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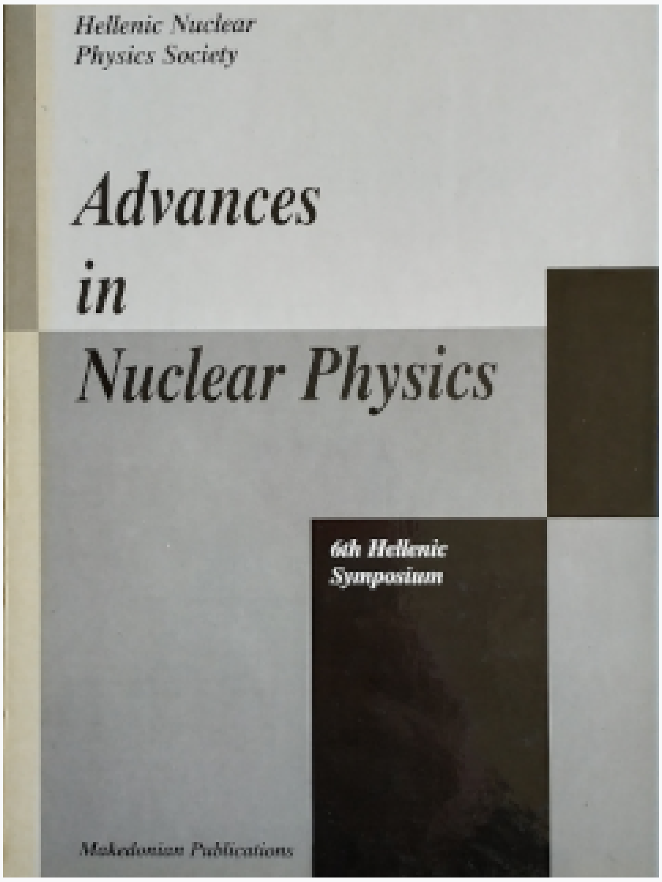

Polarized electrons at NIKHEF

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Abstract

A design for producing a beam of longitudinally polarized electrons stored in the AmPS ring has been made by a collaboration between NIKHEF, the Budker Institute for Nuclear Physics (BINP) and the Institute of Semiconductor Physics (ISP) from Novosibirsk. The polarized electrons are produced by illuminating a photoemissive cathode with circularly polarized light. A 100 keV electron beam with a peak current up to 40 mA and a pulse length up to 4 μs is extracted from the cathode at a maximum repetition rate of 2 Hz.

1 Introduction

At the *Amsterdam Pulse Stretcher and Storage* (AmPS [1], fig. 1) ring the time required for radiative polarization is much larger than the beam lifetime, so that polarized electrons have to be injected. A design for producing a stored beam of longitudinally polarized electrons has been made by a collaboration between NIKHEF, the Budker Institute for Nuclear Physics (BINP) and the

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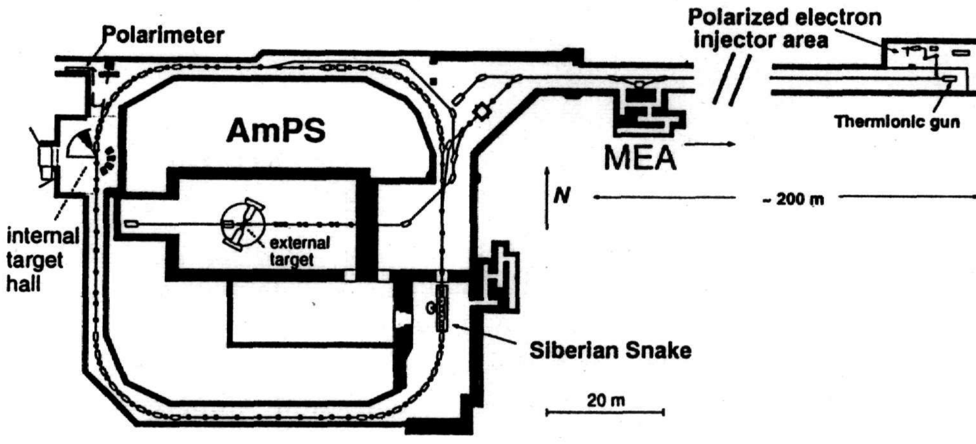

Fig. 1. The *Amsterdam Pulse Stretcher and Storage* ring

Institute of Semiconductor Physics (ISP) from Novosibirsk. In this design the most recent insights in the field and the necessary requirements for coupling of the polarized source to the existing injection system of the accelerator have been incorporated.

In fig. 2 the injection area of the NIKHEF facility is shown with the existing thermionic gun and the polarized source. Polarized electrons are produced by illuminating a photoemissive cathode with circularly polarized light. A Z-shape spin manipulation system rotates the polarization vector over any arbitrary angle. The degree of polarization is measured with a Mott polarimeter. A post-accelerator increases the energy of the electrons to 400 keV required before the electron beam can be injected into the MEA linac (the linear accelerator of NIKHEF). In storage rings the spin precesses relative to the electron momentum. In order to maintain the polarization longitudinal at the interaction point, a *Siberian Snake* has been installed in the East straight section of the AmPS ring, opposite to the interaction point. The polarization degree in the ring is measured by a Compton laser backscattering polarimeter [2].

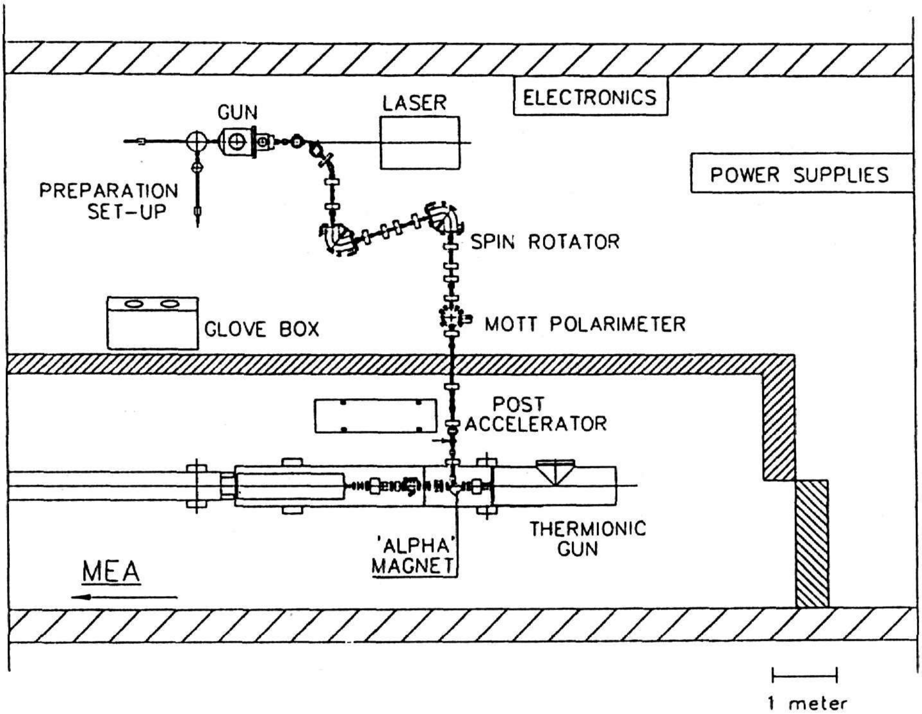

Fig. 2. The NIKHEF injector area with the unpolarized and polarized electron sources.

2 The AmPS polarized electron beam

Our photocathode gun has been designed to deliver a variably pulsed (0.7-4μs) polarized electron beam of 100 keV kinetic energy. The extracted peak current can be as high as 40 mA at a repetition rate 2 Hz. The polarized electron injector consists of the following main parts: the preparation set-up, the photocathode gun, the laser and the optical circuit, the Z-shape spin manipulator, the Mott polarimeter and the post-accelerator (Figure 2).

In our design the preparation of the photocathode to Negative Electron Affinity (NEA) state is performed in a preparation set-up, permanently connected at the rear side of the photocathode gun and isolated from it by a UHV valve. Lifetime and quantum efficiency measurements can also be performed. This procedure can be done while the gun is in operation. The photocathodes are transferred from the preparation set-up to the gun chamber with a magnetically driven manipulator under UHV environment. This design has three major advantanges. It makes the preparation procedure of the photocathodes more efficient, it preserves the UHV conditions in the photocathode gun and it gives the ability to activate photocathodes while the photocathode gun is in operation.

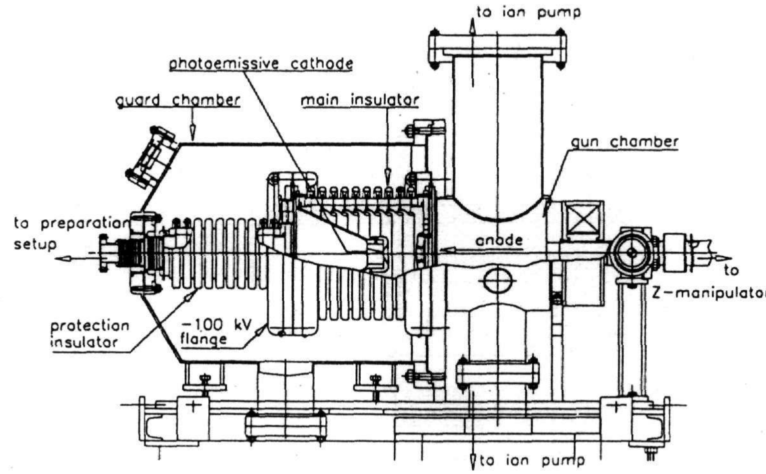

Fig. 3. The mechanical design of the NIKHEF's photocathode gun.

The photocathode gun can be divided into the following sections starting from the back: the protection insulator, the main insulator and the gun chamber. A large guard chamber covers both insulators (Figure 3).

The main insulator is made of 9 ceramic rings sandwiched between 10 rings of conducting material. A voltage divider decreases gradually the high voltage from -100 kV at the flange connecting the protection insulator to the main insulator, to zero at the anode flange. In this way adjacent rings are held approximately to one tenth of the maximum voltage minimizing the possibility of sparking, which could result a damage of the insulator. A set of 8 screens protects the inside of the insulating material from direct electron hit. The cathode position is at the end of a stainless steel cone.

The protection insulator is installed between the connection tube to the preparation set-up and the main insulator. It has the same design as the main insulator. The gun chamber is located immediately after the anode flange. It has a cylindrical shape and supports the ports where the ion pumps, the vacuum gauges and the mass spectrometer are connected. A large guard chamber covers the protection and the main insulators. It is held to vacuum of the order of 10^{-6} mbar protecting the insulators to come in contact with the ambient atmosphere. It supports and isolates the high voltage connection from the surrounding environment.

A laser and an optical circuit provide the circularly polarized light. A tunable (700-900 nm) flashlamp-pumped Ti:Sapphire laser provides long ($\sim 30\mu s$) linearly polarized (> 99%) light pulses at a repetition rate of 2 Hz. An electrooptic pulse slicer with variable delay and width cuts the desirable up to 4 μs rectangular pulse out of the long one. The optical circuit consists of a remotely controlled power attenuation system that regulates the laser power from pulse to pulse, a remotely controlled $\lambda/4$-plate for providing right or left helicities, a set of lenses to focus the laser beam onto the photocathode and a photodiode for on-line pulse-shape and power measurements.

A spin-manipulating system is required to precess the net polarization such that the beam will be longitudinally polarized when it arrives at the target. The Illinois-CEBAF design [3] with some minor changes has been adopted for the spin-manipulating system. The system, consisting of two electrostatic deflectors and eight solenoids, provides an easy means to rotate the polarization vector over any angle with respect to the beam direction while at the same time providing the necessary compensation for the variation in the optical properties introduced by the solenoidal fields.

A Mott polarimeter sensitive to transverse polarization, obtained with the spin manipulator, measures the polarization degree. Thin gold foils are used as scattering targets. Two silicon detectors, symmetrically mounted with respect to beam momentum, measure the expected asymmetry while two other identical detectors monitor instrumental asymmetries.

The post-accelerator consists of two cavities, one for bunching and the other for accelerating the electron beam to 400 keV. The acceleration of the electron beam is necessary because the existing thermionic gun delivers a 400 keV unpolarized electron beam. An 'alpha'-magnet deflects the polarized electron beam over 270^0 without dispersion into the MEA linac. A valve, installed between the post-accelerator and the 'alpha'-magnet, offers a complete isolation of the whole system from MEA linac. With this scheme either a polarized or an unpolarized electron beam can be injected.

A set of beam diagnostics consisting of two beam current monitors, several TV screens and a multiwire scanner has been designed for monitoring the electron beam throughout the system.

The post-accelerator capture efficiency of 20% results in an 8 mA peak current electron beam injected into the MEA linac. By three-turn injection 20 mA is then captured in the AmPS ring. Consecutive pulses accelerated in MEA are stacked into the ring until an intensity of over 100 mA is reached. A beam with energy up to 700 MeV can be injected directly into the ring. The stored beam can also be ramped up till a maximum energy of 900 MeV.

In storage rings the spin precesses relative to the electron momentum, and no longer be longitudinal at the interaction point (IP). If a device, which rotates the spin over an angle with respect to the beam momentum is inserted in the East straight section of the AmPS ring, opposite to that where the IP is located, longitudinal polarization is preserved at the IP, independently of the beam energy. A mirror-symmetric system, consisting of two solenoids with a normal quadrupole in the middle and two skew quadrupoles at each end, has been optimized in order to cancel the vertical oscillation coupling, introduced by the solenoidal field outside the insertion, and to produce a transport matrix equivalent to the drift length physically occupied by the insertion. Such a scheme is called *Siberian Snake*.

3 Conclusions

At present the polarized injector has been undergoing commissioning tests. The vacuum at the gun and the preparation set-up is better than 10^{-10} mbar while the vacuum at the spin manipulator, the Mott polarimeter and the post-accelerator is of the order or better than 10^{-8} mbar. Activation of strained In-GaAsP photocathodes in the preparation set-up showed a lifetime of the order of several hundred hours. Several photocathodes placed in the gun chamber, illuminated by the Ti:Sapphire laser gave polarization in excess of 50% (in two cases in excess of 65%) with a peak current of 20-30 mA and lifetime of the order of 100 hours. The Z-manipulator has been successfully tested. The *Siberian Snake* has be installed in the ring and first cooling of the two superconducting solenoids has been done successfully. The commissioning of all parts is continuing and first polarized beam in the AmPS ring is expected at Spring of 1996.

Acknowledgments

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