# STATUS OF THE PETRA III DAMPING WIGGLERS

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*Abstract*

After mid-2007, the present PETRA storage ring at DESY will be reconstructed towards a dedicated third generation light source operating at 6 GeV. An emittance reduction down to 1 nmmrad can be achieved by means of damping wigglers. 20 permanent magnet wigglers will be installed in two of the long straights of the machine. The wiggler segments are compact fixed gap devices surrounded by iron enclosures to reduce the leakage flux. Each device will provide a damping integral of 4 $T^2$m per segment and generate a synchrotron radiation power of 42 kW. Every wiggler segment will be followed by an SR-absorber to protect all downstream components, the accumulated on-axis power of about 120 kW will be taken up by a final absorber at the damping section end. The wiggler's magnetic design, field properties and correction schemes have previously been proven by a short prototype. At present, the first full length (4m) prototype wiggler has been assembled and characterized magnetically.

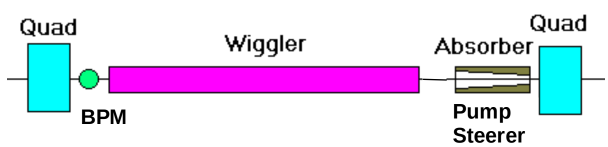


Figure 1: Layout of a regular cell in the damping section.

## INTRODUCTION

The PETRA II ring at DESY, at present used as a booster for HERA, will be converted to 3rd generation light source in 2007/2008 [1]. The new storage ring will operate at 6 GeV and 100 mA nominal current. One octant of this machine will be completely remodeled for installation of 14 undulator beamlines with exceptional brilliance, particularly suited for experiments with small or diluted samples requiring small beam size or extreme focusing conditions [2,3]. In the other octants, a series of old components will be refurbished or replaced, among these the entire vacuum system, most of the magnet coils, power supplies of the rf-system, beam diagnostics and beam position control system. Additionally, the top-up mode operation requires a partial upgrade of the pre-accelerator chain.

DBA cells will be built in the new octant while the previous FODO structure will remain in the rest of the machine, the latter limiting the emittance to about 4 nmrad. A further reduction to a value of only 1 nmrad will be achieved by installation of damping wigglers [4]. In total, 20 wiggler segments will be installed in the dispersion-free long straight sections in the West and North of PETRA III.

Fig. 1 shows the layout of a regular cell in the damping sections. Within the 5.3 m long drifts between two quadrupoles, a 4 m long wiggler segment, a synchrotron radiation (SR) absorber, steering magnets, a BPM, and a vacuum pump are accommodated. The power deposition onto each absorber is a superposition of the SR generated in all upstream wiggler segments. Therefore, the first absorber will be placed behind the third wiggler while the two last FODO cells at each damping section will be equipped with long absorbers only.

## WIGGLERS

### *Design*

The design and parameters of the permanent magnet wigglers have been reported previously [4]. All 20 devices will be identical. They have a length of 4 m and a fixed magnetic gap of 24 mm which is determined by the required 17 mm beam-stay-clear for the injected beam together with a sufficient shading of the wiggler vacuum chamber by the upstream absorber.

The segments are built as modified hybrid structures with wedge-shaped poles, additionally powered by side magnets. An iron enclosure of the magnet structure serves both as a mechanical support and as a magnetic yoke. These measures reduce the leakage magnetic flux and minimize the required volume of magnet material being the cost driving factor of the wigglers. Care has been taken to choose the magnet dimensions according to an optimum working point. The complete device has a compact cross section of about 300×350mm$^2$ (H×W).

The axial magnets between the poles are split into two parts. They are separated by a soft iron V-notch sitting on the iron yoke and acting as a zero-potential plate. By that means, adjacent poles are largely decoupled which eases the magnetic tuning considerably. Corrector bolts inserted from the sides underneath the poles are used for individual adjustment of the strength of each half period. The adjustment range is 400 Gs.

### *Prototyping*

Investigation of a short, one period long prototype initiated some minor mechanical changes. It also showed that Vanadium Permendur poles should be used instead of iron for the further wiggler segments in order to decrease saturation and to improve the transverse field homogeneity. The full length prototype wiggler has recently been manufactured at BINP (Fig. 2). The magnets, in particular the side magnets, have been sorted

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for minimization of transverse field components. After insertion, the two wiggler halves have been put together by means of a support mechanics, which will also be used later to re-open the structure for insertion of the vacuum chamber.

Figure 2: Pre-assembled wiggler half before insertion of magnets (top) and completed 4m long prototype (bottom).

## *Measurement Results*

Fig. 3 shows first magnetic measurements of the long prototype. Data are taken with an array of 7 transversely spaced Hall probes which is moved through the wiggler gap by a linear stage. Transverse guiding of the array is provided by the plain surfaces within the aperture which have been machined with high precision.

Requirements for horizontal trajectory straightness within the wiggler segment are moderate as it only has to be ensured that the mean SR power emission occurs along the beam axis. Nevertheless, it turned out that the pole strength can be adjusted easily and fast by means of the corrector bolts. For a peak field of 15.6kGs, a variation of only $\sim 5\cdot 10^{-4}$ remains in the longitudinal field dependence in Fig. 3a). A transverse field roll-off of $10^{-3}$ at $x_0$=1cm has been obtained in agreement with calculations (3b).

Figures 3c) and d) display the longitudinal and transverse dependence of the first field integral, respectively. It can be seen that a variation of about 400Gscm within a transverse region of ±1cm remains as a residual value. This transverse dependence is then flattened by help of finger correctors consisting of 10 individual magnets which will be attached at both ends of the wiggler. They will provide an ample adjustment range of ~2000Gscm. For a more precise measurement of integral magnetic multipole components, a stretched wire probe is currently manufactured. It will allow for higher spatial resolution, and will also be used for characterization of the total horizontal field integral.

First preliminary data of the horizontal magnetic field component have been taken with a Hall probe. Fields have been observed in the order of up to ±20Gs which may be due to imperfections of the permanent magnets. As an integral value, a horizontal field integral of about 800Gscm has been found. This significant perturbance is accumulated in a localized region at one side of the magnet structure and needs detailed inspection. For correction of these horizontal field integral errors, shim magnets will be placed within the end parts of the magnetic structure.

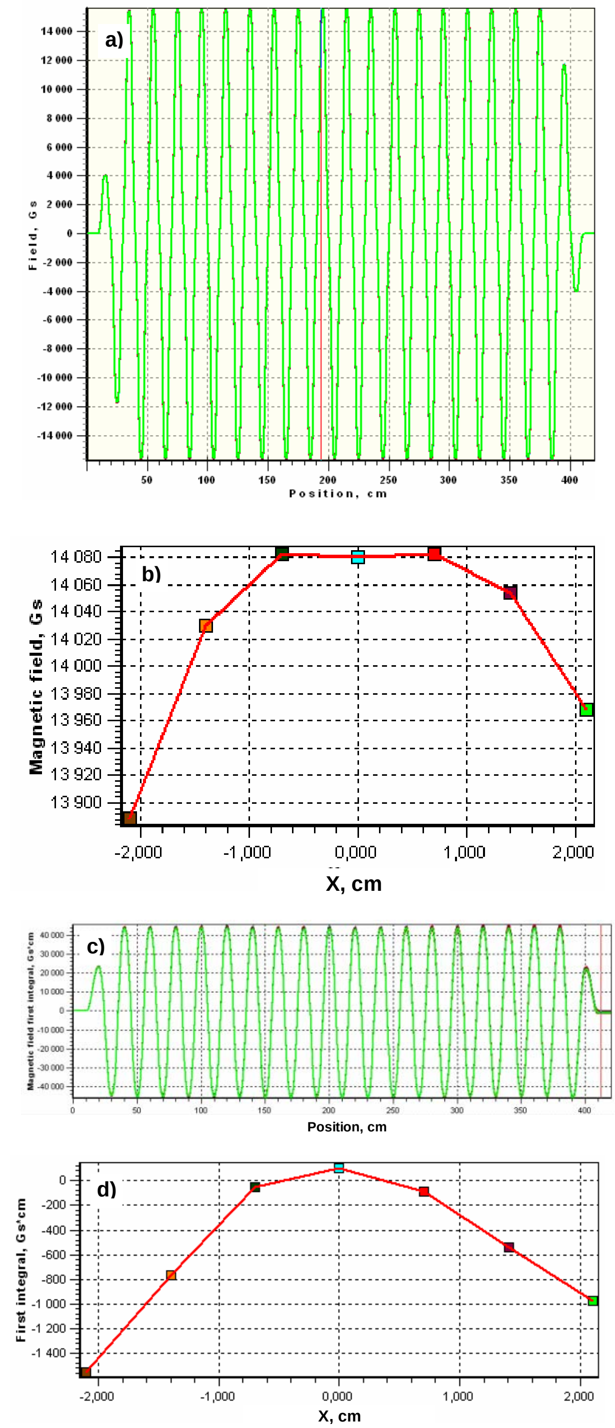


Figure 3: First Hall probe results of the long prototype: a) longitudinal field dependence, b) transverse field profile, c) 1st field integral, and d) its transverse distribution at the end of the structure (without finger correctors).

## VACUUM SYSTEM

Each damping section will be divided into two vacuum parts, a first section containing all wigglers and regular absorbers, and a second with the two long and the final absorber. The vacuum system of a regular cell consists of four different vacuum chambers and 2 types of bellows. The cross-sections of the quadrupole and BPM chamber have been reviewed and optimized so that the impedance of the regular cells is reduced considerably.

The wiggler chamber will be made by aluminium extrusion. A first prototype chamber has been tested previously, and series production of these chambers can now start after a slight modification of the extrusion tools. The chamber will be fully NEG-coated to achieve efficient pumping along the entire wiggler. For activation of the NEG material, the wigglers have to be opened in the tunnel by means of a special mechanics. A heat load calculation has been performed for the wiggler chamber at the worst case location assuming a COD of 1mm. Fig. 4 shows that the maximum absorbed power density will be up to ~1mW/mm$^2$. The maximum total power absorbed by the chamber will not exceed 100W.

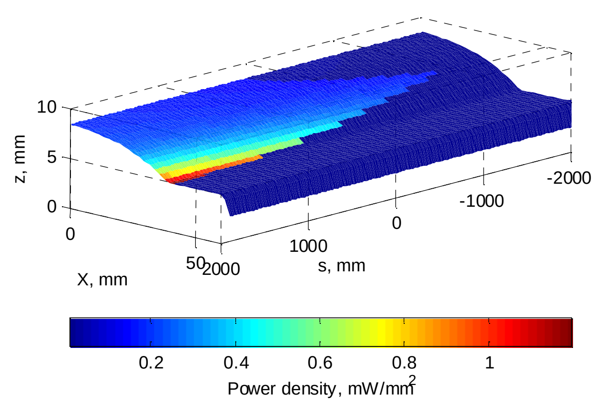


Figure 4: Power density distribution across the wiggler chamber (one quarter is shown).

## ABSORBERS

The layout of all absorbers has been done for a beam current of 200mA for a potential later upgrade. The final solution has been found through a manifold iteration of the absorber concept and geometry. Two general types of regular absorbers with an alternating vertical aperture of 9mm or 17mm are used in the FODO cells. For manufacturing considerations, the regular absorber has been separated into two parts, a 50cm long absorber body followed by a 16cm long collimating absorber mask. Fig. 5 shows the cross sections of absorber body and mask at their downstream end for the two cases of odd (9mm) and even (17mm) type. A maximum power limit of 25kW for the body and 6kW for the mask has been chosen as a design criterion for safe operation. In this case, a linear power density of 200W/cm along the absorber will not be exceeded. The power uptake of each absorber is determined by the size of the minimum transverse half-apertures B and A for body and mask, respectively. Fig. 6 compares the absorbed power for all regular absorbers for a perfect beam and in case of a vertical COD of 1mm amplitude which has been investigated for various initial phases. Absorber No. 7 turned out to be most delicate and also is very sensitive to orbit distortions.

The layout of the two long absorbers and the final absorber will follow the same mechanical concept as has been found for the regular ones. Absorber No.9 and 10 will be designed for a power absorption of 90kW each. The remaining power load of about 120kW has to be taken up by the final absorber behind the dipole magnet at the damping section end.

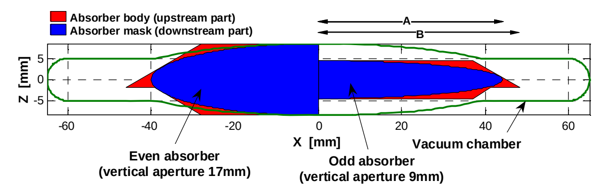


Figure 5: General layout of the absorber cross sections for the 2 types of odd and even regular absorbers. The wiggler vacuum chamber cross section is shown for comparison.

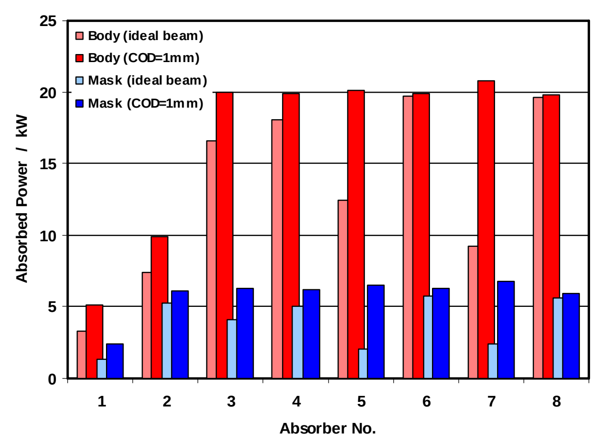


Figure 6: Power load on the body and mask part of the regular absorbers.

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