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Status of precise measurements of electron-beam polarization changes during long term operation

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For the high-precision measurements in the experiments at the new Mainz Energy recovering Superconducting Accelerator (MESA), it is necessary to know exactly the long-term spin properties of the electron beam. For this purpose, a test setup has been built at the Institute for Nuclear physics. Comparison is made between two processes for activation of a photocathode using oxygen and nitrogen trifluoride.

The aim is to examine the possible advantages of an oxygen-free preparation, especially with regard to the influence on the evolution of spin polarization during the experiment. The setup and the first preliminary results are presented here.

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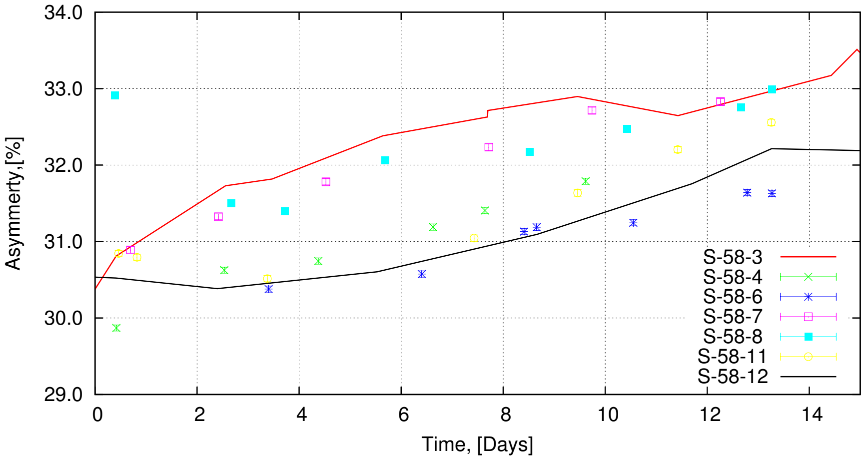

Figure 1: The asymmetry changes during operation. These Mott scattering measurements have been taken at the MAMI accelerator. These measurements have been made with the same cathode at different reactivations as indicated by the last two digits in the legend entries. The first and last usage of the cathode is printed in solid lines. Taken from [1].

1. Motivation

In Mainz a new energy-recovering superconducting accelerator called MESA is under construction [4]. This project shall be able to perform in two different modes, feeding two different experiments. One experiment will use the energy-recovering mode (ERL-Mode) while using unpolarized electrons with currents up to 1 mA at 105 MeV. The other experiment called P2 [3] will use the full energy of 155 MeV but with polarized electron beams in the external beam operation. P2 aims to measure precisely the weak mixing angle and is therefore a key experiment to the MESA project.

1.1 Generation of polarized electrons

Spin polarized electrons are produced from GaAs-based photocathode-heterostructures. Moreover, the NEA state is mandatory to achieve sufficient polarization since well defined S-like electronic states exist only at the bottom of the conduction band. NEA state requires covering the surface with dipoles which may be formed by Cs:O or Cs:NF_3. A drift of beam polarization, as depicted in fig. 1 is observed for Cs:O covered surfaces in our experiments at the Mainz Mikrotron (MAMI). The purpose of this work is to observe if such changes also occur for Cs:NF_3 NEA surfaces. To do so we have modified one of our apparatuses, the so-called "Polarisierte Kanone-2" (PKA2) test apparatus, for both NEA options. In order to observe the drift of polarization a stable measurement is necessary. We describe the modifications of PKA2 with respect to this features in the following. The idea is to exchange the oxygen in the NEA surface with nitrogen trifluoride (NF_3) and to look at relative time dependent changes of the asymmetry. The quantum efficiency tends to be more stable with NF_3 than with oxygen [2].

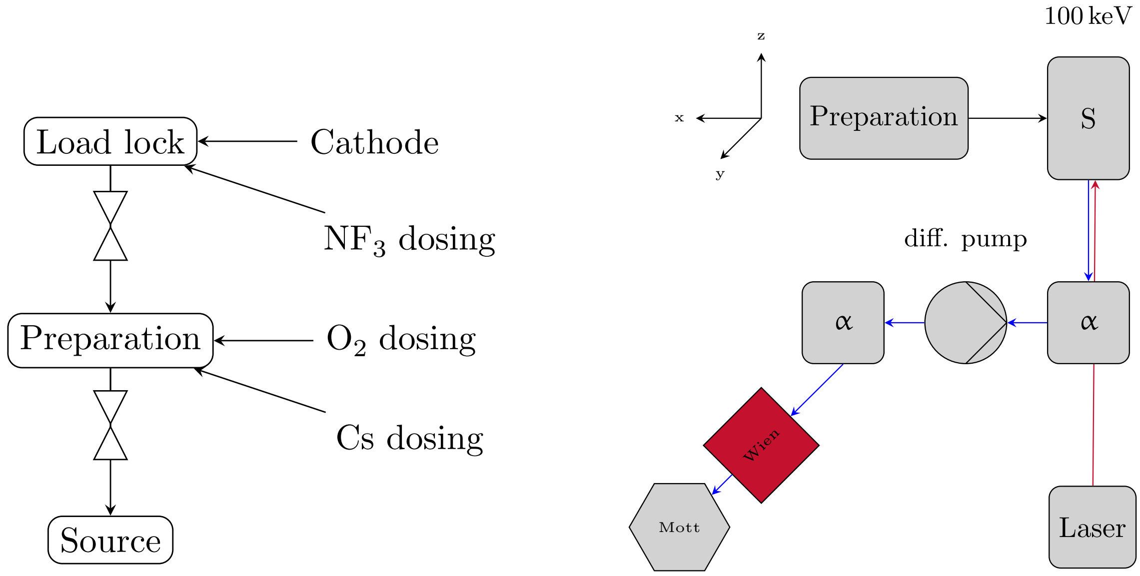

Figure 2: A schematic view of the experimental setup. On the left a scheme of the load lock and preparation chamber is presented with indications of dosing system positions. On the right is a sketch of the whole system. After a cathode is introduced into the system and undergone the preparation process it can be transferred into the source (S). Laser light will excite electrons which will travel through the beamline, bend with an alpha magnet into the x-axis, passing through a differential pumping stage before passing the second alpha magnet. This will bend the beam into the y axis and into the Mott scattering experiment after it passed the spin rotation system (Wienfilter) to change the spin direction of the beam from longitudinal to vertical.

2. Experimental Setup

A schematic view of the whole apparatus is presented in fig. 2, on the left side a more detailed sketch of the load lock and on the right side the presentation of the beamline. Fresh photocathodes can be introduced via load lock system where the NF_3 dosing system with leak valve is implemented as indicated in left side of fig. 2. The NF_3 dosing system was retrofitted to the existing load lock of the preparation chamber of the test apparatus. This was possible without great effort and has no disadvantages for the preparation process since the conductance of the open valve is large. Due to the small volume of the load lock acceptable vacuum conditions have been achieved after baking. From load lock cathodes and NF_3 gas are transported into the preparation chamber. The infrastructure of photocathode preparation consists of a Laser (674 nm) with cesium dispenser and a small ring anode. The partial pressure of NF_3 and O_2 can be measured with a mass analyzer which is directly connected to the preparation chamber. Alternatively, oxygen preparation is possible since a leak valve and reservoir for oxygen is implemented at the preparation chamber itself. After the preparation the photochatode is introduced into the source chamber which allows producing the 100 keV beam. The electrons travel through about 5 m beam transport line with several beam focusing elements into the Mott polarimeter. A successful activation with NF_3 has already been done and served to produce the data discussed below.

Mott scattering refers to the back scattering process of polarized particles on unpolarized nuclei. Typically gold nuclei in thin foils are used as target and a spin rotating system in order to rotate

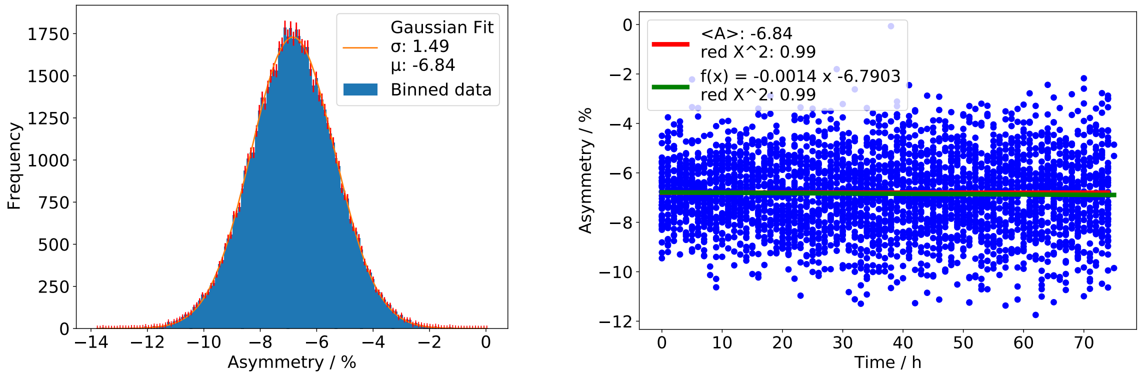

Figure 3: On the left side the histogram of the asymmetry measurement is shown with its Gaussian fit. The right hand side shows the time dependent evolution of the asymmetry. The time evolution was tested against a model proposing constant asymmetry (red) or a linear changing asymmetry (green).

the polarization vector orthogonal to the scattering plane since the initial polarization direction is parallel to the beam momentum. In this experiment a Wienfilter [5] is used to rotate the spin of the electrons. Since using a 100 keV source, the back scattering angle for Mott scattering is at 120° fixed. This angle was chosen since the Sherman function which describes the proportionality of the asymmetry to the polarization, has the maximum absolute value close to this angle for this electron energy.

3. Preparatory measurements

A number of factors have been investigated in order to evaluate the system for long-term measurements. A shorter measurement of the asymmetry that lasted for three days revealed a Gaussian distributed asymmetry fig. 3 with a mean value μ of 6.8 % and a standard deviation σ of 1.5 % in the histogram. These data have been measured with a gold target of 98 nm thickness and a fixed back scattering angle at 120°. Important to note these measurements have been performed with quantum efficiency as low as 0.05 %, which is almost an order of magnitude below the QE at which the data of fig. 1 have been taken. A stable state of the cathode can be assumed. The time evolution of the asymmetry during the three day run shows no significant changes; a fit under the assumption of stable electron spin polarization shows a reduced χ^2 of 0.99. However, a fit with a linear decreasing asymmetry yields the same χ^2 as is compatible with a relative increase of the polarization of about 1 % in two days. This indicates the need for further and longer measurements to investigate the time dependent behavior.

In order to achieve even better results the beam conditions needs to improve since the transmission during operation was 75 %. Better comparison with the MAMI experiment is achieved if a masked activation which limits the excess of activated area, is used. As was shown, this is a tried-and-true technique at the MAMI accelerator [6].

4. Summary

A method of photocathode activation with nitrogen trifluoride has been implemented. We will now start investigations if the NF_3 based activation will change the drift behaviour as seen in fig. 1.

The NF_3 infrastructure was installed and successfully tested.First asymmetry measurements after NF_3 activation showed reliable and consistent results and a further improvement of the procedure and apparatus are ongoing. The asymmetry has been measured with a low quantum efficiency which may lead to less drastic changes in asymmetry as seen in fig. 1.

Acknowledgments

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References

[1] V. Tiokine, K. Aulenbacher, *Polarized Atomic Hydrogen Target at MESA*, *PoS PSTP2019* (2020).

[2] N. Chanlek *Quantum Efficiency Lifetime Studies using the Photocathode Preparation Experimental Facility Developed for the ALICE Accelerator*, *PhD thesis*, *Manchester* (2011).

[3] D. Becker, R. Bucoveanu, C. Grzesik et. al *The P2 experiment*, *Eur. Phys. J. A*, (2018), **54**, 208.

[4] F. Hug, K. Aulenbacher, D. Simon et. al *Beam Dynamics Layout of the MESA ERL*, *Proc. ERL´19* (2020), 28–33.

[5] V. Tioukine, K. Aulenbacher *Operation of the MAMI accelerator with a Wien filter based spin rotation system*, *Nucl. Instrum. Methods Phys. Res., Sect. A*, **568**, (2006), 537–542.

[6] K. Aulenbacher, V. Tioukine, M. Wiessner et. al *Status of the polarized source at MAMI*, *AIP Conf. Proc.*, **675**, (2003), 1088.