NEW INSTALLATIONS AND BEAM MEASUREMENTS AT MAMI [1]

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Abstract

During the past 3 years the cw racetrack microtron cascade MAMI [1] has been significantly improved, thus extending the scope of experiments in nuclear and radiation physics. The 100keV injection was successfully reconstructed for the installation of a second source of polarised electrons and for increased capture efficiency ([2],[3],[6]). At the high energy end of the accelerator a new transport line was installed to guide the beam to two of the old experimental areas for experiments with coherent x-rays (collaboration X1). The beam diagnostics were further extended by: 1) synchrotron radiation monitors in the last two microtrons (RTM2&3), enabling emittance measurements at higher cw beam currents, 2) improved rf position and 3) a larger number rf phase monitors. Two of the latter, working at 9.8GHz, are used for a second high resolution beam energy measurement. On the occasion of transverse beam optical measurements in RTM3 beam current-depending nonlinearities were detected. There were most probably caused by ion-trapping in the electrical potential of the beams on the linac axis.

1 THE 100KEV INJECTION

The 100keV injection lines of MAMI described in [4] and [5] were modified in 1996 mainly in order to enable the injection of polarised electrons from a second GaAsP-photogun close to the injector linac and to improve the beam capture efficiency [6].

The correct functioning of the harmonic prebuncher described in [6] was demonstrated shortly after completion. By setting the amplitudes in both the 2.45GHz-cavity and the 4.9GHz-cavity close to the calculated values, 50% of the dc current from the thermionic gun could be accelerated to full energy without measurable degradation in beam quality. Fig.1 shows the result of the particle transformation to the entrance of the injector linac for the cavity amplitudes obtained from the beam test. Nearly all particles starting

with a phase extension of 200° are collected in the acceptance area. Although the longitudinal phase space at 3.5MeV (s. photograph, fig.1) is significantly increased in comparison with the normal operation it fits well into the RTM1 acceptance and does not produce an additional beam halo. The total transmission from the photogun to the target was increased to 94% by short laser pulses synchronised to the MAMI frequency [3]. By switching the laser modulation to a subharmonic frequency, single bunches could be produced for precise and easy detector calibration in the nuclear physics experiments.
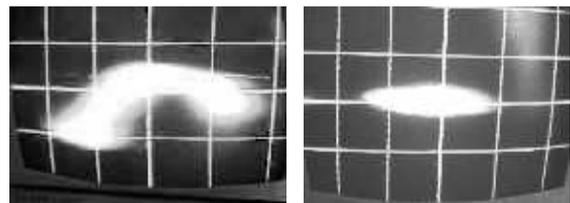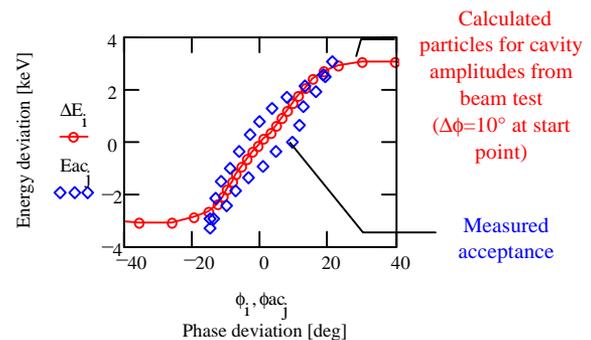

Figure 1: Longitudinal phase space at the entrance of the injector linac (above) and at 3.5MeV with standard (right) and with harmonic prebuncher (15% resp. 50% total transmission). Screen cal.: 2°/div. hor. and 4keV/div. vert.

Due to both its shorter distance to the injector linac and the smaller number of optical elements the tune-up time for the new polarised gun is only 10min. compared to about 10h for the old setup. The normalised 1σ-emittance

was decreased from about $0.1\pi*10^{-6}$m to $0.05\pi*10^{-6}$m. Also for the thermionic beam an emittance reduction to about 1/3 could be observed at low currents. This was presumably due to a reduction of spherical aberrations by weaker focusing in the first two solenoid lenses.

The accelerator was prevented from mistuning of the guns by an additional 2.5mm collimator. In combination with the first collimator of the chopper system [4] an emittance limitation to $1.3\pi*10^{-6}$m was obtained. The beam intensity is slightly modulated (10^{-3}-10^{-2}) on its passage through the collimators, which is accounted for by small 50Hz position fluctuations and acceptance mismatch.

2 TRANSPORT SYSTEM FOR X1

At the high energy end of MAMI a new beam transport system (s. fig. 2) was installed for experiments with coherent x-rays produced by the electron beam (collaboration X1). The existing transfer system is bypassed by an achromatic bending system behind the RTM3 to obtain a 20m long straight line for experiments with undulators. To obtain maximum flexibility for the beam parameters, the system was designed to be equivalent to a simple drift space of about equal lengths in both planes.
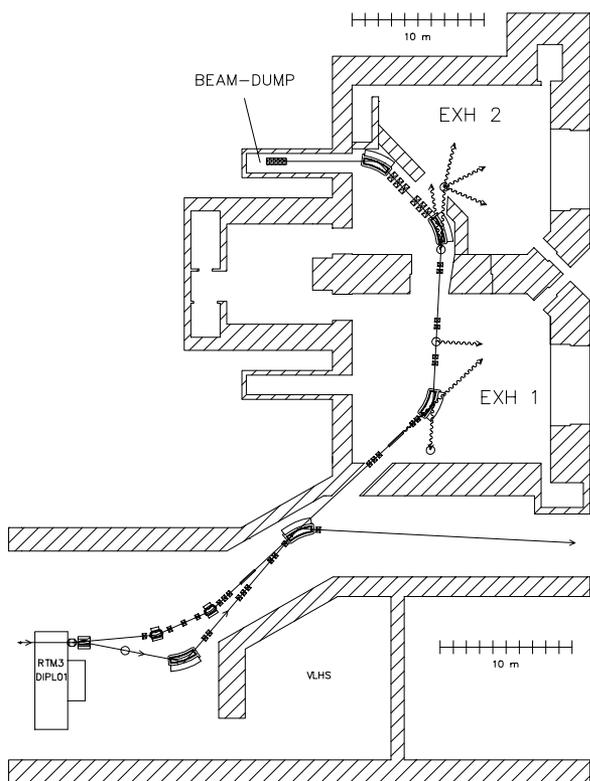

Figure 2: Transport system for the X1 experiments.

Behind the dipole in EXH1 the beam is used for experiments with parametric x-rays and transition radiation. An achromatic transformation to this line is achieved by tuning the first part of the system in such a way that the dispersion of the EXH1-dipole is compensated.

The deflecting system to the beam dump was optimised for high transverse and longitudinal acceptance. Thanks to the large aperture of its components (gap distance 11cm and quadrupole aperture 14cm) more than 99% of the beam diffused by a 1mm thick Be-radiator are transmitted to the dump. The beam line has been successfully in operation since its completion in September 1997.

3 MONITORS

For beam diagnostics along the X1-beam line and for a parity violation experiment a new version of rf position monitors has been developed [7]. Here, the signal of the TM_{110}-mode is extracted by two antennas (instead of one loop at the former design) excited with 180° phase difference. The disturbing common mode signal from the TM_{010}-mode is significantly suppressed after subtraction in a 180° -hybrid. Further reduction is achieved after passage through the mixer because of about 90° phase difference between the two modes. Fig. 3 shows the signal excited by a pulsed beam (92μA, 10ns) at 2mm displacement and at the centre of the monitor. The remaining distortion at the beginning of the pulse does not depend on the beam position. It is thought to be caused by the remaining influence of the TM_{010} mode.
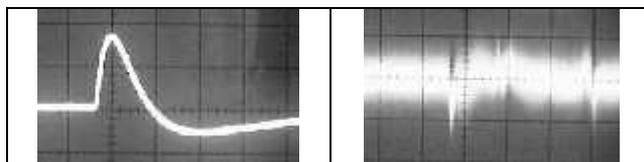

Figure 3: Rf-monitor signals. *Left*: 2mm displacement of the pulsed beam. *Right*: Centred beam (0.06mm/div.).

The transverse beam matching to RTM2 and RTM3 was very much simplified by the installation of synchrotron radiation monitors at the end of the linac axes of these stages.
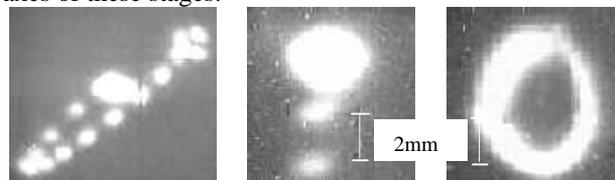

Figure 4: Beam spots from synchrotron radiation at the end of the accelerator axes. In RTM2 (left) the last 15 turns and in RTM3 the last 2 turns are displaced. On the right the different beams in RTM3 are displaced one by one to form a circle.

Although all of the 51 resp. 90 beam spots are on top of each other, the optimisation for minimum spot size is very easy and leads to good results. For turn by turn observation a beam bump can be shifted through the RTM3 by an automatic control of the steering coils in the

return paths. This opens for the first time at MAMI the possibility to measure the beam emittance at high cw currents. The bump routine was tested successfully at intensities up to 30μA.

In addition to the energy measurement device described in [8], a second system was installed at RTM3. This utilises the energy dependent time of flight through one of the 180° bending magnets. For this purpose two TM_{010}- cavities operating at 9.8GHz were installed in front of and behind the second RTM3 bending magnet on the 855MeV extraction path. Beam energy fluctuations are detected by measuring the phase difference of the rf-waves excited in these resonators by the electron bunches. The system turned out to be very sensitive and precise to about 1keV. This limitation is due to the fact that small fluctuations of the horizontal beam direction at the magnet entrance also lead to different path lengths.
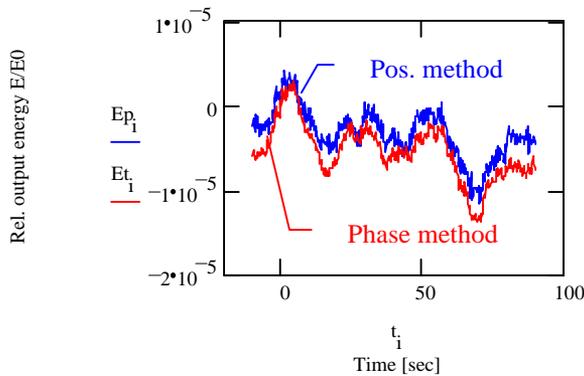

Figure 5: Energy variations at the RTM3 output.

4 ION-TRAPPING

During investigations of the transverse beam optics in RTM3 a non-linear behaviour was detected at higher currents. Fig. 6 shows the signal of the 9.8GHz position monitor [8] in the last return line for a triangular modulation of the beam direction in front of RTM3.
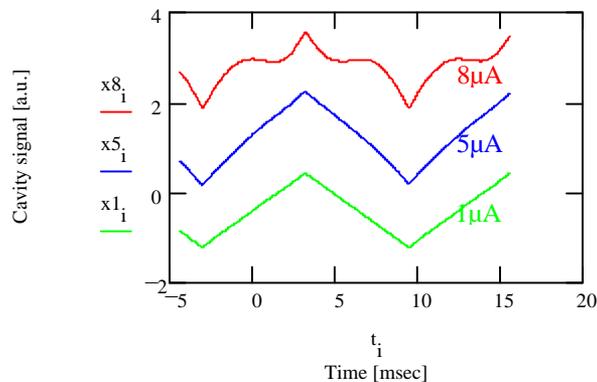

Figure 6: Horizontal beam motion in turn 90 at different cw beam currents.

The non-linear motion at 8μA can be explained by a small additional focusing, produced by the electric field of positive ions trapped in the potential of the 90 beams

on the linac axis. This potential is maximum if all beams are well centred there. At high betatron amplitudes the mean beam size is larger, leading to a smaller potential so that the ions are partly released. In agreement with this, the threshold of nonlinearity was shifted to a higher beam current (8μA) in case of the hollow beam configuration (s. fig.4, right). In fig.7 the measured focal strength increase is shown with and without a "clearing voltage Vc" at electrodes on both ends of the accelerator axis.
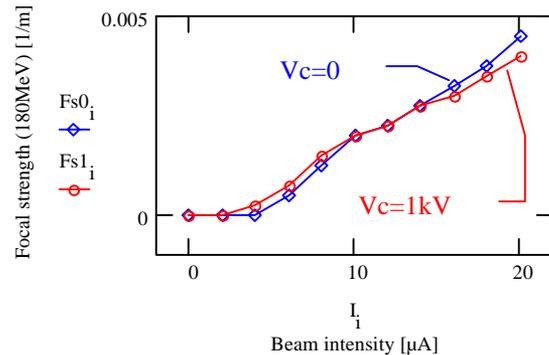

Figure 7: Additional focusing by ion-trapping.

5 SUMMARY

The capabilities of the cw electron accelerator MAMI were successfully extended by an improved injection system including a second polarised gun, and by a special beam transport system for coherent x-ray experiments. In addition, the monitor system was further developed in order to meet the increased requirements from the experiments. Ion-trapping effects were detected during beam optical measurements.

6 REFERENCES

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