ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-MOP035

CRYOGENIC INFRASTRUCTURE AT BESSY II – CURRENT INSTALLATIONS AND FUTURE DEVELOPMENTS

S. Heling†, W. Anders, J. Heinrich, A. Hellwig, K. Janke, S. Rotterdam,
Helmholtz-Zentrum Berlin, Berlin, Germany

Abstract

In Berlin-Adlershof the Helmholtz-Zentrum Berlin (HZB) is operating the synchrotron radiation source BESSY II. Two superconducting wave-length shifters magnets are built-in the storage ring of BESSY II which are cooled with liquid helium. Additionally several test facilities for superconducting cavities are operated at HZB needing helium at 1.8 K. The required helium is supplied by two helium liquefiers.

Parallel to operation of the existing facilities the bERLinPro project will qualify as test facility for ERL science and technology. In order to guarantee the required supply with helium at different temperature levels one of the existing helium liquefiers has been relocated to the new accelerator building and the existing cryogenic infrastructure has been upgraded with a new 10,000 L dewar, three valve boxes, a cold compressor box, warm pumps and a 80 K helium system.

This paper specifies the setup of the above described helium cryoplants in detail and gives insight into the challenges of developments. The paper concludes with an outlook of the upcoming developments of the cryogenic infrastructure at HZB.

INTRODUCTION

At HZB the electron storage ring BESSY II is operated. BESSY II is a third-generation synchrotron radiation source that produces extremely bright X-ray light. Researchers from all over the world use this light for their experiments. Two superconducting wave length shifter magnets (WLS) are installed within the storage ring requiring cooling with liquid helium. One helium liquefier is operated in order to guarantee the helium supply for those magnets. Furthermore at HZB several test facilities for superconducting cavities are operated, requiring helium at 1.8 K and 4.5 K.

Additionally bERLinPro, a test facility for ERL science and technology, is currently installed. A second helium liquefier, currently under commissioning after relocating, will be used in order to supply the test facilities with liquid helium.

In this paper the above mentioned helium liquefiers and test facilities, including all cryogenic infrastructure, are described in detail. Using the example of extending cryogenic infrastructure for bERLinPro, challenges in design are discussed.

The paper concludes with the currently planned developments for the cryogenic components required for BESSY VSR, an upgrade of the storage ring.

† svenja.heling@helmholtz-berlin.de

OVERVIEW OF THE CRYOGENIC INFRASTRUCTURE

At BESSY II a complex infrastructure for the supply of liquid helium is installed. A supply with liquid nitrogen is also installed for pre-cooling of the helium liquefiers as well as some other consumers. This paper focuses on the infrastructure of liquid helium hence the logistics of liquid nitrogen are not discussed here.

An overview of the cryogenic infrastructure Berlin-Adlershof is shown in Fig. 1 [1].

As shown in Fig. 1 two helium liquefiers are operated. Table 1 gives an overview of basic data of both liquefiers.

Table 1: Linde TCF50 and L700

	Linde TCF50	Linde L700
Installation	2003	2009
Liquefaction	170 L/h (incl. LN2 precooling)	710 L/h (incl. LN2 precooling)
Compressors	Kaeser ESD 441	2 x Kaeser ESD 441
Dewar	2,000 L	10,000 L
Buffer	74 m^3	2 x 400 m^3

As can be seen in Fig. 1 the both helium liquefiers are connected on a low pressure, medium pressure and on a 4.5 K level. The connection of all plants on these different temperature and pressure levels allows a very flexible helium supply for all consumers and it is possible to react towards maintenance work or shutdowns.

Helium liquefier TCF50 usually runs continuously in order to guarantee supply of liquid helium for the WLS as well as supplying test facilities. When both TCF50 and L700 are running several consumers, like a WLS and a test facility can be provided with liquid helium simultaneously. In this case low pressure of both liquefiers are not connected. If one of the liquefiers is turned off intendedly or due to a failure the connection between low pressure piping is opened and the still running liquefier can retract the evaporating helium from the respectively other system. Helium gas stays in the closed circuit and is not lost.

In order to equalize helium inventory in both systems, helium can be transferred via the buffer system at medium pressure. The connection of both systems on a 4.5 K level guarantees liquid helium for all consumers independent of the running helium liquefier TCF50 or L700. While planning each extension of the existing cryogenic system connection of all components on those temperature and pressure levels is taken into account.

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-MOP035

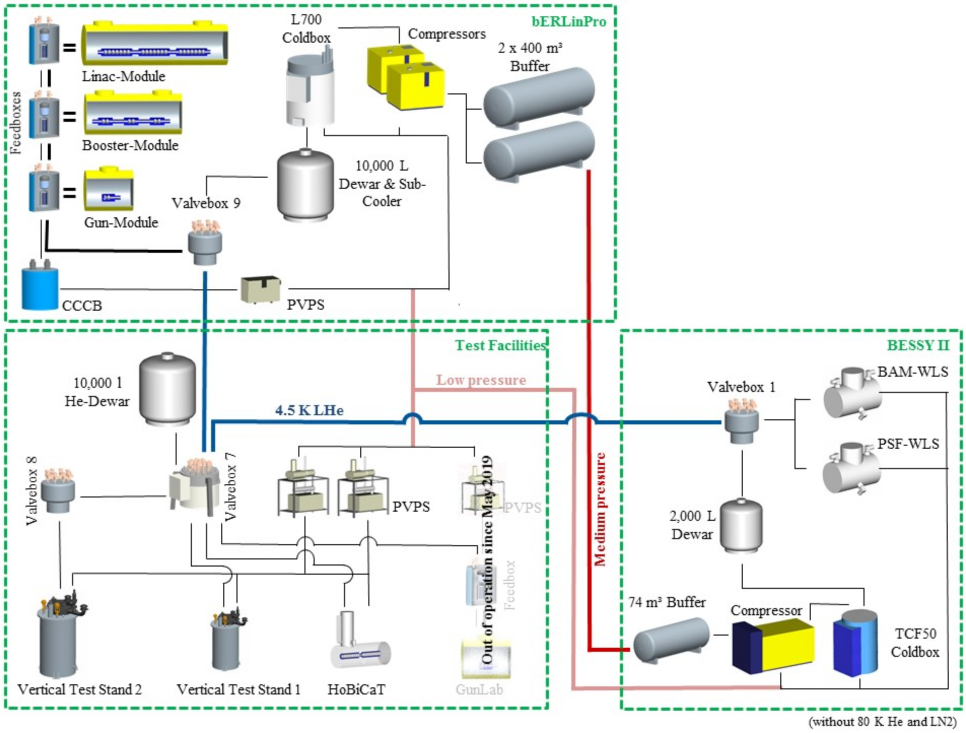

Figure 1: Cryogenic infrastructure at BESSY II.

As shown in Fig. 1 consumers of liquid helium can generally be divided into three groups: BESSY II, test facilities and bERLinPro.

BESSY II

In the storage ring of BESSY II two WLS are installed. The superconducting magnets are cooled to 4.5 K in a liquid helium bath with a volume of about 200 L. Both WLS are equipped with a cryo cooler for shield cooling and two recondensers. Since an upgrade and renewal of both WLS in 2018 heat intake into the helium bath is very small and helium evaporation is minimized. Therefore both WLS only need refilling with helium after a quench (sudden loss of superconductivity) or controlled warm up.

Test Facilities

In order to test superconducting components, e.g. superconducting cavities, several test facilities are installed. For horizontal testing HoBiCaT (**Ho**rizontal **Bi-Ca**vity **T**esting facility) is operated while for vertical testing a vertical test stand (VTS 1) is running. A larger vertical test stand is currently in commissioning (VTS 2).

HoBiCaT In HoBiCaT superconducting cavities are tested horizontally. The cryostat contains a small helium reservoir with a 4.5 K counter flow heat exchanger and a Joule-Thompson valve. The tested cavities are usually cooled down to 1.8 K at 16 mbar gas pressure. The cryostat is designed for a maximum cooling capacity of 80 W at 1.8 K. The pressure of 16 mbar is generated by a process vacuum pump stand (PVPS), consisting of two rotary vane pump and two roots pump. The pumps are able to generate a pressure stability of +/- 0.05 mbar at 16 mbar.

Vertical Test Stand 1 In order to test superconducting cavities (one to two cells) vertically a vertical test stand with a diameter of 1 m and a height of 1.9 m is operated. Additionally tests with a superconducting quadrupole resonator can be performed. The test stand is designed as bath cryostat with a helium volume of 360 l and a cooling capacity of 80 W at 1.8 K. The cryostat is filled in discontinuously. The required pressure of 16 mbar in the cryostat is generated with the same PVPS as used for HoBiCaT.

Vertical Test Stand 2 Currently a second, larger vertical test stand, with a diameter of 2 m and a height of 4 m, is installed. This test stand is designed to test larger cavities including cavities with assembled waveguide extensions. The new test stand is designed as bath cryostat with a helium volume of 2,000 l and a cooling capacity of 80 W at 1.8 K. VTS 2 is also using the pump stand of HoBiCaT and VTS 1, hence a parallel operation is not possible.

GunLab The test facility GunLab was set-up and used to test the Gun-Module which contains a superconducting electron source. This Gun-Module will later be used in bERLinPro for bERLinPro project. Operation of GunLab was finished in May 2019 to renovate and relocate the Gun-Module into the bERLinPro building. Hence cryogenic infrastructure for this module is not discussed further in this paper.

bERLinPro

The bERLinPro project (Berlin Energy Recovery Linac Project) will qualify as test facility for ERL science and technology. Figure 2 shows the principal set-up of the planned bERLinPro accelerator [2].

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-MOP035

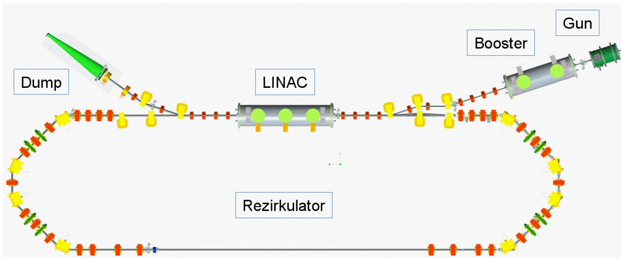

Figure 2: Principal set-up ERL.

The accelerator itself is still work in progress. A principal description of the planned set-up of the accelerator is described here. The Gun-Module contains a superconducting electron source, the Booster-Module serves as pre-accelerator and the Linac-Module functions as energy recovery module as well as electron accelerator.

A new building has been built for the bERLinPro, which is divided into an underground accelerator hall and an over ground technical hall. In an overview of the cryogenic infrastructure in the bERLinPro building is shown.

All three cryogenic modules require a helium supply at different temperature levels. The installed superconducting cavities are operated at 1.8 K and 16 mbar. Additionally to the cavities there a several other cryogenic consumers, e.g. RF-couplers, which have thermal intercepts at 4.5 K and 80 K. An 80 K helium shield is also installed within all modules [3], [4].

Due to safety restrictions in the bERLinPro building no components are allowed to be directly cooled with liquid nitrogen in the accelerator hall. Hence cooling at 80 K is done with gaseous helium. The so called 80 K-system, developed at HZB, is operated in the technical hall in order to provide helium at 80 K. In a coldbox helium is cooled down with liquid nitrogen. The gaseous helium is routed in a closed circuit while compression of the gas is conducted with oil-free turbo compressors using gas bearings.

As can be seen in Fig. 1 the helium liquefier L700 will provide the required cooling power for the cryogenic modules. For cooling at 4.5 K supercritical helium at 3 bara is provided. For the connection of the L700 as well as the 80 K-system in the technical hall with the cryogenic feedboxes in the accelerator hall two flexible 75 m long helium transfer lines are installed. Gaseous 80 K helium is used as shield in the transfer lines. Both flexible transfer lines feed into the rigid multiple transfer line (MTL) in the accelerator hall which connects all three feed boxes. All three feedboxes are designed similarly and adapted to the heat loads of the modules. The required 1.8 K helium is generated by sub cooling liquid helium in the feedboxes in a heat exchanger and then relaxing it to 16 mbar via a Joule-Thompson valve. Figure 3 shows both feedboxes for the Gun- and for the Booster-Module. The return of the sub-atmospheric helium from the cavities is also routed in the MTL where a branch leads to the cold compressor coldbox (CCCB). In the CCCB cold helium gas is pressurized to 100 mbar, heated and then pressurized to ambient pressure in the process vacuum pump stand (PVPS) located in the technical hall building. Finally it is fed into the low pressure system of the L700.

Figure 3: Feedboxes Gun- and Booster-Module.

CHALLENGES DURING UPGRADE OF CRYOGENIC INFRASTRUCTURE FOR BERLINPRO

During planning and installation of the cryogenic infrastructure for bERLinPro several aspects were considered. A few of these challenges are described here.

Flexible Helium Transfer Lines

During operation of bERLinPro radiation, including gamma and neutron radiation, is expected in the accelerator hall. Due to the negative influence of radiation on electronics and materials, most of the cryogenic infrastructure is placed outside the accelerator hall. However this led to the issue of long distances between cryogenic consumer and supplier and long helium transfer lines are required. Figure 4 shows the cryogenic infrastructure in the bERLinPro building.

Since several components inside the radiation protection area are connected to other components outside the radiation protection area those helium transfer lines need to be routed via a tight radiation protection labyrinth. This requires even larger transfer lines and due to limited space, installation of those transfer lines is complex.

In order to keep the pressure drop small within in the transfer lines, the inner diameter of the pipes were designed larger. When using flexible helium transfer lines the bending radius increases with increasing diameter. However in the bERLinPro building bending radiuses are limited due limited space in the labyrinth.

Particularly for both of the 75 m long flexible helium transfer lines, connecting the underground accelerator hall with the over ground technical hall a compromise between pressure drop and bending radius needed to be found. Installation of those long transfer lines with limited space in the building was found to be very challenging. Hence for future projects different concepts for the routing of transfer lines need to be found.

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-MOP035

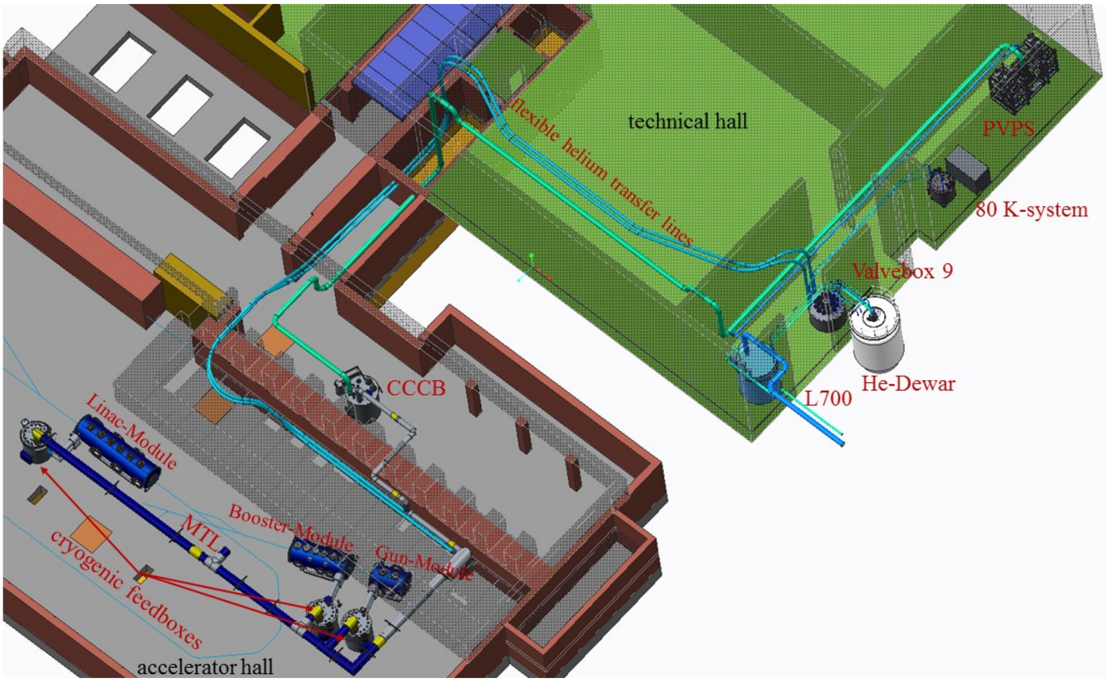

Figure 4: Cryogenic infrastructure bERLinPro.

Integration into the Existing Cryogenic Infrastructure and Automation

As can been seen in Fig. 1 the required cooling capacity for bERLinPro is provided by the helium liquefier L700. Therefore the helium liquefier L700, previously installed in a different building, was relocated to the bERLinPro technical hall. However the attached compressors stayed in the old building, so 120 m long piping of high and low pressure between both buildings were installed.

Additionally, in order to connect the cryogenic infrastructure of bERLinPro on a 4.5 K temperature level to the existing infrastructure, a 120 m long flexible helium transfer line, connecting Valvebox 7 and Valvebox 9 was installed.

The relocation of L700 as well as integration of all new piping into the existing cryogenic infrastructure was executed during operation of TCF50. Except for a short shutdown period supply of liquid helium war guaranteed for all test facilities.

Not only mechanical but also automation-wise the new cryogenic components for bERlinPro need to be integrated into the existing system. During modification of the cryogenic infrastructure for operation of bERLinPro the overall PLC communication was revised. Previously every plant component used its own PLC which communicated individually among each other. These separate communication was not flexible enough for operation of bERLinPro. Therefore a central management PLC has been installed being responsible for data exchange.

OUTLOOK

At HZB currently the project BESSY VSR (**V**ariable Pulse-Length **S**torage **R**ing), an upgrade of the existing storage ring, is ongoing. Aim of this project is to generate long and short pulses simultaneously while maintaining high currents. Key components for this new technology are superconducting RF-cavities to modify the RF-voltage gradient seen by the electron bunches. Those cavities need to be cooled with helium at 1.8 K.

Four cavities are installed in one cryogenic module, the VSR-Module. Additionally to the cavities other components e.g. RF-couplers will be installed within the module. Those components have thermal intercepts at 4.5 K and 60 K [5]. In order to guarantee the supply with helium at different temperature levels a third helium refrigeration plant is ordered. The cooling capacity at 1.8 K is specified with 280 W. The new cryoplant is based on a complex coldbox including cold compressors. Additionally to the plant a new helium dewar, helium buffers and a valve box are planned.

Since the VSR-Module is built into the storage ring, which usually operated with an availability of about 97 %, a permanent and continuous supply with liquid helium is essential. Therefore a large part of the components requiring frequent maintenance, e.g. warm compressors, are installed redundantly. Depending on the operating mode and disruptions in the storage ring the cooling load varies. Hence it is essential that the new cryoplant can react to varying operating conditions and heat loads. Figure 5 illustrates the designed integration of the new cryogenic infrastructure into the existing infrastructure on the different temperature and pressure levels of 4.5 K, low pressure and medium pressure.

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-MOP035

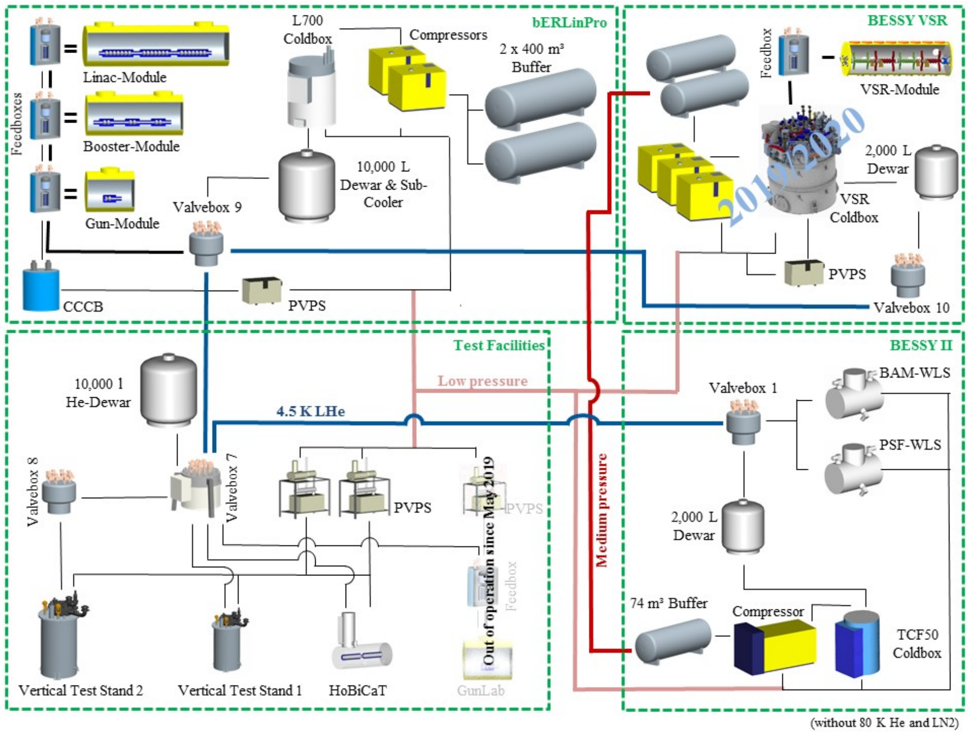

Figure 5: Cryogenic infrastructure – Outlook 2019/2020.

CONCLUSION

As described in this paper, in Berlin-Adlershof Helmholtz-Zentrum Berlin operates a complex cryogenic infrastructure.

The upgrade of the cryogenic infrastructure for the project bERLinPro shows that many factors need to be taken into consideration for a detailed planning of extensions and upgrades.

HZB has a long experience in planning and operating of helium cryoplants including infrastructure. This expertise, especially the experiences with the bERLinPro project, is currently used for the upgrade of the cryogenic infrastructure for BESSY VSR.

APPENDIX A: ABBREVIATIONS

bERLinPro	Berlin Energy Recovery Linac Project
BESSY	Berlin Electron Storage Ring Society for Synchrotron Radiation
CCCB	cold compressor coldbox
ERL	Energy Recovery Linac
GHe	gaseous helium
HoBiCaT	Horizontal Bi-Cavity Testing facility
HZB	Helmholtz-Zentrum Berlin
LHe	liquid helium
LN2	liquid nitrogen
MTL	multiple transfer line
PLC	programmable logic controller
PVPS	process vacuum pump stand
RF	radiofrequency
VSR	Variable Pulse-Length Storage Ring
VTS	Vertical Test Stand
WLS	wave length shifter magnets

REFERENCES

[1] J. Heinrich, *et al.*, “Cryoplants at Helmholtz-Zentrum Berlin”, CryoOps Batavia, 2016.

[2] Helmholtz-Zentrum Berlin, Conceptual Design Report BERLinPro, 2012.

[3] W. Anders, *et al*., “Cryogenic system for BERLinPro”, Advances in Cryogenic Engineering AIP Conf. Proc. 1573, 207-214, 2014.

[4] D. Pflückhahn, *et al.*, “Cryogenic Concept of the Berlin Energy Recovery Linac Project”, ICEC 24-ICMC Fukuoka, 2012.

[5] Helmholtz-Zentrum Berlin, Technical Design Study BESSY VSR, 2015.