COMMISSIONING OF THE 100 MEV RACETRACK MICROTRON OF THE METROLOGY LIGHT SOURCE*

K. Buerkmann, T. Birke, J. Borninkhof, P. Budz, R. Daum, V. Duerr, J. Feikes, W. Gericke, H. Glass, H.G. Hoberg, J. Kolbe, R. Lange, G. Mielczarek, I. Müller, K. Ott, J. Rahn, G. Schindhelm, T. Schneegans, T. Schroeter, D. Schüler, D. Simmering, T. Westphal, (BESSY GmbH, Berlin), R. Klein, G. Ulm (Physikalisch-Technische Bundesanstalt (PTB), Berlin)

Abstract:

In 2003, the Metrology Light Source (MLS), a low energy electron storage ring as central instrument in the future Metrology Laboratory of the Physikalisch-Technische Bundesanstalt (PTB) was approved. Design, construction and operation of the MLS are realized by BESSY [1], based on the PTB requirements for a permanently accessible radiometric source, optimized for the spectral range from the UV up to the VUV [2] [3]. The MLS is tunable in energy between 200 MeV and 600 MeV. Based on the experiences at BESSY, a highly stable and reliable Race Track Microtron (RTM) for injection was realized by Danfysik. The commissioning of the 100 MeV microtron at MLS started in January 2007. The concept and construction as well as the main parameters of the microtron are introduced.

INTRODUCTION

For the MLS a microtron was chosen as injector because of the high electron beam quality in terms of emittance and energy spread, the compact design and the lower investment costs compared to a linac.

Table 1: Main parameters of the racetrack microtron

	Specified	Achieved
Electron gun current	400 mA	400 mA
Gun Voltage	90 kV	70 kV
Gun pulse length	3.3 µs	6 µs
Energy	100 MeV	104.5±0.5 MeV
Energy spread	< 100 keV	to be measured
Energy gain/turn	5.3 MeV	5.5 MeV
Pulse current	>8 mA	>10 mA
Pulse length	0.3 µs–1.5 µs	0.1 µs– 2 µs
Repetition-rate	10 Hz	10 Hz
Emittance	≤ 0.1 mm mrad	$\varepsilon_{n,rms}$ h ≤ 0.17 mm mrad $\varepsilon_{n,rms}$ v ≤ 0.55 mm mrad
Bending-field	1.13 T	1.14 T

In November 2004 the 100 MeV RTM was ordered at Danfysik A/S. Table 1 column 2 shows the specified main parameters of the machine.

Figure 1: MLS RTM100 placed in the bunker with the movable fluorescence screen monitor (FOM) extension arm on the right side.

BASIC CONCEPT

The design of the 100 MeV racetrack microtron is based on the Aarhus and Max-Lab [7] (100 MeV), the ANKA [8] (50 MeV) injectors and the experiences of 25 years of operation with the 20 MeV pillbox microtron at BESSY I and later on with the 50 MeV RTM at BESSY II. The drawbacks of the above mentioned machines taught to divide the microtron at all into basic subsystems, that should be inherently safe, and in principle independent, as there are:

1. Gun:
   A standard cylindrical Piercetype gun, powered by a semiconductor 90 keV modulator controlled by its own Programmable Logic Controller (PLC) is used.
2. RF-System:
   A 3 GHz klystron powered by a 4 MW semiconductor modulator is also controlled by an independent PLC.
3. Magnetic Structure:
   New 180 ° bends and an extraction magnet were designed by Danfysik. The design of the corrector magnets was improved with respect to the decoupling of steerer influences.

*Work supported by PTB, Abbestr. 2 - 12, 10587 Berlin, Germany

4. Power Supplies
   The main magnets PS are chosen out of the standard types used at BESSY. All the low power, bipolar PS are BESSY in-house developed 50 W units.
5. Vacuum System
   A full metal UHV system with separable gun sector was demanded, pumped only by getter pumps.
6. Monitoring
   Beyond the synchrotron radiation monitor and a subset of fast current transducers (FCTs) the beam diagnostic was extended by installing a movable fluorescence screen monitor and FCTs for almost every turn.

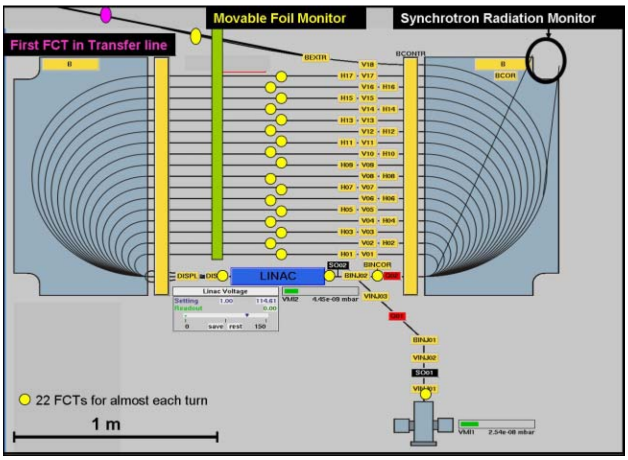

Figure 2: Beam diagnostics overview.

7. Computer control
   The complete microtron is operated by the EPICS based BESSY control system and the communication with all the subsystems including the PLCs is provided by CAN bus controllers.

To proof the required high stability and good reliability of the injector system two tests have to be passed:

- 8 hours stability test with 8 mA output current without any manual adjustment.
- Start up after complete power down in less than 30 min with a 8 mA output current is to be achieved without any manual adjustment.

To minimize investment costs as well as maintenance costs the concept was to utilize synergetic effects based on the use of hardware and software well established at BESSY for the above mentioned computer control, the power supplies and the vacuum components.

COMMISSIONING AT THE PTB SITE

The microtron achieved 100 MeV beam for the first time end of May 2006 at the manufacturer site and was delivered in November 2006 to PTB. After installation and receipt of the radiation permission in January 2007, the systems were started up again. Within four hours 100 MeV beam at the FCT in the extraction beam line was observed. The commissioning at the PTB site succeeded in a pulse current of 10 mA achieved at the end of January 2007.

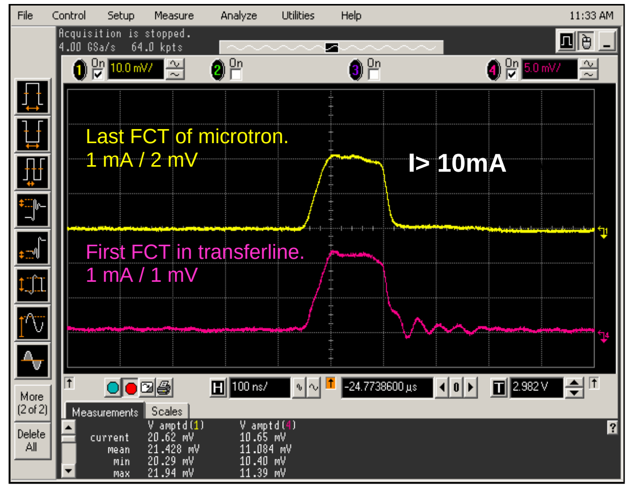

Figure 3: 10 mA at 100 MeV.

Radiation Safety

The microtron is placed in a separated bunker to provide independent operation of the storage ring and the preinjector.

To achieve a radiation level outside the bunkers within the surveillance area requirements (< 1 mSv/a) detailed FLUKA calculations [6] have been carried out. The diagram below show the expected gamma dose rates for a 10 Hz microtron operation for extraction of 10 mA at 100 MeV and a 1 µs pulse duration.

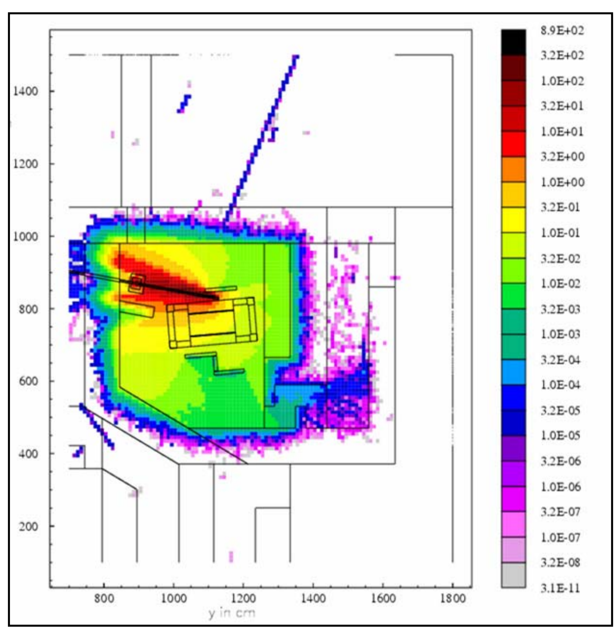

Figure 4: Gamma dose rate in Sv/h [4].

Comparisons of the FCT signals from turn to turn show, that in the first two acceleration stages the 70 keV gun pulse of about 2 µC is reduced to about 5 nC. At the remaining 17 acceleration stages the charge losses are nearly constant from turn to turn and end up in a 2.5 nC pulse of about 250 ns.

Due to these unexpected high losses from turn to turn at higher energies, additional local shielding had to be implemented in the shielding concept, already considered in the below pictured calculations.

Caused by the high neutron level in the microtron bunker, all electronic equipment is threatened by radiation damage. During operation start up at the Danfysik site some IGBTs of the gun modulator were damaged [5], as well as some gauge heads. These experiences influenced the layout at the final site and the placement of subsystems like klystron modulator, gun modulator and all the PLCs who are now positioned outside the shielding.

Energy Measurement

The first injection efforts to the storage ring foreboded, that the electron energy has to be several percentages higher than the expected 100 MeV.

Fixing of the actual electron energy was done by measuring the relative deflection of the beam by changing the 30 ° transfer line bending magnets settings. The deflection was measured via a frame grabber system connected to a fluorescence screen monitor video signal. The foil monitor is placed upstream the dipole magnet.

Result for the Energy of the extracted beam:

104.5(5) MeV

This value goes very well with the preliminarily estimated 106 MeV based on the storage ring dipole magnet settings.

To release the magnets and power supplies (some of them are running on 96 %) to get larger margins for optimization, the energy has to be reduced to the 100 MeV in the long term.

Emittance Measurement

First preliminary measurements of the emittance were performed by defining the beam dimensions with a frame grabber, while scanning a quadrupole in the transfer line.

Results for the natural emittance of the MLS microtron:

Horizontal $\varepsilon_{n,rms}\, h \leq 0.17$ mm mrad
Vertical $\varepsilon_{n,rms}\, v \leq 0.55$ mm mrad

SUMMARY

The MLS microtron of the PTB in Berlin is now running for five months. Nevertheless, some specified parameters are not met or not proved up to now. Especially the energy spread and beam size at the extraction of the microton are not measured.

The finalization of some outstanding and improvable issues is done now in parallel to the commissioning of the MLS storage ring. Half the day there are acceptance tests at the preinjector, followed by production of electron beam for the storage ring commissioning Under these circumstances, all the subsystems as well as the whole microtron prove their high reliability and reproducibility.

REFERENCES

[1] D.Krämer et al.: Der Metrologie-Speicherring MSR des Wiliy Wien Labors der Physikalisch Technischen Bundesanstalt bei BESSY BESSY GmbH, Berlin July 2003

[2] R.Klein et al: *The Metrology Light Source - An Electron Storage Ring Dedicated to Metrology* EPAC 2006 3299-3301 (2006)

[3] G.Brandt et al: *Status of the Metrology Light Source* Nucl.Instr. and Meth B 258 445-452 (2007)

[4] K.Ott: *Sicherheitsbericht für den Probebetrieb der Speicherringanlage Metrology Light Source MLS.* BESSY GmbH 7.März 2007

[5] E.Normand et. al.: *Neutron-Induced Single Event Burnout in High Voltage Electronics* IEEE Transactions on Nuclear Science, Dec 1997

[6] K.Ott: *The shielding design of the Metrology Light Source*, Proc. PAC 2003, 776-778 (2003)

[7] M.Eriksson: *Race-Track Microton Injectors for SR-Sources* Nuclear Instrumentation and Methods in Physics research A261 (1987) 39-42

[8] L.Præstegaard: *Investigations of the ANKA Injector.* Danfysik A/S Jyllinge, Denmark, Institute for Storage Ring Facilities University of Aarhus, Denmark April 2001

