An Undulator at PETRA II - A New Synchrotron Radiation Source at DESY

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Abstract

PETRA, currently operating as a proton and positron injector for HERA, has been modified to serve also as a synchrotron radiation source in 1995. Running at 12 GeV with currents up to 60 mA the machine will be a unique source. The PETRA injector optic will be changed locally to suit the requirements of an undulator beam. In addition a new low emittance optic has been examined both theoretically and experimentally. The undulator with a period length of 33mm and a maximum field of 0.59 T at a gap of 14mm has been installed in the straight section North East. The photon energy range up to 200 keV can be covered using the 1st, 3rd and 5th harmonics. At 12 GeV, 60 mA and using the low emittance optic a photon brilliance in excess of 10^{18} photons/(s 0.1%BW 0.1 $mrad^2$ mm^2) will be obtained. To allow for compatibility between injector and synchrotron radiation operation a keyhole shaped vacuum chamber, with both a wide and narrow aperture for the two operational modes respectively has been constructed. The photon beam travels along a 120 m long beamline until it reaches the experimental hall. The beamline includes elements of the beam position control system and the safety system needed to avoid damage to machine components due to the high power undulator beam.

I. INTRODUCTION

The former electron positron collider PETRA has been turned into a preaccelerator for HERA.Since 1988 PETRA has filled HERA-e with both positrons and electrons and since 1991 HERA-p with protons. The major changes to PETRA were the removal of most of the electron cavities and the installation of a bypass in the straight section south so that the protons do not have to traverse the remaining electron cavities[1].Thanks to a powerful feedback system[2] large electron and positron currents can be stored. When operating as the HERA injector PETRA idles in standby mode for approximately 50% of the scheduled time. In 1993 it was therefore decided to use PETRA as a synchrotron radiation source during the idle time. For this purpose an undulator should be installed in the straight section north east. This undulator can produce synchrotron radiation of world wide unique characterictics making interesting experiments possible[3]. In 1994 the experimental hall was built. During the next winter shut down 94/95 the modifications of the vacuum system and the PETRA tunnel were made the undulator installed and the beam line was completed. During the start up of PETRA this year the first undulator beam was observed at the end of the beam line (see fig.1). Parts of the beam position control system and the safety system were tested succesfully.

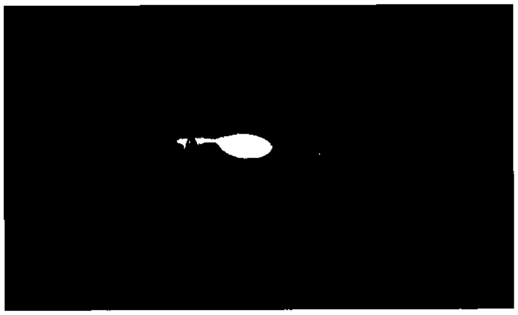

Figure 1 Beam spot at the end of the beamline

II. MACHINE PARAMETERS

The circumference of PETRA is 2304 meters. The energy of electrons and positrons can be varied between 7 and 13 GeV. The upper limit is defined by the available rf power. Currents of up to 55mA can be ramped to 12 GeV but in principle 60 mA should be possible. The current is distributed in 42 bunches but other filling schemes are possible. One constraint is given by the bandwidth of the feedback system which limits the distance between adjacent bunches to 96 ns. Single bunch operation is also possible with currents between 5 to 10 mA. The life time of the beam is at least 5 hours which is sufficient for the foreseen run time of approximately 5 h. During this year a modified injection optic is used for synchrotron radiation operation. The injection optic has a FODO like structure with a betatron phase advance of 45° which results in a horizontal emittance of 18nmrad at 7 GeV. This optic is locally changed to fulfill the requirements for an undulator beam to obtain an electron beam with small divergence. In addition optics were investigated theoretically with a larger phase advance yielding a smaller emittance at 7 GeV for example 5nmrad. At the end of the last machine run in 1994 first experimental tests of a 8nmrad optic were performed and it could be proven that the machine is also working with a phase advance of 70°. Further tests are now in progress.

III. THE UNDULATOR

The object of the PETRA undulator is to provide high brilliance radiation at photon energies well above 100 keV. Fig. 2 shows a comparison between the PETRA undulator with a number of insertion devices in other facilities.

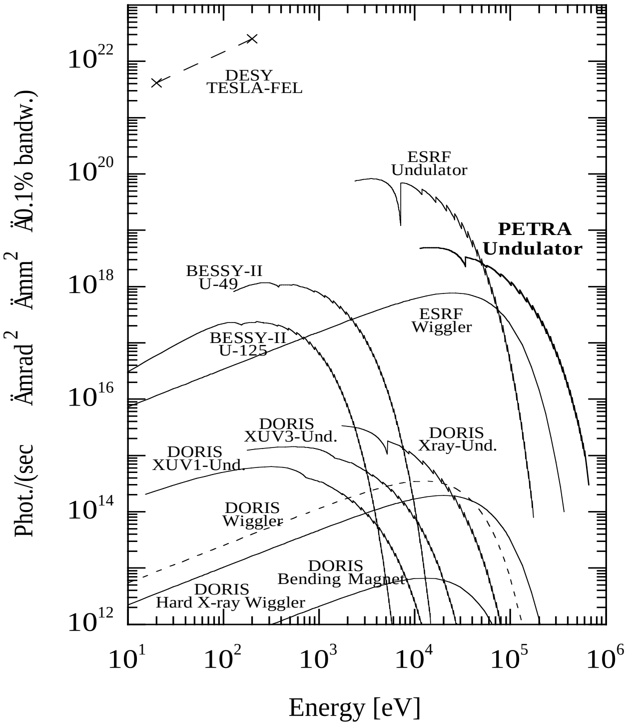

Figure 2: brilliance of the PETRA undulator compared with that of other insertion devices

Above 100 keV it has unique properties[4]. A short period undulator is needed to obtain these radiation properties. Table 1 gives an overview of undulator and relevant storage ring parameters.

undulator parameter	
period length	33 mm
number of periods	121
total length	4 m
min. gap	14 mm
max. field (14mm gap)	0.59 T
max. K-parameter	1.81
total power	6 kW
power density	500 kW/mrad^2
storage ring parameters	
hor. emittance	18 nmrad (12GeV)
emittance coupling	3%
σ_x	0.6 mm
σ_y	0.1 mm
$\sigma_{x'}$	24 µrad
$\sigma_{y'}$	4.2 µrad

Table 1: PETRA undulator parameters

As was already pointed out PETRA II is an integral part of the HERA injection system. It has to accelerate electrons as well as protons. For proton operation and for electron injection a very large aperture of 80x80 mm is needed. For synchrotron operation a very small magnetic gap and therefore a very small chamber height is required. In order to solve this aperture problem a keyhole shaped vacuum chamber which can be translated horizontally has been designed and built. Fig. 3 shows its principle.

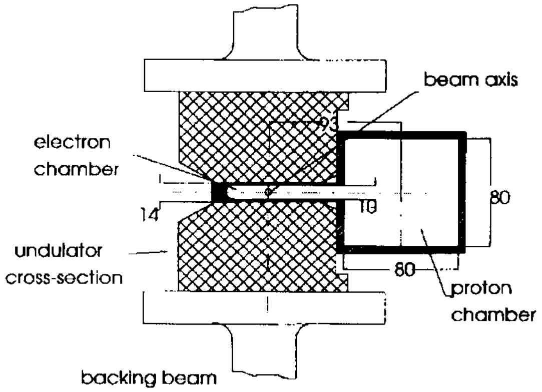

Figure 3: sketch of the keyhole shaped vacuum chamber

The wide region is used for proton operation and for electron injection. To operate the undulator the chamber is translated horizontally and moved over the stored beam. Now the undulator can be closed to its minimum gap position. Great care was taken in the design of the transition regions between the movable keyhole shaped chamber and the fixed PETRA vacuum system. The transitions include bellows, smooth movable RF guiding inserts and smooth tapered sections without discontinuities to avoid higher order mode losses. More details can be found in Ref. [4-6]. The problem of higher order mode losses has been investigated using thermal sensors attached to the tapered sections. No heating could be observed indicating that these losses are indeed negligible. For the first run period a vacuum aperture of 10 mm was allowed with a resultant magnetic gap of about 14mm. In future a new vacuum chamber allowing for a magnetic gap of 11mm will be built.

IV. BEAM POSITION CONTROL AND SAFETY SYSTEM

The power density of the undulator beam is very high (see table 1) so that care has to be taken that no element of the machine or the beamline is hit by this beam. A special monitor has been designed as a beam detector. As long as the undulator beam is detected there is no danger of equipment melting. If there is no undulator beam signal detected by the monitor the positron beam is instantaneously dumped. The detector consists of a 1mm thick carbon filter and a 50 mm wide carbon foil 0.13 mm thick. The photoemission of this thin foil is measured. Confirmation of undulator beam transmission through the beamline is given when the measured emission exceeds a preset threshold. The purpose of the filter is seen in Fig. 4 which shows a comparison of the PETRA bending magnet spectrum with two undulator spectra for different gap heights (14mm and 28mm). The gap height of 28mm is chosen as the power density limit where misalignments of the beam become dangerous for elements of the beamline and the machine. At this gap height the dump monitor has to detect the beam. The comparison in fig. 4 shows that even at 100m from the undulator source (this is 80m from the bending magnet) the contribution of the bending magnet radiation to the total photoemission yield is higher than that of the undulator. Introducing a carbon filter (1mm thick) between source and detector foil cuts off the low energy radiation and the contribution of the undulator dominates the photoemission yield. These theoretical considerations have been verified experimentally. When the yield is below the threshold the positron beam is dumped.

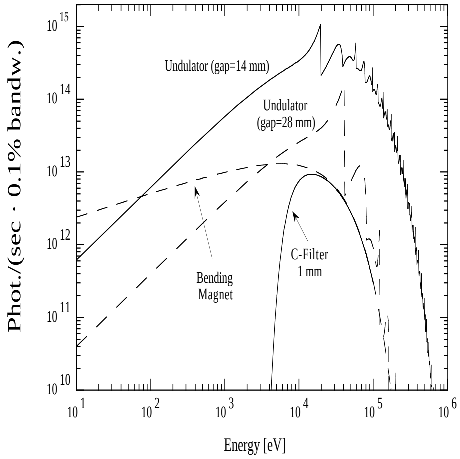

Figure 4: Comparison of spectral flux of the PETRA undulator at different gaps with the flux of the bending magnet (0.8 mrad horizontal width). For the bending magnet the transmission of a 1mm thick C-filter is added.

To keep the undulator beam stable within a small fraction of its size and divergence, a beam position control system for the horizontal and vertical plane was successfully established. It is based on two pick up monitors for the positron beam, two photoemission monitors for the photon beam and four correction magnets for each plane. The pick up monitors, with a position resolution of 50 µm to 100 µm, are located directly in front of and behind the undulator. At the beginning of each run they guide and control the positron beam. Simultaneously the photon beam is guided into the acceptance range of the two photon beam position monitors, which are 57 m and 100 m away from the centre of the undulator. Information from these monitors allows precise on-line control of the positron beam position. The tungsten blades of the photon beam position monitors can measure the beam position with a resolution of a few µm. All adjustments of the positron beam are performed using localised four corrector orbit bumps.

V. REFERENCES

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