Journal of Physics: Conference Series **100** (2008) 092028 doi:10.1088/1742-6596/100/9/092028

New Fast Closing Shutter for the PETRA III Beamlines

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Abstract. The conversion of the PETRA storage ring at the Deutsches Elektronen Synchrotron (DESY) to the third generation synchrotron radiation light source PETRAIII [1] poses a challenge to the design of the beamline transport system. One of these challenges is to supply 14 beamlines and experiments windowless with the extremely collimated undulator radiation from the storage ring. The windowless connection includes the risk of accidental venting of the storage ring by experiments connected to the beamlines. To stop the inrush of such an accidental venting fast closing shutter (FCS) systems with closing times in the 10msec range are mandatory. The strong radiation background in the storage ring tunnel requires the installation of all metal valves. A new small fast closing shutter with an aperture of 40mm fitting to the strong collimated undulator beams and with a closing time < 10msec was developed. The all metal sealing principle achieves leak rates smaller than 10mbarl/sec. This leak rate of the fast closing shutter combined with a standard all metal valve prevents venting of the storage ring and the beam time losses for all users. The mechanical and electronic layouts as well as first experiences with the new fast closing shutter system developed for PETRAIII are presented.

1. Introduction

Beginning in 2007 DESY will rebuild the 2304 m circumference storage ring PETRAII into the 3rd generation synchrotron radiation source PETRA III[1]. With the particle energy of 6GeV, a beam emittance of 1nmrad, and an initial current of 100mA, 14 independent undulators will deliver high quality beams for experiments. For the beam transport between the undulator and the experimental hall a generic beamline is developed which contains all the elements which are needed to guide the beam to the experiment.

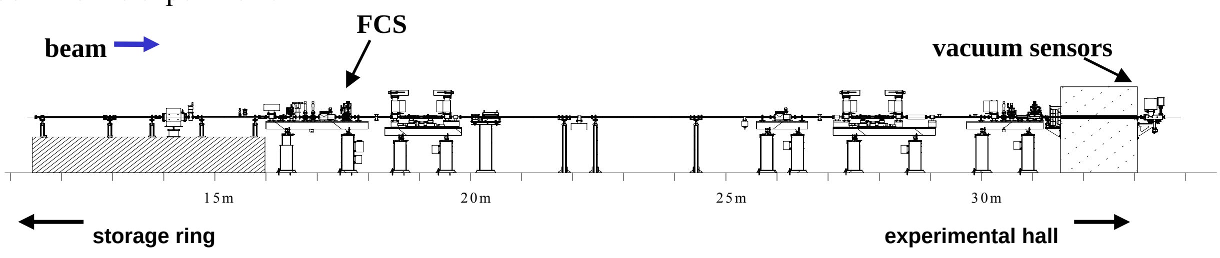

Figure 1: Overview of the beamline with the positions of FCS and vacuum sensors

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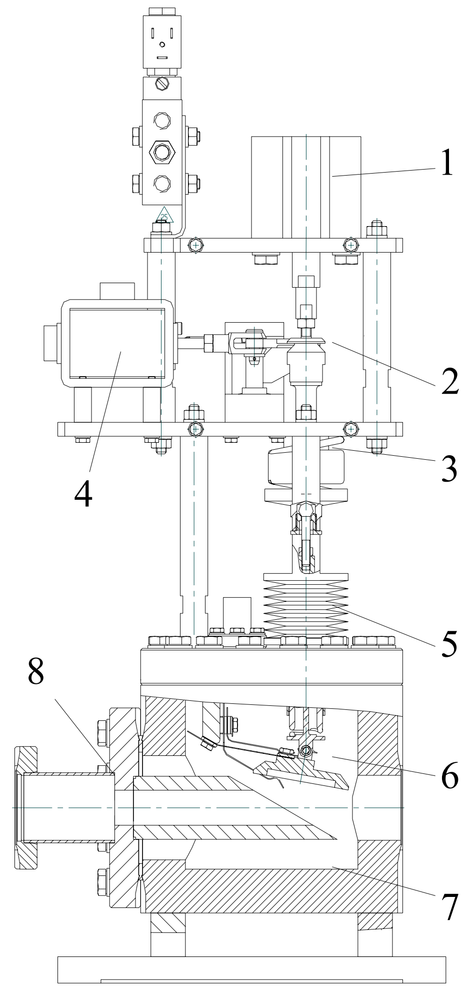
All beamlines supply the experiments windowless with the undulator radiation from PETRAIII. The windowless connection causes the risk of accidental venting of the storage ring by experiments connected to the beamlines. To stop the inrush of such an accidental venting fast closing shutter or valve (FCS) systems [2, 3, 4, 5] have to be installed. The needed closing time depends on the distance between FCS and the installed pressure rise detectors. In case of the PETRAIII beamlines, which can be seen on figure 1, a distance of about 15m has to be considered. Worst case assumptions calculate with an inrush speed of shock waves, which is three times the speed of sound. With a distance of 15 m an FCS overall closing time of 15 ms is needed.

The extremely collimated beams of the PETRAIII undulators allow using small aperture sizes down to 20mm for beamline components in the storage ring tunnel. This gives the possibility to develop a FCS with a closing aperture size between 20 and 40 mm.

The FCS will be combined with an all metal ultrahigh vacuum valve which closes within 1 second. The thin pipe connection and the strong pumping (ion pump 300 l/sec) between beamline and storage ring gives the possibility to accept a leak rate of the FCS which is smaller than 10mbar·l/sec.

2. Mechanical Layout and Operating Principle



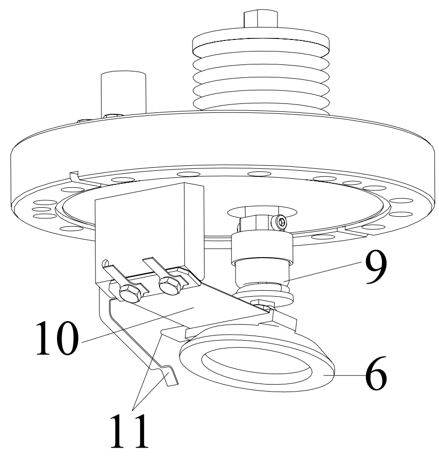


Figure 2: Cross-section of the fast closing shutter. An enlarged insert shows the lay out of the shutter plate more in detail. The main parts are the shutter body(7), the shutter seat assembly(8) and the shutter plate assembly with air cylinder(1), latch(2), compression spring(3), stroke magnet(4), bellow feed through(5), shutter plate(6), damping spring(9), leaf spring(10) and limit switch(11) in open position (with the shutter plate in closed position the contact is closed).

Figure 2 shows on the left a cross-section drawing of the fast closing shutter (FCS). The design follows the ideas:

- reduce the number of moving parts in the vacuum, place all main parts of the actuator in air
- use a linear driven pivoting movement of the shutter plate with solid state hinges
- use a circular shutter plate
- reduce the linear drive range by tilting the shutter seat
- limit switches directly connected to the shutter plate

The shutter body (7) is a stainless steel cube with incorporated Conflat™ flanges for the attached shutter seat assembly (8) and shutter plate assembly. The shutter seat consists of an elliptical pipe (40mm wide and 20mm high) which is brazed on one side of a 63mm flange while the other side is the connection to the beam pipe. The sealing seat is machined and lapped plane under an angle of 30º.

The shutter plate assembly drives the circular Titanium shutter plate (6) on and off the shutter seat (8). The sealing face of the plate is also lapped. An air cylinder (1) pulls the shutter plate off the seat compressing the spring (3). The pivoted latch (2) fixes the plate with its driving rod in the open position. The linear motion of the rod is decoupled from the vacuum by the bellow feed through (5). The shutter plate is pivoted on the main flange by a leaf spring (10) which guides the plate on to the plate seat while closing. The closing process is initiated by the vacuum sensors followed by the fast action of the stroke magnet (4) which releases the latch and the driving rod. The spring driven closing process is damped by another compression spring (9). The limit switch (11) detects the closed position of the shutter plate. The sealing of the FCS is accomplished by the lapped surfaces of shutter plate and seat. The qualities of these surfaces define the leak rate of the shutter.

3. Shutter Electronics

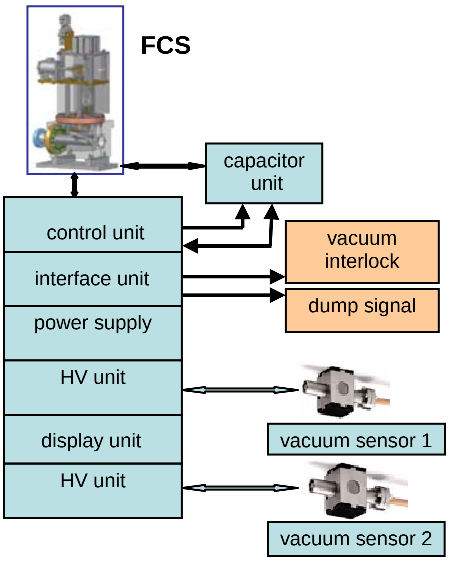
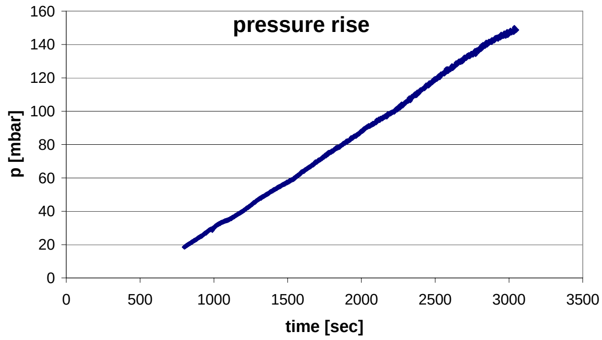


Figure 3: The modular layout of the shutter electronics

For the new shutters a modular electronic operating system was developed (see Fig. 3). The design follows the well proven patented [6] operating system of the DORIS FCS at DESY. The operating principle uses two 2 l/sec ion pump vacuum sensors to detect the fast pressure rise. The trip of the shutter is activated, when the pressure readings of both vacuum sensors stay longer than 1 msec on more than 10^{-5}mbar. Then the charged set of capacitors of the capacitor unit is unloaded by transferring the stored electrical energy to the stroke magnet of the FCS. Thus the magnet releases the mechanical shutter drive within a msec. The shutter closes within the next five msec and actuates the internal limit switch. The internal clock of the control unit was started by the trip and is stopped now by the limit switch. This allows reading the overall closing time. Figure 3 shows the layout of the shutter electronics. The electronics accomplishes the local and remote control of the valve as well as the interface to the vacuum interlock of the beam line and the beam dump system. In the case of a shutter action the stored electron beam has to be dumped by the machine dump system. This stops the intense power of the undulator radiation, which would destroy the shutter plate within less than a second. Simultaneously the trip will cause the vacuum interlock to close the all metal valve which separates the beamline from the storage ring.

4. Prototype Tests

Leak rate measurement using the pressure rise method:



Calculation of the leak rate Q with p_1 = 30.18 mbar at t_1 = 1000 s, p_2 = 146.96 mbar at t_2 = 3000 s, and test volume V=124.2 dm^3

$$Q = \frac{\Delta p}{\Delta t} \cdot V = 7.2 \underline{\underline{\frac{mbar \cdot l}{s}}}$$

Figure 4: Prototype shutter

Figure 4 shows the first FCS prototype manufactured at DESY. First tests of the prototype were carried out to show the performance of the valve:

- <u>Overall closing time :</u> The average closing time over ~100 tests is 9msec
- <u>Leak rate:</u> 7.2mbar·l/sec (pressure rise method) after 1000 closing cycles
- <u>Lifetime:</u> After 1000 closing cycles the shutter is still fully operational.

5. Conclusion

A new small fast closing shutter FCS with an aperture of 40mm, a closing time < 10msec and a leak rate < 10 mbar·l/sec was developed and the first prototype successfully tested.

The design was applied for patent.

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