STATUS OF THE SYNCHROTRON LIGHT SOURCE DELTA

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Abstract

The Dortmund Electron Accelerator (DELTA) changed its scope during the last years from a test accelerator mainly dedicated to the development in the field of accelerator physics (including FEL) into a merely local 1.5 GeV synchrotron light source. DELTA is now operated for 3000 h per year including 2000 h beam time for synchrotron radiation (SR) use. The present status of the accelerator complex is presented together with the installation and commissioning of beam lines and insertion devices. To serve user demands of photon energies up to more than 10 keV a 5.5 T superconducting asymmetric multipole wiggler has been installed and is now successfully under operation since 2000.

To ensure reliable and effective operation of DELTA as a synchrotron light source major effort was concentrated on enhanced orbit and beam stability and a reduction of injection time. Necessary improvements of the DELTA hardware and control software undertaken will also be presented together with plans for an upgrading.

1 INTRODUCTION

The storage ring facility DELTA is operated by the Institute for Accelerator Physics and Synchrotron Radiation at the department of Physics (university of Dortmund). The facility consists of a 75 MeV S-Band LINAC, a ramped full energy injector storage ring BoDo and the 1.5 GeV main storage ring Delta (Fig.1).

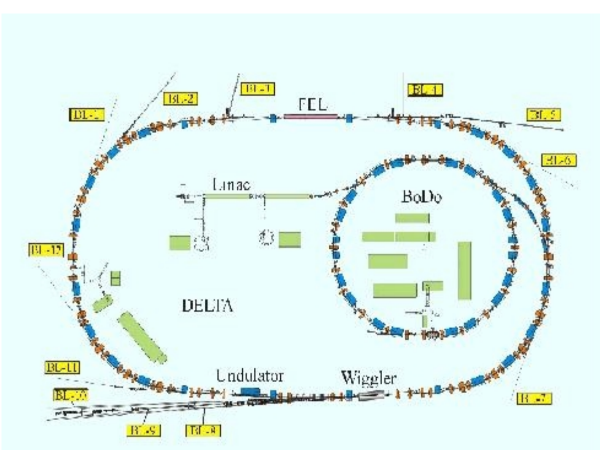

Fig 1: The DELTA accelerator complex

The most important beam parameters are summarised in table 1.

max. beam energy	1.5 GeV
circumference	115.2 m
max. beam current	120 mA multibunch @ 1.5 GeV 25 mA single bunch @ 550 MeV
beam lifetime	> 10 h multibunch @ 1.5 GeV 20 min single bunch @ 550 MeV
hor. emittance	16 nm rad @ 1.5 GeV

Table 1: Delta Storage Ring Beam Data

2 BEAM LINES AND INSERTION DEVICES

Presently several sources for synchrotron radiation (SR) are available (see table 2). Three insertion devices are operated at the storage ring: two undulators (U250 and U55) designed for the operation in the VUV and the soft X-ray regime and a superconducting asymmetric multipole wiggler (SAW) serving three beamlines in the hard X-ray regime (E_c = 7.9 keV) with also circular polarisation.

Beam-line	Experimental Station	Source Energy	Status
BL-2	reflectometry, magneto optical spectr./microscopy	dipole 1 – 100 eV	under constr.
BL-5	photoemission, coinc. measurements, spec-troscopy	U250 5 – 400 eV	regular user operat.
BL-8 SAW3	material science, EXAFS, diffraction	wiggler 4 – 30 keV	operat. in 2004
BL-9 SAW2	inelast. X-ray scattering X-ray diffraction, grazing incidence	wiggler 4-30 keV	regular user operat.
BL-10 SAW1	EXAFS	wiggler 4-30 keV	under constr.
BL-11	photoemission, photo-electron diffraction	U55 50–1500 eV	operat. in 2003
BL-12 TGM3	angle resolved photo-emission	dipole 20-200 eV	operat. in 2002

Table 2: Overview on DELTA Beamline Status and Parameters

The construction and the operation of the different beamlines is done by the regional universities and laboratories such as the universities of Bonn (BL-10), Dortmund (BL-8,11,12), Düsseldorf (BL-2), Wuppertal (BL-8) and the Forschungszentrum Jülich (BL-5).

3 IMPROVEMENTS AND OPERATION EXPERIENCE

Since 1999 DELTA delivers 3000 hrs of beam time per year including 2000 h for user operation at 1.5 GeV. Beam current is injected four times a day to presently 120 mA. A typical curve can be seen in figure 3.

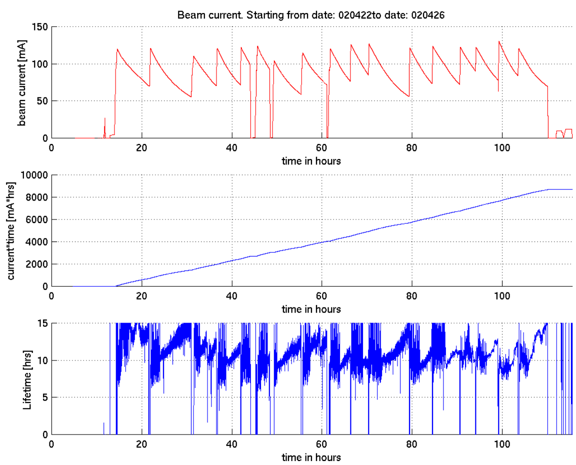

Figure 3: Beam current, integrated beam current and lifetime versus time during a user run in 2002.

DELTA is routinely operated from Monday 15.00 to Friday 14.00 in user operation. A lot of experience was gained to start up the complete accelerator system in only a few hours starting on Monday at 7.00. The main problem to reach reproducibility of the accelerator system was found to be temperature drift of magnets (up to +/- 500 µm) leading to significant orbit drift. Reducing this effect by improving the chamber and magnet cooling as well as the air cooling the stability was increased in such a way that without further optimisation beam can be stored after all components have been switched on. The drift of quadrupole magnets on Monday is still measurable during several hours [1]. Nevertheless the drift is small enough to keep the electron beam inside the acceptance of Delta.

Delta already operates with all three insertion devices. The two undulators do not have any significant effect on the electron beam.

To enlarge the SR-spectrum towards higher photon energies (4-30 keV) a superconducting asymmetric wiggler (SAW) [2] was installed and commissioned since the year 2000 [3].

The development of the integrated beam current per user week can be seen in figure 4. During one user run with 100 h beam time an integrated beam current of 7-8 Ah is now routinely reached.

The increase of the integrated beam current is correlated to an improvement of the average vacuum pressure in Delta and due to this an increase of the lifetime. The second effect is the increase of the injected beam current from 100 to 120 mA. With 120 mA the beam current reaches the limit due to RF-power.

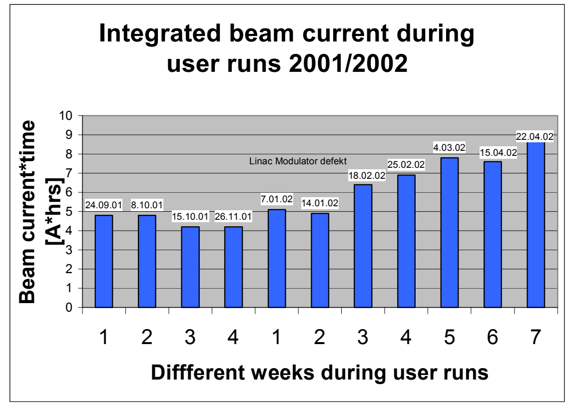

Figure 4: Development of the integrated beam current during one week of all user runs in 2001 and 2002 with all insertion devices switched on.

Great effort was necessary to improve the hardware of the accelerators in a step-by-step process. Especially the cooling of many components was not sufficient leading to a high failure rate of key components. Due to consequent exchange of limiting components, debugging of hardware interfaces and systematic improvements of the cooling system stable operation of DELTA with an overall availability during the last 11 user weeks of 87 % (see figure 5) has been achieved.

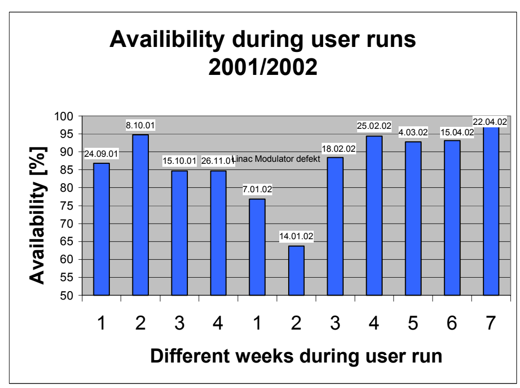

Figure 5: Availability during all user runs in 2001 and 2002 with all insertion devices switched on.

Subsequent improvements concerning the injection chain have considerably decreased the time necessary for beam accumulation. The 75 MeV S-band linac has been reconstructed in 1999 by replacing two old travelling wave structures by one single section obtained from the decommissioned DESY-SBTF-Linac together with the installation of a state-of-the-art RF-power station [5]. A total charge of 0.5 – 1.5 nC within 20 ns is now routinely stored and accelerated in the booster. This is 20% - 50%

of the theoretical limit (beamloading induced energy spread in the linac) taking a booster momentum acceptance of +/- 0.5% into account). By further optimisation of the injection chain and reducing the booster emittance the injection efficiency into the storage ring DELTA was nearly doubled from 20% to 40% [6]. The effective injection time (closed shutters) for topping up from 60 mA to 120 mA is now in the order of 20 min.

To achieve a stable electron trajectory a slow orbit feedback based on measured response matrices using most effective correctors for the orbit correction has been implemented in the frame of the control system to stabilise the orbit [4].

The sources of orbit drifts have been clearly identified:

- Current dependent movement of quadrupole magnets [1]. The magnets are moving due to the synchrotron radiation heat load on the outside of the vacuum chamber leading to mechanical stress of the chamber which pushes the quadrupole magnets wherever the quadrupole magnet has contact to the chamber.
- Persistant current variations inside the wiggler (SAW). Without feedback different resistive contributions of the individual coils of the SAW lead to a time dependent local kick of the electron beam. The drift is 1 mm/h measured on the most sensitive beam position monitor (BPM).

Both effects are counteracted with the slow orbit correction system.

Large differences between calculated optics and measured beta-functions and tunes have been found. To improve the optics model of Delta all relevant components such as power supplies and magnets have been re-measured. Significant corrections were found to be necessary concerning quadrupole power supplies. It turned out to be essential that the influence of the cross-talk between sextupole and quadrupole magnets has to be part of the model [7]. The influence of the SAW on the optics showed the expected behaviour [3].

4 FUTURE DEVELOPMENTS.

Further improvements are expected in the near future by enhanced modelling and modifications of the optics. Increased temperature stabilisation and a de-coupling of vacuum chamber and quadrupole magnets will further improve the machine stability.

Further improvements of the injector chain including slight modifications concerning the linac and the transfer lines (better transverse matching) will decrease the injection time for topping up to less than 10 min.

The installation of a second cavity and RF-system is foreseen in 2003/2004. The upgrade will allow for currents between 150 and 200 mA, limited only by cooling of the vacuum chamber.

Additional insertion devices can be included into the Delta structure. The availability of test sections (provided in a large shutdown in 2003) will allow the fast installation of test equipment into the accelerator with minor influence on vacuum and beam lifetime. One of the first experiments will be the in-situ test of a HOM-damped RF-cavity which is presently developed within the framework of an EC-collaboration [8].

Due to the still low impedance of the machine [9] DELTA offers also high peak currents in single bunch mode for FEL operation. On a medium time scale it is envisaged to extent the FEL-project at the storage ring [10] towards shorter wavelengths.

5 CONCLUSION

After two years of commissioning DELTA now runs as a local user synchrotron radiation source with an annual beam time of 3000 h (2000 h are dedicated to SR use) After accomplishing the envisaged beam lines, the DELTA facility offers a wide span of possible SR-experiments in an university environment together with the potential of research and development in the field of accelerator physics.

6 ACKNOWLEDGEMENTS

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