STATUS OF THE 1.5 GEV SYNCHROTRON LIGHT SOURCE DELTA AND RELATED ACCELERATOR PHYSICS ACTIVITIES*

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Abstract

The Dortmund University is operating the 1.5 GeV storage ring based synchrotron light source DELTA. The machine is operated 3000 h/year, 2/3 dedicated to synchrotron radiation research at 7 beamlines and 1/3 to dedicated accelerator physics research. With the first SR beamline starting operation in 1999 DELTA today is a synchrotron radiation source which serves users from different laboratories in the region.

This paper covers the actual status of machine, beamlines and operation and gives an overview on accelerator related research. Major progress has been achieved over the successive years concerning machine modelling, orbit stability, orbit control, beam instability detection and a frequent injection mode for increased overall photon flux. The prototype of a 500 MHz higher order mode damped cavity, developed in the framework of an EU-collaboration has been successfully tested.

INTRODUCTION

DELTA with its medium electron energy of 1.5 GeV nevertheless offers today a broad variety of photon energies for users. A multipole asymmetric superconducting wiggler serving three beamlines is the backbone of SR use extending the photon energies well beyond 20-30 keV. Two undulator beamlines and two dipole beamlines cover the low energy regime. The facility operates presently at 3000 h per year with increasing availability. Even though teaching and supervising of undergraduate and graduate students at the machine and the beamlines is a major task, the availability of the beam increased significantly over the years and was as high as 94% in 2004 and only slightly lower in 2005 [1].

MACHINE STATUS AND INSERTION DEVICES

Accelerators

The accelerator complex consists of a 75 MeV S-band linac [2], a full energy booster (ramped storage ring with a repetition rate of approximately 0.1 Hz (see fig. 1) and the storage ring with low emittance optics [3]. Nominal beam parameters at 1.5 GeV are: beam current 130 mA, lifetime ~10 h, horizontal emittance 16 nm rad. In standard user runs the beam is injected 4 times a day. The duration for beam injection is 15-30 minutes at injection efficiencies of 50%.

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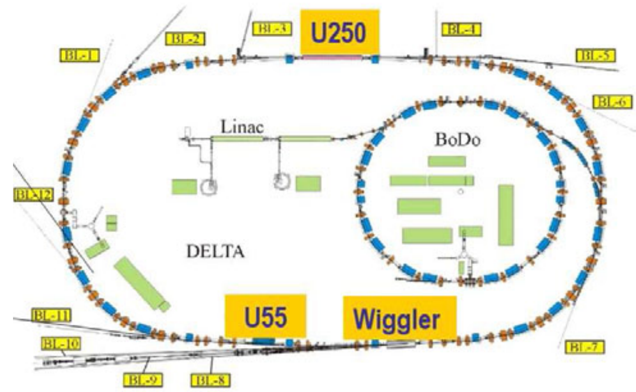

Figure 1: Layout of the DELTA accelerators and locations of insertion devices and beamlines.

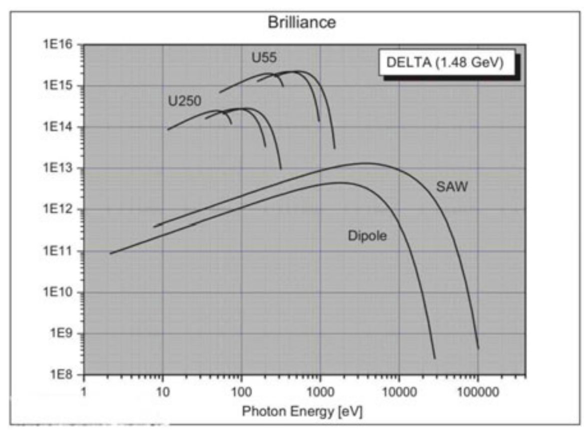

Figure 2: Brilliance of insertion devices (undulators with 1st, 3rd, 5th harmonic) for 1 mA beam current and a horizontal emittance of 16 nmrad at 1.48 GeV .

Insertion Devices

At present DELTA operates seven beamlines. The superconducting multipole wiggler (first one operated worldwide) provides in the asymmetric mode a peak field of 5.3 T at a critical energy of 7.9 keV. Built by the company ACCEL [21] the wiggler is fully operational since 2002 and serves three hard X-ray beamlines (BL 8-10). Two undulator beamlines for photon energies between 5 and 400 eV (BL-5, U250) and between 55 and 1500 eV (BL-11, U55) are in operation. The brilliance of the DELTA radiation sources is summarized in fig. 2. For more details see [4].

The superconducting wiggler [5,6] is operated in its high field asymmetric mode with only minor problems. Beam optics (mini-beta location of the wiggler), Q-shift and beam injection at 10 mm full vertical vacuum gap are well under control [6]. A slow orbit drift (appr. 1 mm/h) however is induced in the persistent current operation mode due to the residual intrinsic losses of the individual corrector magnet circuits spoiling the field integral. This effect is handled by a slow orbit feedback system [1].

Orbit Control and Stability

Orbit control is achieved by a global slow feedback system (0.1 - 1 Hz) via singular value decomposition (SVD) based on a measured orbit response matrix [7]. The versatile correction scheme can take current limitations of the correctors into account and, due to a limited number of BPMs and correctors, can put high emphasis on specific BPMs where orbit stability is of highest interest (at insertion devices e.g.).

The overall orbit stability is limited by thermal drifts of the vacuum chambers which are in mechanical contact with the quadrupoles. Nevertheless a given reference orbit is reproducible within +/- 250 µm horizontally and +/- 150 µm vertically for several consecutive weeks of user operation [1,7]. Presently the machine is subject to a surveillance and magnet repositioning program.

ACCELERATOR PHYSICS ACTIVITIES

Beam Test of the EU-HOM-Damped-Cavity

In the framework of an EU-project a normal conducting 500 MHz single cell resonator with damped higher order modes (HOM) has been designed and built under the leadership of BESSY [8]. Fig. 3 shows the cavity prior to the insertion into the DELTA storage ring. The HOMs are coupled to three tapered ridged waveguides and a coaxial transfer line to external loads. A cavity design with nose cones and a reduced beam tube diameter result in a shuntimpedance R_s comparable to that of the DORIS-type cavity still operating in several medium sized light sources [9].

Figure 3: Prototype of the EU-HOM-Damped 500 MHz resonator (R_s=3.1 MΩ, Q_0=27000).

Time domain calculations taking almost all of the complex geometry into account resulted in residual longitudinal impedances of only a few kΩ. sufficient to allow stable operation without the excitation of coupled bunch modes (CBM) of almost all existing light sources at nominal energy and current (see fig. 4) [10].

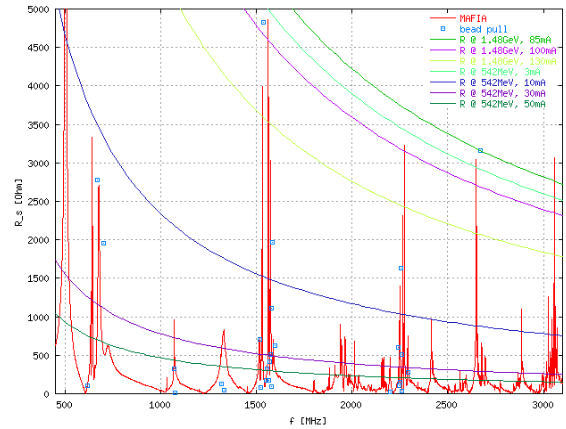

Figure 4: Calculated and measured (o) longitudinal impedance versus frequency together with instability thresholds for the DELTA storage ring at 1.48 and 0.54 GeV and different beam currents.

The calculated data could be verified by means of bead-pull measurements with a very good agreement [9].

In a first period (5/2004-9/2004) the EU-HOM-Damped-Cavity was installed at the DELTA storage ring as the only RF-source. After RF preconditioning at BESSY [9] in early 2004 the cavity was reconditioned within 2 days, the nominal beam current of 130 mA stored after two weeks of beam operation. After repair of a water to vacuum leak in one of the HOM dampers the cavity was reinstalled in a period from 7/2005 to 8/2006. In contrast to the measurements with the DORIS-type cavity [12] without HOM damping antennas, bunch instabilities originating from the EU-cavity at nominal energy were not observed [13]. For more than one year DELTA was routinely running with the EU-cavity-prototype in regular user shifts. The RF loss power capability of the prototype however was limited to 20-30 kW due to a not sufficient RF contact between cavity body and HOM-damper causing a high local heat load and mechanical stress. The new HOM-damper design of BESSY with in-vacuum ferrites will avoid this problem [14].

ALBA, the new 3 GeV light source presently being constructed at Barcelona and the Metrology Light Source in Berlin will be equipped with the new cavity type including the new damper design [15,16].

Fast CBM Instability Investigation

DELTA is operating without a fast bunch by bunch feedback system. Beam quality degradation caused by coupled bunch mode instabilities is therefore still a major issue above 90 mA (see fig. 5). The CBM instability investigation is routinely done by scanning the synchrotron sidebands of the revolution harmonics between 500 and 750 MHz [12, 18] using a spectrum analyzer. This offline procedure is time consuming (15min). Our new system [19] is fully digital and samples the sum signal of a beam position monitor (BPM) at a nominal rate of 2 GS/s and an analog bandwidth of 1 GHz. By an over sampling technique (shift between RF frequency and sampling frequency) the signal is taken bunch by bunch over hundreds of revolutions. Digital filtering directly reveals the bunch filling pattern of the storage ring and a successive FFT the phase modulation of the beam signal and thus the longitudinal oscillation spectrum within a second. The system is now fully integrated in the control system and allows realtime observations of CBMs.

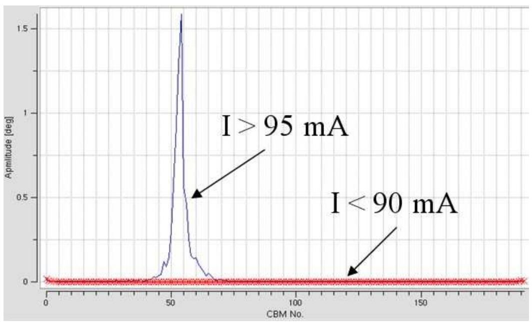

Figure 5: Excitation spectrum showing the bunch oscillation amplitude (degree) versus the mode number of longitudinal coupled bunch modes (CBM) below and above threshold.

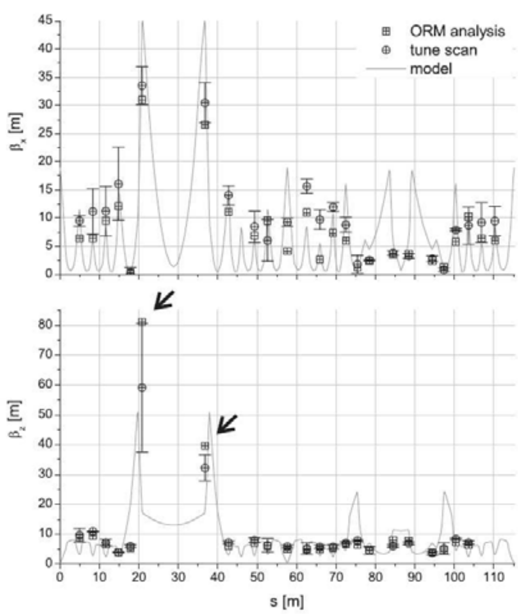

Figure 6: β-functions of the standard optics at 1.5 GeV. Errors obtained with ORM analysis are less than 5%. Arrows indicate the discrepancy between model and measurement around the U250 straight section.

Modelling of the Machine Optics

Significant progress has been achieved concerning the understanding of the storage ring optics. Using an orbit response (ORM) analysis based on a measured orbit response matrix the optical β-functions can be determined with better accuracy compared to the standard tune-scan method. Both methods are routinely used giving information at different locations. Within the error limitations both methods lead to comparable results (see fig. 6). While systematic deviations could be explained by calibration errors of the BPMs, the sensitive phase advance estimations of the ORM analysis however allow to check the model assumptions such as magnet positions and field strengths with a quite high precision [17].

Frequent Injection

Frequent injection with beamline shutters open is a very promising possibility to increase the average beam current by simultaneously stabilizing the heat load on the vacuum chambers with a great impact on machine and beamline stability. First successful tests with shutters closed have been performed with beam current stabilities of +/- a few percent [20]. Discussions with the SR-users and the approval authorities are ongoing.

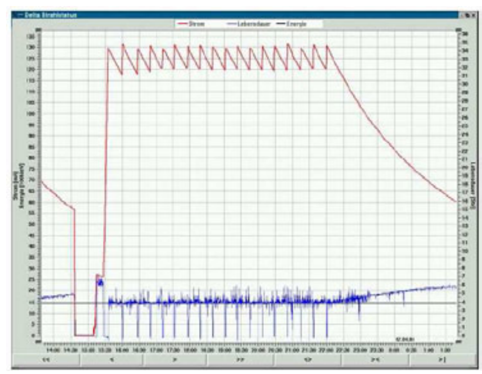

Figure 7: Frequent Injection Mode with beam shutters closed. The graph shows beam current (upper curve, <I> = 125mA) and beam lifetime (lower curve) versus time during 7 hours with +/- 5% beam current stability.

REFERENCES

[1] D. Schirmer et al., Proc. 2004 EPAC (2004) 2296
[2] A. Jankowiak, T. Weis et al., Proc 2000 EPAC (2000) 636
[3] D. Schirmer, K. Wille, Proc. 1991 PAC (1991) 2859
[4] U. Berges et al., Status of the Light Source DELTA, Proc. 2006 SRI (Synchr. Rad. Instr.), Korea, in print
[5] D. Schirmer, Int. J. Mod. Phys. 2B (1993) 644
[6] D. Schirmer et al., Proc. 2000 EPAC (2000) 2337
[7] M. Grewe et al., Proc. 2004 EPAC (2004) 2568
[8] F. Marhauer, E. Weihreter et al., Proc. 2001 PAC (2001) 846
[9] F. Marhauser, E. Weihreter, Proc. 2004 EPAC (2004) 979
[10] F. Marhauser et al., Proc. 2002 EPAC (2002) 2172
[11] F. Marhauser et al., Proc. 2003 PAC 1189
[12] R. Heine et al., Proc. 2004 EPAC (2004) 1990
[13] R. Heine et al., Proc. 2006 EPAC (2006) 2856
[14] E. Weihreter et al., Proc. 2006 EPAC (2006) 1280
[15] F. Perez et al., Proc. 2006 EPAC (2006) 1346
[16] K. Buerkmann et al., Proc. 2006 EPAC (2006) 3299
[17] O. Kopitetzki et al., Proc. 2006 EPAC (2006) 1945
[18] C. Pasotti et al., Proc. 1998 EPAC (1998) 990
[19] J. Kettler et al., Proc. 2006 EPAC (2006) 1034
[20] G. Schmidt et al., Proc. 2004 EPAC (2004) 2299
[21] ACCEL Instruments GmbH, D-51429 Bergisch Gladbach