OPTICS CALIBRATION AT THE MLS AND AT BESSY II

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Abstract

In this paper we present the results of our studies employing LOCO and MML for optics calibration at the MLS and at the BESSY II storage rings. Both the standard user modes and dedicated low alpha modes are analyzed.

INTRODUCTION

In this document we describe what we encountered when we brought the Matlab middle layer (MML) to the control systems of the two synchrotron light sources operated by the Helmholtz-Zentrum Berlin, BESSY II and the Metrology Light Source (MLS) owned by the Physikalisch Technische Bundesanstalt (PTB). Furthermore, some results of optics studies involving LOCO are given. Documentation regarding LOCO and MML can be found elsewhere [1, 2].

STATUS AT THE MLS

The lattice of the MLS comprises a double bend achromat lattice with two identical super cells. The beam is injected at an energy of $105\,\mathrm{MeV}$ and typically ramped to an energy of $629\,\mathrm{MeV}$ [3]. Furthermore, the MLS can be operated in dedicated low alpha modes, providing short bunches very suitable for generating significant coherent radiation in the Terahertz regime [4].

Getting a grip on the MLS optics was not easy: First, with the help of the tools provided by the MML it was found that the quality of the BPM readings was hampered by sudden jumps exceeding $50\,\mu\mathrm{m}$. Secondly, the fringe field effects of the peculiar C-shaped RBENDs, each deflecting the beam by 45° and of a magnetic length of $1.2\,\mathrm{m}$, has to be accounted for. Thirdly, the MML-based beam-based alignment (BBA) method can only be employed at 20 BPMs. The offsets at the remaining eight BPMs have to be determined manually or by optics-based methods since the phase advances between BPM and adjacent quadrupole are excessive. When these obstacles were overcome, an accurate measurement became possible. Nevertheless, the vertical focussing of the dipole magnets is not perfectly modeled. Fitting down to the noise level has thusly not been achieved. For a typical BPM noise of $400\,\mathrm{nm}$ RMS horizontally and $300\,\mathrm{nm}$ vertically at a beam current of $15\,\mathrm{mA}$ an agreement of std(model-measurement) of $2.3\,\mu\mathrm{m}$ has been achieved. The LOCO code was applied for studying the user optics at $629\,\mathrm{MeV}$ and at intermediate energies. The results for the user mode are shown in Figure 1.

Elucidating the low alpha optics at differing synchrotron frequencies proofed successful. Scaling laws known beforehand allowed checking if the optics settings predicted by LOCO seemed realistic (see Figure 2). The horizontal emittance for these configurations as a function of the synchrotron frequency f_s are shown as well (see Figure 3).

Figure 4 shows that the concept of three sextupole families and an octupole family allows adjusting the slope and the curvature of the momentum compaction factor $\alpha(\delta_p)$ in the way proposed in [5] leading to an increased life time for off-momentum particles.

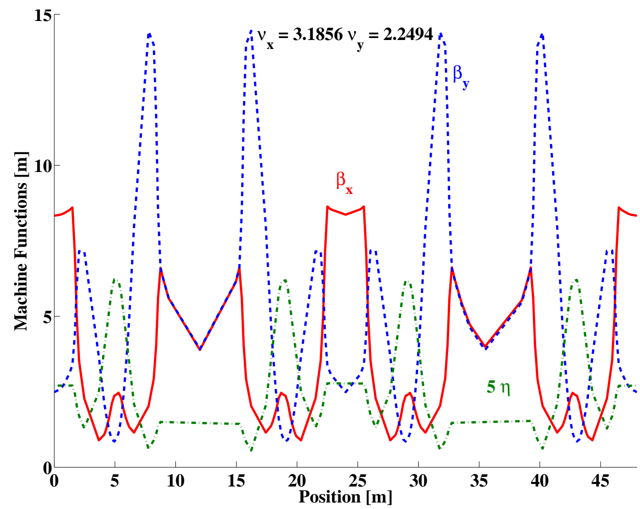

Figure 1: Optical functions for the user mode at $629\,\mathrm{MeV}$, $f_s = 90\,\mathrm{kHz}$, $U_{cav} = 330\,\mathrm{kV}$.

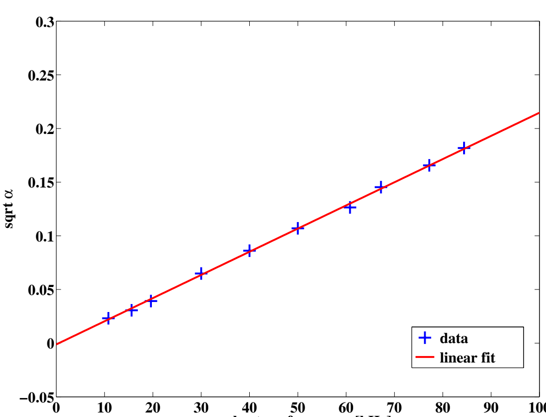

Figure 2: Square root of the momentum compaction factor α_1 as a function of the measured synchrotron frequency at $U_{cav} = 250\,\mathrm{kV}$ and a beam energy of $629\,\mathrm{MeV}$.

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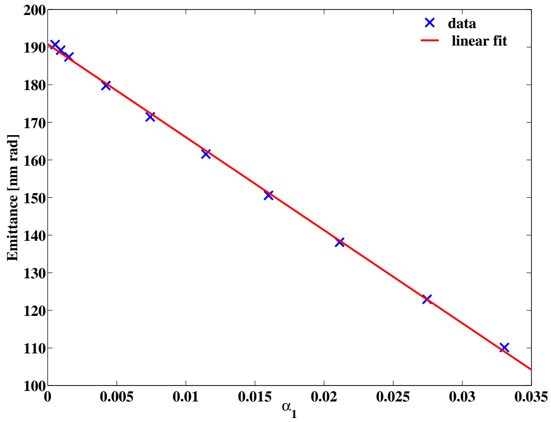

Figure 3: Horizontal emittance vs. momentum compaction factor α.

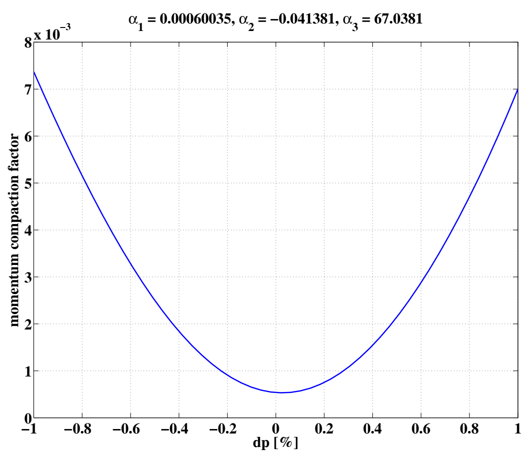

Figure 4: Momentum compaction factor α as function of fractional momentum deviation δ_p for a synchrotron frequency of 10 kHz and a bunch length of $0.9\,\mathrm{mm}$.

STATUS AT BESSY II

BESSY II is a third generation light source consisting of eight supercells including low beta insertions [6]. Doing a full LOCO measurement at BESSY II varying 80 steerer magnets horizontally and 64 vertically takes about 50 minutes. The beam noise fluctuates about $600\,\mathrm{nm}$ RMS horizontally and $400\,\mathrm{nm}$ vertically at a current of $15\,\mathrm{mA}$, sampled at $0.5\,\mathrm{Hz}$ acquisition rate.

The LOCO analysis proved unsuccessful at first: The predicted variations in the quadrupole gradients were far beyond expectations. According to magnetic measurements the variations should be below $5‰$ within a quadrupole family. Instead variations exceeded 3%. Improvement was made when the scaled Levenberg-Marquardt algorithm was chosen as the fitting algorithm reducing the variations to about 0.5%. A possible explanation is that the phase advance between BPM and adjacent quadrupole is to small that with the limited number of BPMs in the achromat disentangling of the individual contributions of the quadrupoles does not work out for the original version of LOCO [7]. Fitting with resolution close to the noise level of the BPMs ($\approx 800\,\mathrm{nm}$) was achieved for sextupoles at lowest possible settings. The result of such an analysis is shown in Figure 5 for the bare lattice without wavelength shifters.

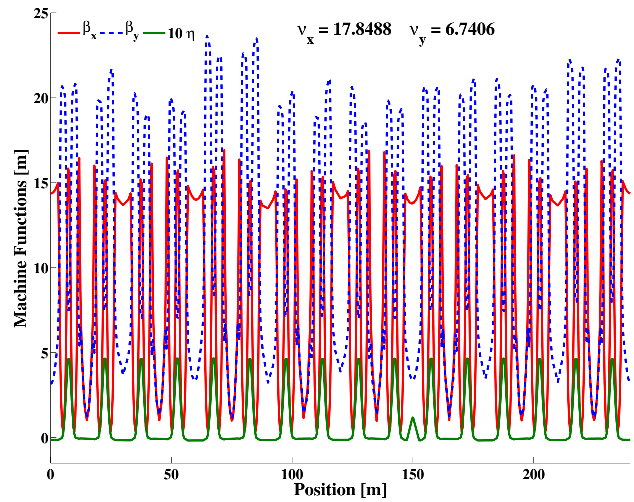

Figure 5: Beta functions for the bare lattice. The three superconducting WLSs and the HMI wiggler are turned off.

With these development LOCO proved to be a very valuable tool. Symmetrizing the optic and thereby reducing the beta-beat was achieved. After four iterations the beta-beat for the bare lattice without wavelength shifters could be reduced from 5% to $.5\%$. The required variations for the ganged quadrupoles as a function of the power supply number are depicted in Figure 7.

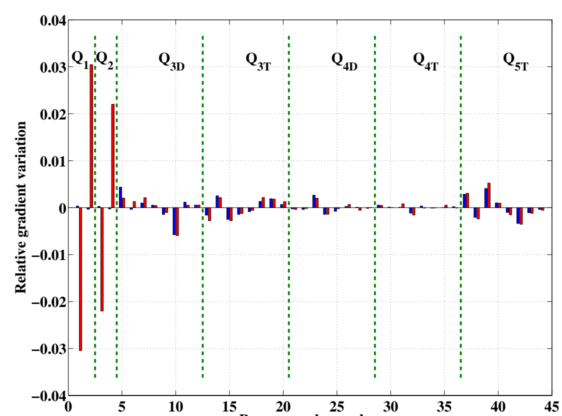

Figure 6: Qudrupole gradients determined by the two fitting algorithms. The red bins are for the Gauss algorithm. The blue bins represent the scaled Levenberg-Marquardt routine.

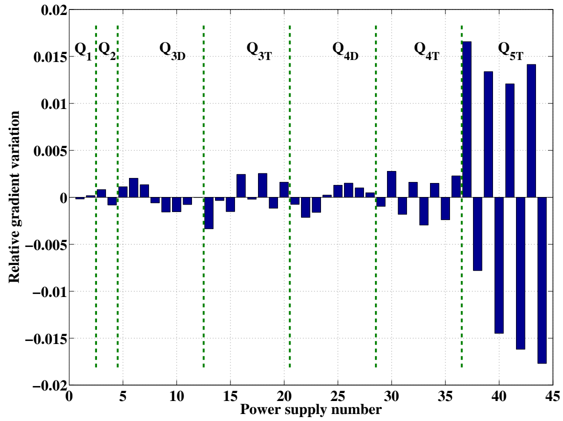

Figure 7: Quadrupole gradient variations required for reducing the beta beat to $.5\%$.

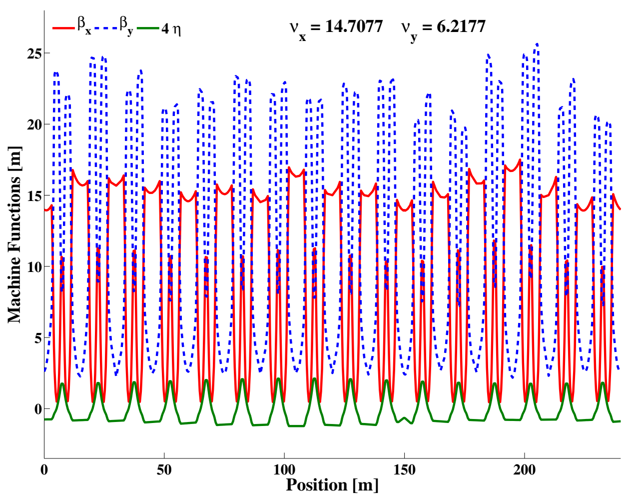

Figure 8: Beta functions in low alpha mode.

Secondly, successfully analyzing BESSY II's typical low alpha user mode with a bunch length of about $1\,\mathrm{mm}$ was achieved (see Figure 8).

The calibrated model allows predictions about properties of the optics like the momentum compaction factor α as a function of the relative momentum spread δ_p, which are in good agreement with the literature [8].

Additionally, reducing the coupling in a controlled fashion for various configurations of the lattice can be achieved.

Furthermore, the BPM offsets determined by the MML-based BBA procedure lead to a reference orbit that was as good as the one gotten by the standard procedure according to the local orbit expert.

CONCLUSIONS

The refined version of the LOCO code and MML has proven to be a very valuable tool for calibrating the optics, troubleshooting defective components and bringing the machine configuration closer to the model.

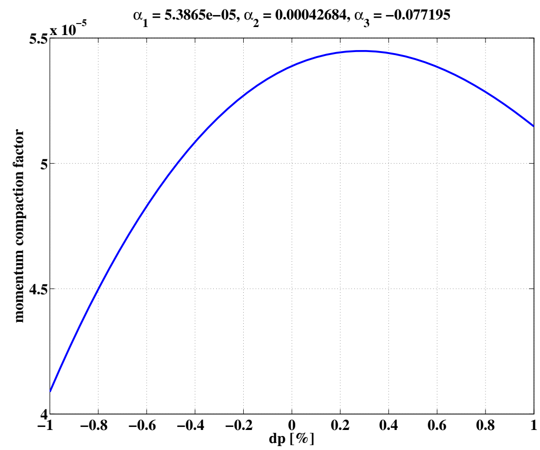

Figure 9: Momentum compaction factor α as function δ_p for BESSY IIs low alpha optic. The synchrotron tune is at $2\,\mathrm{kHz}$. The combined RF-voltage is $1.2\,\mathrm{MV}$.

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REFERENCES

[1] J. Safranek and al. Matlab-based loco. In *Proceedings from the 2002 European Particle Accelerator Conference (EPAC 02)*, pages 1184–1186, Paris, June 2002.

[2] J. Corbett and al. Accelerator control middle layer. In *Proceedings from the 2003 Particle Accelerator Conference (PAC 03)*, pages 2369–2371, Portland, May 2003.

[3] R. Klein and al. Operation of the Metrology Light Source as a primary radiation source standard. *Phys. Rev. ST Accel. Beams*, 11:110701, 2008.

[4] G. Wüstefeld and al. Coherent THZ measurements at the Metrology Light Source. In *Proceedings of the 1st International Particle Accelerator Conference (IPAC 10)*, Kyoto, June 2010.

[5] M. Abo-Bakr and al. Der Metrologie-Speicherring MSR des Willy-Wien-Laboratoriums der Physikalisch-Technischen Bundesanstalt bei BESSY. Technical Design Report, BESSY, 2003.

[6] E. Jaeschke and al. Status of the high brillance synchrotron radiation source BESSY-II. In *Proceedings of the 16th IEEE Particle Accelerator Conference (PAC 95)*, pages 713–715, Dallas, May 1995.

[7] ICFA Beam Dynamics Newsletter 44, December 2007. LOCO theme section.

[8] G. Wüstefeld. Short bunches in electron storage rings and coherent synchrotron radiation. In *Proceedings of the 11th European Particle Accelerator Conference (EPAC 08)*, pages 26–30, Genoa, June 2008.