Proceedings of the 1981 Linear Accelerator Conference, Santa Fe, New Mexico, USA

OPERATING EXPERIENCE WITH MAMI I

H.Aufhaus, H.Euteneuer, H.Herminghaus, W.Heyne, K.H.Kaiser, H.J.Kreidel, U.Ludwig-Mertin, K.Merle, H.v.d.Schmitt, H.Schoeler, G.Stephan

Institut für Kernphysik,Universität Mainz, W-Germany

Summary

MAMI I, a 14 MeV room temperature racetrack microtron for c.w. operation, has been run for about 1200 hours during the past two years, showing quite satisfactory performance. We were especially pleased by the good reproducibility of beam optimization and excellent long term stability of the beam during a run. Nevertheless, the operating experience gave us several good hints on the construction of MAMI II (175 MeV).

Introduction

MAMI I is the first of a cascade of 3 room-temperature race track microtrons for c.w. operation |1| The parameter of which are compiled in Tab. 1. MAMI has been set into operation in spring of '79 and has been run for about 1200 hours, mostly for machine studies, but also for nuclear physics experiments |2|, |3|, |5|, |6|, |7|.It is, to the best of our knowledge, the first room temperature microtron for c.w. operation.

		stage I	stage II	stage III
General				
Input energy	MeV	2.1	14	175
Output energy	MeV	14	175	840
Number of recyclings		20	51	74
Total power consumpt	kW	280		900
Magnet system				
Magnet distance	m	1.66	5.59	11.83
Magnetic field	T	0.10	0.54	1,54
Max.orbit diameter	m	0.97	2.17	3.65
Magnet weight (each)	to	1.3	43	240
Gap width	cm	6	7	10
r.f.system				
Number of Klystrons		2		5
Linac length	m	0.80	3.55	10.4
Total r.f.power	kW	9	64	197
Beam load	kW	1.2	16	67
Energy gain turn	MeV	0.59	3.16	9.0
Beam performance (design, at 100 μA)				
Energy width	keV	± 9	± 18	± 60
Emittance	mm mrad	0.17π	0.04π	0.1π
Status		operating	under constr.	not yet funded

Injector: at present van de Graaff, later injector linac

Klystrons: Thomson-CSF TH 2075, 50 kW c.w.

Frequency: 2449,3 MHz

Tab.1 Main parameters of MAMI

With such a machine a couple of problems arise from the low accelerating field gradient of a room temperature c.w. accelerator. Some of these are treated by special papers of this conference.

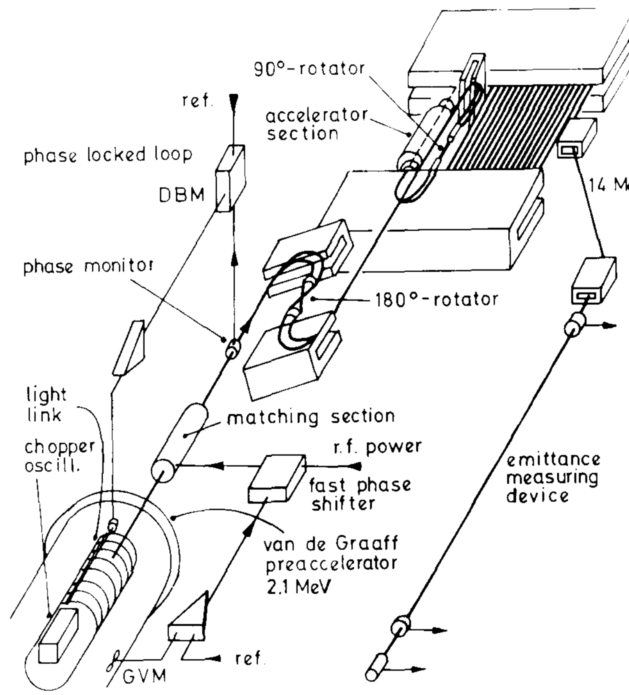

Fig. 1 Scheme of MAMI I with some analog control loops

Injector and Interface

A schematic view of MAMI I is shown in Fig. 1. The beam is chopped in the terminal of the van de Graaff by a coaxial cavity driven by a triode oscillator at half the operating frequency. This oscillator is phase locked from a bunch phase monitor at ground potential. This system works very satisfactorily.

The matching interface between van de Graaff and the microtron (described in more detail in ref. |4|) consists mainly of two achromatic straight sections for transverse matching and an r.f.section followed by two 180° bends (providing longitudinal dispersion) for longitudinal matching. Between the bends a pair of solenoid lenses rotates the beam by 180°, so that the transverse dispersions of the bends cancel on the following straight section. Inflection is done by an upright standing 180° bend.

The beam downstream the van de Graaff shows an energy ripple of several keV amplitude due to voltage ripple of the van de Graaff. The acceptance of the microtron, however, allows a shift of about 2 keV only. Thus an error signal from the van de Graaff terminal voltage is used to shift the phase of the r.f. in the matching section by means of a quick phase shifter in such a way as to cancel the energy ripple of the van de Graaff to first order downstream the matching section. This system has proven to reduce the energy ripple reliably to a few hundred volts which is more than sufficient to allow stable operation of the microtron.

Much care proved to be necessary to adjust the interfacing system both with respect to longitudinal matching and dispersion free injection into the microtron. This once being done, however, the system works quite satisfactorily and stably. Transverse matching is done by two quadrupole doublets on the second straight section of the interface. With these quadrupoles being set to the values as calculated for optimum matching the beam is accepted by the microtron. It is, however, also accepted at somewhat different settings and it is hard to say which of the settings would really provide optimum matching (and thus the largest margins of safety against misalignments). Since we have no diagnostics for the beam envelope in the microtron a special matching procedure is presently being tried using the position monitors in the microtron.

The microtron

The microtron itself is shown with its diagnostic and correcting elements in fig. 2. The monitoring system involves beam position, beam intensity and bunch phase. It consists of r.f. resonant cavities which are excited by the bunched beam. Distinction between revolutions is done by marking the beam by 10 nsec bursts or blackouts respectively. Both horizontal and vertical deviations are detected in one cavity simultaneously. This system which has been described in detail elsewhere |1|, |3|, |9|, |8| is working quite reliably and satisfactorily in burst mode. Beam offset of a few tenths of a mm from the linac axis is easily detected for each revolution. In the blackout mode the system works well at relatively low beam intensity. At intensities higher than about 20 μA however, its r.f. detectors suffer from overload. On the other hand, the beam is usually so stable that the use of the blackout mode for monitoring during operation at high beam intensity is less important than expected previously. Nevertheless, modified monitors have been developed which are essentially free from overload |10| yet are more sensitive and easier to manufacture. They will be used in the following stages.

The magnets are homogenized by means of correcting coils as described in detail in |4| to $\pm 1\cdot10^{-4}$ over the inner pole face area. They are turned on and off by a ramping procedure and may, if necessary, be cycled in a special manner. With a field error of $\pm 1\cdot10^{-4}$ the correcting steerers should not need to be excited to more than a few tenths of a mrad deflection to center the beam in the linac if the magnets are correctly positioned. We need, however, at a few steerers more than one mrad. We conclude that the field distribution in the fringe field region (which could not be measured with high accuracy) might not be adequate. Unfortunately, it is not possible to do accurate measurements there now without dismantling the whole microtron. For the following stages we will design the steerers for some more steering capability than planned initially.

The positioning of the main magnets is very critical indeed, as expected, and it turned out that, in practice, the only adequate criterion for minimizing steerer excitation is given by the beam behaviour in the operating machine. Therefore, in the following stages we will provide the possibility of magnet adjustment during operation by means of remotely controllable supports.

The r.f. system of MAMI I proved to be very reliable indeed. We are especially pleased by the fact

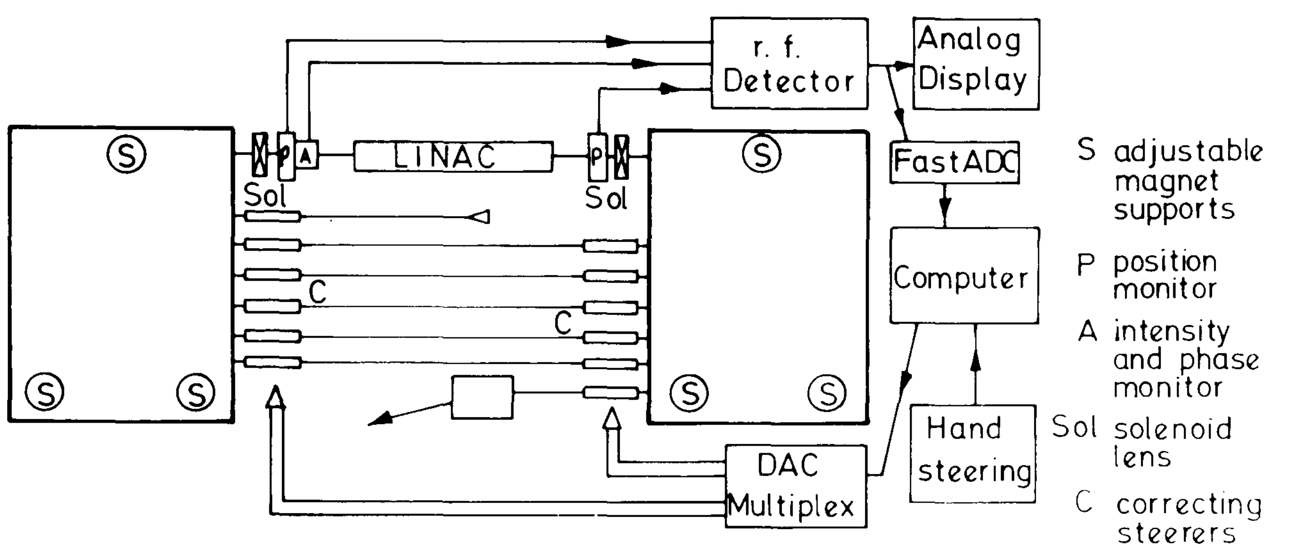

Fig. 2 Scheme of diagnostic and correcting elements of MAMI I

that we never experienced any difficulty with multipactoring in the accelerator section which is a slightly modified on axis coupled biperiodic structure of the Chalk River design |11|, |3|.

The beam transmission of the machine depends, of course, on the bunch length for which we usually use the chopping ratio (i.e. the beam intensity with the chopper turned off divided by beam intensity with chopper turned on) as a measure, the latter being adjusted by the power of the chopper oscillator. Beam transmission is 25 ... 30 % with an unchopped beam. It grows to 80 ... 90 % at a chopping ratio of about 10 and to 95 ... 100 % (within errors of a few percent) at a chopping ratio of 16. These numbers do not depend strongly on the beam intensity, but, generally, the lower number applies for high intensities ($\geq$ 50 μA). The maximum intensity reached so far is ≈5 μA, at a bunching ratio of about 10, limited by gun emission.

Computer control allows us to set MAMI into operation to a large extent automatically by restoring all setting of one of the previous runs. Usually, if adjustments, etc., have not been changed in the meantime, the beam then will be available immediately at the output of the microtron. Small misalignments that might show up after the automatic setup procedure are quickly smoothed by the automatic beam-steering procedure described in the paper of H. J. Kreidel. Generally, the microtron itself proved to be considerably less critical than the injection system.

Emittance measurements have been done both in the interfacing system and downstream the microtron, using wire scanners and a pair of collimators and steerers respectively. All these measurements were perturbed more or less by some transverse beam jitter caused by spurious a.c. magnetic fields in the van de Graaff and along the injection path. Shielding is not everywhere possible and cumbersome in many places. Provisionally installed systems to suppress this jitter by countersteering were partly successful but difficult to handle. From the geometry of the gun we expect a normalized emittance of 0,7 π mm mrad vertically and 1,4 π horizontally. Downstream the microtron we measure values around 5 π which are clearly mainly given by beam noise. Incidentally, this value corresponds fairly well to the original design value |1|, which had been assumed to be more than adequate. Clearly there will be ways to suppress beam jitter finally. Anyway, this effect is not strong enough to influence beam transmission significantly. The ΔP/P width has been found to be around $1 \cdot 10^{-3}$.

MAMI has been running for users' experiments for about 200 hours total. Usually the machine behaved perfectly stable throughout a run (up to 10 hours), so it was possible to operate the machine by the user himself during the night, and the only know-how needed was how to turn off the machine properly after the run.

|1| H.Herminghaus et al., Nucl.Instr. & Meth.138 (1976) 1

|2| Lecture notes on Physics, No. 108, Springer 1979

|3| Jahresbericht 1978/1979 Institut für Kernphysik, Universität Mainz

|4| H.Herminghaus, K.H.Kaiser and U.Ludwig-Mertin, Nucl.Instr. & Meth. 187 (1981) 103 - 107

|5| U.E.R.Berg et al., Proc.Int.Symposium on Highly Excited States in Nuclear Reactions, Osaka, Japan, May 1980

|6| J.Buchart, Diplom Thesis, Institut für Kernphysik, Mainz 1980

|7| G.Gräff et al., to be published

|8| B.Mertin, Diplomarbeit, Institut für Kernphysik, Universität Mainz, KPH 5/80

|9| W.Heyne, Diplomarbeit, Institut für Kernphysik, Universität Mainz, KPH 20/81

|10| H.Herminghaus, Institut für Kernphysik, Universität Mainz, Int.Note MAMI 8/80

|11| S.O.Schriber et al., Proc. of the 1976 Proton Linear Accelerator Conf. Chalk River, AECL-5677, p. 338, p. 405

Discussion

Our initial pin-diode problems were only because the company shipped reverse-polarity diodes and it wasn't noticed. The total maximum power that the VCX pin-diode system would have to absorb is about 100 W of reactive power. The frequency band of the VCX is now 150 Hz; still small but increased from about 80 Hz initially, when we had problems with the amplitude control from things like the exact operating frequencies of the turbopumps, and so on. At 150 Hz, we don't have those problems. Also, if we run the linac at full fields, we are in lock 90% of the time and have to recondition resonators on the average of one every 2 to 3 days. If we can run at 80 to 85% of full field, we can run for months without reconditioning and with essentially 100% lock-in.

For Ni^{58}, our proposed end energy is about 15 MeV/amu. For carbon and oxygen, it is about 25 MeV/amu; by the time you get to magnesium it is down to 21 to 22 MeV/amu and drops on down.

Our energy gain per meter is about 2.4. We don't completely understand what breaks down when we reach the maximum. Sometimes there is electron loading; sometimes not, but rather seemingly periodic breakdowns that do not seem to reflect the Q falloff. We suspect different types of cooling problems in the individual resonators. Qs are mostly at 10^8 or 10^9, but in some cavities there is a Q falloff--dramatically at higher field levels. We will be studying this further.

We have tested the Cockcroft-Walton system for the higher frequency system and it agreed with design calculations; we have not tested the prototype yet.

We have let the cavities up to both clean, filtered nitrogen and helium. We honestly don't understand what happens when we recondition resonators. The degradation we recondition for varies dramatically from resonator to resonator, but let me point out that unless there is an accident, there is no serious degradation. We go through the reconditioning cycle, and when we succeed in finding a field level that gives stable operation for a few days, there will be no deterioration for a couple of months--our longest running time so far. From some accidents, we have concluded that large condensable gas loads on the surfaces are not an intrinsic problem--something else happens to the surfaces.