STATUS OF THE BERLIN ENERGY RECOVERY LINAC PROJECT bERLinPro*

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Abstract

The Helmholtz-Zentrum Berlin is constructing the Energy Recovery Linac Prototype bERLinPro, a demonstration facility for the science and technology of ERLs for future light source applications. bERLinPro is designed to accelerate a high current (100 mA, 50 MeV), high brilliance (norm. emittance below 1 mm mrad) cw electron beam. We report on the project status. This includes the completion of the building and the installation of the first accelerator components as well as the assembly of the SRF gun and GunLab beam diagnostics, which are now ready for commissioning.

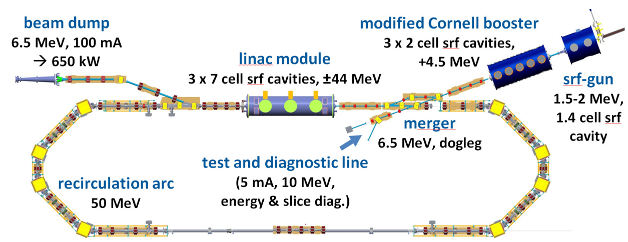

Figure 1: Basic bERLinPro layout.

INTRODUCTION

bERLinPro [1] is an Energy Recovery Linac Prototype, currently under construction at the Helmholtz-Zentrum Berlin (HZB), Germany. Application of super conducting radio frequency (SRF) will allow to accelerate currents of storage ring levels. The layout is shown in Fig. 1, the project's basic set of parameters is listed in Table 1. The 6.5 MeV bERLinPro injector consists of a 1.3 GHz, 1.4 cell super conducting gun, followed by a booster module containing three 2-cell SRF cavities. The beam is merged into the main linac with a dogleg chicane and accelerated by three 7-cell, SRF cavities to 50 MeV. With a racetrack magnetic lattice the beam is recirculated for deceleration through the linac a second time and then sent into a 650 kW 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.

The installations of the first project phase is currently ongoing: the so called "Banana", initially operated with a medium current GUN-1 ($I_{max} \sim 5$ mA), covers the complete low energy beam path including the high power (650 kW) beam dump and a diagnostics line. Depending on the availability of the 100 mA, full current GUN-2 and the booster module during this first project phase both components will be subsequently installed.

In the second stage of the project the main linac and the recirculation loop will be installed and commissioned to demonstrate efficient energy recovery with the full current, 50 MeV beam.

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Prior to installation in the bERLinPro accelerator hall all guns will be extensively tested and characterized in GunLab [2,3], bERLinPro's gun test laboratory on the HZB site. The first run with GUN-1 module will start in June 2017. Here we provide an overview of last year's progress of the various subproject groups and give an update on the project time line.

GUNLAB & PHOTOCATHODE R&D

The GunLab facility (Fig. 2) consists of three systems enabling the operation and characterization of advanced SRF gun systems: a drive laser, a photo injector gun module, and an electron beam diagnostics beam line.

The **drive laser system** for GunLab consists of a diode-pumped mode-locked Yb:YAG oscillator with diode-pumped regenerative amplifier. The infra-red output of the amplifier is converted in a two stage harmonic generator first to 515 nm and finally to UV at 258 nm. The single pulse repetition rate can be set to six fixed values between 10 Hz

Table 1: bERLinPro's Main Parameters

max. beam energy / MeV gun / booster / recirculator	2.5 / 6.5 / 50
max. average current / mA	100
norm. emittance / μm rad	1.0
bunch length / ps	2.0 (0.1)
rep. rate / GHz	1.3
losses	$< 10^{-5}$

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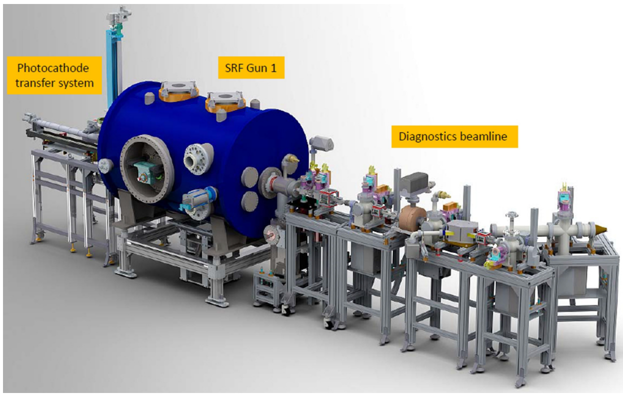

Figure 2: Drawing of Gunlab.

and 12 kHz. By means of a movable grating pulse-stretcher bunches from 2.2 to 29 ps FWHM length can be generated. The laser is fully operational since mid 2016, installations in the laser - cathode beam line are currently completed.

Photocathode preparation: for the operation of bERLinPro electrons will be generated from Cs-K-Sb photocathodes. Their preparation is performed in a laboratory with a dedicated growth and analysis system [4]. This system is equipped with in-situ surface analysis tools to study the influence of growth parameters on the composition of the materials and to find correlations with electronic structure and emission properties. The growth process of bi-alkali antimonide photocathodes on particle free, ultra-smooth, polycrystalline Mo plugs has been optimized resulting in a quantum efficiency (QE) of about 10% at 515 nm. For the determination of the workfunction a setup for measuring the spectral dependency of the QE at the photocathode preparation has been commissioned [5].

The complete transfer chain for the photocathode, including the transfer system at the preparation system to load the vacuum suitcase has been assembled and tested under particle free conditions as well as a second transfer system at the SRF-photoinjector to unload the vacuum suitcase and to insert the photocathode into the back wall of the superconducting Nb-cavity. Up to four cathode plugs can be transferred from the growth chamber in the laboratory to the SRF photoinjector under UHV conditions with this load-lock system [6].

The **GunLab diagnostics beam line** allows commissioning of SRF gun systems and a complete 6D phase space characterization. The transverse emittance is measured with a slit based system at the first emittance compensation point, the bunch length can be measured with a normal-conducting transverse-deflecting RF cavity operating TM110 mode at 1.3 GHz. Directing the streaked bunches into a dipole spectrometer also a longitudinally resolved (sliced) energy and energy spread measurement becomes possible.

All hardware installations were completed in April 2017, so that the diagnostics beam line is ready for operation. Some final cabling work is still ongoing and first commissioning tests without beam have been started.

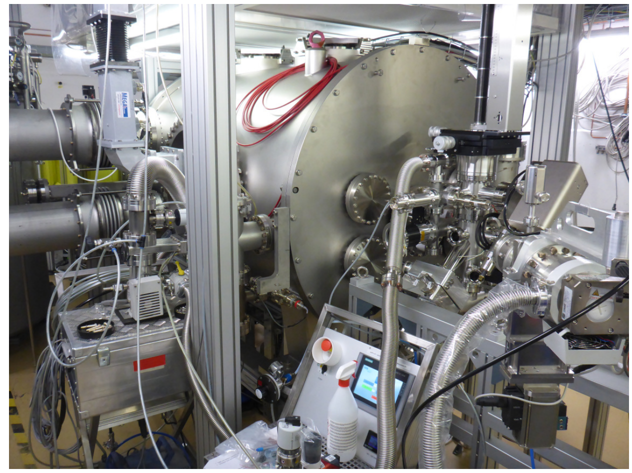

Figure 3: Gun-1 module in GunLab. In front of the module the cathode transfer system can be seen. From the left the cold box cryo supply lines are connected to the module.

SRF MODULES

Three Modules, containing one (gun) and three (booster & linac) 1.3 GHz SRF cavities, will finally be operated in bERLinPro:

Gun Module: the GUN-1 cold mass has been fully assembled in the HZB clean room. A horizontal test of the cold string in HoBiCaT showed a preserved quality factor and field level compared to previous tests at JLab and HZB. The set up of the module within GunLab (Fig. 3) was completed in March - a first cool down via coldbox is underway this month. Preparations for the RF commissioning are currently running [7].

The production of a spare cavity for GUN-1, the so-called GUN-1.1, has been completed. The cavity is currently being chemically (BCP) processed and will be finally tuned afterwards [8].

Booster Module: four booster cavities (including one spare cavity) are in house since 6/2015. Before being delivered they were vertically tested at JLab. At HZB they were geometrically measured to adjust the drawings for the coupler production at Toshiba [9]. Currently the preparations for horizontal acceptance tests are running as precondition for the integration into module. The module itself is almost completely designed and procurement of components has begun. The module assembly will start when the high power couplers are delivered and conditioned, presumably in Q1/2018.

Linac Module: in collaboration with JLab, a prototype HOM load for wave guide damped cavities has been designed and manufactured [10]. The technical cavity design is finished, manufacturing studies with an industrial partner have been successfully accomplished.

RF & CRYOGENICS SYSTEMS

RF systems: three high power klystrons of 270 kW each will provide RF power for the gun cavity and two of the three


Figure 4: bERLinPro accelerator hall in April 2017.


Figure 5: bERLinPro building in May 2017.

booster cavities. All have been delivered. Two of them had problems and are currently in repair under warranty at the vendor. The third one is in test operation at HZB.

Two transmitter power supplies are now placed in the bERLinPro building, the coaxial cables for the linac module are also installed.

Cryogenics system: the main "Flex lines" connecting the refrigerator box with the cold compressor box have been installed in the beginning of this year. The main components have been ordered and their delivery and staged installation is expected to start in Q3/2017.

WARM SYSTEMS

Magnets [11]: by the end of February all girders and magnets for the complete bERLinPro machine have been installed by the BINP co-workers in the accelerator hall (Fig. 4). The GUN-1 Module and the "First Meter" with gun diagnostics will be installed in spring 2018. Until installation the delayed booster and also the linac module are substituted by stainless steel vacuum chambers. Some quadrupole magnets from the recirculator are temporarily mounted there to compensate for the lack of rf focusing.

Vacuum system: the basic design for the complete machine is finished. The contract for the Banana components was issued in May 2016. It includes also the installation of the vacuum system at the bERLinPro site under ISO5 clean room and UHV vacuum conditions. Delivery is planned by December 2017, installation will be finished until April 2018.

Beam dumps: the 30 kW medium power beam dump at the end of the diagnostics beam line was already delivered in December 2015 and will be installed together with the Banana vacuum components, as well as the main beam dump, in January 2018. Following manufacturing of the latter it was equipped with 80 additional thermo sensors. At this point a vacuum leak was created and some re-engineering is required with completion scheduled for September 2017.

Beam diagnostics: the overall concept is worked out and further detailing and first tests of single components have been started. The current monitors (ICTs and DCCTs) are delivered and their integration in the vacuum chamber is prepared. Prototypes of the beam loss monitors are produced and installed in GunLab for testing. The layout and material of the screen monitors are under investigation - lifetime, resolution and saturation tests depending on screen material and thickness will be performed in GunLab.

BUILDING

The building construction will be complete by June 2017. Most of the acceptance tests with the companies will be finished in May. The remainder of the acceptance tests with official authorities will occur in June.

PROJECT TIME LINE

As bERLinPro progresses, technical and scientific challenges are encountered, as is to be expected for an R&D installation. As a result, the bERLinPro schedule has slipped considerably w.r.t. the original plans. Furthermore tight schedule constraints for HZB's BESSY VSR upgrade of BESSY II is taxing available personnel and infrastructure resources. Table 2 provides the current time line.

Table 2: bERLinPro's Updated Time Line

Q1/2017	building ready for machine installation (Fig.5), start of cryo system installation & comm.
Q2/2017	first electrons from GUN-1 (GunLab)
Q2/2018	start SRF operation GUN-1 (bERLinPro: Banana)
Q3/2018	first electrons from GUN-1 (bERLinPro: Banana)
Q4/2020	first electrons from GUN-2 with booster (bERLinPro: full machine w/o linac)

A date for recirculation is not listed since it currently is the subject of re-evaluation given the BESSY VSR constraints.

Note: further details on the bERLinPro progress are reported in these conference contributions [12-16].

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