Operational Experience with the MAMI-Source of Polarized Electrons

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Abstract

The MAMI source of polarized electrons is based on the photoelectron emission of III–V–semiconductors. At present strained layer GaAsP cathodes are applied, which produce an electron beam spinpolarized to a degree of 75 % typically. Quantum efficiencies around 0.4 % are observed routinely. In the period 1994/96 the source was applied in MAMI -experiments for more than 1500 hours. It was used mainly in measurements of nucleon form factors via the reactions $H(\vec{e},e'\vec{p})$, $D(\vec{e},e'\vec{p})$, $D(\vec{e},e'\vec{n})$ and $^3\vec{H}e(\vec{e},e'n)$ performed by the MAMI -collaboration A3.

A substantial progress in operational reliability was achieved by attachment of a load lock system to the source gun. It allows quick replacement of cathodes without breaking the gun vacuum and high voltage processing without a cathode in place. Clean vacuum conditions are achieved by preserving UHV in the gun chamber for extended periods. In this report the experimental setup and operational experience are discussed.

1 INTRODUCTION

Many nuclear physics experiments at the c.w.-accelerator MAMI require a polarized electron beam with high brightness for several hundred hours operation time [2, 3, 4, 5]. A reliable, stably running source of porized electrons is of paramount importance for the success of such investigations. The present work describes operational experience with a source that has been developed by the MAMI B2-collaboration in recent years. It was applied successfully in the period 1994/96 in measurements of nucleon form factors via the reactions $^3\vec{H}e(\vec{e},e'n)$, $D(\vec{e},e'\vec{p})$, $D(\vec{e},e'\vec{n})$, $H(\vec{e},e'\vec{p})$.

2 THE POLARIZED ELECTRON SOURCE

The MAMI source of polarized electrons uses photoemission from III–V–semiconductors [1]. The photocathode is installed in a conventionally designed 100 keV electron gun and is irradiated by a circularly polarized laser beam (fig. 1) [5]. In spring 1995 an ultrahigh vacum system consisting of a load lock and a preparation chamber was added to the gun [6]. Crystals are introduced into the preparation chamber via the load lock. In the preparation chamber cathodes are stored (up to six), heatcleaned and covered with a submonolayer of caesium and oxygen to get negative values of electron affinity (NEA). Replacement of a cathode in the gun by a fresh sample stored in the preparation chamber is done with help of vacuum manipulators indicated in fig.1. Fig.2 gives some details of the transfer procedure.

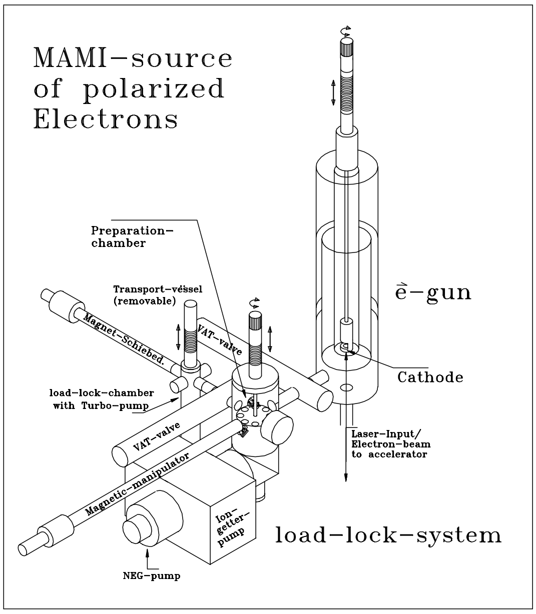

Figure 1: MAMI source of polarized electrons with the load lock system added

The essential advantages of this system are :

- The cathodes may be exchanged without breaking the gun vacuum. Because of that clean vacuum conditions are achieved in the gun chamber for extended periods (at present $1 \cdot 10^{-11}$mbar). An excellent vacuum is a prerequisite for long lifetimes of the cathodes. [4, 7].
- At the end of the operation time of a crystal a quick replacement between the preparation chamber and the gun is possible. This process requires about three hours, including the time to adjust the elektron beam to the accelerator and the injection into it. A duty fac-

tor of 85 % and more during beamtimes was attained regularly.

- The transfer of a new crystal into the apparatus takes one day. Therefore it is possible to investigate various cathodes within a short time. Before the installation of the load lock system this operation required several weeks.
- The mounting of the crystal is pivoted in the electrode of the source. So the eccentric arranged laser beam hits a fresh region of the crystal by revolving the cathode during a beamtime without displacement of the spot of emission with respect to the geometry of the electron optics of the source. This procedure doubles the operation time.
- Problems connected with sparking due to caesium covering of the high voltage insulator surface and the electrodes can be solved by high-voltage conditioning without keeping a crystal in the source.

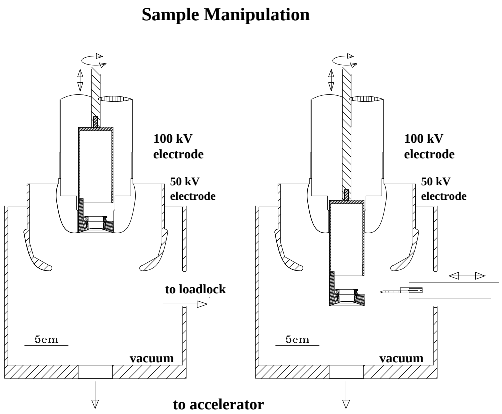

Figure 2: Transfer of a crystal into the electron source in detail [6]

3 USE OF STRAINED LAYER CRYSTALS

Strained layer semiconductors of structure : $In_{.50}Ga_{.50}P$ were applied to investigate the reaction $^3\vec{H}e(\vec{e},e'n)$ [2, 3] during 600 h beamtime. These crystals were built at the Institute of Semiconductor Physics in Novosibirsk [8]. They produce an elektron beam polarized to a degree up to 52 % and possess rather high quantum efficiencies between 1 % and 3 % at the wavelength of 675 nm typically (fig.3). The quality factor is $P^2 \cdot QE = 0.5^2 \cdot 10^{-2} = 2.5 \cdot 10^{-3}$. The light source used consisted of a commercially available c.w.-dye-laser system pumped by an Argon-ion-laser.

At present the standard cathode is a straind layer crystal (structure : $GaAs_{.95}P_{.05}$), which was produced at the Ioffe Institute of St. Petersburg in collaboration with St. Petersburg State Technical University by means of MOCVD

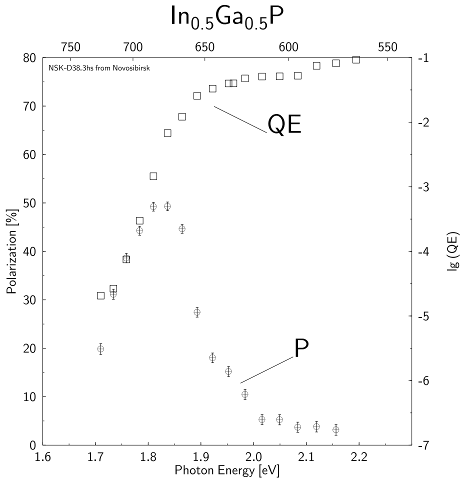

Figure 3: Photo electron emission from sligthly strained $In_{.50}Ga_{.50}P$. Polarization P of emitted electrons and quantum efficiency QE as a function of photon energy of irradiating light.[10]

techniques. Several cathodes of this type were tested at the Institut für Physik in Mainz [9, 11]. Fig.4 shows the behaviour of two different crystals out of these series. Maximum polarization values of 70 % and 80 % respectively are observed at 830 nm. At this wavelength quantum efficiencies around 0.4 % were measured regularly. The figure of merit reaches values up to $2.3 \cdot 10^{-3}$. Strained layer cathodes were used for the experiments of the reaction $D(\vec{e},e'\vec{n})$ for about 1000 h.

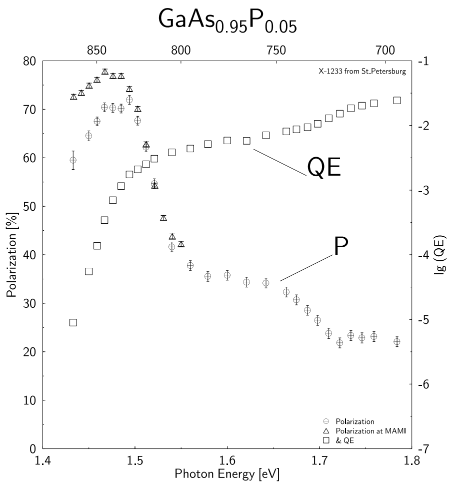

Figure 4: Photo electron emission from strained $GaAs_{.95}P_{.05}$. Polarization P of emitted electrons and quantum efficiency QE as a function of photon energy of irradiating light.

4 LASER SYSTEM

For the use of strained layer GaAsP-cathodes a Ti:sapphire laser was constructed [12, 13]. Fig.5 shows a horizontal cross-section of the laser. With the use of a Lyot-filter it is possible to tune the wavelength in a range from 780 nm to 860 nm. It is pumped by an Argon-ion-laser and reaches an output power of 1.2 W. This system was used during the above mentioned investigation of the reaction $D(\vec{e}, e'\vec{n})$.

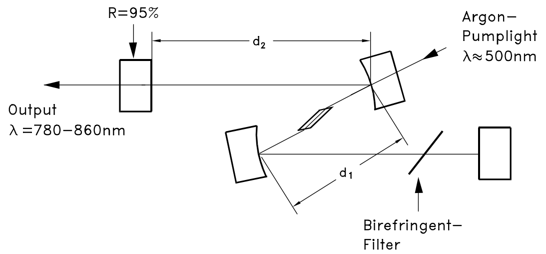

Figure 5: C.w.-Ti:Sapphire-laser [12].d_1 = 35 mm, d_2 = 55 mm

5 CONCLUSION

The most important parameters of the polarized electron source of MAMI at present are summarized in the following list :

Electron-polarization	P^e =75 % (GaAsP)
Emitted current	$I_e \geq 20\ \mu A$
Current density	40 mA · cm^{-2}
Phase space	$\epsilon = 0.5 \cdot \pi \cdot$mm · mrad
length of operation	$\tau \geq$ 100 h
Duty factor	85 %

6 OUTLOOK

A GHz mode locked Ti:Sapphire laser has been developed to drive the source with a light pulse train of frequency equal to the MAMI RF of 2.45 GHz, in order to improve the capture efficiency of the chopper buncher system at the injection point of the accelerator (at present 85 % of the beam is lost). In addition it is planed to build up a polarized electron source very close to the injector to make sure, that the electron bunches do not spread due to space charge.

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