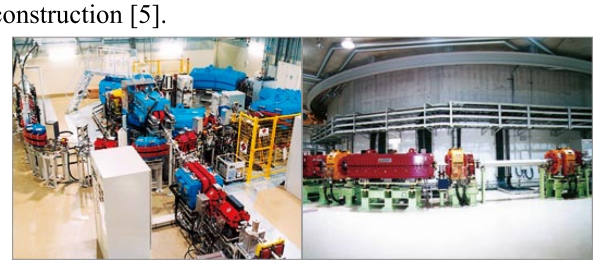

Figure 4: Proton (left) and proton/carbon (right) therapy system by Mitsubishi.

Joint Institute for Nuclear Research (JINR) of Russia [6], Institute of Morden Physics (IMP) of China [7] also carried out hundreds of patient treatment with proton and heavy ion beam from their cyclotron and synchrotron facilities.

Electron and X-ray Therapy

Most of the electron and x-ray therapy equipments are based on s-band rf linear accelerators. The products from VARIAN, SIMENS, ELEKTA still occupy a very large part of market in Asia. Domestic companies or centres are playing more and more important role in this area. SHINVA(Xinhua) and HaiMing in China, can supply electron and x-ray therapy products[8]. NPKLUTS of Russia developed LUER-20M and SL75-5-MT electron and photon therapy linacs [9]. SAMEER of India developed the first medical linac in 1990, and now they have the ability to develop 6-15MeV medical linacs [10] (see Fig. 5).

Figure 5: Medical linacs developed in Asia. XHA600C of SHINVA(left), SL75-5-MT of NPKLUTS (middle), Siddharth of SAMEER(right)

Radioisotope Production

Radioisotope (RI) medicines are usually produced using cyclotrons. Sumitomo of Japan can supply very compact cyclotron products with proton beam energy of 10MeV, 12MeV and 18MeV, which can be used to produce ^{18}F, ^{15}O and ^{11}C medicines for PET and other applications [4].

Samyoung Unitech of Korea with cyclotron technology transferred from KIRAMS (Korea Institute of Radiological & Medical Sciences), has 13MeV proton cyclotron product KOTRON-13 for ^{18}F medicine producing, and also is in progress of development of 30MeV cyclotron [11].

There are several institutes or centres are developing compact cyclotrons for RI medicine, such as NPKLUTS in Russia and CIAE, IMP and CAEP in China.

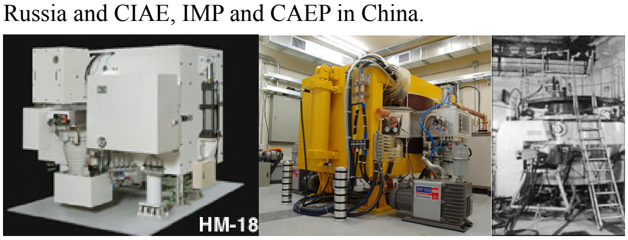

Figure 6: RI Cyclotrons developed in Asia. HM-18 of Sumimoto (left), KIRAMS-13 of Samyoung Unitech (middle), RITs-30 of NPKLUTS(right)

Electron Beam Processing

Electron beam processing is the most popular accelerators application area in Asia. According to the data of China Isotope & Radiation Association (CARA), there were totally 129 accelerators above 5kW in use with total beam power 8322kW, and another 26 were under construction at the end of 2008. Among them, 101 accelerators were manufactured by the companies or institutes of China and 53 from Russia, 6 from Japan, 6 from USA, 3 from Korea, 3 from France and 2 from Belgium. In china, IHEP, CIAE and Tsinghua University (TUB) have developed 10MeV/20kW s-band linacs successfully. A 10MeV L-band linac with electron beam power of 40kW is developing by IHEP collaborating with El Bond [12]. And a very compact mobile sterilization system using a 2.5MeV/1kW linac with MG5193 magnetron has been developed by TUB collaborating with Nuctech (see Fig. 6) [13].

Figure 7: New electron radiation processing technology developed in China. The L-band 10MeV/40kW TW linac waveguide by IHEP (left), the mobile sterilization system with 2.5MeV/1kW SW linac by THU (right)

ELV [14] and ILU [15] type accelerators developed by BINP of Russia are widely used for electron beam processing (see Fig. 7). ELV accelerators are based on high voltage rectifier technology, and more than 110 sets have been produced. The electron beam power of ELV-12 can reach 400kW with electron energy of 0.6-0.9MeV, and the electron energy of ELV-8 can be 1.0-2.5MeV with beam power of 90kW. The ILU machines are based on rf acceleration, and they covers the energy range from 0.6MeV to 5 MeV, and the maximum beam power is 50 kW. A 5MeV/300kW ILU accelerator is developing in BINP.

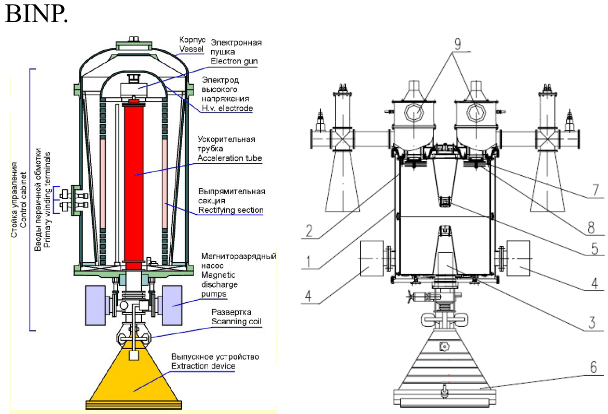

Figure 8: ELV-4(left) and ILU-10 (right) developed by BINP

KAPRA (Korea Accelerator & Plasma Research Association) and POSTECH of Korea developed an L-band linac with the energy of 10MeV and electron beam power of 30kW [11]. IHI of Japan, RRCAT and BARC of India also developed rf linacs for electron beam sterilization or radiation processing.

Non-Destructive Test

Non-Destructive test (NDT) with high energy x-ray normally uses linac of 1MeV-15MeV as its x-ray source. The linac is specially designed to get small spot size, for the spot size is very important for high special resolution of a NDT system. Granpect and SPRI of China produce high energy x-ray industry computer tomography (ICT) systems, with linacs energy from 2MeV to 15MeV. And RIAMB in Beijing can supply a series of NDT linac products of 2MeV, 4MeV, 6MeV, 9MeV and 12MeV, with spot size less than 2mm in diameter. They had produced totally about 73 linacs until the end of 2009, which were used in machine, casting, pressure vessel and petroleum industry (see Fig. 9) .

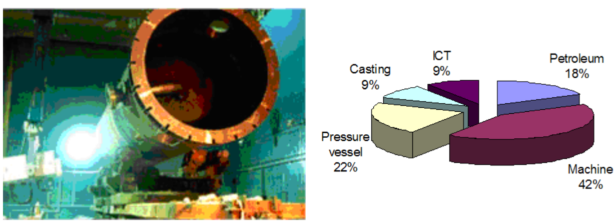

Figure 9: NDT applications of linacs of RIAMB, the linac in use (left), application areas of the RIAMB linacs(right)

Granpect developed several kinds of ICT systems using linac as the x-ray source. Fig. 10 gives the HEXTRON-3000 linac developed by TUB and the ICT image [13].

Figure 10: HEXTRON-3000 linac (left)and the ICT image (right)

Electron accelerators as the high energy x-ray sources to do cargo inspection, is a relatively new area of accelerator applications. The demands for cargo inspection systems are increasing very fast, because of the homeland security. NUCTECH is an important cargo inspection vender in the world. Except the fixed (9MeV TW or SW linac), relocatable (6MeV SW linac) and mobile (s-band or x-band 2.5MeV linac) systems, NUCTECH developed dual-energy cargo inspection system capable of the material identification and fast-scan cargo inspection systems, which can scan 200-400 units of 40ft containers per hour. The fixed dual energy system uses an S-band SW linac with electron energy of 9/6MeV (see Fig. 11), and movable dual energy system using a dual energy linac of 6/3MeV. NUCTECH has combined the dual energy and fast scan technologies together and got material identification images with the truck moving at a speed of 15km/h (see Fig. 12) [13]. To date, NUCTECH already installed more than 300 sets of cargo inspection systems at about 80 countries in the world.

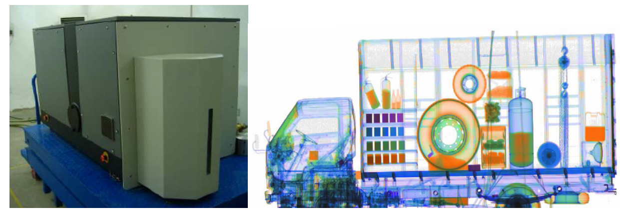

Figure 11: The dual energy linac 9/6MeV (left) and the dual energy image of a van with different materials(right)

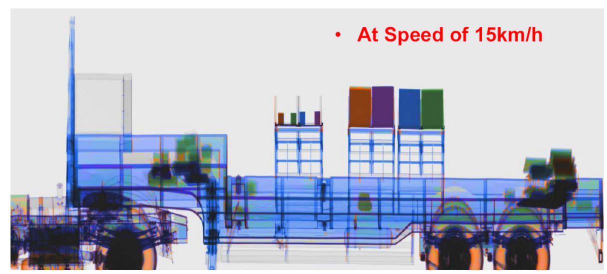

Figure 12: The image of the dual energy cargo inspection system combined with fast scan technology.

R&D OF ACCELERATOR AT INDUSTRY AND ACADEMIA

The industry and academia normally collaborated closely at the R&D of accelerators, but the situation is different from country to country. Table 2 gives the status of the accelerator technology developed for industry by the national laboratories and universities, and the relationship with accelerator vendors in China.

Table 2: The Academia-Industry Collaboration in China

Academia	Technology	Related Industry
IHEP	Accelerating Structures (SLAC TW structure and others), Magnets , Low energy electron linacs (S&L-band) for Irradiation and NDT.	EL Pond (Irradiation) ; Ningbo (Irradiation). …
TUB	Normal conducting RF structures (L, S & X-band); TW and SW electron linacs (S,L & X-band). RF Gun and other instrumentations.	NUCTECH (Cargo inspection and Irradiation); Granpect (ICT) ; RIAMB (NDT) ; SHINVA(Radio therapy).

CAEP	DC high voltage acc. Low energy electron linacs (S-band)	FERES(Irradiation) SPRI (ICT and other NDT)
CIAE	Low energy electron linacs for Irradiation and NDT, Cyclotron.	HTA (NDT and Irradiation)
SINAP	DC high voltage accelerator, Cyclotron.	
NSRL	Low energy electron linacs for Irradiation.	
IMP	DC high voltage accelerator, Cyclotron, Magnets.	

The academia and industry established joint institutes or centres to make the technology transfer smoothly in China. As an example, Fig. 13 illustrates the joint institute between TUB and NUCTECH.

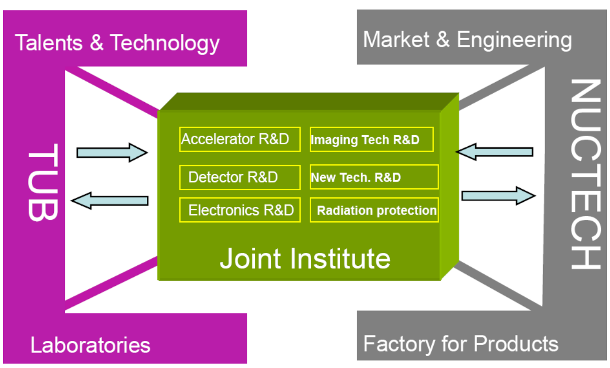

Figure 13: Tsinghua university and NUCTECH collaboration by establishing a joint institute.

SUMMARY

The accelerator industry in Asia is mainly at the area of medial therapy, NDT, irradiation and radioisotope production. Homeland security is still a relatively new area of the accelerator applications, but it is becoming more and more important now. New application area of accelerator means new market and new opportunity of accelerator industry. There are lots of accelerator facilities in Asia, such as synchrotron radiation light sources. They are playing an important role for developing new accelerator applications. For an accelerator, even a small one, is never a simple industry product, the academia-industry collaboration is always an essential issue for the accelerator industry.

ACKNOWLEDGEMENT

This paper gives an overview of the accelerator industry status in Asia. But the author does not intend to give detail introductions to all of the companies, centres and institutes related to the accelerator development， although some of them are introduced here as examples. And high voltage ion accelerators for ion implantation are not included in this paper.

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