PETRA III UPGRADE

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Abstract

PETRA III, the new third generation light source at DESY, has been running as a user facility since middle of 2010. All 14 undulator beam lines have been commissioned and up to 12 of them are currently in operation. However, already during the planning phase of PETRA III it turned out that the number of beamlines will not be sufficient to fulfill the request for beam time. The pressure to add more beamlines to PETRA III even increased after the decision to shut down DORIS III at the end of 2012. To increase the number of experimental stations two additional halls will be built each housing 5 additional beam lines and about 100 m of the accelerator close to each of the new buildings will be completely remodeled to install additional undulators. The upgrade has been formally approved and should be accomplished during a 6 month shut down in 2013. In this paper the layout of the upgraded accelerator will be shown. The impact of the upgrade on machine performance has been studied both theoretically and experimentally and the results of these studies will be presented.

INTRODUCTION

The new synchrotron radiation source PETRA III has been operated as a user facility since middle of 2010 [1]. The basic parameters of PETRA III are given in table 1 and more details can be found in the following references [2], [3].

Table 1: PETRA III Parameters

Parameter	PETRA III	
Energy / GeV	6	
Circumference /m	2304	
Total current / mA	100	
Number of bunches	960	40
Emittance (horz. / vert.) /nm	1 / 0.01	
Number of insertion devices	14	

During the last few years it became obvious that the number of beamlines offered by PETRA III would not be sufficient to fulfil the request for beam time in particular after the decision to shut down DORIS at the end of 2012.

To increase the number of beamlines two new halls will be built, one in the East and one in the North, each housing 5 beamlines. Figure 1 shows a schematic view of PETRA III with the new buildings.

Figure 1: Schematic layout of PETRA III. Two new halls in the North and East will be added to offer ten more beam lines.

The upgrade will be carried out during a seven month shut down in 2013. The accelerator will be re-commissioned in autumn 2013 and user operation will be resumed in December 2013. Start of the commissioning of the new beam lines will be in 2014 and the first beam lines will become operational in the second half of 2014.

In the following we describe the changes of the lattice and the impact on dynamic aperture and operation. Finally we give a status of hardware development.

LATTICE CHANGES

One beam line in the North will be fed by the radiation of the damping wigglers installed in long straight section north [4]. In the East a wiggler and an undulator will be installed in the straight section so that the first beam line can be either fed by an undulator or wiggler. The optics in this straight will be modified to realize two straights of 5 m length with a horizontal beta of 20 m and a vertical beta of 3.5 m. This will allow installing 5 m long IDs with a minimum magnetic gap of 9.5 mm.

The other beam lines in the North or East respectively are fed by four undulators that are installed in two canted DBA cells that will replace the existing FODO cells.

Figure 2 shows a comparison of the existing and the new optics with the two DBA cells.

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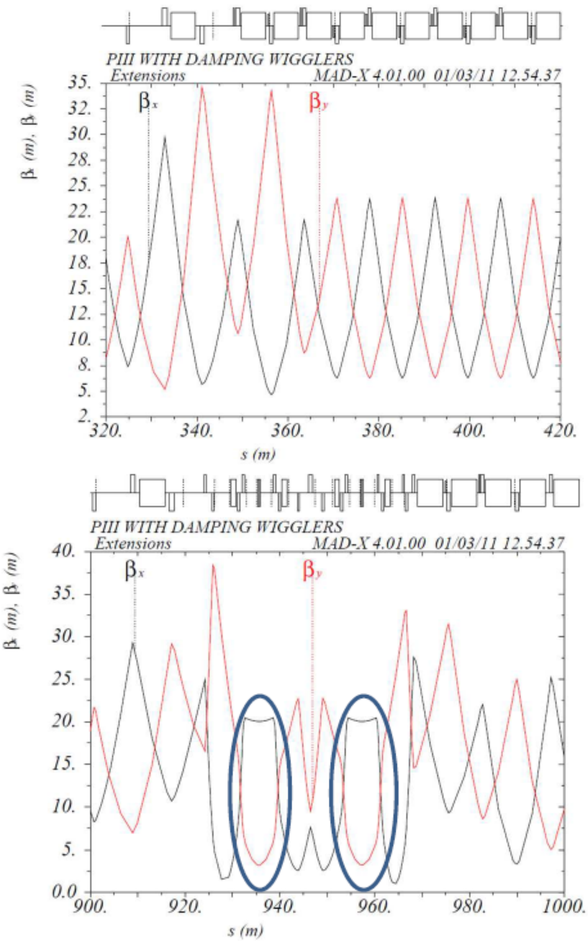

Figure 2: Comparison between existing optics and new optics with two DBA cells indicated by the blue ellipses.

To install the DBA cells five dipoles and a number of quadruples have to be removed and replaced by shorter quadrupoles and dipoles. In the middle of each cell a dipole magnet is installed to cant the particle beam by 20 mrad. Each cell will house two 2m long undulators finally.

In addition to the removal of the dipoles and quadrupoles five focusing and five defocusing sextupoles have to be uninstalled as well. The remaining sextupoles have to be increased in strength to correct the chromaticity. The impact of this measure will be discussed in the next section.

IMPLICATIONS ON BEAM DYNAMICS

Nonlinear Effects

In the current optics sextupoles are installed in the FODO cells of the old octants. Each of the seven old octants contains 10 focusing or defocusing sextupoles respectively. The phase advance of a FODO cell is 72° and each cell contains a focusing and defocusing sextupole. To first order all resonance driving terms are cancelled behind five cells. That is the reason why 5 focusing and defocusing sextupoles have to be removed in the east and north. Chromaticity correction requires an increase of strength of the remaining sextupoles because of the removal of sextupoles and the fact that the new optics requires stronger focusing. The higher strength leads to a larger detuning and a larger non-linear chromaticity causing a reduction in on- and off-momentum aperture. The reduction has been determined by tracking and it is expected that the on-momentum aperture will be smaller by 20 % and the off-momentum acceptance decrease from 1.7% to 1.5%.

To verify the tracking results experimentally we disconnected 10 sextupoles in the North and East from the power-supplies. The strength of the remaining sextupoles was increased to ensure chromaticity correction. The set-up of this experiment is not identical to the situation after the upgrade but is very close to it. Both off- and on-momentum acceptance have been measured and compared with the current values to figure out the change in dynamic aperture. The measured decrease in on-momentum acceptance was 10 % and the off-momentum acceptance reduced from 1.6% to 1.45% so that only a slight degradation of the performance is expected.

Current Limitations

The installation of additional insertion devices requires replacing standard vacuum chambers by small gap chambers which will be NEG-coated. The impedance of the present machine has been studied carefully [5] which allows predicting the increase in broad band impedance and thereby the single bunch current limitation after the upgrade.

The present single bunch current limitation is about 2 mA limited by transverse mode coupling. By increasing the vertical chromaticity to +5 and the gain of the vertical coupled bunch feedback system currents of up to 5 mA could be stored in a single bunch. Even higher currents may be possible but the current was limited intentionally in order not to destroy the BPM-electronics.

The expected increase of the impedance is about 40% which should still allow storing single bunch current of higher than 2.5 mA required for the 40 bunch mode with 100 mA.

TECHNICAL LAYOUT AND STATUS OF HARDWARE DEVELOPMENT

Two new halls will be built and each will house 5 new beamlines. Figure 3 shows a schematic and figure 4 shows an artistic view of one of the new halls. The existing accelerator tunnel will be reused. Beamline front ends will be housed in an area in the new hall that is surrounded be a 1m thick concrete shielding wall. In order to install two DBA like structures in the arcs in the North and East about 50 m of accelerator structure have to be replaced. Care has been taken to minimize development of hardware. Magnets [6] and powersupplies that had already been designed for PETRA III will be used and the diagnostics such as the BPM system and electronics are similar to the ones already in operation [7].

Magnets have been already ordered and the production of power supply hardware will start soon.

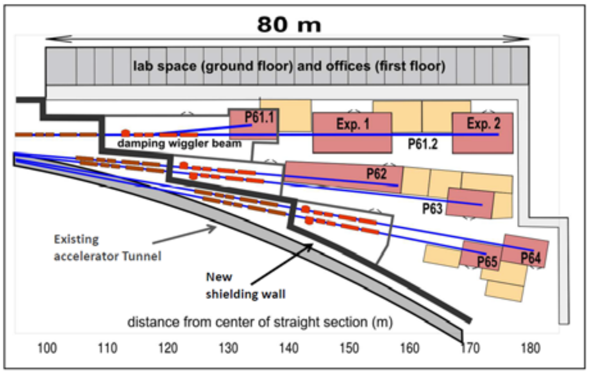

Figure 3: Schematic view of the new experimental Hall North.

Figure 4: Artistic view of the New Hall Petra North including the existing and new FLASH buildings.

In contrast to other third generation light sources the magnets and other accelerator components will not be installed on girders but on simple concrete blocks and will be aligned with standard tools. Present experience shows that these supports will not compromise orbit stability significantly.

The orbit feedback [8] will be extended to guarantee the required pointing stability of the particle beam. In this context it should be noticed that the ID's and the experiments do not share the same slap but that accelerator tunnel and the floor of the new halls are separated. This separation may lead to relative movements of the tunnel with respect to the experimental floor which is particularly harmful in the vertical plane. Presently two methods to measure the relative vertical movement are studied namely a hydro static levelling system or a stretched wire system. X-BPMs installed in the beam lines are also under discussion to determine the pointing stability of the photon beams.

The vacuum system for the new sections will be developed along the lines set up for PETRA III [9]. The design is basically similar to the new octant but redesign of several components is necessary to take into account the different bending angles of the dipoles and to avoid problems that have been encountered during operation of PETRA III. A number of massive copper blocks will absorb the radiation of the bending magnets and make sure that the stainless steel vacuum chamber is not hit by synchrotron radiation. The undulator chambers will be extruded aluminium profiles and will be NEG coated to achieve the required pressure level. The vertical aperture of the chambers amounts to 7 mm to allow minimum undulator gaps of 9.5 mm.

The principle layout of the components has been done and a 3-D model is under way to verify the consistency of the overall design.

The straight sections in the canted DBA cells will be finally equipped with 2m long undulators similar to those that have been built and installed in PETRA III [10]. The support structure will be modified so that the IDs fit into the existing accelerator tunnel.

In order to achieve the required temperature level and stability of about 23° ± 1° C near the undulators the existing air conditioning system of PETRA III has to be either extended or modified. During commissioning the temperature level and stability will be checked and if not sufficient a local air conditioning system can be installed close to the undulators to fulfil the requirements.

SUMMARY

To extend the number of beam lines of PETRA III an upgrade project has been launched. A new optics has been developed that will only slightly effect machine operation. Hardware component are presently developed or have been already ordered. The project is still on schedule so that machine operation can be resumed after a seven month interruption in winter 2013 and the new beamlines will be commissioned starting from spring 2014.

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