RECENT DEVELOPMENTS AT THE METROLOGY LIGHT SOURCE

J. Feikes , T. Birke, K. Bürkmann-Gehrlein, O. Dressler, V. Dürr, D. Engel, F. Falkenstern, B. Franksen, H. Glass, A. Heugel, H.- G. Hoberg, F. Hoffmann, J. Kuszynski, J. Rahn, M. Ries, G. Schindhelm, P. Schmid, T. Schneegans, D. Schüler, G. Wüstefeld,
Helmholtz-Zentrum-Berlin, Germany
R. Klein, PTB, Berlin, Germany

Abstract

The Physikalisch-Technische Bundesanstalt (PTB), the German national metrology institute, owns the electron storage ring Metrology Light Source (MLS) which was built and is operated by the Helmholtz-Zentrum Berlin [1, 2]. The MLS has been in regular user operation since April 2008 and supports synchrotron-radiation-based metrology and technological developments in the IR, UV, VUV and EUV spectral range. Here we report on recent progress to develop the MLS into a reliable, flexible and stable user facility.

INTRODUCTION

At the MLS, as a user owned facility, the owner being the (PTB), machine state changes are much more frequent than at other synchrotron light sources like BESSYII. The users may change its demands several times a day and may ask each time for another, often very different, machine setting. Therefore it is very important to be able to operate the machine as flexible and, at the same time, as reliable as possible.

EXTENDING THE STATE MACHINE

Table 1 shows the wide range of operating modes and parameter settings of the MLS. As outlined in [3], making mistakes in the transitions between different energy states requires a complex and time consuming procedure to restore the correct hysteresis conditions. Therefore state changes at the MLS are done automatically.

Table 1: Machine and Operating Parameters

Operational Energies	105 MeV to 630 MeV
Injection Energy	105 MeV
Qx / Qy	3.18 / 2.23
Circumference	48 m
Beam Current	1 pA (1e-) to 200 mA
Abs.Values of "Momentum Compaction Factor α	$1*10^{-5}$ to $7*10^{-2}$
Insertion Device	Electromagnetic Undulator 23x180 mm

All procedures (transitions) that changes the actual machine state into any other possible state are performed by a complex program, the "Operation Master" (Fig. 2). The operation master is a so called "state machine". It contains the knowledge of all possible machine states and all procedures necessary to go from one state to any other. This concept, presented in [3], was further improved.

The master offers the possibility to select specific machine modes. In each mode a floating parameter adjusts that mode to the specific user conditions required.

- **Ramp mode -** injection at 105 MeV and ramping to any energy E_{ramp} with 105 MeV < E_{ramp} < 630 MeV.
- **Low Alpha Mode -** used for generating short bunches. The parameter is the value of the synchrotron frequency as it is, at low currents, proportional to the bunch length.
- **User Mode** – optimized for UV, VUV and EUV user demands. The vertical source size is adjusted by changing the transverse coupling.

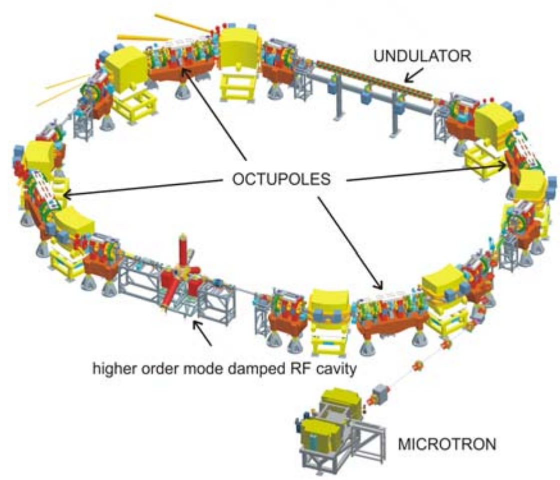

Figure 1: MLS hardware.

The operator defines the desired operating parameters and the operation master performs the correct actions to reach that state. By its use the flexibility, inherent in the MLS design, can be fully worked out.

As the Operation Master is continuously tracking and supervising all state changes it also records the complete state history as shown in the down part of Fig. 2.

IMPROVING ACCUMULATION

After re-working on the injection septum setup the injection trigger rate could be increased from 1/5Hz to 2Hz [4]. Reducing its stray fields made the accumulation process much more reproducible and stable. But highest currents can only be accumulated if vacuum and ion effects do not blow up the beam size by scattering processes beyond a certain level. After installation of a NEG coated vacuum chamber inside the undulator section during last shut down (Dec 2010) a significant improvement of the vacuum conditions can be observed there (Fig. 3). As a consequence beam currents of up to 200 mA can be accumulated routinely.

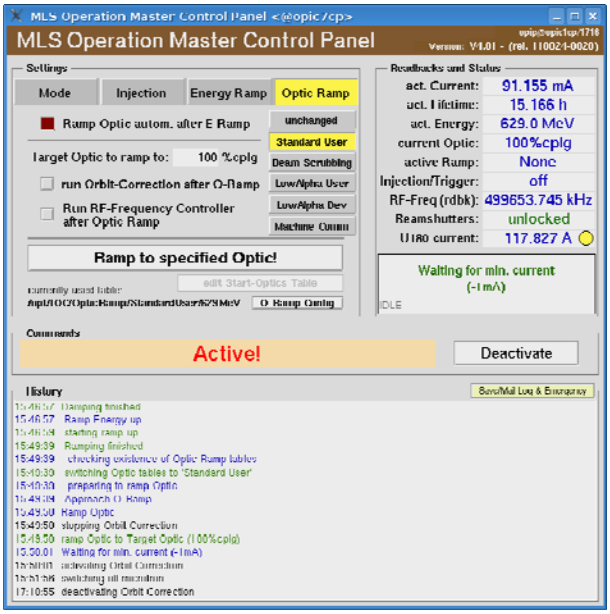

Figure 2: Interface of the "MLS Operation Master".

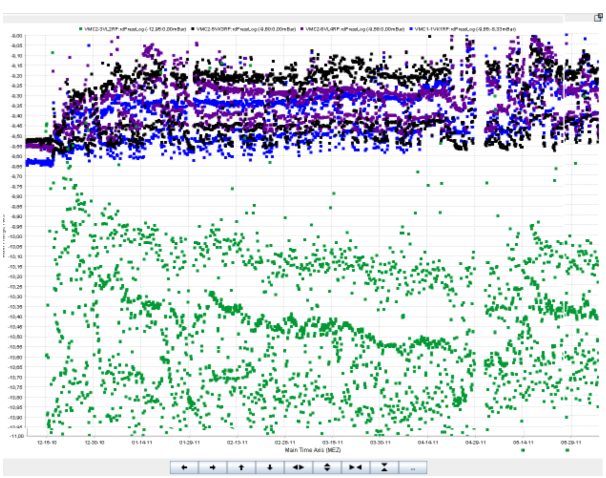

Figure 3: Time chart of pressures (logarithm scale) inside the NEG coated undulator chamber (green dots) and outside (black, blue dots). The first 5 month of operation with the NEG chamber are shown. The Y-axis extents from -11 to -9.

INDIVIDUAL POWER SUPPLIES

During the last shut down (Dec 2010) each of the 24 quadrupoles was equipped with an individual power supply. This allows a better local control of the dispersion for e.g. at the cavity position. By adjusting the dispersion there to zero (but leaving α unchanged) a longitudinal transversal coupling is suppressed which would otherwise prevent to achieve very small bunch lengths in the low alpha mode [5].

After the shut down, it was not longer possible to ramp up more current than 20 mA. Simultaneously an intense excitation of the beam during the ramp was observed. Its source is still unknown, but a countermeasure to recover nearly the former ramp efficiencies was found. The delivery rate for the power supply values during the ramp was raised from 10 Hz to 40 Hz, restoring ramped currents of up to 180 mA.

SETTING THE REFERENCE ORBIT

At the MLS only 20 out of the 28 beam position monitors (BPMs) are located next a quadrupole magnet while for the other eight BPMs the transverse phase to the adjacent quadrupole exceeds at least 10°. As a consequence not all BPMs can be calibrated by the standard beam based alignment (BBA) methods where the beam is steered into the magnetic center of a nearby quadrupole and the corresponding read out of the adjacent BPM is defined as its orbit reference value (or "golden orbit value") [6].

The challenge to find an orbit reference which guaranties a central orbit inside all quadrupoles at the MLS was performed as follows:

1. all major magnetic elements beside the quadrupoles and dipoles are turned off. Steerer magnets remain "on".
2. a section of the storage ring which contains exact three quadrupoles is selected defining a "region of interest". In Fig. 4, where the structure of one MLS achromate is depicted, the section may be confined for example to the quadrupoles Q1, Q2, Q3.
3. all orbit correctors inside the "region of interest" (defined by the position of the first and the last quadrupole) are turned off.
4. a stored beam is adjusted with the goal to center it into all three quadrupoles **simultaneously**.

To do so, especially designed orbit bump ("anti-bumps") were very useful which consist of three steerer magnets outside the region of interest. Its current ratios are determined by inversion of an experimental orbit response matrix so that the bump changes the orbit in one quadrupole only leaving the orbit inside the other two quadrupoles unchanged (orbit knots). "Anti-bumps" usually create huge orbit distortions outside the region of interest (Fig 5). As this distortions may not become larger than the physical aperture the existence of suitable anti bumps is not evident and demand for a proper choice of the correctors used.

5. after having achieved a simultaneous centring the values of all BPM readings inside the region of interest (in our example BPM2 and BPM3) are the reference orbit values.

Defining the complete reference orbit (inclusive BPMs not located adjacent to quadrupoles) enabled a SVD orbit correction to reduce the orbit rms-value from 300µm down to 65µm. All beam lines in operation had the beam spot afterwards exactly on the position expected from their mechanical beam line alignment.

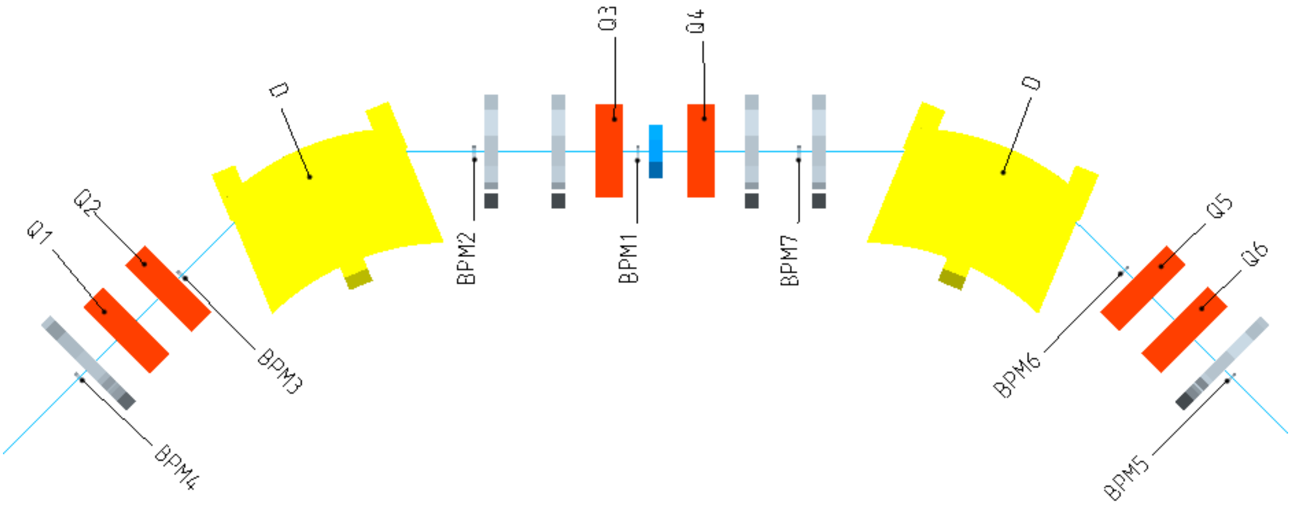

Figure 4: Magnet structure of one MLS-achromate. Yellow: dipoles, red: quadrupoles, gray: sextupoles and correctors. In total 7 BPMs are installed. BPMs #2 and #7 are located far from the adjacent quadrupole and can therefore not be calibrated by usual BBA methods (e.g. Matlab Middle Layer program "quadcenter" [8]).

MULTI BUNCH FEEDBACK SYSTEM

At standard user beam currents (I>120 mA) strong multi bunch instabilities are observed blowing up the effective bunch size in all three spatial planes. A digital MB feedback system was installed [7] and was setup with the goal to damp them. The damping capability of the system is reflected by an impressive decrease of lifetime when the sytem is switched on (Fig. 6) Due to the small bunch volume of the heavily damped beam Touschek scattering is strongly enhanced

.

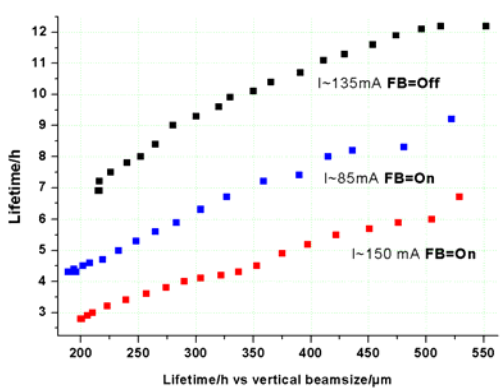

Figure 6: Lifetime vs. the vertical beam size measured at a beam imaging system for different beam currents. Black dots with feedback turned off, blue, red dots FB=on.

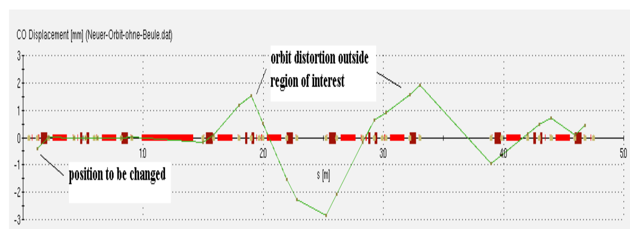

Figure 5: Horizontal orbit generated by an anti bump.

REFERENCES

[1] R. Klein et al., Phys. Rev. ST-AB 11, 110701 (2008).
[2] J. Feikes et al., Phys. Rev. ST-AB 14, 030705 (2011).
[3] T. Birke et al, PAC'2009, Vancouver (Canada) p.1798 (2009)
[4] O. Dressler, IPAC'2010, Kyoto (Japan), p. 1773
[5] M. Ries et al.,"Simultaneous Long and Short Bunch Operation in an Electron Storage Ring - a Hybrid Mode based on Nonlinear Momentum Compaction,IPAC2011 San Sebastian 2011..
[6] Measurement and control of charged particle beams, M. G. Minty, F. Zimmermann, Springer Verlag 2003
[7] Dmitry Teytelman, privat com. www.dimtel.com
[8] G. Portmann, D. Robin, and L. Schachinger, PAC 1995, Dallas, (USA) p. 2695