STATUS OF THE SYNCHROTRON LIGHT SOURCE DELTA

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Abstract

Since 1999, the Dortmund 1.5 GeV electron storage ring DELTA was continuously extended. The facility serves universities and industries as a source of synchrotron radiation on a regional level. By now, DELTA, operated for 3000 hours per year, has reached a reliability comparable to other facilities in the world.

Improvements have been achieved in the installation of the beamlines. At present, two undulator beamlines and several dipole beamlines are in operation. The 5.3 T superconducting asymmetric multipole wiggler (SAW) serves three beamlines in the hard X-ray regime with circular polarized radiation. Also the accelerator physics research program has been promoted. The vacuum system was revised during the last year to provide extra space for test sections and additional diagnostics. Substantial progress was achieved by SVD based orbit correction as well as detailed coupled bunch mode (CBM) studies. Future developments for machine improvements, such as a DSP-based fast local orbit feedback and a frequent injection mode are in preparation.

INTRODUCTION

During synchrotron user mode operation peak currents of 120 mA are injected. Beam lifetimes of 7 hrs and injection times of approximately 15 minutes have been obtained. The average integrated beam current per standard user week is up to 8.5 A hrs. The average availability of the accelerators remained nearly constant at the last years level of approximately 84 % with an enhancement to a level of 92 % in the first half year of 2004, demonstrating, that DELTA has become a stable synchrotron radiation facility with competitive machine parameters.

BEAMLINE STATUS AND ACTIVITIES

Up to now, DELTA provides seven beamlines. In addition to the three hard X-ray SAW beamlines (BL-8,9,10), two undulator beamlines for photon energies between 5 and 400 eV (BL-5, U250) and between 55 and 1500 eV (BL-11, U55) as well as two bending magnet beamlines up to 200 eV are in operation or in the commissioning phase. The brilliance of the various DELTA synchrotron radiation (SR) sources are shown in figure 1. The SAW center beam-

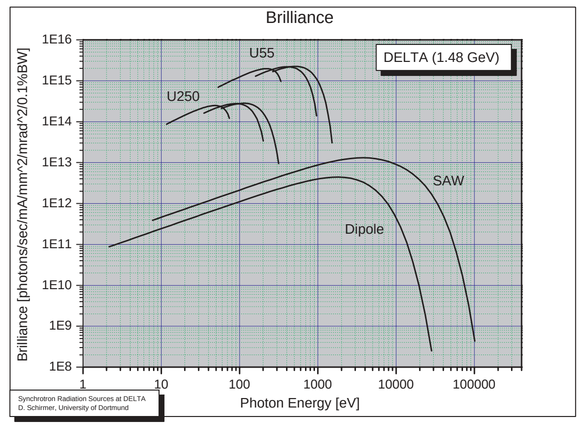

Figure 1: Brilliance of various SR-sources at DELTA (electron beam current: 1 mA, horizontal emittance: 16 nm rad at 1.48 GeV).

line (BL-9) of DELTA is fully operational since January 2002. The radiation supplied by the SAW, which has a critical photon energy of 7.9 keV, is monochromatised by a Si 311 double crystal monochromator. The second sagittal focusing monochromator crystal allows for a horizontal beam size less than 2 mm at the sample position. The monochromator covers an energy range from 5 keV up to 30 keV with a photon flux of about 3×10^{10} photons/s/mm^2 at 9 keV (electron beam current: 120 mA). A complete program with numerous external users from different places has been established at this beamline.

The University of Wuppertal (Germany) took over the responsibility for the remaining SAW beamlines BL-10 and BL-8. The latter has been already ordered by the company ACCEL (Germany), which is currently working on this project.

The Dortmund undulator beamline BL-11 (U55) was delivered and mounted during the summer shutdown 2003 by the company FMB (Berlin, Germany) and is in the commissioning phase at the moment.

The ”Forschungszentrum Jülich” (Germany) will continue the utilization of the undulator U250 and operation of BL-5.

First light was seen at the bending magnet beamline BL-

12, the former TGM-3 of BESSY-I, now operated by the University of Dortmund.

The ”Institute for Analytical Sciences” (ISAS) in Dortmund, took over the responsibility and support for the soft X-ray dipole beamline BL-2. ISAS is working mainly in the field of the development of analytical tools for industrial applications. It is planned to install a scientific program in the field of applied spectroscopy. Until beginning 2005 all beamlines are expected to be operational.

MACHINE STATUS AND ACCELERATOR PHYSICS RESEARCH PROGRAM

The last years of accelerator operation focused on stabilizing and improving the performance as reached in the year 2002 [1]. During the summer vacuum shutdown 2003 first upgrades of DELTA were installed and future accelerator physics studies such as the EC-HOM-damped-cavity test [4] were prepared. The shutdown was also used to integrate photon absorbers at all beamlines and to install additional diagnostics. Mainly additional rf-pickup beam position monitors (BPMs) in the wiggler, Free Electron Laser (FEL) and injection region have been assembled to allow a more effective orbit stabilization [2]. Essential for possible upgrades of DELTA was the separation of additional sections for future installation of insertion devices or accelerator test equipment in the northern part of the magnet lattice.

Nearly the complete accelerator was vented during the shutdown period. The venting was carried out vacuum section for vacuum section, each individual venting followed by one or more weeks of beam operation to allow immediate control of the work on the vacuum system and to do vacuum conditioning with high beam currents. Due to this scheme a beam lifetime of nearly 2 hrs at 100 mA have been reached in a few weeks.

The installation of the DELTA hall cooling, finished end of 2001, allowed to operate DELTA during the hot periods of summer 2003. The full cooling power was needed and the cooling system has now been completely and successfully tested.

Also the injection efficiency has been improved by a more effective orbit control along with an optimized DC-injection-bump, obtained by the installation of an additional BPM and a steerer magnet, both in the center of the injection region of the storage ring. The realignment of the vacuum chamber as well as two additional steerer magnets in the transfer line have contributed too. By now, the average transfer efficiency from the synchroton to the storage ring has been stabilized and increased from less than 30 % to more than 50 %.

SVD-Based Orbit Correction

A slow orbit feedback ($0.1 \sim 1\,\mathrm{Hz}$) based on singular value decomposition (SVD) of a measured orbit response matrix has been implemented into standard operation at DELTA. For the use of orbit correction, DELTA currently comprises 51 BPMs. Additionally, external monitors may be included for correction such as photon-BPM information supplied by beamlines. 30 dipole correctors are installed to correct for horizontal, 26 for vertical orbit displacements. Dispersion correction may also be considered for the horizontal plane by solving for the response of a rf detuning first. Further elements have been implemented into the algorithm as to balance different dipole families with respect to conservation of beam energy and to employ a set of dedicated (dc) correction coils for providing a local orbit bump needed to compensate for insufficient injection kickers. To enhance stability of orbit correction, input as well as output variables are monitored: BPMs are collaterally averaged to evaluate standard deviations for each monitor. Upon exceeding given lower or upper limits, evaluation of this monitor is extrapolated according to current circumstances. Also, the state of all correcting elements (such as correctors) are observed with regard to their expected performance. In case of an erroneous behaviour, the pertaining corrector won’t be used for correction until the faulty condition is lifted. The orbit correction also takes into account current limitations of correctors as described in more detail in [2].

In contrast to previously employed techniques of determination and application of the most effective corrector and local bumps, the presented concepts not only allowed for a significant increase of orbit stability during user operation, but also enhanced reproducibility during beam injection phases. Although DELTA may still be subject to severe thermic drifts, a given reference orbit was reproducible within about $\pm 0.25\,\mathrm{mm}$ horizontally and $\pm 0.15\,\mathrm{mm}$ vertically for several consecutive weeks of user operation. Future developments include a feed-forward for compensating the orbit drift due to a refresh cycle of the superconducting wiggler (SAW).

CBM Instability Investigations

After a complete reconstruction of the storage rings rf section in order to provide a fast and easy replacement of the DORIS type cavity by a HOM damped cavity [3] developed and built within an EC funded collaboration for in-situ tests, Delta has been fully characterized concerning CBM behavior with the DORIS type cavity installed at that time. The aim is to compare these results with those of the mode damped cavity.

The characterization has been performed at the storage ring energy of 542 MeV and 1.5 GeV at various beam currents, while the cavity’s temperature was varied between $35°\mathrm{C}$ and $60°\mathrm{C}$. The results of the characterization together with theoretical estimations are presented in [4].

FUTURE DEVELOPMENTS

Frequent Injection Mode

DELTA is now operated for 3000 hrs per year including 2000 hrs beam time for standard synchrotron radiation use. The maximum beam current of 120 mA is limited by the rf system, consisting of a 60 kW klystron powering a single DORIS type cavity. A possibility to increase the average beam current is to use a frequent injection scheme, where the peak current is not enlarged but the number of injections is increased to establish a nearly constant beam current. For a constant maximum beam current around 120 mA during frequent injection and a machine operation of 100 hrs/week Delta would deliver 12 A hrs/week in comparison to 8.5 A hrs/week to present-day standard operation. The advantage for the beamline user is the constant heat load on the experiments as well as on the vacuum chamber of the storage ring that directly reduces the magnet and chamber movements and for this reason increases the over-all machine stability.

First tests and developments have been done [5]. Depending on the results during the test phase and on the permission of authorities, the goal is to achieve a running injection with shutters open to allow further investigation of this mode of operation.

Fast DSP-Based Local Orbit Feedback

A test environment for a digital signal processor (DSP) [6] based local orbit feedback has been established in the area of the FEL undulator U250. The set-up consists of four BPMs and four corrector magnets. Two BPMs, up and downstream of the undulator, detect the vertical beam displacement and corresponding angle, both to be controlled. The other two BPMs take additional data outside the local orbit bump to ensure the closeness of the bump. A signal processor is fed with the measured orbit position data and calculates a correction for two vertical steerer magnets upstream and downstream of the insertion device respectively. The data are sampled with 8 kHz and 16 bit (ADC). The properties of the feedback loop, the signals have to pass, is mainly given by the eddy currents in the vacuum pipe which can be modelled by a low pass filter of 900 Hz and the inductivity of the corrector coils of 1 mH. The system is also limited by the effective sample rate and low pass filter of the BPM electronics to 1 kHz as well as the sample delay of 0.25 ms.

The first approach of a feedback algorithm was a PID system, with a 0 dB frequency at 300 Hz and -18 dB at 50 Hz, but the broad band noise, overlaying the BPM data, prevented a successful reduction of the RMS value with closed feedback loop. In addition to explore methods of enhancing the signal to noise ratio, the application of a fir-filter (finite impulse response) with up to 30 coefficients is under investigation. These coefficients need to be adapted to the BPM data spectrum to forecast the actual value, to compensate the latency and to filter out non predictable amounts of BPM data. Details of the implemented algorithm together with first local orbit feedback measurements are presented in [7].

Fast Tune Measurements

A new tune measurement system based on coherent beam excitation and turn by turn beam position measurement is currently in preparation at the storage ring DELTA. Compared to the previous system the measurement time is reduced by two orders of magnitude (100 Hz are aimed) and, due to the application of Lasker's NAFF-Algorithm [8], the precision of the measurement can be improved to better than 0.1 %.

CONCLUSION

Very positive developments have taken place at DELTA during the last two years. After declaring the consolidation program finished in summer 2002, the machine has maintained stable routine synchrotron operation with an average availability of approx. 85%. Orbit stability and injection efficiency have been improved significantly. Promising future projects in the field of accelerator physics research program like frequent injection, fast local digital orbit feedback and fast tune measurement are in preparation.

Important progress has been made in the installation and commissioning of the beamlines which will be finished 2005. Furthermore, a research program with various users from different fields and places as well as new cooperation partners have been established.

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