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ABSTRACT

The hard x-ray wiggler (W2) at the storage ring DORIS can provide very high power densities to beamline components.

We present the beamline design between the storage ring outlet and the entrance flange of the experiment. Our emphasis is put on the constructive solution for all the components which are subject to beam heating like different absorbers and Be windows. Finally the basic idea of the vacuum interlock system is presented.

INTRODUCTION

The wiggler W2 (HARWI = hard x-ray wiggler) was designed and built for the purpose of extending the spectral range of the already existing wiggler W1, which is in operation at a different straight section of DORIS, to higher energies, namely 10-50 keV. The wiggler parameters were optimized for hard x-ray experiments such as the angiography experiment, the higher energy Compton scattering or the high resolution inelastic phonon scattering.

Such a wiggler produces a very high total power which has to be handled not only by the first optical element of the monochromator but also by all other components of the beamline which are hit by the beam.

The purpose of this paper is to describe the technical solution chosen in our laboratory for various critical components of a high power beamline.

WIGGLER

The wiggler W2 is installed in one of the two long straight sections of the storage ring DORIS. It is realized as a hybrid magnet structure composed of SmCo permanent magnets and highly permeable iron plates for concentrating the field on the orbit of the electrons. 10 periods of 24 cm period length provide a maximum field of B_o = 1 T on the orbit when the magnet gap is 42 mm. DORIS being a partly dedicated SR-source is run in two different modes causing different sets of characteristics for the insertion device listed in table I. At present the gap height of 42 mm is fixed by the requirements of the higher energy physics runs (C in table I). A vacuum chamber with variable vertical gap size to set a smaller gap at lower energies is under construction.

In order to minimize the difference between magnetic and vacuum gap a recently developed rib chamber [1] was installed. A stainless steel foil (0.3 mm thin) supported by ribs yields a wall thickness of 1 mm.

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TABLE I

Operation modes of DORIS and corresponding radiation power densities (B is a planned operation mode with reduced gap height and increased beam current for dedicated SR operation).

		A	B	C
Electron energy	[GeV]	3.7	3.7	5.3
Electron current	[mA]	100	200	50
Wiggler magnetic field	[T]	1	1.3	1
Gap height	[mm]	42	30	42
Total synchrotron radiation power	[kW]	2.1	7.1	2.1
Horizontal opening angle	[mrad]	6.3	8.2	4.5
Vertical opening angle	[mrad]	0.14	0.14	0.10
Peak power, vertically integrated	[W/mrad]	440	1140	645

The wiggler beam leaves the storage ring vacuum chamber at 8.6 m away from the center of the wiggler. The main problem for the following beamline is the high power density of the photon beam. At the maximum it has to withstand about 1100 W/cm vertically integrated at 10 m distance from the source point. For comparison, the synchrotron radiation absorbers in the bending magnets are constructed for a thermal load of 120 W/cm.

BEAMLINE

From the outlet flange of DORIS to the experiments the beam passes three different sections, illustrated in figure 1. Section I extends from the front end to the monochromator. Section II contains under helium atmosphere the monochromator and section III leads again under UHV to the experiment.

SECTION I - FRONT END

This section (seen in the upper part of fig. 1) has to fulfill several functions.

Here the beamline has to operate under the UHV conditions of the storage ring, as there is a windowless connection.

The wiggler beam is collimated in two steps to a width of 12 x 70 mm^2 at 14.5 m from the source point to pass a narrow lead collimator. This collimator in connection with a beamstop behind the monochromator has to protect patients of the angiography experiment from high energetic Bremsstrahlung background produced by rest-gas scattering in the long straights of the storage ring.

The front end starts with a combination of a fixed and a moveable absorber. The fixed absorber is the first step of the beam collimation. It protects in this way the direct irradiation

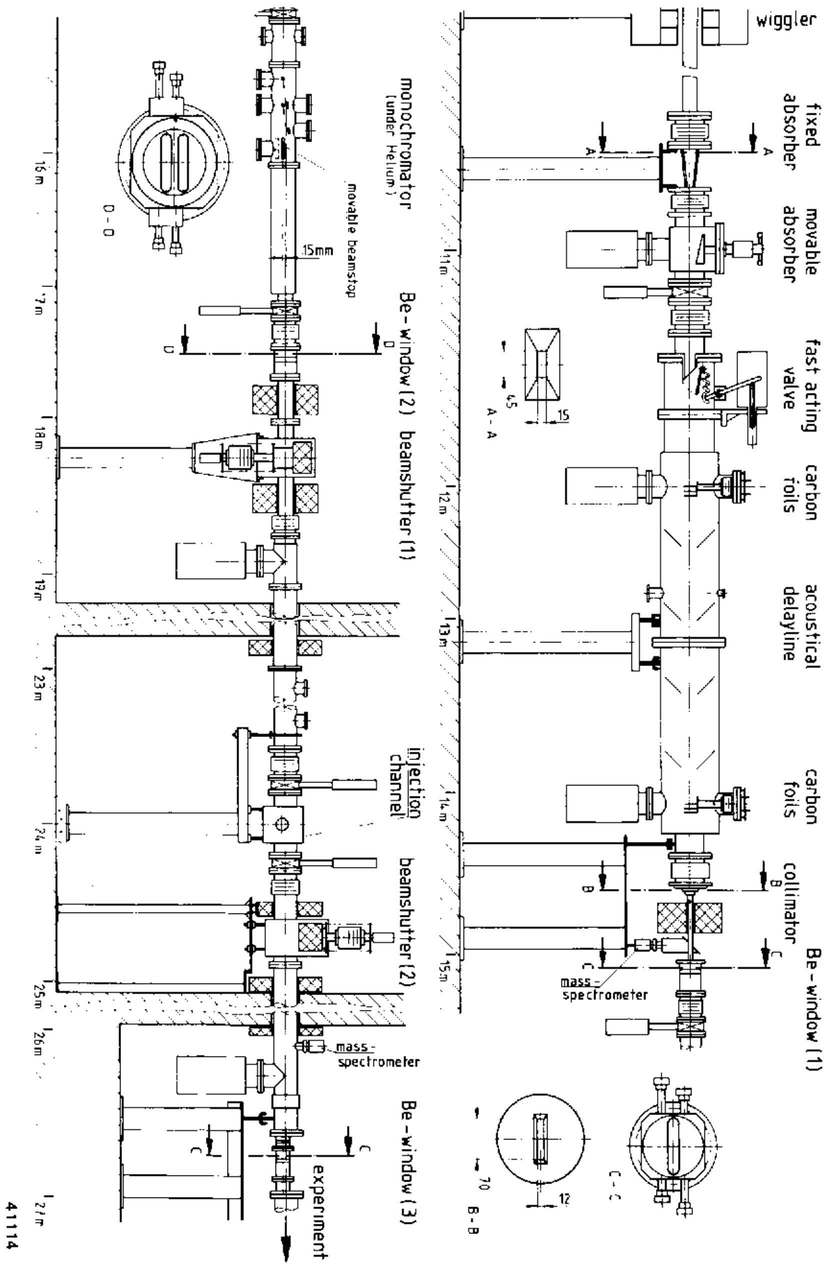

Figure 1 The HARWI beamline

of the open fast acting valve and parts of the acoustical delay line. For this purpose the nominal beam position and the possible deviations of the electron beam have to be taken into account. A formula fixing the dimensions of the beam collimators with respect to the dimensions of parts to be protected is given in a section at the end of this paper. The moveable absorber works as beam stop and has to be closed before the valves or beam shutters of the beamline can close.

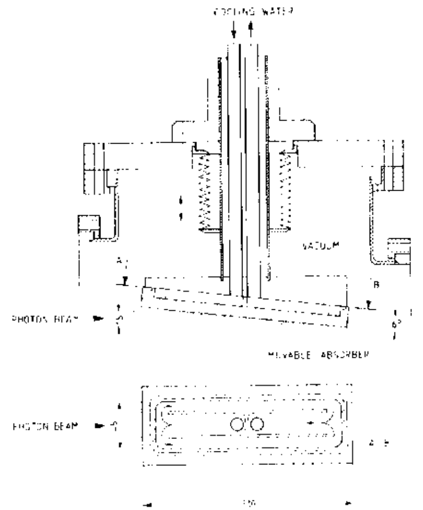

Figure 2 Cross sections of the moveable absorber

For the layout of both absorbers we took into account that the power density of the wiggler beam at the distance where the absorbers are placed is about 10 times higher than that at the synchrotron radiation absorber of a bending magnet at DORIS. Therefore we positioned all absorber surfaces under an angle of 6° to the beam axis. Comparable solutions are reported from Avery [2] and Ulc et al. [3]. Fig. 2 shows cross sections of the moveable absorber. The lower part of fig. 2 shows a cut through the absorber plates. The cooling channels machined into the copper block are designed to maintain a uniform cooling of the plate. The groove around the circumference has a connection to air via the support pipe. This avoids a direct connection of water and vacuum in case of a leak in the soldering. The four absorber plates of the fixed absorber are constructed in the same way and soldered together to form a truncated pyramid.

The valves of the front end are all-metal valves. Previously installed valves with elastomer sealings at other DORIS beamlines caused trouble due to radiation damage.

The acoustic delay lines has to slow down the shock wave which occurs when the Be window of the monochromator cracks. Since the fast acting valve [4] closes within 8 ms, and since the distance between window and valve is only 4 m, we have to prolong the running time of the shock wave by a factor of two.

The power of the low energetic photons must be extracted from the beam to reduce the thermal load on the Be window. For this purpose we use the free space between the baffles to insert a series of 10 carbon foils, starting with a 10 µm thick foil and summing up to a total thickness of 400 µm to absorb all photons with energies up to about 5 keV. The thickness of the first foils is determined by the balance between energy input by absorption and output by radiation. They reach at maximum a temperature at which the carbon evaporation does not affect the UHV. The foils are surrounded by a watercooled thermal shield to protect the vacuum pipes from heating.

The beam leaves the first section through a 1 mm thick Be window. The soldered seam is protected by the collimator with the aperture of 12 x 70 mm^2. The construction of this device is comparable to the fixed absorber only with reduced length since the beam is precollimated.

The Be window separates the UHV system from the helium atmosphere of the monochromator. The thickness of the Be window was determined by a stress analysis using a finite element computer program. The analysis included the effects of a static pressure difference (1 bar), a thermal load (corresponding to 3.7 GeV, 100 mA and 1.6 T) and allowed for a three dimensional buckling of the Be plate. The thermal load was specified in the input data as a temperature profile. As numerical examples are given the values for two cases. In case 1, 200 µm C absorbers and 1.5 mm Be were considered. The maximum temperature rise in the center was 77 $^{\circ}$C. In case of a plane Be plate a maximum stress σ = 275 N/mm^2 was found. Using a precurved window an even higher stress of 395 N/mm^2 occured. In case 2 a total thickness of 300 µm C absorbers and 1 mm Be window was used. The maximum temperature rise was 66 $^{\circ}$C. The plane window showed a maximum stress of 239 N/mm^2. This has to be compared with the maximum tensile strength of Be which is 300 N/mm^2.

SECTION II - MONOCHROMATOR

The white beam can either pass the monochromator directly or after monochromatization with an offset of 15 mm. The He atmosphere is used to cool the ultra thin monochromator crystals. A detailed description of the monochromator is under preparation [5]. On the other hand the gas is needed to detect microcracks in the Be window. For filling the monochromator with He, the system has to be evacuated and then filled. The valves on either side of the monochromator are used to prevent unnecessary "pressure cycling" of the Be windows during the filling process. As the beam is split in the monochromator box, the exit Be window assembly (Fig. 5) has to provide two exits. The upper stripe for the monochromatic beam is 400 µm thick and the lower one for the direct beam has again a thickness of 1 mm. The windows are soldered to a water-cooled copper block. A cross section of the window is shown in Fig. 1 cut D - D.

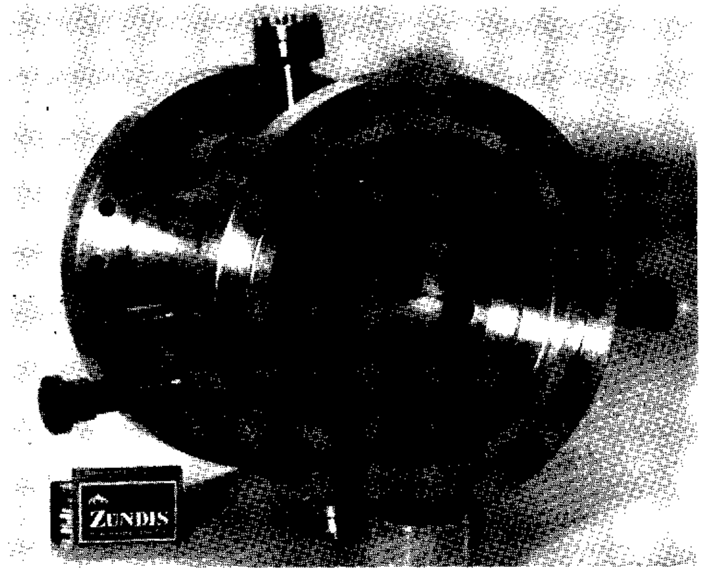

Figure 3 The Beryllium window assembly (2).

SECTION III - INJECTION CHANNEL CROSSING

Since the beamline crosses the injection channel of the storage ring we implemented another UHV-section between monochromator and experiment. It contains as major components two radiation safety beam shutters, a cross chamber and the final Be window.

The splitting of the beam shutters into two separate ones was dictated by the lack of space between injection channel and shielding wall to accomodate 40 cm of lead required for the large amount of Bremsstrahlung from the straight sections.

The cross chamber is separated by four valves (two vales in each channel). So there is a clear partition between the storage ring vacuum system and that one of the beamline.

This part of the beamline is terminated by another fixed absorber, which protects the Be window assembly in the direct beam. This Be window (3) is of the same type as window (1) when the direct beam is used. For using the monochromatic x-ray beam the Be window can be replaced by another 400 µm thin one.

DIMENSIONING THE FIXED ABSORBER SYSTEM

In this section we want to explain how the apertures of the fixed absorber system were calculated. Fig. 4 defines the geometry. We start with the simplifying assumption that our source is a point source which may deviate perpendicularly to the beam from its

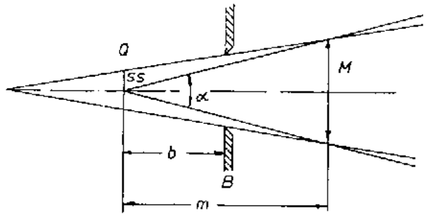

Figure 4

theoretical position. The distance between its two extrema is denoted by SS. M is the width of a slit or any other object which shall be illuminated. B is the minimal width of the aperture. Together with the distances b and m we obtain the width B:

$$B = SS + b/m\,(M-SS) \qquad (1)$$

For α, the acceptance angle of M, we assume, that it is smaller than the opening angle of the source.

The next question is, which diameter or aperture width following the first absorber B is protected. The geometry of this case is shown in Fig. 5. The width D which the beam can hit at a distance d from the source is given by:

$$D = d/b\,(B + SS) - SS \qquad (2)$$

The main point of these considerations is the contribution of the possible beam deviation, which is not negligible with partly dedicated storage rings (between 5 and 10 mm). Dedicated machines will have better properties, so that his problem will become small.

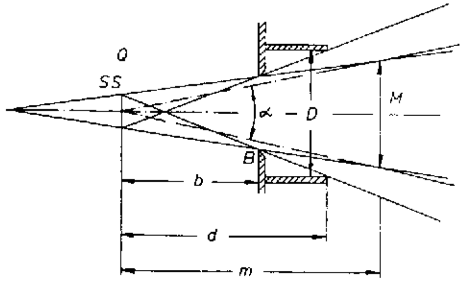

Figure 5

VACUUM SAFETY SYSTEM

The vacuum interlock system has to perform different tasks.

It must be impossible to vent any part of the storage ring or the beamline system by operating a valve. Sections of bad vacuum pressure are automatically separated from the rest of the beamline by closing the appropriate valves.

It must be impossible to irradiate unshielded components. All valves and beam shutters are thermally shielded by the movable absorber. This device can only be opened when all valves and beam shutters of the beamline are in open position and the cooling circuits are on.

When the mass spectrometers detect a higher He partial pressure than $1 \cdot 10^{-10}$ mbar all valves of the section must close and Be windows have to be examined.

The combination of acoustic delay line and fast-acting valve has to stop shock waves from accidental venting or failure of Be windows. In this way a Be contamination of the storage ring must be avoided.

SUMMARY

We described the major components in the HARWI beamline. They were designed to withstand the high power load of 7.1 kW produced by the wiggler W2. First tests of the wiggler line in 1987 performed at 3.7 GeV and 100 mA, corresponding to a total power of 2 kW, showed no problems.

ACKNOWLEDGEMENT

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