# THE NEW POLARIZED BEAM INJECTION AT MAMI

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*Abstract*

A new,very compact set-up for the injection of the polarized beam at MAMI has been realized in the last two years. The new injection does not require the integration of a spin-rotator. Longitudinal polarization at the experiments is achieved by adjusting the accelerator energy which results in an additional spin rotation of 3.9 deg for a relative variation of the MAMI-energy of $10^{-4}$. As a result of the shorter injection we need less beam start-up time and achieve much better long term stability. The emittance of the beam at the injection point has been reduced by 70%.

## 1 INTRODUCTION

The Mainz racetrack microtron cascade MAMI delivers a c.w. electron beam of energies up to 855 MeV [1]. The physics program at Mainz requires highly polarized electron beams up to a current of 20 $\mu$A for periods of several thousand hours per year [2, 3].
The MAMI - source of polarized electrons is based on electron photoemission from III - V semiconductors like all other sources at accelerator centers in the world. Presently strained layers of GaAsP [4] are used that emit electron ensembles spin polarized up to a degree of 75 % at a wavelength of circularly polarized light irradiating the cathode of 830 nm. Quantum efficiencies around 0.1 % are obtained regularly.
In order to increase the transmission of the interface between source and accelerator electron bunches with a repetition rate of 2.45 GHz equal to MAMI - RF are produced by laser systems that possess the same time structure [5][6]. Spinpolarization is not affected by this method [7]. To preserve the electron beam structure the 100 keV beamline has to be as short as possible, so that the beam will not spread due to space charge. In addition the buncher system was modified to achieve a greater caption efficiency [8]. Transmissions about 93 % between source and target are obtained reliably [9]. Present work describes the experiences with the new source installed right at the injection point of MAMI.

## 2 THE POLARIZED ELECTRON SOURCE

Figure 1 shows the setup of the source of polarized electrons at the injection point of MAMI. The source is located one meter above the injection line of the accelerator. The polarized beam produced by the photosource is focussed with a vertical quadrupol triplett Q1 and guided to the horizontal beamline by a single alpha magnet $\alpha 1$. The combination of the second triplett Q2 and a solenoid S2 produce the correct phase space for optimal transverse acceptance of the accelerator. The transverse transmission is about 97 %. 3 % are lost at two collimators that work as an emittance filter. The emittance is measured by means of a wirescanner and determined to 0.25 $\pi$ mm mrad using the smallest laserspot diameter of 280 $\mu$m (all 4 $\sigma$). The beam quality of the photosource is at least as high as that of the thermionic gun with regard to halo and stability. The radiation in the accelerator halls caused by electron losses at the vacuum components was reduced by a factor thousand in comparison to operation in the old configuration. A lot of care was taken in separating the gun vacuum ($< 10^{-11}$ mbar) and the accelerator vacuum ($10^{-6}$ mbar). This is done by means of multistage differential pumping

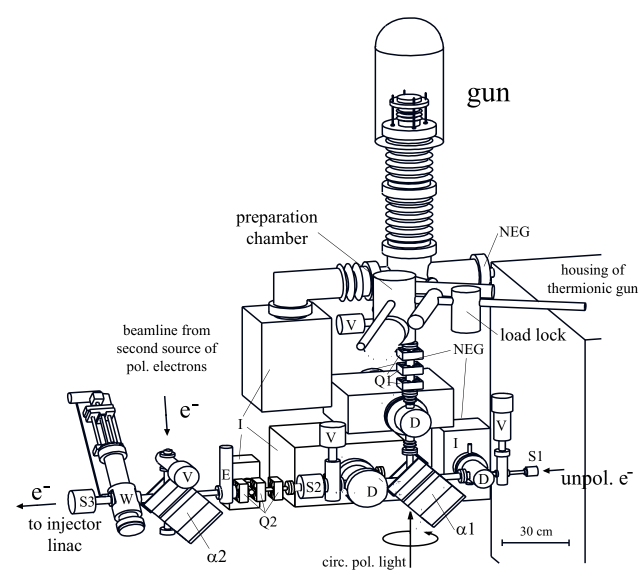


Figure 1: MAMI - source of polarized electrons at the injection point. $\alpha$: alphamagnet, D: diff. pumping stage, E: emittance filter, I: ion getter pump, Q: quadrupol, S: solenoid, V: all metal valve, W: wire scanner

stages with small conductivity and high pumping speed produced by ion getter - and Neg - pumps. Total pressure in the gun recipient is limited by the hydrogen partial pressure of $4 \cdot 10^{-11}$ mbar, while all other contributions to the residual gas stay in the low $10^{-12}$ mbar range or below during source operation.
A load lock system is attached to a sideport of the source recipient. It consists of the preparation respective storage chamber and the load lock (for details see [10]). The problem of limited cathode lifetime has been sidestepped by this measure, since an exchange of a freshly prepared cathode may be done very quickly. Two hours are needed for preparation and transfer of a cathode between source and preparation chamber.
The new setup was successfully applied in a first measurement of the electric neutron formfactor at high momentum transfer (17 fm$^{-2}$) via the reaction $^3\vec{H}e(\vec{e}, e'n)$ [11] and an experiment to find E2/C2 contributions in $N \rightarrow \Delta$ transitions through the $H(\vec{e}, e'\vec{p})\pi^0$ reaction [12]. The status of the new source is shown in table 1.

| | |
|---|---|
| Cathode | strained $GaAs_{.95}P_{.05}$ |
| Polarization | $73\,\% - 77\,\%$ |
| Quantum efficiency | $(1 - 1.5)\,\mu A/mW$ |
| Wavelength | $832\,nm$ |
| Dark lifetime | $> 1000\,h$ |
| Lifetime at 20 $\mu A$ | $\approx 100\,h$ |
| Transmission pulsed | $93\,\%$ |
| Transmission d.c. | $50\,\%$ |
| Current density | $20\,mA/cm^2$ |
| transverse emittance | $0.4\,\pi\,mm\,mrad$ |
| Vacuum conditions | $H, H_2 : 4\,10^{-11}\,mbar$ |
| | $Rest < 10^{-11}\,mbar$ |

Table 1: Status of the source of polarized electrons at the injection point of MAMI.

## 3 SPINDYNAMICS IN MAMI

Because of the anomalous magnetic moment $a$ of the electron the polarization vector precesses faster than momentum in the two dipol magnets of the microtron [13]. Therefore one needs a procedure to align the spin at the target, where longitudinal polarization is wanted in most experiments. In the new arrangement no spinmanipulator was implemented, because of its strong dispersive property and the shortness of the low energy beamline. The adjustment to longitudinal spindirection at the target is done by slight energy variation of the third microtron stage instead. The injection energy $E_0$ and energyshift per turn $\Delta E$ must be varied by a common factor $dE_n/E_n$. That produces a variation of the spinorientation

$$\Delta\phi = \frac{2\pi a}{m_0 c^2}(n+1)(E_0 + \frac{n}{2}\Delta E)\frac{dE_n}{E_n} \tag{1}$$

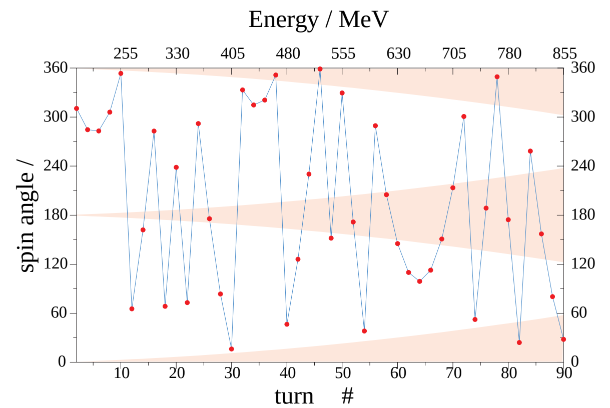


Figure 2: Spindirection in experimental hall A1 for extraction; case of standard accelerator adjustment. The grey regions symbolize the areas, where a longitudinal spindirection may be adjusted by slight ($\leq 0.15\,\%$) energy variation.

where n symbolizes the number of the extraction turn. n=90 leads to

$$\Delta\phi = 45\,°\,/\,MeV \tag{2}$$

This result is experimentally verified. With three measurements of spindirections at different energies a prognosis of the spinangle for all possible energies can be given with an accuracy of 3°. Depolarization in the third microtron stage calculated with an enlarged trace program [14] is in the range of $10^{-4}$ and mainly caused by the magnetic field of the linac cavities.

## 4 14 MEV - MOTTPOLARIMETER

A 14 MeV - Mottpolarimeter (figure 3) was installed behind the first microtron stage where the polarization vector is orientated 141° with respect to momentum. Only one dipol has to be switched off to guide the electron beam to the gold target of the polarimeter. Scattering angle is 172° defined by two coincidence arrangements consisting of two $\Delta E$ - and one stopdetector S. The energie resolution is about 20 %. The theoretical Sherman function is

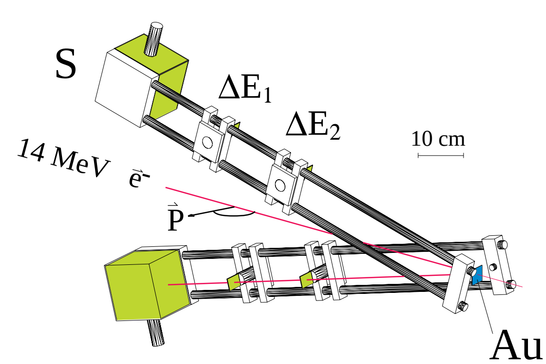


Figure 3: The 14 MeV Mott - polarimeter

S(14 MeV, 79, 172°) = -0.256 [15]. First tests agree the results of J. Sromicki [16]. The polarimeter is absolutely calibrated by foil thickness extrapolation and by comparison with a 100 keV - Mottpolarimeter in the beamline of the old source.

## 5 CONCLUSION

The spinpolarized electron beam available at MAMI has gained in operational stability and maximum current by

- Installation of a source right at the injector linac. Beam emittance and halo are at least as low as that of the standard unpolarized beam.
- Addition of a harmonic cavity to the prebuncher section of the injector linac and running the source in pulsed mode. A capture efficiency at injection of 93 % is obtained.
- Adjustment of spin orientation at target by slight variation of accelerator energy. Longitudinal polarization may be obtained for most energies available from the final mictron stage.

The demands of all current experiments with polarized electrons at MAMI may be satisfied by the new source configuration.

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