THE PULSED POLARIZED ELECTRON SOURCE FOR NUCLEAR PHYSICS EXPERIMENTS AT AmPS.

B.L. Militsyn, P.W. van Amersfoort, F.B. Kroes, G. Luijckx, M.J.J. van den Putte, NIKHEF, Amsterdam, The Netherlands; S.G. Konstantinov, I.A. Koop, V.Ya. Korchagin, S.G. Popov†, G.V. Serdobintsev, Yu.M. Shatunov, Yu.F. Tokarev, BINP, Novosibirsk, Russian Federation; A.M. Gilinsky, S.V. Shevelev, A.S. Terekhov, ISP, Novosibirsk, Russian Federation; C.W. de Jager, TJNAF, Newport News, USA (Present address); N.H. Papadakis, IASA, Athens, Greece (Present address).

Abstract

The polarized electron source of the NIKHEF accelerator facility AmPS is described. The facility consists of an electron linac and a 900 MeV storage ring. It is in use for nuclear physics experiments with internal gas targets. Spin polarized electrons with an energy of 100 keV are obtained by photo–emission from cathodes made of III–V–semiconductor crystals. With a Z–shape spin manipulator the electron spin can be oriented in any angle. The manipulator allows to compensate for the spin precession in the linac and its beam switch yard magnets before injection of the beam into the AmPS storage ring. The beam polarization degree of the source is measured by a Mott-polarimeter installed after the Z–manipulator. The source delivers 2 μs long beam pulses at a repetition rate of 1 Hz. With strained layer InGaAsP photocathodes a highly polarized current of 200 mA has been obtained in the ring. By pulsing the 100 kV power supply of the gun a photocathode lifetime of 200 hours has been achieved.

1 INTRODUCTION

The accelerator facility at NIKHEF has been upgraded to produce stored beams of longitudinally polarized electrons in the Amsterdam Pulse Stretcher ring AmPS [1]. The facility is used to study scattering of longitudinally polarized electrons on polarized light nuclei [2]. As the time required for polarization by means of the “Sokolov–Ternov” effect [3] for the energy range of AmPS is much larger than its beam lifetime, polarized electrons have to be injected into the ring. To produce spin polarized electron a polarized electron source (PES) [4] has been implemented as second injector of the AmPS facility. PES consist of a 100 keV source and a 400 keV post–accelerator. The electrons produced by the PES are accelerated to the desired energy of AmPS, by means of a linear medium energy accelerator MEA. A Siberian Snake [5] is installed in the AmPS ring in order to maintain the longitudinal polarization at the internal target (IT). The polarization degree of the electron beam at the IT is measured by means of a Compton backscattering polarimeter [6].

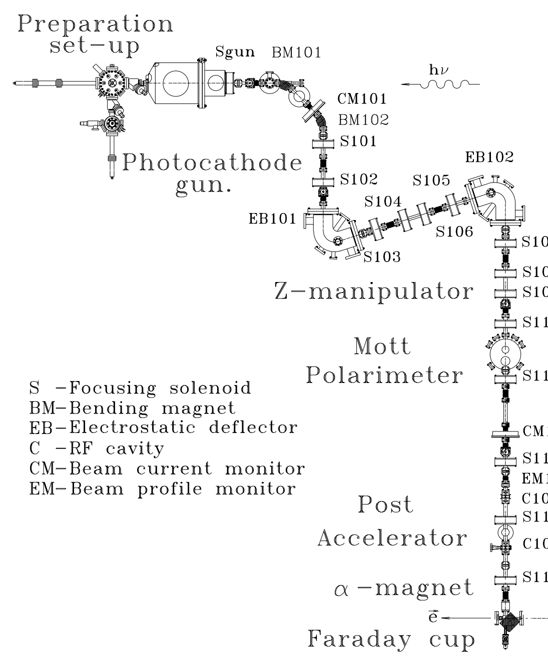

Figure 1: An overview of the polarized electron source.

2 100 KEV SOURCE.

An overview of PES is given in Figure 1. Spin polarized electrons are obtained by means of a laser light stimulated photo-emission from III–V-semiconductor crystals (photocathodes) in an extra high vacuum 100 keV photocathode gun [7]. The surface of the photocathode is illuminated with circularly polarized light produced by an optical system and a tunable Ti-Sapphire laser.

2.1 Photocathodes preparation.

To obtain photo-emission from a photocathode its surface needs to be activated to the Negative Electron Affinity (NEA) state. This is accomplished in the preparation set-up (PS). The set-up consists of a glove-box, a transfer vessel, a loading chamber (LC), and a preparation chamber (PC).

Photocathodes enter the system in a glovebox, where they are etched in HCl acid in a pure nitrogen atmosphere.

After etching they are rinsed in methanol and placed in the transfer vessel, which can contain up to three photocathodes. The hermetically sealed transfer vessel is then moved to the LC, whilst the photocathodes are kept under nitrogen atmosphere.

After mounting the transfer vessel in the LC, the last one is pumped down to a vacuum of 10^{-7} mbar, by means of an oil free turbo vacuum pump and an ion pump. The LC is separated from the PC by an UHV valve. By means of a magnetic manipulator (MM) photocathodes are transported to a carousel in the PC, which can contain up to four photocathodes. In the PC photocathodes are thermally cleaned and then activated up to the NEA state by means of a Cs – O "Yo–Yo" procedure. A vacuum in the PC of better than 10^{-11} mbar is maintained by means of an ion pump (250 l/s), and a NEG pump.

2.2 The photocathode gun.

The primary source of the polarized electrons is a 100 keV photocathode gun. Its conception is based on a Pierce type electrode optical system with an acceleration gap of 65 mm. The cathode assembly allows for the installation of a photocathode with an active diameter of 12 mm. The diameter of the emitting part of the photocathode (ED) is determined by the laser light spot diameter on its surface, which can be varied in the range of 1–7 mm.

The gun is designed with a double ceramic high voltage insulator which allows for a permanent connection with the PC. The PC is separated from the gun by an UHV valve. A freshly activated photocathode is exchanged with the one mounted in the gun, by means of a second MM, within a typical time of 15 minutes. Such a solution allows to remove process of the photocathode preparation, which leads to deterioration of vacuum and pollution of the clear surface, out of the gun. Also it allows the replacement of photocathodes without opening the gun vacuum chamber. Moreover this allows to activate a photocathode whilst the gun is operating.

The gun has two concentric vacuum chambers: an extra high vacuum acceleration chamber, where the photocathode is mounted, and a guard vessel (outer chamber). The guard vessel reduces the risk of creating vacuum leaks between the metallic and ceramic parts of the insulators. Should nevertheless small leaks occur, as a consequence of the baking process, the guard vessel dramatically reduces the flow of gases, which can contaminate the photocathode surfaces.

The frontal surface of the photocathode in the gun is illuminated by a laser system built on the base of a tunable pulsed Ti:Sapphire laser. The system provides 2μs light pulses with a repetition rate of 1 Hz. The wavelength of the light may be varied in a range of 720–850 nm. The maximal power in the pulses measured at the gun entrance window is 500 W.

The acceleration chamber is pumped by two ion pumps (100 and 250 l/s) and a NEG pump. The vacuum of the inner chamber is $3 \cdot 10^{-12}$ mbar. The guard vessel is pumped by an ion pump of 160 l/s. Its pressure is in the lower range of 10^{-7} mbar.

The gun is fed by a pulsed high voltage power supply (PPS), which provides a Gauss like pulse, with a full width of 600 μs, and an amplitude of -100 kV. The PPS is operated in a "soft high voltage slope" mode, in view of the high impedance of the gun (5 MΩ). The laser pulse and the high voltage pulse have been synchronized, such that the laser system fires its pulse on top of the high voltage pulse produced by the PPS. With the use of the PPS a photocathode lifetime in saturated mode of 200 hours has been achived [8]

2.3 The 100 keV beam line.

The 100 keV electrons provided by the photocathode gun, are deflected from the laser light path by means of two 45° bending magnets BM101 and BM102 into an electron optical system know as a Z–shape spin manipulator [9]. With this manipulator the electron spin can be oriented in an arbitrary angle within 4π. It is used to compensate for the spin precession in MEA and its beam switch yard magnets before injection of the beam into the AmPS ring.

Depending on the helicity of the light produced by the optical system, the electron spin points parallel or antiparallel to the trajectories of the electrons leaving the photocathode gun. The first electrostatic deflector EB101 bends the electron trajectory 107.7° degrees in the horizontal plane. After passing the deflector the polarization vector is perpendicular with respect to the trajectory. The inner pair of solenoids S104 and S105 is operated with parallel magnetic fields. With this set the spin is rotated, and its initial azimuth angle is set. The outer pair of solenoids S103 and S106 is operated with opposite magnetic fields and focuses the beam at the entrance of the second electrostatic deflector EB102 Their effect on the spin rotation cancels. By locating the electron beam waist between the inner solenoids, the focusing effects of the last ones can be minimized. The second electrostatic deflector EB102 rotates the electron trajectory backwards by 107.7°, so that it coincides with the projection of the spin on the horizontal plane and initial azimuth angle is transformed into the polar angle. With the subsequent set of inner solenoids S108 and S109 the desired azimuth angle of the spin is set.

Transport solenoids S107 and S110 focus the beam on the focal plate of the Mott–polarimeter [10], which is installed behind the Z–manipulator. It is used for the analysis of the polarization degree of the beam in the source. Two solenoids S111 and S112 transport the beam into the entrance of the post–accelerator.

3 INJECTION OF THE POLARIZED ELECTRONS INTO MEA.

To match the parameters of the polarized electron beam to MEA a two–cavity scheme post–accelerator has been im-

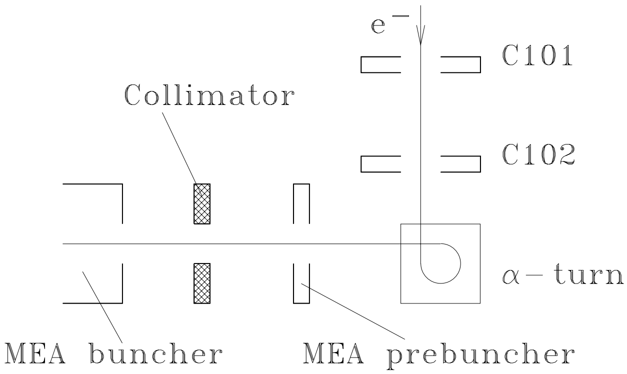

Figure 2: RF elements of the PES–MEA interface.

plemented. The cavity C101 is dedicated to modulate the beam energy, while the cavity C102 accelerates electrons to an energy of 400 keV. An α–magnet installed behind the post–accelerator allows to alternate injection from either the thermionic gun or PES.

A scheme of RF elements of the PES-MEA interface is shown in fig. 2. The electron beam with a diameter of 1.5 – 2 mm and an envelope divergence of 5 – 8 mrad enters the cavity C101. The cavity modulates the beam energy with an amplitude of ±7.5% and with 2865 MHz the frequency of MEA. Passing a straight section between C101 and C102 with a length of 0.48 m, the longitudinal charge density of beam redistributes and, at the entrance of the cavity C102, bunches with a phase length of 30° carry 55% of particles. Cavity C102 accelerates electrons to an energy of 400 keV. The RF phase of the cavity is chosen such that the bunch head's energy is 2.2 % higher than the energy of the central part of the bunch. At the entrance of the α–magnet the bunch length is 65°. The α–magnet bends the beam over an angle of 270°. The length of the trajectory in the α–magnet for electrons with an energy of 400 keV is 0.19 m. The deflection angle of the α–magnet is independent of the particle energy, but the trajectory length changes with a ratio of 0.195°/keV. At the entrance of the MEA prebuncher the bunch length is increased up to 110°. By increasing the field strength in the prebuncher with a factor of two the bunch parameters at the entrance of the MEA buncher are equal to the beam parameters from the thermionic gun.

Typical injection efficiencies, defined as a ratio of the current of the high energy electrons in the AmPS injection line to the gun current, up to 40% have been achieved. The nominal value is 35%. In fig. 3 an oscillogram of the photocathode gun current, measured with the beam current monitor CM101, and the current in the AmPS injection line are shown.

4 SOURCE PERFORMANCE.

The polarized electron source has been used since September 1996. Within the research program on photocathodes the majority of the effort has been concentrated on the use of strained layer InGaAsP photocathodes [11]. Typically pulsed currents, up to 150 mA, at a repetition rate of 1 Hz, has been obtained from the gun. The polarization degrees depend of the photocathodes, installed in the gun, and for best samples are about 80%. During experiments the source routinely provides pulses with a current of 15 mA with polarization of 65–75%. At an injection efficiency of 35–40% it gives a current in MEA of 5–6 mA at an energy of 720 MeV. The operational lifetime of the photocathode in such a mode is about 4–5 weeks. With a gas in the internal target polarized beams with a current up 200 mA could be routinely stored in the AmPS ring. The polarization measurements in the ring with the Compton backscattering polarimeter has not shown a significant loss of the beam polarization in the current range up to 150 mA.

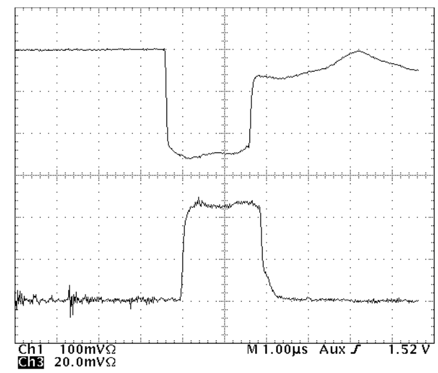

Figure 3: Oscillogram of the gun current (upper trace, sensitivity is -5 mA/div) and the current in the AmPS injection line (lower trace, sensitivity is 2 mA/div).

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