STATUS REPORT OF THE BERLIN ENERGY RECOVERY LINAC PROJECT bERLinPro*

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Abstract

The Helmholtz Zentrum Berlin is constructing the Energy Recovery Linac (ERL) bERLinPro on its site in Berlin Adlershof. The project is intended to expand the required accelerator physics and technology knowledge essential for the design, construction and operation of future ERL based large scale facilities. The project goal is the generation of a high current (100 mA), high brilliance (norm. emittance below 1 mm mrad) cw electron beam.

We report on the project progress: The building will be ready for occupancy in January 2017. The planning phase for the first project stage is completed. Most of the components have been ordered and are in fabrication or have already been delivered. An update of the status of the various subprojects as well as a summary of upcoming activities will be given. Project milestones and details of the timeline finally will be reviewed.

INTRODUCTION

The bERLinPro [1] layout as a single-pass ERL is shown in Fig. 1, together with the project's basic set of parameters. The 6.5 MeV bERLinPro injector consists of a 1.3 GHz, 1.4 cell super conducting radio frequency (SRF) gun, followed by a booster module containing three super conducting (sc) 2-cell-cavities. The beam is merged into the main linac with a dogleg chicane and accelerated by three 7-cell, sc cavities to 50 MeV. With a racetrack shaped magnetic lattice the beam is recirculated for deceleration through the linac a second time and then sent into a 650 kW, 6.5 MeV beam dump. Space is provided in the return arc to install future experiments or insertion devices to demonstrate the potential of ERLs for user applications.

A staged installation of bERLinPro is planned, initially focused on the development and successful operation of a high current SRF gun. Depending on the availability of the 100 mA, full current Gun2 in this first installation phase, called "banana", a medium current ($I_{max} \sim 5$ mA) from Gun1 [2] will be accelerated in the booster, characterized and optimized and finally sent to the dumpline. The maximum kinetic energy is 6.5 MeV, since the linac is not yet installed at this time. For the second stage with the full current (Gun2) the main linac and the recirculation loop will be installed and commissioned to demonstrate efficient energy recovery with the full current, 50 MeV beam.

Here we report on the last year's progress of the various subproject groups and give an update on the project time line.

SRF GUN DEVELOPMENT

GunLab is the diagnostic beamline for the bERLinPro gun tests [3]. Two lead coated cavities had already successfully been setup and operated in HoBiCaT [4]: a backwall coated one in 2011 [5, 6] and a plug version in 2013 [7].

In this year the next phase of the SRF gun development program is running: the setup and commissioning of GunLab and the first gun Gun1 with an electrically and thermally isolated cathode insert, allowing incorporation of a high quantum efficiency (QE), normal-conducting photocathode. All vacuum parts have been delivered, the magnets and other external equipment (cameras, optics, coils) are in house. The installation within the HoBiCaT radiation shelter started in April this year. Initial operation and first beam is projected for autumn 2016. After about one year of commissioning time Gun1 will move to the bERLinPro accelerator hall in the end of 2017. In the beginning of 2018 Gun2 tests and characterization will start with GunLab.

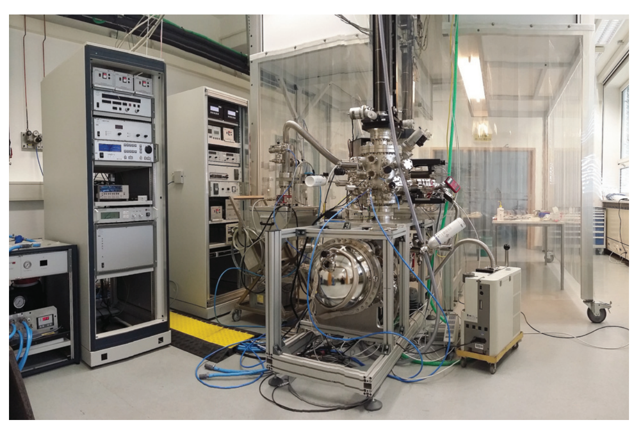

Figure 2: View of the fully operating Photocathode Preparation and Analysis system with the transfer system #1 in a clean room cell at HZB.

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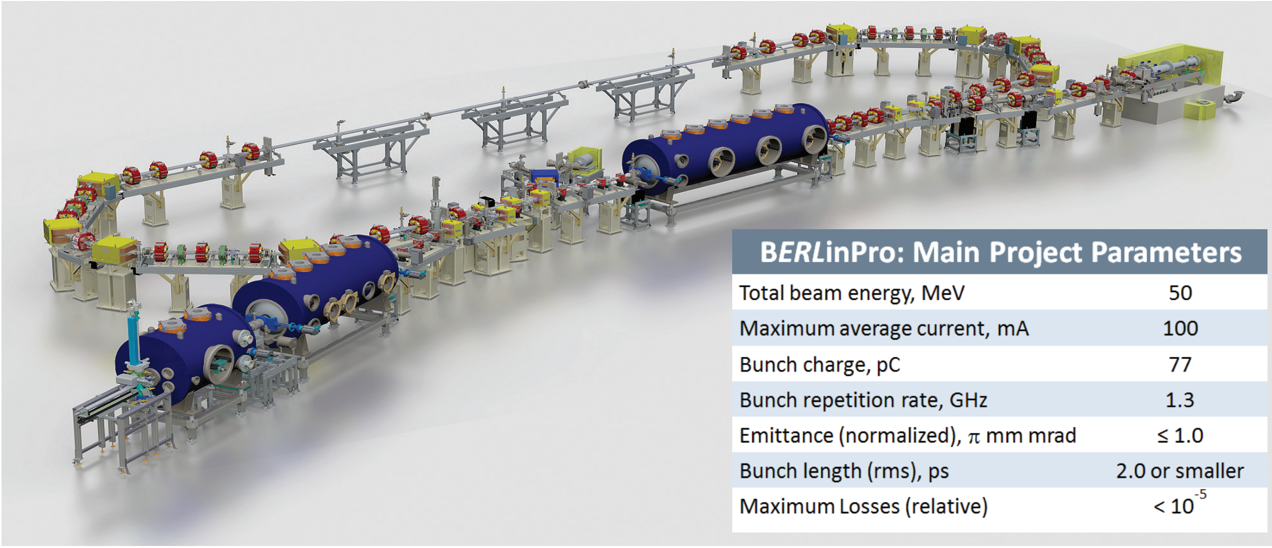

BERLinPro: Main Project Parameters	
Total beam energy, MeV	50
Maximum average current, mA	100
Bunch charge, pC	77
Bunch repetition rate, GHz	1.3
Emittance (normalized), π mm mrad	≤ 1.0
Bunch length (rms), ps	2.0 or smaller
Maximum Losses (relative)	$< 10^{-5}$

Figure 1: Draft of the major SRF and magnet components of bERLinPro with a summary of its main goal parameters.

Photocathode R&D: the initial commissioning of Gun1 will be performed with a metal photocathode. For further operation the bi-alkali antimonide CsK_2Sb photocathode system will be exploited. Within the last year a photocathode **P**reparation and **A**nalysis **S**ystem (PAS) was successfully commissioned at HZB (see Fig. 2) and the preparation of photocathodes with high QEs of about 5% at a wavelength of 532 nm was demonstrated by sequential growth on polished molybdenum sheets [8]. Further detailed in-situ growth studies were carried out in terms of deposition techniques, composition and surface roughness in collaboration with BNL and LBNL [9, 10].

The photocathode plug transfer system #1 with a vacuum suitcase ($p < 1 \cdot 10^{-10}$ mbar) was set up and commissioned at the PAS in a clean room environment. All parts for the second transfer system #2 are ordered. It will be set up and commissioned in the clean room as well to avoid particle contamination of the gun cavity before it will be mounted onto the module.

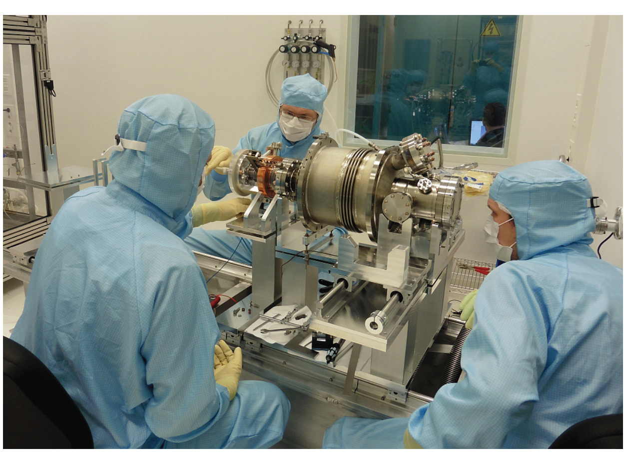

Figure 3: Cold string assembly in the HZB clean room in February 2016.

SRF CAVITIES

The main emphasis was put on the gun cavity assembly: in preparation for the first-time in-house assembly of an SRF string key personnel was sent to a clean room and assembly training at Fraunhofer IPA and DESY. Test fitting using dummy components was practiced in the HZB's clean room. In February 2016 the critical part of the cold string was mounted with the support of DESY colleagues, see Fig. 3. The complete Gun1 cold string, including its blade tuner, couplers and the cathode insert group is shown in Figure 4 Prior to the upcoming installation into the module, the cavity in the cold string has extensively been tested in HoBiCaT once more, demonstrating that both, the quality factor as well as the required field level remained unaffected by the assembly procedure [11].

The booster cavities are all in house now and awaiting their first horizontal acceptance tests. The call for tender for high power couplers has been issued and the module design is being finalized.

The linac cavity RF design was completed in 2015 already. The full, coupled structure of the three cavities in the module

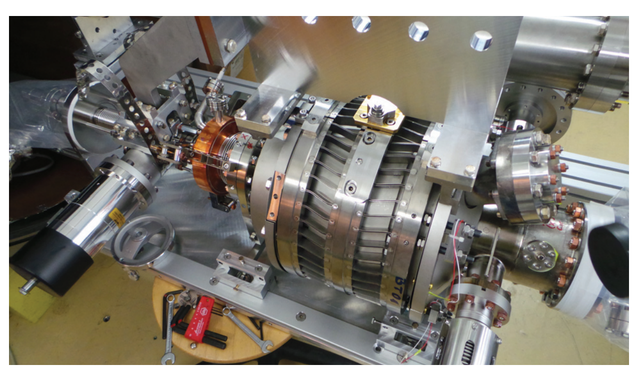

Figure 4: The Gun1.0 cold string with the cavity in its cryo tank, the surrounding blade tuner, the couplers and the cathode insert group.

was studied. The arrangement was optimized with respect to HOM damping, minimized coupler kicks and wake fields. Cavity manufacturing issues, in particular the production of the end groups have been investigated [12, 13].

WARM SYSTEMS

Optics & Theory: beside regular updates of the optics model to match hardware modifications, much effort has been spent to improve the agreement between the used beam dynamics codes: ASTRA, Elegant and OPAL. The OPAL code development work [14] together with a minor adjustment of the fringe field integral used in the Elegant simulations leads to good agreement between the codes. Tolerance and orbit correction studies for the full machine [15] have been done as well as dark current studies for the Booster module [16]. Commissioning plans and the machine protection system have been detailed further. Investigations on the machine performance in short pulse operation are ongoing [17].

Magnets: the production of magnets and girders by Budker Institute (BINP) will be finished in June 2016. First results of magnetic measurements show very good agreement to the specified parameters. In spring 2017 all girders and magnets (the complete machine) will be installed by the BINP.

Vacuum components: the basic vacuum system design for the complete machine is finished. Calculated pressure distributions confirm the SRF requirements of $p < 5 \cdot 10^{-10}$ mbar in the vicinity of the SRF modules and an overall average value of $\bar{p} < 10^{-10}$ mbar and $p_{\max} \sim 2 \cdot 10^{-10}$ mbar in injector and recirculator (in the dumpline the pressure increases due to the thermal outgasing from the dump surface). Steel chambers will be used in the low energy parts (injector & dump line) and aluminum at high energy, with some of the recirculator vacuum components, coated with NEG. The contract for the "banana" components will be signed end of May 2016. It also includes the installation of the vacuum system to guarantee clean room class 5 requirements. Installation is planned for June 2017. All remaining vacuum chambers for the recirculation loop will be ordered by mid of 2017.

Beam dumps: while the 30 kW medium power dump had already been delivered in December 2015, the high-power, 650 kW main beam dump has been fully equipped with 80 thermo sensors, enabling a spatially resolved temperature monitoring. A high temperature test, up to the specified 250°C will be conducted at HZB site.

Beam diagnostics system: without major modifications the purchasing process has been continued. Two DCCTs have been delivered and will be tested soon. A diode based "beam loss monitoring" (BLM) system has been designed, a prototype is under construction now. In order to enable the measurement of the bunch length an electron-beam probe concept has been developed [18].

Figure 5: bERLinPro construction site in April 2016.

BUILDING CONSTRUCTION

The trough construction for ground-water management started in February 2015 and was finished in time, fulfilling all watertightness requirements of the local authority. Following the preparation of the construction site in September 2015 the building construction was started. The base plate of the accelerator hall has been poured in a one work step to minimize ground vibration amplitudes and frequencies that may disturb the accelerator operation. The radiation protection wall of the accelerator hall was finished in March 2016: the specified concrete density was not quite achieved and an additional 18 cm normal concrete front-wall-installation was added to ensure the achievement of all radiation protection demands. Since January 2016 the construction of the technical hall is under way.

The completion of the interior will run until the end of the year, the hand over of the whole building is scheduled for beginning 2017 with start of first (RF) installation at end of 2016 already. Figure 5 shows the construction site of the bERLinPro building in mid of April 2016.

TIME LINE

The table below gives the updated, present overview of major steps and milestones in design, construction and commissioning of bERLinPro.

Q4/2016	first electrons from Gun1 (GunLab)
Q1/2017	building ready for machine installation, start of cryo system installation & comm.
Q1/2018	start SRF operation Gun1 & Booster (bERLinPro)
Q2/2018	first electrons from Gun1 & Booster (bERLinPro)
Q2/2019	Linac & recirculator installed
Q4/2019	start recirculation & energy recovery

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