PROGRESS REPORT ON PETRA III

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Abstract

Starting from the middle of 2007 the existing storage ring PETRA II at DESY will be converted into a hard x-ray light source PETRA III. The project was launched in 2002 and in preparation of the conversion a technical design report was published in 2004. Since then detailed design and construction of technical components has begun. Prototypes have been built and tested and the procurement of major parts of the machine components such as magnets and vacuum chambers has started. The project is well underway and in-line with the goal to start the rebuilding in 2007 and the commissioning in 2009. In addition to an overall status report the development of components and measurement results of prototypes will be presented.

INTRODUCTION

At DESY the exiting storage ring PETRA II with a circumference of 2304 m will be converted into a dedicated light source PETRA III [1], [2]. This new source will be a third generation, hard x-ray facility similar to APS, ESRF and SPRING8 and should serve as a supplement to the X-FEL which will be build at DESY. The basic parameters are given in table 1.

Table 1: PETRA III parameters

Parameter	PETRA III	
Energy / GeV	6	
Circumference /m	2304	
Total current / mA	100	
Number of bunches	960	40
Lifetime / h	24	2
Emittance (horz. / vert.) /nm	1 / 0.01	
Number of insertion devices	14	

The emphasis of the conversion is on achieving a very small horizontal emittance and to solve the stability problems that are usually connected with high brightness beams.

The number of insertion devices is rather modest for a machine of this size but this due to the fact that the conversion should be cost effective.

PETRA II consists of eight almost identical parts which are usually called octants. One of the octants will be completely removed and replaced by a new experimental hall of almost 300 m length and 30 m width (see figure 1).

Figure 1: Ground Plan of the DESY site with the PETRA ring. The new experimental hall (red) is situated between the PETRA halls North-East and East.

This new hall will house the experimental huts and will supply 9 straight sections in a DBA lattice to install insertion devices. The concept of canted undulators will be applied so that 14 undulators can be installed.

The geometry and the lattice of the remaining seven so called old octants will be kept. The existing hardware will be reused if possible but refurbished and modernized to fulfil the high demands on reliability of a light source.

The conversion will start in the middle of 2007 and commissioning of the new machine is foreseen at the beginning of 2009.

ACCELERATOR ISSUES

In order to accomplish the small horizontal emittance several lattice options have been studied. There was a clear preference in terms of dynamic aperture to combine the existing FODO lattice in the old octants with a DBA lattice in the new octant and to enhance the radiation damping with twenty 4 m long damping wigglers to achieve the design emittance [3], [4]. A large dynamic aperture is needed for high injection efficiency a prerequisite for top-up operation. The investigation of the dynamic aperture of PETRA III has been continued including all relevant effects like alignment and field errors as well as the effect of the insertion devices [5].

The experimentalist can only take advantage of the small emittance if the beam is sufficiently stable. The required orbit stability in the vertical plane is as small as 0.5 μm which can be achieved with orbit feedbacks only [6]. Besides orbit stability careful control of the dispersion is necessary. Different schemes to correct and adjust especially the vertical dispersion have been investigated in detail [7].

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As indicated in table 1 two modes of operation are foreseen for PETRA III. One with a very high number of bunches (960) and one with a rather small number (40) to allow for time resolved measurements. In order to be able to offer full current in the latter case care has been taken to minimize the impedance of the machine. A study program has been initiated to investigate the impedance of all relevant objects [8], [9], [10]. The investigations have indicated that it should be possible to run the machine at full current with 40 bunches.

STATUS OF MACHINE COMPONENTS

Magnet System

All magnets for the DBA cells of the new octant have been designed. Prototypes of the two different quadrupoles as well as the dipoles have been built and tested. The field quality of the dipoles fulfilled the requirements immediately whereas in the case of the quadrupoles slight modifications to the design were necessary to reduce the octupole component. The spacers in the midplane had to be strengthened and some extra spacer had to be introduced between the upper and lower poles. The series production of both the dipoles and quadrupoles has been started.

The iron core corrector magnets for the new octant have been designed for both the horizontal and vertical direction and prototypes of the more sophisticated vertical correctors have been built and tested. The series production of the vertical correctors has been started and will be launched for the horizontal correctors in the middle of 2006.

Air coil magnets needed for the fast orbit feedback have been specified and designed and prototypes have been ordered.

As has been mentioned above the magnets of the old octants will be reused. Nevertheless the coils will be replaced because of radiation damage. The spare coils of the different magnets have been ordered and the first have be delivered to DESY.

Girders

Similar to other third generation light sources the demand on magnet alignment is rather stringent. To fulfil these requirements the magnets in the new octant will be mounted on girders.

An alignment strategy has been developed that allows the magnets to be positioned with an accuracy of 50 µm. In order to maintain this high accuracy the magnets are glued to the girder (see figure 2). The alignment and fixation procedures have been tested and proven to fulfil the requirements.

The girders will be equipped with movers similar to those foreseen for DIAMOND to allow fast realignment of the machine to compensate for ground settlements.

The eigenfrequencies of the girder without movers have been determined and are above 40 Hz which is sufficient. A measurement of the eigenfrequencies with movers is still lacking but will be done in autumn 2006.

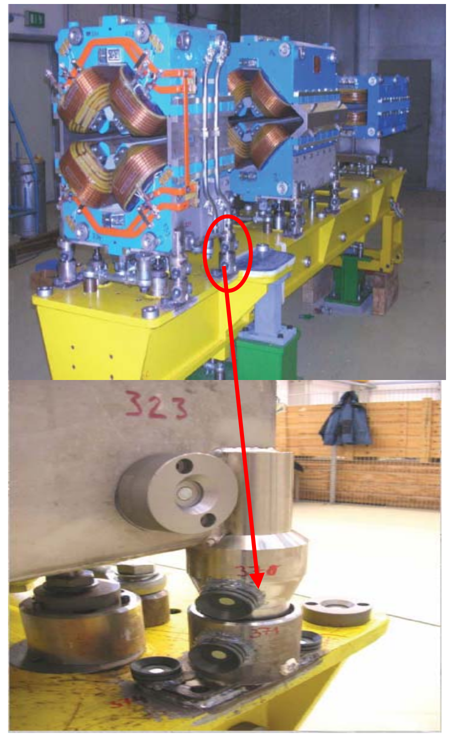

Figure 2: In order to maintain the quality of the alignment of the magnets they are glued to the girder.

Vacuum System

Not only the vacuum system of the new octant has to be designed and built but it has been decided to renew the vacuum system of the old octants as well [11]. This is necessary since the demands on pressure and conditioning are much higher than for the present machine and the demands on orbit stability require changes.

The production of the different components of the vacuum system for the old octants has been started already. The almost 5.5 m long extruded aluminium profile for the dipole chamber is ready. The stainless steel chambers for the quadrupoles, sextupoles and BPM's that are located in between two dipoles are being produced at this time. The aluminium and stainless steel chambers are linked by explosion bonded connections that have been ordered. The assembly of the system for the old arcs will start in the second half of 2006.

In order to check that the assumptions on conditioning for the new vacuum system are valid a test chamber has been installed in PETRA II. This test chamber contains two new long dipole chambers and the stainless steal connection. It could be shown that the pressure rise with current as a function of integrated particle current behaved as expected (see figure 3). According to this measurement the design pressure will be reached after 100 Ah but reasonable operation is possible after 30 Ah.

The vacuum system for the new octant has been designed completely. Special care has been taken that the synchrotron radiation does not intercept the stainless steel vacuum chamber but can be removed by copper absorbers. Critical items of this system are the absorbers which have to remove large amounts of radiation power and the chambers for the insertion devices. These critical items as well as the other parts will be reviewed in July and then the production of the chambers should start in autumn this year.

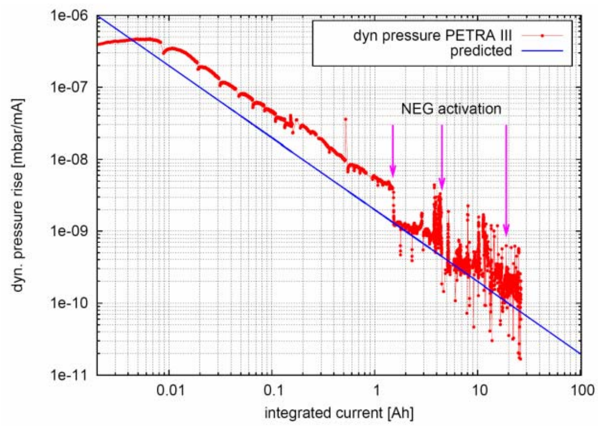

Figure 3: Comparison between expected and measured dynamic pressure rise as a function of integrated current for the test chambers installed in PETRA II.

Damping Wigglers

The twenty 4 m long damping wigglers play an important role in producing the small horizontal emittance [12]. Half of the wigglers are installed in the long straight section west and the other half in the long straight section north. The peak field of the permanent magnet wigglers is 1.5 T and the period length 20 cm. Each wiggler generates 42 kW of radiation power at 200 mA so that the total power per wiggler section is about 400 kW. This large power has to be removed by a sophisticated absorber system.

The design of the wiggler magnets is finished. A short prototype has been built that essentially fulfilled the requirements. Meanwhile the first 4 m long wiggler has been built and several tests have been performed to check the field quality in general and the field quality after opening and closing the wigglers. Measures such as magic fingers and other correction methods are being tested in order to improve the field quality even further. The first five wigglers should be shipped to DESY in autumn this year [13].

The construction of the vacuum system is nearly completed and prototypes of the wiggler chambers have been built. The wiggler chamber is an extruded aluminium profile which will be sputter with NEG-material to achieve the required pressure. The first complete wiggler chamber will be ready in autumn this year.

The design work on the absorbers is progressing. The calculation of the power load distribution on the different absorbers is almost finished which included closed orbit distortions and alignment errors. The first prototypes will be produced in autumn this year and tests with electron beams will be performed in order to verify the results of power load simulations [13].

Diagnostic and Control System

In order to control the small emittance of the beam a high quality BPM system including electronics is required. For the time being extensive theoretical and experimental tests are under way to specify and check the complete monitor system. In order to measure emittances a dedicated bending magnet beam line is foreseen. In addition a laser wire scanner should be installed in PETRA III similar to that which has been already tested in PETRA II [14], [15].

The control system for PETRA III will be renewed which includes also the pre-accelerators. Details can be found in a companion paper to this conference [16].

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