A BYPASS FOR SYNCHROTRON RADIATION EXPERIMENTS AT THE STORAGE RING PETRA II

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The electron positron collider PETRA now being reconstructed into a 14 GeV electron proton booster for HERA would be an excellent source for next generation synchrotron radiation experiments. Insertion devices in such a high energy storage ring would have unique properties in the photon energy range from 20 to 50 keV and open the possibility for new experiments above 100 keV. However, all plans have to take into account that PETRA II has primarily to be used as a booster. A bypass at PETRA II seems to be the way to use the ring also as a synchrotron radiation source without reducing the qualities of its booster functions. Results of first considerations, which lead to a bypass with two undulator beamlines, are presented.

I. INTRODUCTION

The number of synchrotron radiation users who want to do experiments with high photon energies increases steadily. Demand exists especially in the photon energy range between 20 and 50 keV and above 100 keV. Storage rings above 10 GeV like PETRA, PEP or TRISTAN are excellent tools to cover this field of synchrotron radiation research.

All these rings are originally built for high energy physics. Particularly PETRA has been reconstructed to an electron and proton booster for HERA, now named PETRA II [1]. Therefore all considerations have to take into account that the qualities of PETRA II as a booster have to be preserved, if the function is extended to a synchrotron radiation source.

Another important condition is a short time of reconstruction not disturbing the booster operations. The corresponding work has to fit into a normal shut down period. Investigations were concentrated on the modification of one of the four short straight sections of PETRA II. The section located in the northeast part is the most favorable place because of three reasons. This part is placed above ground, it has no injection or ejection elements, and the location of an experimental hall seems to create no special problems. What is the potential of such a straight section with regards to the number of suitable synchrotron radiation beamlines?

II. THE PETRA II-SR-BYPASS

For synchrotron radiation users an electron beam of 10 to 15 GeV and undulators with a length of about 5 meters would be desirable. To fulfil the magnetic field requirements for this scenario the undulator(s) have to be closed to a gap of 10 to 15 mm. However, the protons need a vacuum aperture of 30 to 40 mm. This problem can be solved either by a flexible vacuum chamber or by an electron bypass parallel to the straight section (Fig.1). The second way opens in addition the possibility for more than one photon beam and the vacuum

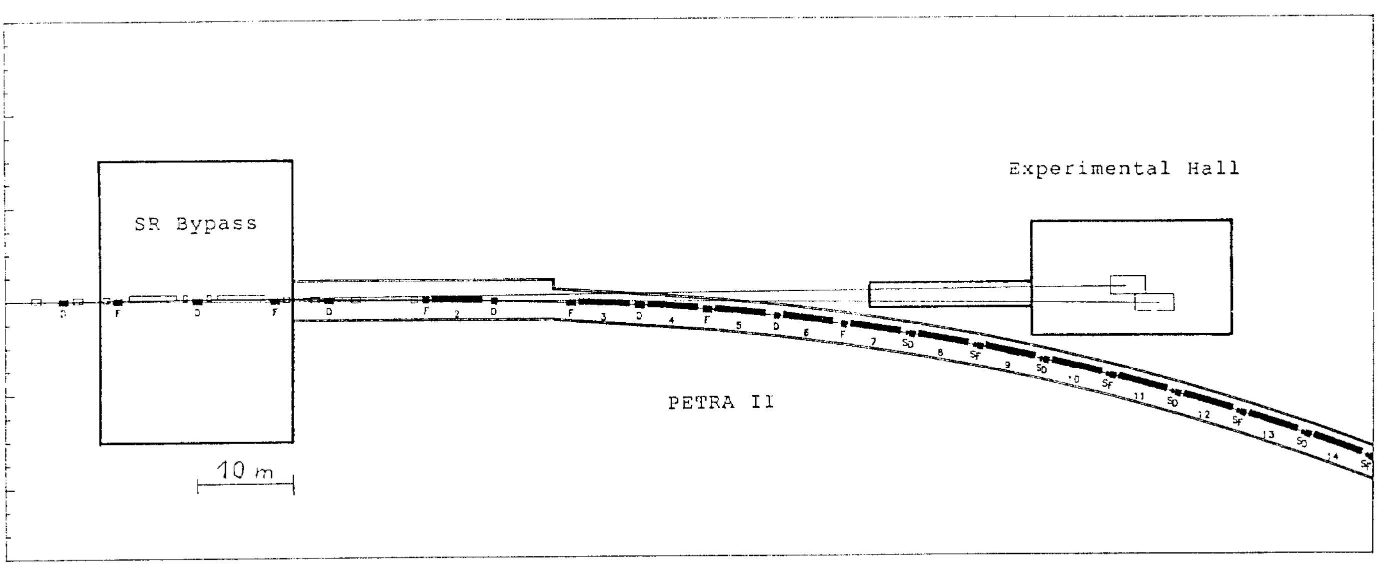

Figure 1. PETRA II with bypass, undulator beams and experimental hall.

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system should will be less complicated since no flexible vacuum chambers are needed.

A. Geometry

PETRA II has a harmonic number of 3840 and uses a 500 MHz RF system for the electrons. Normally a bypass has to add an integer to the harmonic number so that the particles can run on the design orbit with the same frequency. This is not possible in our case, because the bypass would become much more extended than the short straight section itself. Therefore PETRA II together with the electron bypass has to keep the harmonic number. As a consequence the RF is a little too high for the longer design orbit. A frequency increase of not more than about 5 kHz in comparison to the design frequency should cause no problems for PETRA, because the electron beam is still damped. That means a maximum additional length of the bypass of 23 mm is allowed. As PETRA II is already running at 1.7 kHz above its design frequency for electrons because of HERA reasons, an additional length of 15 mm should be the limit for a bypass design. The bypass shown in Fig. 2 has a length of 60.3 meters and increases the circumference of PETRA II by only 2.3 mm. So there are reserves for more bypasses or a different bypass design.

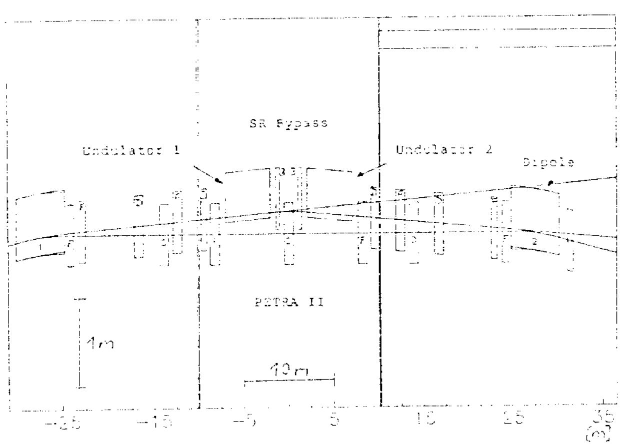

Figure 2. The PETRA II bypass for synchrotron radiation.

For the realization of this bypass two dipoles which are nearest to the former interaction point (IP) and which were needed to protect the IP from synchrotron radiation of the strong bending magnets have to be removed. To bring the electrons into the bypass 2 of the 6 windings of the first strong dipole at each end of the straight section are shunted. The reduction of field will be compensated by the field of two central bypass dipoles. By this method a maximum distance of 245 mm between ring and bypass can be achieved (Fig. 2). This seems to be enough to install two 5 m long undulators with their narrow bypass vacuum chambers next to the large chambers for the protons. However, it is not large enough to put a bypass quadrupole besides a normal ring quadrupole. Probably the concept of interleaved quadrupoles has to be used (Fig. 2).

Because of the central dipoles there is an angle of 1.87 mrad between the two undulator beams. This leads to a beam separation of nearly two meters in a distance of 100 meters, which is large enough for the installation of experiments. This number fulfils also the condition that the beams have to be separated from the storage ring by a reasonable value (Fig. 1).

B. Electron optics

The experiments which are proposed for the undulator beamlines would already take big advantage of the emittance of the existing electron booster optics, which is 79 nmrad at 13 GeV. Therefore as a first step the optical functions in the bypass were fitted to this optics. The resulting optics including the bypass has the possibility to be used as the electron booster optics as well. This would be an attractive scenario for the operation of PETRA II.

Beta and dispersion functions in the bypass are shown in Fig. 3. In the case of photon energies of several ten keV the beam divergence are dominated by the electron divergence at the source point. Therefore large beta functions in both directions were aspired. However, in the vertical direction the aperture for the electrons must remain big enough. It should be mentioned that also an optics with much smaller emittance can be achieved in PETRA II.

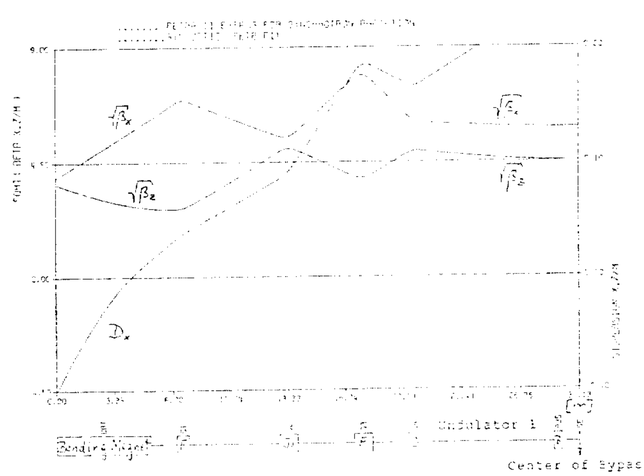

Figure 3. Optical functions of the bypass.

C. Energy and ramp procedure

Due to the 16 seven cell cavities the maximum energy of electron PETRA II is 13 GeV for 60 mA electron current. These cavities are located parallel to the proton bypass in the long straight section "South". There is room for additional cavities to obtain 14 GeV.

As long as PETRA II is running also as a proton booster no cavities can be installed outside the proton bypass region, because the proton beam would become unstable passing the electron cavities. By replacing all the normal conducting cavities by superconducting ones the electron energy could be increased up to about 18 GeV and this was already taken into consideration for the design of the synchrotron radiation bypass.

It is expected to have lifetimes of about 3 hours in electron HERA and 12 hours in proton HERA. To ramp electrons and protons in PETRA II from 7 GeV to 13 GeV and from 7 GeV to 40 GeV respectively 5 to 7 minutes are estimated. To fill the two HERA rings three booster ramp cycles of each type are needed. If HERA and PETRA II would work routinely with these numbers, a timegap of more than 2 hours could be used for a synchrotron radiation run after every ramp procedure. If HERA could be supplied with electrons using the synchrotron radiation bypass optics, only one additional electron ramp cycle would be neccessary to supply PETRA II with electrons for a synchrotron radiation run. Following this procedure PETRA II would be used most effectively.

At last one important point should be mentioned. Already at storage rings with full energy injection a photon beam position control system is very useful. For undulator beams at PETRA II such a system is absolutely neccessary, because prior to every synchrotron radiation run at least a ramp procedure or even a change of the optics has taken place.

III. UNDULATORS FOR THE BYPASS

As mentioned above, there is an increasing demand of high intensity synchrotron radiation above 20 keV. For example ultra high resolution backscattering experiments can best be done above 15 keV. Experiments in the energy range from 100 to 200 keV open new fields in solid state research. A high intensity synchrotron radiation beam of such high photon energy can only be obtained at high energy storage rings in combination with undulators.

To generate high energy photons in an undulator, a short periodic length is required and to have a sufficiently high magnetic field on orbit with such a short period a small gap is essential. On the other hand, large beta functions are needed to have a well collimated beam. With the beta functions choosen, a magnetic gap of the undulator of 11 mm is possible and can technically be realized [3]. The beam divergence would be 0.053 mrad horizontal and 0.012 mrad vertical and would give a beam dimension at the experiment in 100 m distance of 12 x 2.7 mm.

A proposed undulator in hybrid technology [4] with a periodic length of 3.35 cm and a gap of 11 mm emits its first harmonic at 20 keV. By opening the gap the energy can be scanned up to 50 keV with nearly constant intensity. The third harmonic is covering the energy range from 60 to 130 keV and the fifth harmonic from 100 to 200 keV. So the whole range from 20 to 200 keV is covered by one device. The parameters of the undulator are listed in the table.

Gap height	11 mm
Periodic length	3.35 cm
Number of periods	149
Undulator parameter	1.88
Magnetic Field	0.60 Tesla

Fig. 4 shows the brightness of the PETRA II undulator in comparison with a DORIS bending magnet and a DORIS III wiggler. The gain in brightness amounts to 2 orders of magnitude between 20 and 50 keV and about 4 orders of magnitude at 150 keV. Such a synchrotron radiation source will have unique properties in this energy range and will open complete new possibilities for synchrotron radiation experiments.

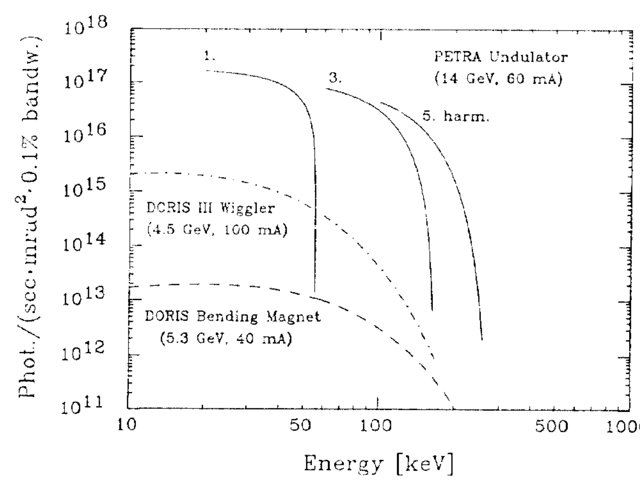

Figure 4. Central brightness of the bypass undulator.

IV. CONCLUSIONS

First considerations show that it should be possible to use PETRA II as a booster for HERA and as a synchrotron radiation source in a time sharing mode. An electron bypass with two undulators seems to be a promising tool for the realization of this scenario. Already an electron beam with the emittance of the normal booster optics will produce undulator radiation of very good quality.

IV. REFERENCES

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