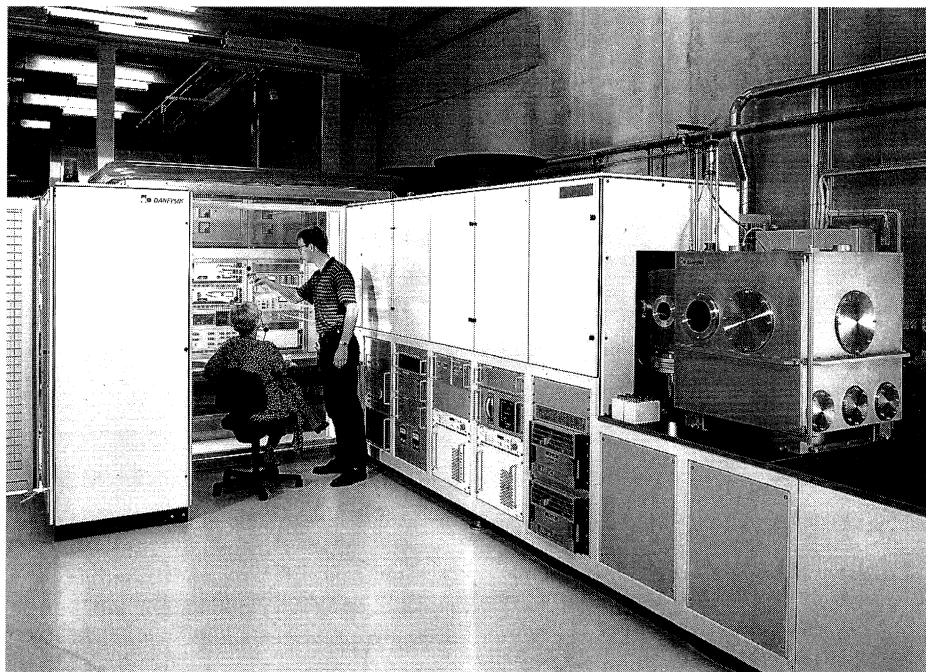


A high-current industrial ion implantation system used for treating metal surfaces.
(Photo Danfysik, Jyllinge, Denmark)



Most industrial ion implantation processing is handled by specialist companies and the demand is increasing. It is a challenge for the implanter manufacturers to satisfy higher demands for efficiency, reliability and reduced cost.

From Bjarne Roger Nielsen, Danfysik, Jyllinge, Denmark.

Ion implantation for semiconductors

Over the past two decades, thousands of particle accelerators have been used to implant foreign atoms like boron, phosphorus and arsenic into silicon crystal wafers to produce special embedded layers for manufacturing semiconductor devices.

Depending on the device required, the atomic species, the depth of implant and doping levels are the main parameters for the implantation

process; the selection and parameter control is totally automated.

The depth of the implant, usually less than 1 micron, is determined by the ion energy, which can be varied between 2 and 600 keV. The ion beam is extracted from a Freeman or Bernas type ion source and accelerated to 60 keV before mass analysis. For higher beam energies post-acceleration is applied up to 200 keV and even higher energies can be achieved by mass selecting multiply-charged ions, but with a corresponding reduction in beam output.

Depending on the device to be manufactured, doping levels can range from 10^{10} to 10^{15} atoms/cm² and are controlled by implanter beam currents in the range up to 30mA; continuous process monitoring ensures uniformity across the wafer of better than 1%.

As semiconductor devices get smaller, additional sophistication is required in the design of the implanter. The silicon wafers charge electrically during implantation and

this charge must be dissipated continuously to reduce the electrical stress in the device and avoid destructive electrical breakdown. Electron flood guns produce low energy electrons (below 10 electron-volts) to neutralize positive charge buildup and implanter design must ensure minimum contamination by other isotopic species and ensure low internal sputter rates.

The pace of technology in the semiconductor industry is such that implanters are being built now for 256 Megabit circuits but which are only likely to be widely available five years from now. Several specialist companies manufacture implanter systems, each costing around US\$5 million, depending on the configuration and remote handling options. Current implanter capacities are around 60 wafers/hr, each wafer being 150mm in diameter with a typical doping level of 3×10^{15} cm⁻².

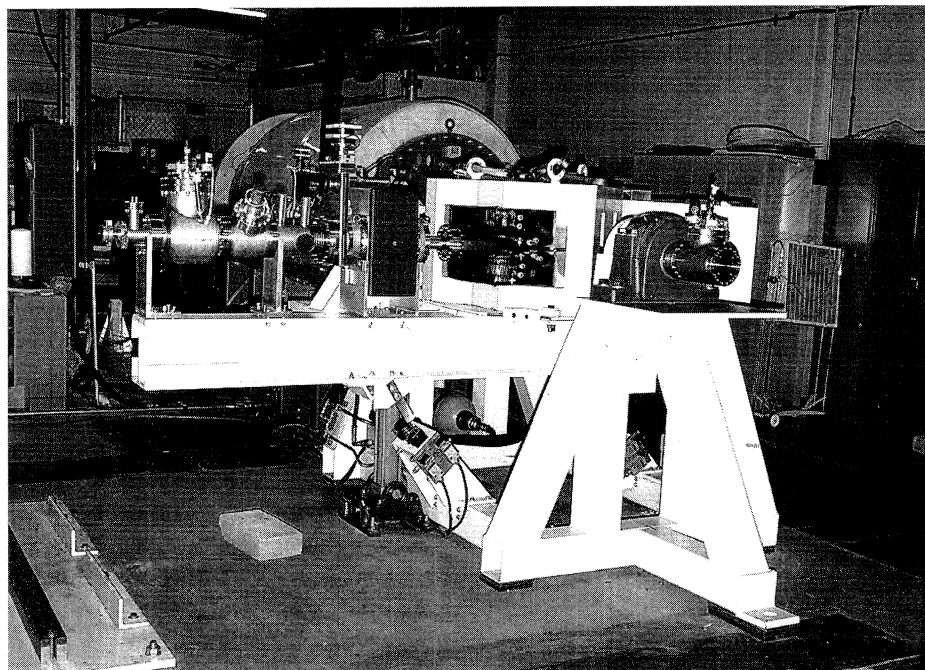
From T. Grey-Morgan, Amersham International, UK

Contraband detection

Inspecting incoming cargo for drugs, explosives and other contraband would quickly overwhelm inspection agencies even if a small percentage of the cargoes were manually searched. Now a new accelerator-based inspection system using pulsed fast neutron analysis (PFNA) allows automated inspection of loaded cargo containers and trucks.

A collimated pulsed beam of fast neutrons, scanned over the side of a cargo container as it passes, excites the nuclei of common elements in

A new accelerator-based inspection system allows automated inspection of loaded cargo containers and trucks. A neutron beam scans the cargo and the detected gamma ray emissions can give a reconstruction with the appropriate signature for drug materials.



bulk materials. The primary signals of interest for contraband are gamma-ray emissions following inelastic scattering of the fast neutrons from carbon and oxygen.

Direct imaging of the contents of the material by time-of-flight analysis identifies the position of the interactions, while gamma-ray spectroscopy identifies the elemental gamma rays. The ratio of elements or other combinations of the elemental signatures are used to identify contraband - a high carbon-to-oxygen ratio, for example, is characteristic of drugs.

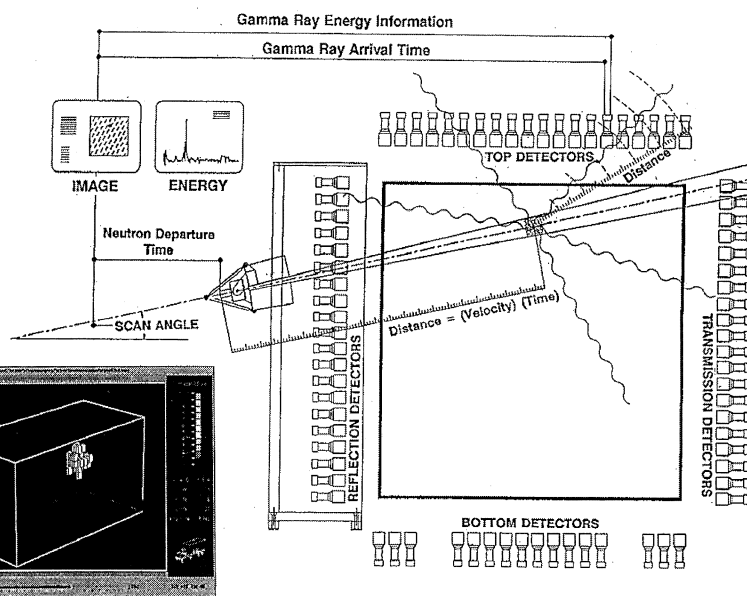
The system incorporates gamma ray detectors, and analogue and digital processors sort the pulses for position and elemental information. Detection algorithms produce three-

dimensional images of possible concealed contraband. From these images the inspector can identify suspicious objects within the cargo container.

One PFNA device uses a beam of 8 MeV neutrons raster scanned

across the face of a truck or container. The beam is produced by an 80 microamp beam of 6.0 MeV deuterons from a National Electrostatics Corporation (NEC) Pelletron tandem Van de Graaff. The ion source is a newly developed Toroidal Volume Ion Source (TORVIS) based on a Brookhaven design with an output of 300 microamps DC of negative ions. The deuteron beam is accelerated to 80 keV and then analysed in a dipole magnet before entering the bunching system. A 5 MHz double drift buncher achieves a bunching efficiency of 40% with a pulse width of 1 ns at full energy. The deuteron beam then enters a self-cooled deuteron gas target, where neutrons are produced.

The neutron beam is achieved by mechanically rastering the accelerated deuteron beam through 90° using a dipole magnet, and the scanning motion is accomplished by mounting the dipole, the 90° beamline and deuterium gas cell on a platform which rotates concentric with the beam axis. Driven by a hydraulic



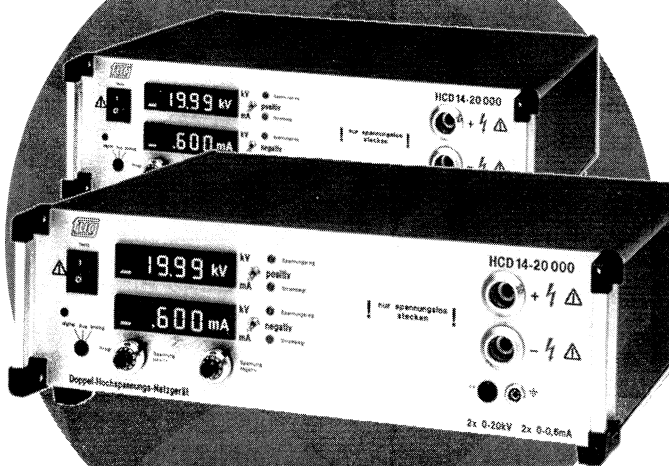
In the PFNA technique for contraband detection, a deuteron beam is injected into a beamline and neutron production target mounted on a rotatable scan arm. The fast neutrons excite nuclei within the bulk material and analysis of the resulting gamma emission identifies possible illegal materials. (Photos SAIC, Santa Clara, California)

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Further details about the group can be found on World Wide Web (http://www.ph.rhnc.ac.uk/research/hep/hep_home.html). Questions related to the post should be addressed to Dr M G Green, Physics Department, Royal Holloway University of London, Egham, Surrey TW20 0EX (phone +44 1784 443454, fax +44 1784 472794, email GREEN@V1.PH.RHNC.AC.UK).

A letter of application and CV should be sent to Mike Green at the above address to arrive by Friday 4 August 1995. Applicants should also arrange for two references to be provided by the same date.

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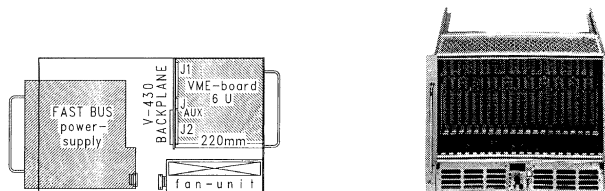
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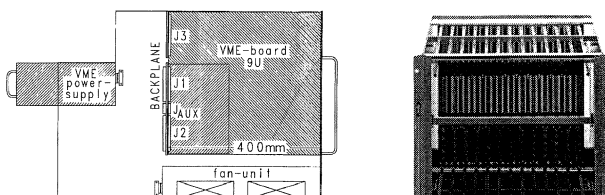
Output modules: -2 V - 50/100/150 A. +5V/-5.2 V - 75/150/200/300 A. +12 V/-12 V - 10/25/40 A. +15/-15 V - 10 A/25 A/35 A. Other voltage/current outputs on request.

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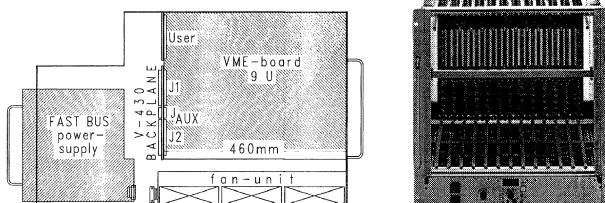


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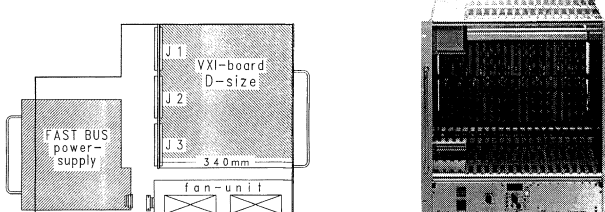
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Research applications

actuator, the scanning speed of the platform is adjustable up to approximately 0.25 Hz. Since the rotating and fixed beamlines are one continuous high vacuum system, a high vacuum rotary union is needed. A non-mechanical, low vapour pressure liquid (ferrofluid) vacuum seal is used. A collimator on the scan arm limits the vertical extent of the neutron beam and there is a fixed collimator in the horizontal plane.

The PFNA concept has undergone numerous tests to demonstrate its efficacy for detecting drugs and explosives. A full-sized system has been built by SAIC in Santa Clara and is undergoing integration testing with a variety of cargoes.

Increase in world trade favours the use of a tool like PFNA cargo inspection for monitoring incoming shipments. PFNA's ability to image elements can be expanded through advanced databases to verify cargo manifests and to monitor shipments. In a modified form, PFNA could also be used to examine the contents of sealed barrels of hazardous waste to avoid manual sampling.

From T. Gozzani, Science Applications International Corporation, Santa Clara, USA

Most types of accelerator were originally designed by accelerator engineers for particle or nuclear physics research. Today, there are some large and very sophisticated accelerators dedicated to a wide range of other research and development work. Particle accelerators provide a very valuable tool for studying the properties of matter.

Synchrotron radiation research

In the many varied application fields of accelerators, synchrotron radiation ranks as one of the most valuable and widely useful tools. Synchrotron radiation is produced in multi-GeV electron synchrotrons and storage rings, and emerges tangentially in a narrow vertical fan.

Synchrotron radiation has been

used extensively for basic studies and, more recently, for applied research in the chemical, materials, biotechnology and pharmaceutical industries.

Initially, the radiation was a by-product of high energy physics laboratories but the high demand soon resulted in the construction of dedicated electron storage rings. The accelerator technology is now well developed and a large number of sources have been constructed, with energies ranging from about 1.5 to 8 GeV including the 6 GeV European Synchrotron Radiation Facility (ESRF) source at Grenoble, France.

A modern third-generation synchrotron radiation source has an electron storage ring with a complex magnet lattice to produce ultra-low emittance beams, long straights for 'insertion devices', and 'undulator' or 'wiggler' magnets to generate radiation with particular properties. Large beam currents are necessary to give high radiation fluxes and long beam

Synchrotron radiation is one of the most valuable and widely useful of all accelerator applications. The European Synchrotron Radiation Facility - ESRF - in Grenoble, France is a 6 GeV, third generation synchrotron radiation source which will provide up to 30 beamlines for fundamental and applied research.
(Photo ESRF)

