EXPERIENCE WITH THE ULTRA-HIGH-VACUUM PROTECTION SYSTEM FOR THE SYNCHROTRON RADIATION BEAM LINES WITH HIGH-POWER WIGGLERS/UNDULATORS AT THE PHOTON FACTORY

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Abstract

There are six high-power wiggler/undulator beam lines at the2.5-GeV synchrotron radiation source at the Photon Factory. In the case of an instantaneous vacuum failure at such a beam line, a normal Fast-Closing-Valve (FCV) system is incapable of functioning to protect the Ultra-High-Vacuum (UHV) of the beam lines and the synchrotron radiation source, since a meltdown of the titanium-alloy FCV is caused by intense photon flux radiation. To avoid such a case, a dedicated UHV protection system has been built where all FCV systems for the high power beam lines have been linked, using high-speed communication links to RF klystrons to allow the FCV systems to initiate blade closure after dumping the positron beam by tuning off the RF power. In this paper, experience with the UHV protection system for the wiggler/undulator beam lines is discussed.

1 INTRODUCTION

There are six high-power wiggler/ undulator beam lines (BL-2, BL-13, BL-14, BL-16, BL-19 and BL-28) and sixteen normal bending-magnet beam lines installed around the 2.5- GeV positron storage ring at the Photon Factory at the National Laboratory for High Energy Physics. The six high-power wiggler/ undulator beam lines are simultaneously in operation, producing very intense synchrotron radiation beams. The high-power beam lines are distributed along the long circumference of the storage ring. These beam lines feed synchrotron radiation to the experimental hall where experiments such as surface physics, x-ray lithography, microscopy and crystal structure analysis are simultaneously carried out.

The pressures in the storage ring and the beam lines are maintained at anUltra-High-Vacuum (UHV) of less than 10 -10 Torr. In order to protect the Ultra-High Vacuum of the storage ring against an instantaneous vacuum failure, fast-closing valve systems (FCV) [1,2] have been installed in the wiggler/undulator beam lines as well as normal bending- magnet beam lines. The FCV system can close a guillotine blade (1.2-mm thick titanium-alloy) in ~ 0.01 seconds. A vacuum failure would be caused by a rupture of the beryllium windows (~200 mm-thick) at an x-ray beam line due to an intense thermal load, or by an instantaneous gas leakage downstream of the VUV (Vacuum Ultra Violet) branch line [4]. Such a failure could result in fatal damage to the components of the storage ring, including the vacuum chambers, beam position monitors, pressure gauges and the doughnut.

The wiggler/undulator can produce synchrotron radiation with a high power density, two orders of magnitude higher than that obtained with a bending-magnet source [4]. At such a high-power wiggler beam line, the impingement of intense photon flux on the closing blade of the FCV causes a melt-down within 0.1 seconds before a water-cooled heat-absorber closes (~1 sec) [5]. Thus, the FCV can not protect the storage ring vacuum for the wiggler/undulator beam lines. There has been no protection system that allows many high-power wiggler/undulator beam lines to simultaneously protect the Ultra-High Vacuum of the synchrotron radiation source from an instantaneous fatal vacuum failure. To avoid such case, the authors have designed and built a dedicated vacuum protection system for the high-power wigger/undulator beam lines [6]. In this paper, the first experience with the UHV protection system for such high power wiggler/undulator beam lines is discussed.

2 SYSTEM CONFIGURATION

In order to ensure that the blade can avoid intercepting intense radiation, the protection system allows any high-power beam line to instantaneously turn off the beam upon the detection of a vacuum failure, by switching off the RF power in the four remote RF cavities. The response time is much less than the closing time of the FCV (~11 ms), preferably less than 0.1 ms. Figure 1 shows a block diagram of the protection system. Each beam li ne has a Fast -Cl osi ng-Val ve syst em wi t h a vacuum sensor. The Fast-Closing-Valve systems are connected to RF klystrons with optical-fiber links. The communication links comprises a high-speed optical transmitter and receiver wi t h a transmi ssi on rat e of 76 MHz. Upon an instantaneous vacuum failure at the experimental hall, the pressure signal of the vacuum detector is transmitted to the Fast-Closing-Valve system. This system initiates a cut-off signal, thereby requesting the RF klystrons to turn off the RF power. At the same time, it simultaneously requests the computer of the beam line control system to shutdown the water-cooled absorber mask (closing time ~ 1sec).

After the RF power in the klystrons is removed, the status signal of the RF power is transmitted to the Fast-Closing-Valve system, notifying the removal of the RF

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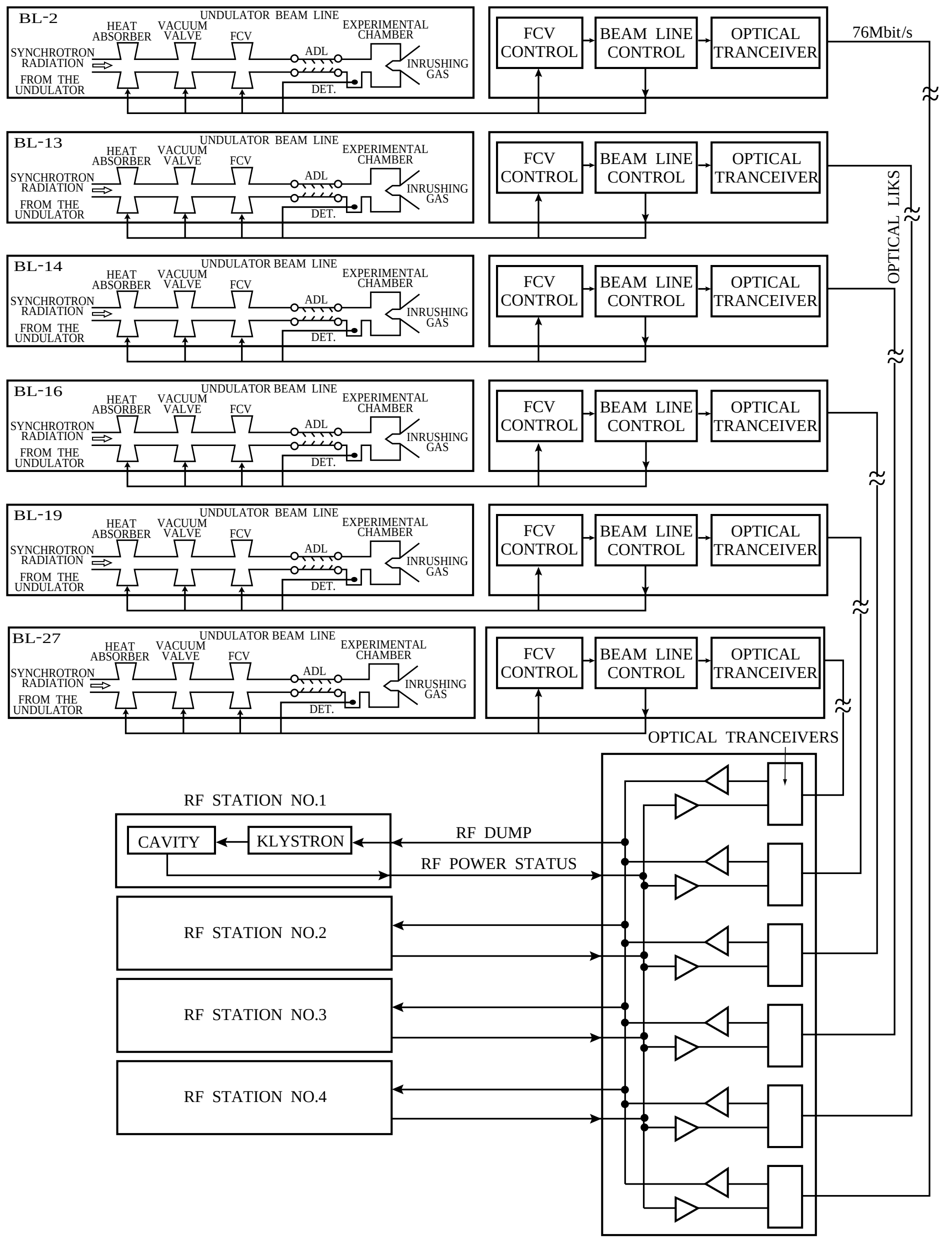

Figure 1 Block diagram of the Ultra-High-Vacuum protection system for synchrotron radiation beam lines with multiple wiggers and undulators

power, and the synchrotron radiation beam. The status signal from the RF klystrons can reach the beam line within 100 microseconds after being sent to the beam line. Upon receiving the status signal from the RF klystrons, the Fast-Closing-Valve system can close its titanium blade in 10 ms to block any inrushing shock wave from the experimental hall. The total response time measured between a vacuum failure and the closure of the Fast-Closing-Valve blade is 12ms. The water-cooled absorber mask can completely close in 1 second after being initiated. Then, the computer of the beam line control system closes the backup vacuum valves (closing time ~ 1sec) to completely close the beam line.

3 ACTURAL VACUUM FAILURE

In April, 1996, there was an actual instantaneous vacuum failure at wiggler beam line BL-19 in the experimental hall. The positron beam current was 366 mA at 2.5 GeV, and the wiggler was providing the intense beam to the experimental hall at BL-19.

Upon an instantaneous vacuum failure, the protection system detected it, and immediately turned off the RF power in the klystrons and then closed the titanium blade of the Fast-Closing-Valve. The positron beam was dumped at the RF klystrons, which, in turn, transmitted a status signal of the RF power in the klystrons to the protection system. The protection system initiated the closure of the FCV blade to block any inrushing shock wave from the experimental hall at the BL-19. The record in the on-line database [7] shows how these protection procedures were successfully achieved.

The pressure in the middle point of the beam line reached almost atmospheric pressure. However, it was found that there was no effect on the pressure at the connecting point of the upstream end of the beam line and the storage ring. The pressure has been successfully protected below 1.1×10^{-10} Torr, the same pressure value before the incident. It allowed the storage ring to resume operation immediately after reinjection of a positron beam, and start synchrotron radiation experiment.

4 CONCLUSION

Experience with the Ultra-High-Vacuum protection system is discussed concerning the high-power wiggler/undulator beam lines at the 2.5 GeV synchrotron radiation source at the Photon Factory. The actual operation for an instantaneous vacuum failure proved that the dedicated UHV protection system can protect the UHV of the storage ring by initiating the Fast Closing Valve after dumping the positron beam by cutting off the RF power in the RF klystrons, using high-speed communicati on links. The system allows the synchrotron radiation source since to avoid an instantaneous vacuum failure during synchrotron radiation experiments under intense photon flux radiation.

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