Rutherford Laboratory

Technical Leaflet

A1

THE NIMROD PROTON SOURCE AND PREINJECTOR

The proton source used on Nimrod is a radiofrequency ion source. It consists of a small pyrex glass bottle into which pure hydrogen is passed at low pressure (about 10^{-2} torr). The high purity is achieved by allowing hydrogen from an ordinary gas cylinder to diffuse through the walls of a hot nickel tube.

Radiofrequency power (125 Mc/s) is fed into a two-turn coil which surrounds the pyrex bottle and the electric field from the coil accelerates free electrons in the hydrogen gas. These knock electrons from the hydrogen molecules and a mixture of positive ions and electrons, called a 'plasma', is formed. A hydrogen molecule consists of two atoms and when an electron collides with the molecule, it may simply knock off one electron, resulting in two electrons and a molecular ion. These 'molecular ions' are no use for our purpose and to create protons (atomic hydrogen ions), the molecules must first be split up or 'dissociated' into hydrogen atoms and then these atoms ionised. Dissociation occurs in most hydrogen discharges but, for proton sources, steps have to be taken to prevent the atoms recombining which happens when they strike a solid surface. Recombination occurs readily on metal surfaces but not on pyrex glass and thus, in an r.f. ion source, the plasma is produced as a discharge in a pyrex vessel. It consists almost entirely of atomic hydrogen, and a beam can be extracted which contains over 80% protons. This is one of the major advantages of a radiofrequency source.

At one end of the pyrex bottle is a pair of electrodes, insulated from each other, with circular holes in them. They form the 'extraction gap' and a high voltage pulse is applied across this gap. The resulting electrostatic field penetrates into the plasma through the hole in the upper electrode and is in such a direction as to repel electrons and draw out ions. By suitable geometry, the resulting ion beam can be made to converge. Because the protons all have a positive charge, they repel each other and the converging beam comes to a 'waist' and then diverges again, thus enabling it to pass through a comparatively small hole in the lower electrode. This small hole or canal impedes the flow of neutral gas from the source and, by vacuum pumping at high speed below the canal, a reasonable vacuum can be maintained, which means that high electric fields can be used without breakdown occurring, to accelerate the beam to higher energies.

In a source of this type, extraction voltage pulses of up to 40,000 V (1 msec long) have been applied, resulting in ion beams of over 180 mA. On NIMROD, a typical operating level is about 15,000 V giving a 50 mA beam current. Each source unit is replaced after several hundred hours of operating time.

The Preinjector

The Preinjector must inject a 600 keV beam into the linear accelerator and produce a 'waist' in the beam near its output end in order to avoid excessive

beam expansion in the Low Energy Drift Space. To achieve this the beam must be slightly converging at the Preinjector input. The beam from the proton source is rapidly diverging and focusing is applied to correct it.

The focusing is achieved by electrostatic lenses. These are formed by stainless steel electrodes of gradually increasing diameter with high and low potentials applied to alternate ones. The electrostatic field in the gaps between these electrodes acts on the protons rather like a simple lens on a beam of light.

Exhibit A1, Injector Hall

The exhibit shows a standard NIMROD proton source and the system of focusing electrodes, the diagrams illustrate the working of these devices.

Exhibit A22, Lab.6, R.1

The demonstration uses a source assembly which has been simplified to make the atomic hydrogen discharge visible. By looking through the small spectroscope, the spectrum of atomic hydrogen, the Balmor series of spectral lines, can be clearly seen. The extracted beam is invisible, but a flash of light can be seen below the source where it strikes a fluorescent screen.

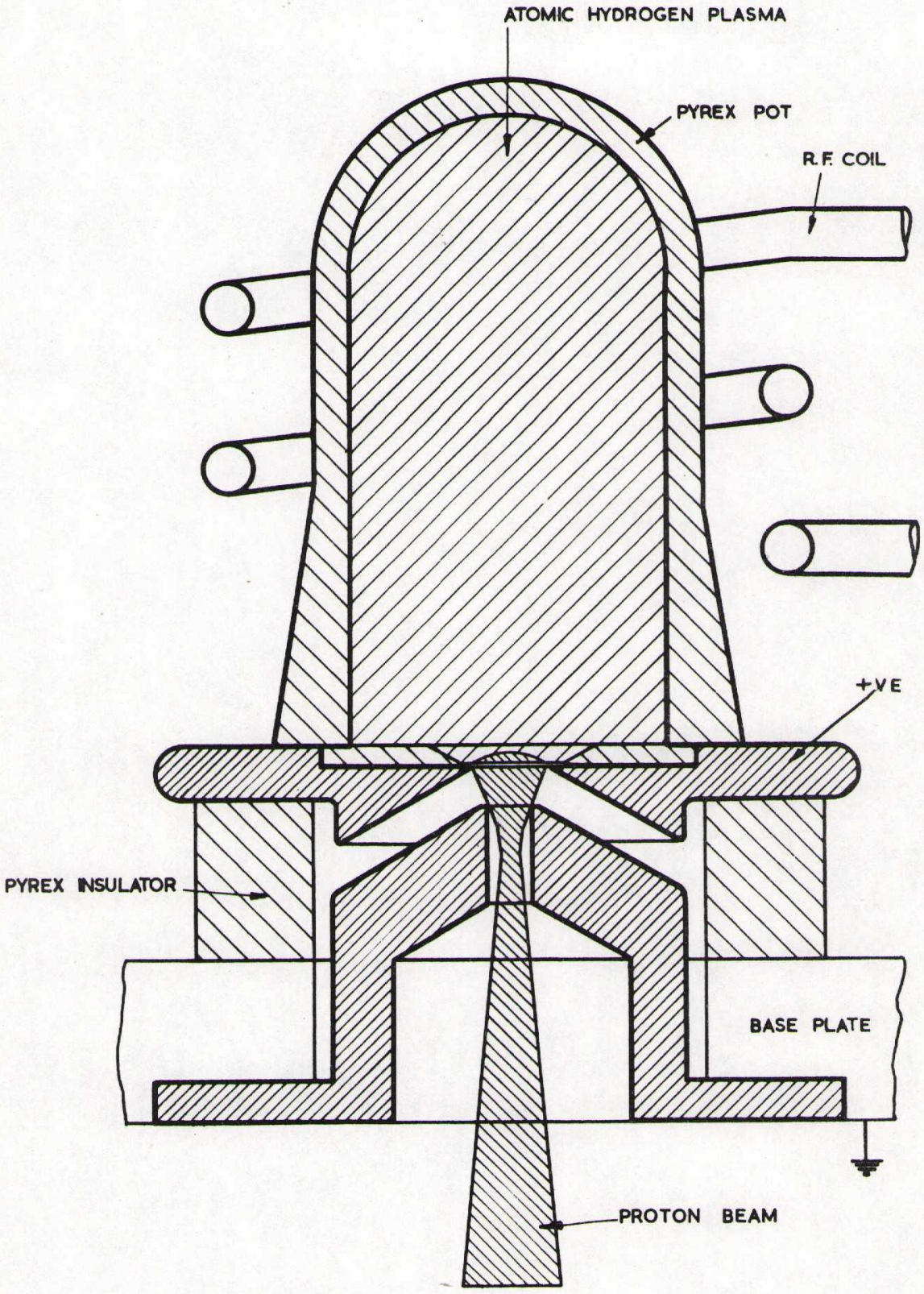
ATOMIC HYDROGEN PLASMA
PYREX POT
R.F. COIL
+VE
PYREX INSULATOR
BASE PLATE
PROTON BEAM

FIGURE 1