1 km Extension of BL29XU

1. Introduction

The 1-km extension of the beamline BL29XU was planned to facilitate various applications of a wide-area coherent beam and to measure the gravitational red-shift using bi-crystal interferometers. The long beamline can be also used as highly sensitive accelerator monitor. For the first long beamline, there are several technical problems to solve in order to guide the beam through the 1-km transport channel, including alignment and vacuum design in the open air.

Construction of the first 1-km beamline was started in November 1998 as an extension of a standard undulator beamline existing in the storage ring building. In January 1999, the detailed designs of the long beamline transport channel and the long beamline building including the concrete basement of the transport channel in the open air were started. These were followed by finalization of the designs and the process of procurement for individual elements by the end of March, fabrication of the components, construction of the building and basement, and partial assembly of the transport channel at the end of the year.

2. Long Beamline Building

The preliminary survey using the theodolite to determine the position of the long beamline building (LBB) was started in April. This was followed by a more precise triangulate survey to fix the position accurately. The ground level of the entire area along the beamline was also measured. The elevation of the LBB site was about 290 m above sea level, whereas that of the experimental hall of the storage ring building (SRB) is nominally 291 m above sea level. The ground level of the building site was raised so that the elevation of the experimental hall is 291 m above sea level. To prevent the site sinking and vibration of the site, several piles were driven into the bedrock.

The building houses the experimental hall which is 16.2 m wide, 18.9 m long, and 8.4 m high. The area for experimental hutch 2 (EH2) in the hall is cut off from the rest of the building to avoid vibration and is separated from external vibration sources. The EH2 with 3 m wide, 6 m long, and 3.3 m high will be placed. The basic structure of the EH2 is the same as the experimental hutch 1 (EH1) in the SRB. The hall has the same temperature control capability of 25±1˚C as the SRB experimental hall. Two preparation rooms (each 55 m^2) are located next to the hall. The LBB also has laboratories and stock rooms.

Construction of the LBB was completed at the end of December 1999. Figure 1 shows the view of the LBB.

The safety interlock and beamline interlock systems are based on a local-area-network using optical fibers between the SRB and the LBB, and they will be equipped by March 2000. Utilities for the experimental station in the LBB including cooling water and compressed air will be completed at the end of March. A cooling tower and an air compressor in the small hutch will be installed next to the LBB.

Fig. 1. View of the long beamline building.
SR X-rays come from the right.

3. Beamline

3.1 Basic Design of the Transport Channel

Problems of the novel transport channel without any optics and standard components are mainly due to vacuum system for extremely long ducts and the fact that the transport channel is constructed in the open environment. Many factors were taken into account for the design, including easier fabrication, assembly, alignment, maintenance, and weatherproof structure.

The transport channel will be extended from the end of the EH1, 56 m from the source, to the LBB located 1 km distant. The part of the transport channel in the open air is about 880 m long. Two-story beamline transport ducts with a height difference of 1 m (nominal height of 1430 mm and 2430 mm from floor level) will be installed between the EH1 and EH2 to measure the gravitational red-shift. Considering the beam size at the LBB and the alignment accuracy of the ducts, we chose ducts of 100 mm in diameter.

The vacuum requirements for the ducts are (i) tolerate pressure of less than 1 Pa, (ii) enabling beamline operation within a few hours after starting evacuation, and (iii) capability of easy maintenance. For the design of the vacuum system, we used a simple formula for the time dependence of the pressure taking into account pumping speed, duct conductance, the volume of the ducts, the out-gas volume from the surface, and the ultimate pressure of the pump. The unit length of evacuation was determined assuming simultaneous evacuation of both upper and lower ducts with a typical oil-sealed rotary pump.

Consequently, we decided to use 12-m-long vacuum ducts with JIS100 flanges for rubber O-rings. Combinations of 12-m-long duct, 400-mm-long bellows, 800-mm-long exhaustion port, and 400-mm-long bellows are repeated as 13.6-m-long vacuum units. The upper and lower evacuation ports are connected by an 870-mm-long flexible tube with NW50 flanges. Another NW25 flange of the lower evacuation port is connected to a vacuum pump through a 1-m-long flexible tube. One pump evacuates two 13.6-m-long ducts and flexible tubes. Figure 2 shows a calculated pressure curve as a function of evacuation time satisfying our vacuum requirements.

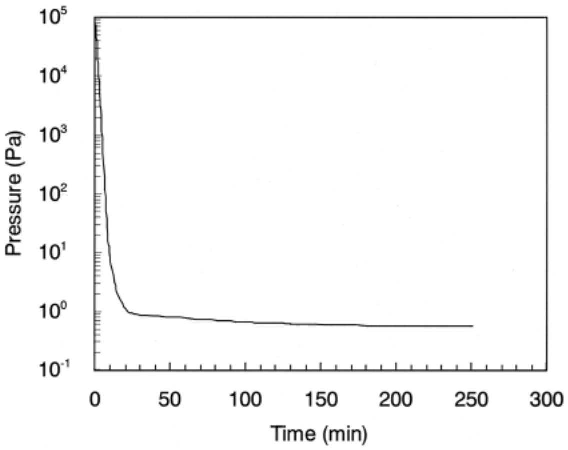

Fig. 2. The calculated pressure curve for unit structure as a function of elapsed time. Exhaustion with an oil-sealed rotary pump of 20 m^3/h pumping speed is assumed.

For our design, connection parts which have flanges and exhaustion units are covered by vacuum component hutches (VCH's). The ends of the 12-m-long ducts, the bellows, exhaustion port, flexible tubes, and exhaustion units are protected in the hutch from rain. The VCH is 3.2 m high, 2.1 m long, and 2.5 m wide. Its wall and roof are made of steel coated with Zn-Al alloy for weatherproofing. A door, light, and fan are equipped to facilitate the assembly and maintenance of the beamline, and to ventilate the hutch. Electric power for the exhaustion units, lights, and fans is supplied from both the SRB and LBB via junction boxes. Only the body of the 12-m-long ducts and supporting posts are exposed in the open air. The weatherproofing of these parts has been given special consideration.

Based on the unit structure, we designed the total layout of the transport channel. Figure 3 shows the schematic of the transport channel. We have four vacuum units in the experimental hall of the SRB, 64 units in the open air with the same number of VCH's, and two additional vacuum sections in the LBB. To keep environment of the experimental halls in both buildings oil-free, we adopted scroll pumps for the six exhaustion units inside the buildings. We use oil-sealed rotary pumps in the VCH's for easier maintenance. The beamline was divided into 13 vacuum segments by 26 gate valves for the convenience of maintenance.

According to the shielding design calculation, we need lead shielding only for the 3-m-long section of the lower duct from the back wall of the EH1 with the lead collimator at the exiting beryllium window. The shielding design facilitates the construction of the transport channel in the open air.

Screen monitors can be installed at the same hutches which have gate valves. We prepared ten monitors for five hutches and we will arrange the proper positions for beam monitoring.

Insulating flanges are inserted in the first and 64th VCH's to prevent lightning damage.

3.2 Basement in the Open Air

The beamline crosses the surrounding road of the SRB at about 200 m from the source. A concrete box-culvert measuring 3 m wide, 3 m high, and 20 m long was placed along the beamline and an overpass was constructed on the box-culvert. The floor of the box-culvert was kept at 291 m above sea level and the transport channel will be directly installed in the box-culvert. Construction of the box-culvert and overpass were completed in September.

Besides the box-culvert, a concrete basement was constructed to support the transport channel components in the open air. The basement is 2 m wide and is partly extended to 4 m wide for the VCH's. The beam axis was determined using a triangular survey as well as the LBB. Elevation ranges from 290 to 291 m above sea level between the SRB and the LBB, whereas the elevation of the experimental hall of the SRB is nominally 291 m above sea level. The basement has platforms up to 1 m high of 2.7 m wide and 2.4 m long for the VCH's and 900 mm wide and 600 mm long for the posts to maintain the elevation of 291 m above sea level.

The concrete basement was separated by expansion joints with period of 54.4 m corresponding to four vacuum units. By a simple model for thermal expansions of the concrete and stainless steel, the maximum expansion and contraction of ±10 mm is calculated assuming a temperature change from -10 to 40˚C. The bellows are designed to have sufficient margins to absorb the expansion.

The transport-channel basement was completed at the end of December 1999.

3.3 Fabrication of the Transport Channel Parts

The following transport channel components were fabricated by the end of November:

(1) Seamless 12-m-long stainless steel ducts,
(2) Vacuum components such as exhaustion ports and bellows,
(3) Exhaustion units including oil-sealed rotary pumps, scroll pumps, and thermocouple gauges,
(4) Posts for the ducts.

Weatherproofed parts (ducts and posts) were kept outdoors before assembly.

3.4 Alignment for the Transport Channel Assembly

Datum points for the beam axis of BL29XU in the experimental hall of the SRB were carefully extended by a triangular survey (triangulated by distance measurement) independent of the survey for the basement and the LBB. Reference lines and points for transport channel assembly were marked on the platforms of the concrete basement. The difference perpendicular to the beam axis between the axis by this survey and center of the basement is at most 20 mm. This is acceptable for beamline assembly when we consider the duct size, beam size, and construction error of the platforms.

For the beam axis height, the level of the target mark of BL29XU at the end of the experimental hall of the SRB is carefully transferred using a surveyor's level toward the LBB. Polygonal transfer of the level in equal pitches (typically 13.6 m for one vacuum unit length) will be carried out to keep the elevation above sea level equal as well as the height of platforms and experimental hall of the LBB.

Any height correction of the ducts due to the globe curvature, therefore will be carried out using the approximation, $\Delta h=L^2/2R$, where L is the distance from the source, and R is the radius of the globe. The maximum correction of 78 mm is necessary at the end of the 1-km beamline.

3.5 Assembly of the Transport Channel

Assembly of the transport channel was started partly in December as:

(a) Installation of the posts in the VCH's,
(b) Assembling the VCH's,
(c) Installation of the posts outside the VCH's,

and following processes will be completed by the end of FY 1999:

(a) Alignment of the posts,
(b) Installation of the 12-m-long ducts,
(c) Alignment of the ducts and management of 1-m-high difference by special jigs,
(d) Connection of the ducts by vacuum parts and installation of exhaustion units,
(e) Installation of junction boxes and cables to supply electric power to the VCH's from both the SRB and LBB,
(f) Installation of the beamline interlock system including connection between the main controller at the SRB and sub-controller at the LBB, and installation of the remote I/O boxes in two VCH's,
(g) Construction of the EH2 in the LBB,
(h) Inspection of individual elements.

3.6 Station Equipment

The following equipment will be prepared in FY 1999 as well as standard detectors and electronics sets:

(a) A multi-axis high-precision diffractometer for the wide-area coherent beam,
(b) A high-precision diffractometer for the bi-crystal interferometer,
(c) A high resolution image detector (CCD based beam monitor, Zooming tube).

4. Schedule of Construction and Commissioning

All the beamline construction will be completed by the end of March 2000, and work on the vacuum exhaustion test and the total inspection of the beamline interlock system will be started.

Commissioning will be started in early summer after permission is granted by the Science and Technology Agency.

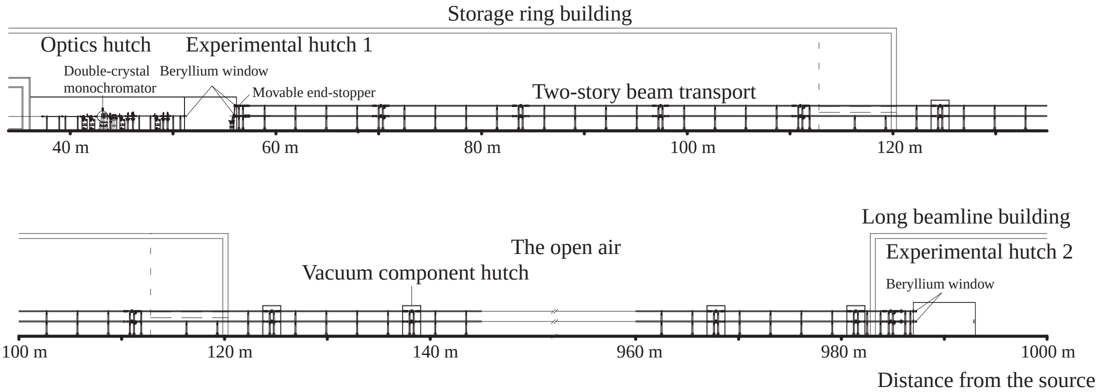

Fig. 3. Transport channel of 1-km-long beamline.