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PROGRESS REPORT OF THE BERLIN ENERGY RECOVERY PROJECT bERLinPro*

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Abstract

The Helmholtz Zentrum Berlin is constructing the Energy Recovery Linac Project bERLinPro on its site in Berlin Adlershof. The project is intended to expand the required accelerator physics and technology knowledge mandatory for the design, construction and operation of future synchrotron light sources. The project goal is the generation of a high current (100 mA), high brilliance (normalized emittance below 1 mm mrad) cw electron beam at 2 ps rms bunch duration or below.

The planning phase of the project is completed and the design phase of most of the components is finished. Many of them have already been ordered. After some delay the construction of the building has started in February 2015. The status of the various subprojects as well as a summary of current and future activities will be given. Major project milestones and details of the project time line will be finally introduced.

INTRODUCTION

In 2008 the Helmholtz-Zentrum Berlin (HZB) submitted a proposal to build an ERL test facility to investigate its potential as accelerator technology for "Next Generation Multi User Synchrotron Light Sources". In October 2010 the Helmholtz Association approved the proposal, the official project started in the beginning of 2011.

The bERLinPro [1] layout as a single-pass ERL is shown in Fig. 2, together with the project's basic set of parameters. The 6.5 MeV bERLinPro injector consists of a 1.3 GHz, 1.4 cell SRF gun, followed by a booster module containing three 2-cell-cavities. The beam is merged into the main linac via a dogleg merger and accelerated by three 7-cell sc cavities to 50 MeV. Following recirculation via a racetrack, the decelerated beam is dumped in 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 Gun-2 in this first installation phase, called "banana", a medium to full current from the gun 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 "recirculation" stage the main linac and the recirculator will be installed and commissioned to demonstrate efficient energy recovery of the full current, 50 MeV beam.

In the next sections progress of the various subproject groups within the last 12 months will be presented together with an updated project time line.

PHOTOCATHODE R&D

As quantum efficiency, intrinsic emittance, temporal response and operational lifetime of the photocathode are key issues for the bERLinPro photoinjector a cathode preparation and characterization test lab has been established at HZB, where various kinds of cathodes can be produced and tested (see Fig. 1). A promising candidate to fulfil the requirements for an electron source is the bi-alkali antimonide CsK_2Sb [2]. An in-situ preparation and surface analysis system for CsK_2Sb photocathodes was commissioned at HZB since October 2014 and first samples have been very recently prepared with the sequential growth procedure. The lab operates two chambers: the preparation chamber, equipped with an effusion cell for Sb and with SAES alkali metal dispensers for K and Cs and the surface analysis chamber, equipped with a SPECS PHOIBOS 100 electron analyzer. An X-ray source for XPS and He ion source for LEIS are also attached to the analysis chamber, as well as an additional port for

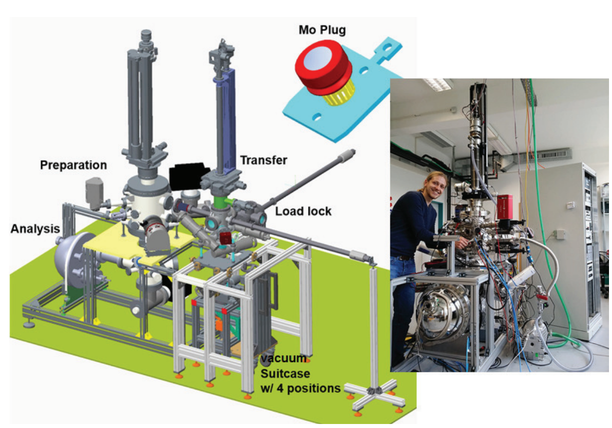

Figure 1: Drawing of the CsK2Sb-photocathode preparation and analysis system equipped with transfer chamber, load lock and vacuum suitcase for photocathode plug transport.

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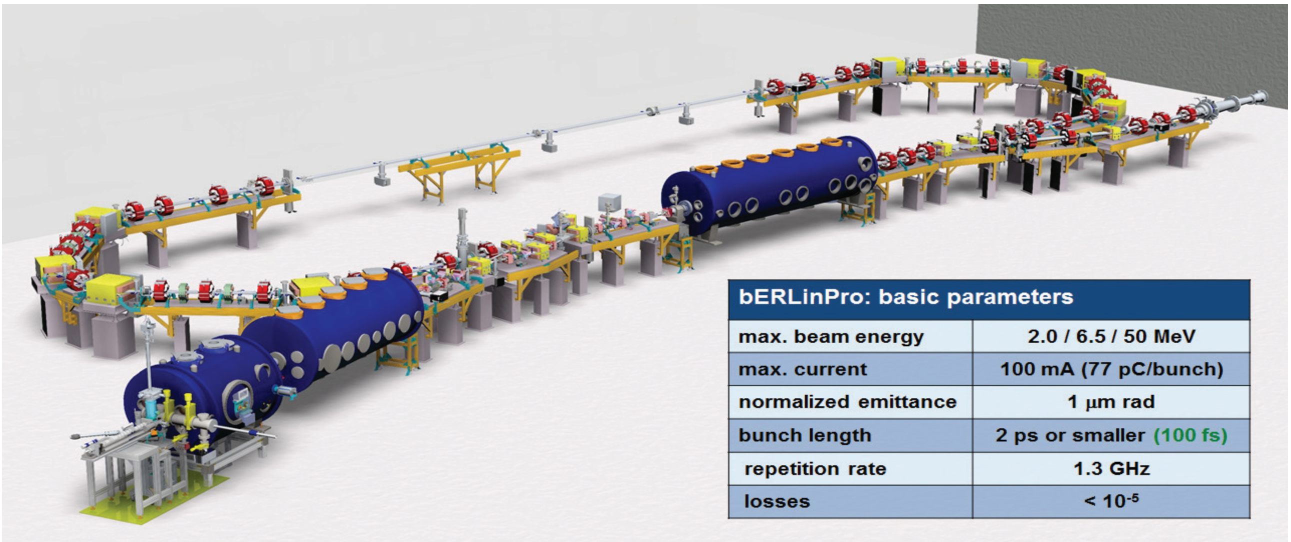

Figure 2: Draft of the major SRF and magnet components of bERLinPro with a summary of its main goal parameters.

the momentatron [3], which allows the measurement of the intrinsic emittance of the photocathode. The vacuum in both chambers is in the low 10^{-10} mbar regime.

In the future photocathode deposition procedures will be optimized in terms of high quantum efficiency and low surface roughness.

In the beginning of 2015 the photocathode plug design was finalized and a UHV-transfer system was designed to provide photocathodes for the photoinjector operation.

1.3 GHz SRF SYSTEMS

A lot of progress has been made during the last year, where activities were strongly focused on gun and booster. Thats why linac cavity design still has to be completed, a final version is expected for the end of this year.

Gun Development and Testing

The first suitable photoinjector gun for bERLinPro (Gun 1.0) has been fabricated by Jefferson Lab last year [4]. Following the fabrication at JLab, the cavity was processed and tested a number of times. In spite of a vertical test performance, less than desired, the titanium helium vessel was electron beam welded to the cavity. A photograph of the cavity following the helium vessel welding is shown in Fig. 3. After leak checking the field flatness and frequency of the cavity were measured and found to be in very good agreement with the estimated values expected after the welding. Moreover, compared to the last test of the bare cavity, results of vertical tests of the cavity in the helium vessel were significantly improved and close to design values. In February 2015 was shipped to HZB for the horizontal testing cryostat. Detailed information on latest vertical and horizontal measurements are found in [5].

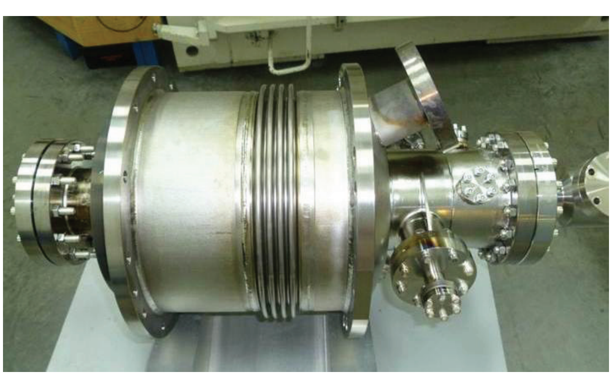

Figure 3: The SRF photoinjector cavity in its Ti vessel.

Booster Cavities

The booster cavities are two cell, elliptical cavities that are based on the Cornell injector design. Three cavities will be installed into the cryomodule, where the first one will be operated at zero-crossing for a first moderate bunch compression, while the downstream two cavities will be used to accelerate the electron beam to 6.5 MeV kinetic energy.

Jefferson Laboratory produced successfully 4 booster cavities. At JLab all of them where welded, chemically etched, heat treated and subsequently given a light BCP and high pressure rinse before vertical testing. All cavities far exceeded the design specification during the first vertical test, the overall frequency spread between the four cavities was excellent at less than 30 kHz [6].

WARM SYSTEMS

Optics & Theory

Adaption of the machine optics to minor changes (positions, apertures, field distributions), arising from constructional issues or from new information on magnets or rf components, has been done. The commissioning planning, especially for the first project phase ("banana"), has been further detailed. The analytical and CST based numerical wakefield & impedance studies are completed [7], minor construction modifications are still confirmed by according simulations.

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Magnets, Vacuum and Diagnostics Components

Magnets: the magnets for bERLinPro will be manufactured by BINP, a contract has been signed in March 2014. Due to the prolongation of the dump line the order has been extended by five additional quadrupole magnets subsequently. Beside the magnets also 27 girders to mount the magnets on are part of the order. The critical design review (CDR) was held October 2014 at BINP. The production for all this components is already released. The agreed delivery date is September 2016.

Vacuum System: the basic design is almost completed. Calculated pressure distributions confirm the SRF requirements when using steel chambers in the low energy parts (injector & dump line) and aluminum at high energy NEG coated for some of the recirculator vacuum components. The components for the first stage of installation ("banana") will be ordered at the end of 2015, for the second stage ("recirculation") all remaining vacuum chambers will be ordered until end of 2016.

Beam Dumps: two beam dumps are required: a high power, 650 kW main beam dump and a medium power, 30 kW dump at the end of the diagnostics beam line. The already manufactured high power beam dump is currently equipped with 80 thermo sensors, enabling a spatially resolved temperature monitoring.

For the 30 kW medium power dump the order has been placed at BINP. The design will be a copy of an unit that is under operation at BINP for many years. The delivery is expected in March 2016.

Beam Diagnostics System: for the successful machine commissioning and operation, as well as to prove reaching the project goal parameters, various beam diagnostics and instrumentation is required. A list of the equipment currently foreseen for installation can be found in Table 1. These devices enable the precise measurement of current, emittance, beam position over the huge current range of the ERL. Moreover options for beam manipulation, ion clearing and machine protection are included.

bERLinPro BUILDING

The construction site for the two bERLinPro buildings (equipment and underground, accelerator hall) was prepared

Table 1: bERLinPro diagnostics equipment for both project phases, * w/wo ion clearing functionality, ** for ion clearing

device type	stage I "banana"	stage II "recirc."	total
Faraday cup	3	-	3
ICT / DCCT	2 / 1	2 / 1	4 / 2
foil monitors	10	8	18
striplines*	11 / -	13 / 7	24 / 7
button electrodes**	-	2	2
SR / THz ports	- / -	4 / 2	4 / 2
collimator	1	-	1
absorber	0	1	1

Figure 4: bERLinPro construction.

until September 2014. All required licenses as approval notice (funding by BMBF), building and radiation protection permission and a lot of more licenses in connection to responsible authorities are present. After some rearrangement of rooms inside the halls, caused by switch of the two hall positions, all planning phases are finished now.

In total there are 30 individual bidding processes until “building ready”. With the first bid in June 2014 for the trough construction (grounding), there was a legal objection from one of the tenderers with the result of a 6 months delay for the beginning of construction work and thus for the entire project. Next bidding processes as building construction, electrical power supply, air conditioning, central heating, cooling system, etc. are currently in process. In February 2015 the construction of the slurry walls, needed for the trough structure, was started. Figure 4 shows a photograph of the bERLinPro site at Berlin Adlershof in April 2015. The start of the building construction is planned for September 2015. “Building ready” is expected for December 2016, but first SRF and Cryo components can be installed already during the TGA (interior) works, starting in February 2016.

TIME LINE

Table 2 gives the updated, present overview of major steps and milestones in design, construction and commissioning of bERLinPro. Included here are also the modifications due to the belated building construction.

Table 2: bERLinPro time line

02/2015	start building construction
06/2016	first electrons Gun-1 (GunLab)
12/2016	building ready for machine installation, start installation & commissioning of 1.8 K Cryo System
11/2017	start SRF operation Gun-1 & Booster (bERLinPro)
03/2018	first electrons from Gun-2 (GunLab)
05/2018	first electrons from Gun-1 & Booster (bERLinPro)
05/2019	Linac & recirculator installed
09/2019	start recirculation & energy recovery

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