THE IASA RACETRACK MICROTRON FACILITY: A PROGRESS REPORT

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Abstract

The design of the 240 MeV two-stage CW cascade racetrack microtron (RTM) accelerator of the Institute of Accelerating Systems & Applications (IASA) is presented. The present status on the performance of the already installed 100 keV line and the diagnostic line for measuring the transverse beam emittance is discussed. Further developments are also briefly outlined.

1 INTRODUCTION

The Institute of Accelerating Systems and Applications (IASA) is pursuing research and facilitates postgraduate studies in traditional and cross-disciplinary areas where accelerators play an important role. The design of a 240 MeV two-stage CW cascade racetrack microtron (RTM), making optimal use of the available linac sections, RF equipment and End-magnets from the NIST/LANL Racetrack Microtron [1] and the University of Illinois R&D RTM projects [2], has been completed. Both the optical design and the civil construction plans for the RTM have been reviewed and met the approval of an international committee of experts. During the on-going period of design and construction of the accelerator vault and associated experimental areas for the RTM Laboratory, a staging area has been set up which provides adequate space and supporting facilities for the installation, testing and operation of important projects for the realization of the accelerator. In this context, the 100 keV line (the first part of the RTM injector) has been installed and, very recently, a diagnostic line for measuring the transverse emittance has been incorporated to the installation. In the following sections a description of the important aspects of the optical design of the IASA accelerator as well as the present status of operation for both the 100 keV and transverse emittance measuring lines will be given.

2 THE ACCELERATOR

The design philosophy of the IASA Accelerator is based on a two stage cascade Microtron and comprises of a 6.5 MeV injector followed by the first stage 41 MeV RTM and the second stage 240 MeV RTM. The layout of the whole accelerator is given in Fig. 1. An incremental number ν=1 has been chosen, leading to a simplified tuning and operation of the accelerator, and modest RF power consumption. The main characteristics of the machine are summarized in Table 1 while other detailed information (as for example for the RF consumption) may be found at the IASA Web site (http://www.iasa.uoa.gr).

Table 1: The main characteristics of the IASA Cascade RaceTrack Microtron.

	INJ	RTM1	RTM2
Injection Energy [MeV]		6.5	41
Gain per Turn [MeV]		1.32	8.0
Number of Recirculations		26	25
Max Output Energy [MeV]	6.5	41	240
Max Current [μA]	600	100	100
Frequency [MHz]	2380	2380	2380
Incremental Number ν		1	1
Magnets Field [Tesla]		0.2196	1.338
Spacing [m]	8.8	3.25	8.7
RF Power Consump. [kW]	116.9	28.9	167.7

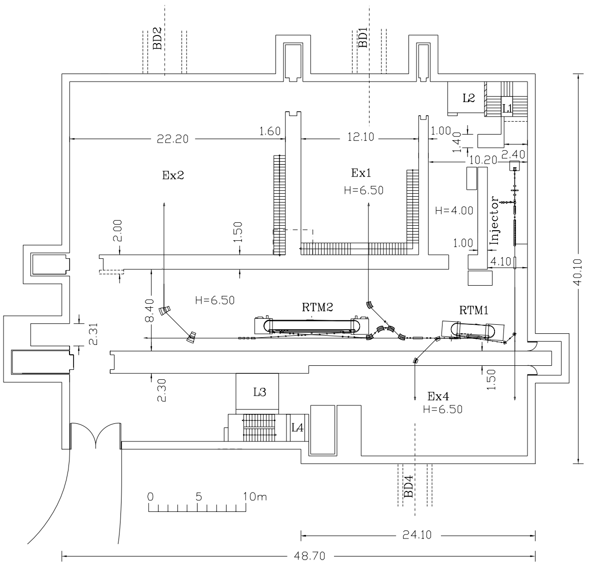

Figure 1: Layout of the IASA two-stage RaceTrack Microtron Accelerator and civil construction.

The injector consists of two electron guns (a thermionic

100 keV electron gun and a polarized electron source), a chopping and bunching system, a capture section, a pre-accelerator and a booster. Its optics has extensively been studied with the code PARMELA [3]. The calculations show that the injector can be tuned such as to match the first Microtron in longitudinal as well as in transverse space without any further measures. Both microtron stages use quadrupole doublets on either side of the Linac for transverse focusing, they use the MAMI schemes [4] for injection and variable energy extraction. The first Microtron (RTM1) is designed to operate with an asymptotic synchronous phase of 18 deg. The choice of that particular value is made on the basis of keeping the longitudinal acceptance of RTM1 sufficiently high while relaxing the need of an extremely demanding control of the RF stability and injector output energy. By incorporating a weak quadrupole in the extraction magnet in the return paths, the beam can be made free of dispersion at the exit from RTM1. This results in very simple beam optics downstream RTM1. The second Microtron (RTM2) is to be operated at a synchronous phase of 16 deg as a best compromise between RF stability and energy width. The extraction philosophy is nearly the same as for the third stage of MAMI.

The civil construction, seen in Fig. 1, has been designed in such a way as to allow a future machine upgrade to energies up to 650 MeV. The optical design of such an accelerator has been preliminary studied, leading to a determination of the additional components (End magnets, RF equipment) required. All building and facility designs have undergone strict safety considerations, based on the results of detailed shielding calculations. Shielding requirements followed the ALARA principle (As Low As Reasonably Achievable) regarding the exposure of both personnel and general public.Therefore, radiation safety is fully met even in the “worst” (most radiation-producing) possible case of accelerator operation.

3 PRESENT STATUS

3.1 The 100 keV Line.

The installed 100 keV beam line, shown in Fig. 2, is designed to define the transverse beam emittance and to chop and bunch the beam [7]. It consists of a pair of transverse emittance limiting apertures, A1 and A2; a pair of RF cavities, C1 and C2; a phase selecting aperture, A3; an RF buncher cavity, B; six magnetic focusing lenses L1 through L6 and six steerers. By exciting the first cavity, C1, in two orthogonal, transverse modes with equal amplitudes and with 90 degrees phase shift between them (TM110 mode) the beam is deflected to form a circle downstream on the aperture A3 (see Fig. 3(a)). An off-axis aperture in the plate transmits a 60 degrees arc of the circle (clearly observable in Fig. 3(c)) with a reduction of the average current to one sixth. A split solenoid lens, L4a,b in Fig. 2, focuses the deflected beam to the axis at the second chopping cavity, C2. The transverse RF modes in this cavity are adjusted in phase and amplitude to exactly cancel the transverse momentum imparted to the beam by the first cavity. A new RF drive system for the 100 keV line has been built. A 2380 MHz, 230 Watt magnetron, injection locked for phase stability, is used to drive the two chopping and the bunching cavities. The system has been designed to make a negligible contribution to the transverse beam emittance during chopping.

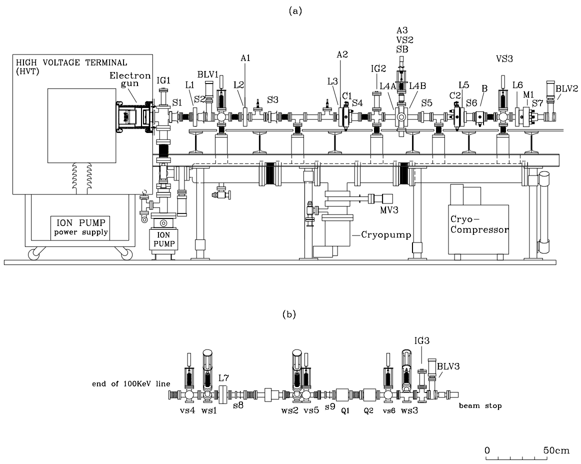

Figure 2: (a) Layout of the 100 keV line and (b) the newly designed and installed T-line for transverse emittance measurements.

The line has been maintained at pressures below 2×10^{-8} Torr for over a year. A DC electron beam of more than 200 μA has been extracted out of the electron gun and guided up to the Faraday cup.

3.2 Transverse Emittance Measurements.

In order to perform transverse emittance measurements a so called T-line has been designed and recently installed at the end of the 100 keV line. It comprises of three successive subsystems (see Fig. 2), each consisting of a lens followed by a wire scanner in a distance of roughly 0.5m.

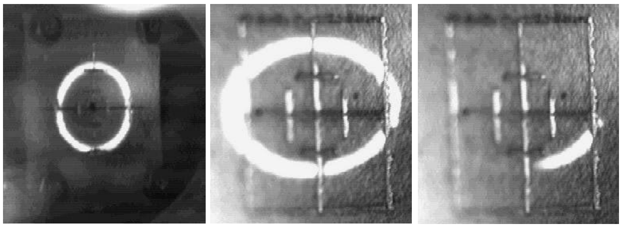
(a) (b) (c)

Figure 3: (a) Photograph of the circular beam pattern on view screen VS2 produced by the action of the chopper cavity C1. The aperture A3 does not intercept the beam. (b) Same as in (a) but observed on view screen VS3 (chopper C2 turned off). (c) The 60 deg beam segment transmitted through the intercepting aperture A3. The chopper C2 is turned off.

View screens are also installed close to the positions of the wire scanners.

The wire positions are measured using a linear variable differential transformer, attached to the pneumatic piston of the wire scanner, as a transducer. Gold on Tungsten wires 20 μm in diameter are used in the scanners, attached in a ”L” pattern to small ceramic standoffs on a metal frame [5]. Current from the wires (due to electron capture) runs through an electrical feedthrough into a low noise amplifier via a flexible, low noise, shielded cable. A current versus position plot gives the current profile of the beam in horizontal and vertical planes. Detailed data has been obtained for the beam position and transducer output voltage for each wire scanner. First measurements with the scanners showed a very high signal to noise ratio (Fig. 4).

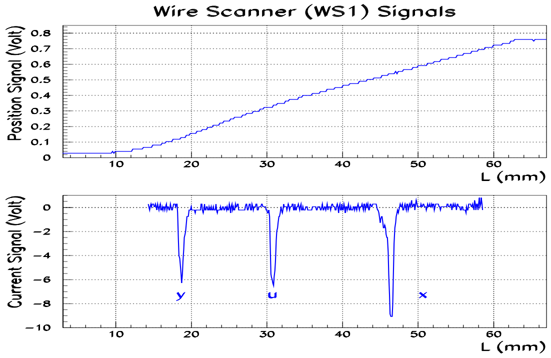

Figure 4: Digitized signals from the wire scanner WS1 in Fig. 2. (a) Transducer signal used for position calibration. (b) Beam profile signals in the y, u (45 deg) and x directions (from left to right). The u signal is to be used for a 3D reconstruction of the beam density.

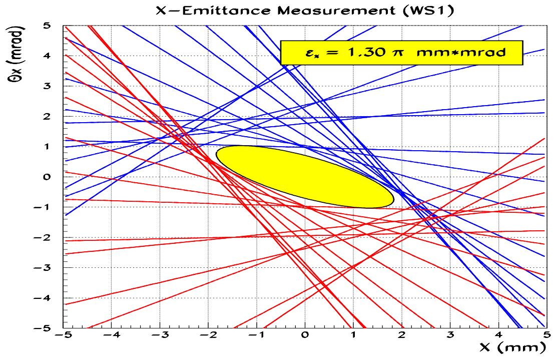

Figure 5: Typical emittance measurement (x-plane). The polygon formed by the straight lines (see text) is approximated by an ellipse.

The control procedure for the wire scanner activation and the digitization of the position and current signals has been implemented on a Tcl/Tk script interfaced to the EPICS control system through MEDM [6]. Both signals are measured simultaneously with a 100 kHz digitizer with a 12 bit resolution. Data calibration is achieved during the signal buffering to the host computer, where a further off-line analysis of the beam profiles is performed.

The T-line is designed in such a way that allows the determination of the transverse emittance using at least two different procedures. One technique is to use all three wire scanners without varying the excitation of any optical element. Another possibility is to vary the excitation of a lens and measure the modified beam size in the wire scanner situated downstream this lens. The beam transfer matrix for the system lens + drift space (up to the wire scanner) is written as $\mathbf{M} = \mathbf{M}_L \mathbf{S}$ where the matrix $\mathbf{M}_L$ refers to the drift space of length L and the matrix $\mathbf{S}$ represents the effect of the lens. Taking as an example the x-plane then, for each value of the lens excitation, and assuming uncoupled x- and y-planes, a pair of straight lines, $\theta_i(x_i)$, is defined as $\theta_i = [-(S_{11} + LS_{21})x_i \pm x_f] \times [S_{12} + LS_{22}]^{-1}$, with x_i and θ_i the beam size and divergence at the lens location and x_f is the measured beam size at the wire scanner location. A set of measurements of x_f as a function of the lens current encloses the beam transverse phase space, resulting in the form of a polygon. Recent measurements with a DC beam and their preliminary treatment are shown in Fig. 5. The extracted value of the emittance is about 1.5 π mm mrad (100 keV) for both planes with an uncertainty of about 20%. This emittance value compares well with the measurements at NIST for a DC beam [7].

4 FURTHER DEVELOPMENT

Recently feasibility studies for the installation of accelerating sections of the RTM have been started. Work on the power station needed for the klystron, the chiller, safety and other important infrastructure needs is under way. In addition a second diagnostics line is being designed for longitudinal emittance measurements.

5 REFERENCES

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