ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-TUP036

COMMISSONING OF KLYSTRON TRANSMITTERS WITH 270 $\mathrm{kW_{CW}}$ AT 1.3 GHz*

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Abstract

The Helmholtz-Zentrum Berlin currently builds "bERLinPro" (Berlin Energy Recovery Linac Project) at its site in Berlin-Adlershof close to the synchrotron light source BESSY II. The SRF system of bERLinPro consists of three klystron transmitters each providing 270 $\mathrm{kW_{CW}}$ and four solid state amplifiers 15 $\mathrm{kW_{CW}}$ at 1.3 GHz.

In this paper the klystron transmitters are shown and the first power test.

INTRODUCTION

Figure 1 shows a picture of the installation of the ERL. BERLinPro's is a single-pass ERL to demonstrate ERL technology for use as a future synchrotron light source with beam currents up to 100 mA. Its 6 MeV injection line consists of a 1.3 GHz SRF photo injector module containing one 1.4 cell SRF-cavity and a booster module using three 2-cell cavities. The beam is merged into the main linac via a dog-leg merger where it is accelerated to 50 MeV in the linac module using three 7-cell SRF cavities following recirculation via the straight section reserved for future experiments. The decelerated beam is dumped in a 600 kW beam dump at 6 MeV.

Figure 1: bERLinPro facility.

The beam loading in the injector path is 600 kW while the beam loading in the linac is low due to the energy recovery principle.

* Work supported by the German Bundesministerium für Bildung und Forschung, Land Berlin and grants of Helmholtz Association
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RF SYSTEM

To provide the energy for the beam loading the SRF gun and the two out of three booster cavities are powered by three klystrons each delivering up to 270 $\mathrm{kW_{CW}}$ at 1.3 GHz. Four solid-state amplifiers 15 $\mathrm{kW_{CW}}$ at 1.3 GHz are used to power the LINAC module and the first booster cavity. The power supplies and solid state amplifiers are located on ground floor level of the building. The klystrons are located in the basement close to the cavity modules behind a radiation shield wall to keep the distance short and to reduce waveguide losses.

Klystron Power Supply

The klystron's power supply is manufactured by FUG [1]. Nominal output is 65.2 kV and 9.2 A with a ripple of less than 0.1% peak to peak. Each power supply consists of 30 switching modules (20 kW) located in two cabinets. In a smaller cabinet the voltage is added. All high voltage parts are in an oil bath. The fourth rack is for connection of the mains and for controls. Figure 2 shows the installed three power supplies.

Figure 2: Klystron power supplies. Each power supply consists of two cabinets 32.6 kV 9.2 A, one combining cabinet and one rack for mains and controls.

Klystron

Figure 3 shows the klystron installation at bERLinPro. The klystron in the rear is the first klystron that has been tested. The klystrons are produced by CPI [2] and have 6 internal cavities. They are optimized for high linearity up to high power levels. Maximum power is 290 $\mathrm{kW_{CW}}$ but operation should not exceed 270 $\mathrm{kW_{CW}}$. Klystrons have

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been developed for bERLinPro and for ARIEL project at TRIUMF [3] to share the development costs.

Figure 3: Installed klystrons.

The klystron specifications are listed in Table 1:

Table 1: Klystron Specifications

Specification	**Value**
Beam Voltage, Typical	61 kV
Beam Current, Typical	8.5 A
Usable CW Output Power	>270 kW
Efficiency	58 %
Gain	45.9 dB
Drive Power	8 W

Circulator and Waterload

Each klystron is protected by a circulator. Figure 4 shows one of three klystrons including the circulator and waterload. The circulator is of type CPR650 manufactured by AFT [4]. It is capable of withstanding 270 kW_{CW} power with full reflection at any phase. Insertion loss is specified to be better than 0.15 dB and return loss at center frequency is specified to be better than −26 dB.

The waterload is manufactured by Ferrite Domen Co. [5] from St. Petersburg/Russia. It is build from three loads. Rated power is 300 kW_{CW} with an input VSWR of better than 1:1.07 (−29.4 dB).

Waveguide System

The klystrons are connected with the cavities by WR650 waveguides. Figure 5 shows the setup of the waveguide system. The gun module contains one cavity and the booster module three cavities. The klystrons are located behind the radiation shielding wall.

Due to the fact that the cavities have two couplers each, there is a waveguide splitter in each power line. To adjust the phase between the couplers a phase shifter is used. The phase shifter is built using two waveguide bellows and a motor

Figure 4: Installed klystron with circulator (left bottom) and 300 kW waterload (left top).

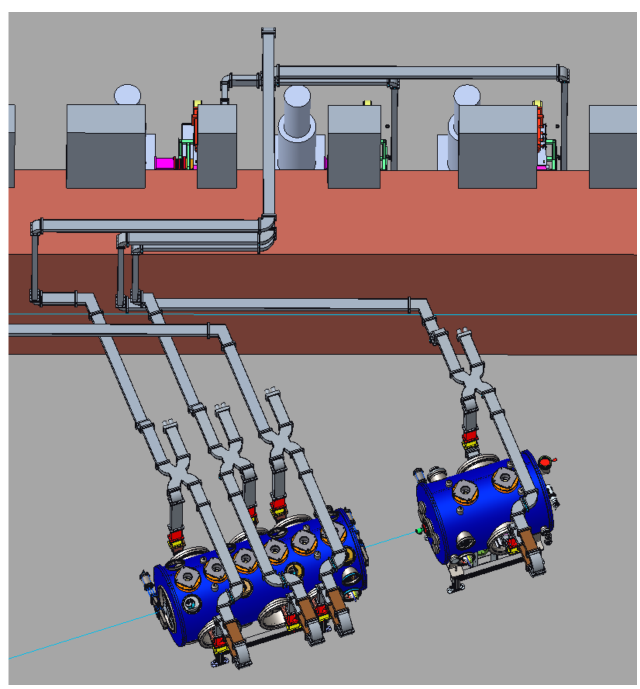

Figure 5: The gun module is on the right and the booster module on the left. Behind the radiation shield wall the klystrons can be seen.

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-TUP036

driven sliding unit. Each bellow can be moved ±24 mm achieving a total phase shift of 150°. Figure 6 shows the phase shifter.

Figure 6: Motor actuated waveguide phase shifter.

The waveguides at 270 kW power level are water cooled. After the splitter and some losses the waveguides are on 120 kW level and no water cooling is required.

POWER TEST

Figure 7 shows the measurement results of the commissioning of the first of three klystrons. The beam voltage is in green, the collector current in yellow and the RF output power in purple. The plotted collector losses (red) are based on calorimetric measurements performed on the cooling water. Body current was low. RF output power is measured with RF demodulators that are calibrated based on calorimetric measurements. The results show an efficiency of more than 50 % at maximum tested power of 270 kW_{CW}.

OUTLOOK

All three transmitter power supplies and klystrons are installed. The first klystron transmitter is commissioned to full power. The next two transmitters will follow. Currently

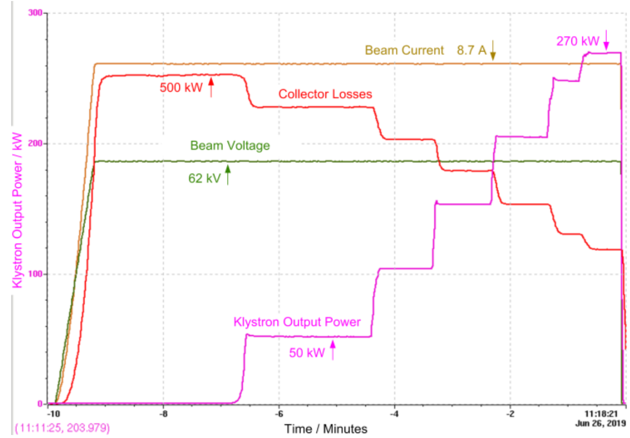

Figure 7: Measurement results.

there are not enough switching power units to reach full power with all transmitters due to cost reasons in the project phase. After successive commissioning of all transmitters to full power the switching power units will be redistributed to have 20 instead of 30 units per transmitter. This will result in 54 kV 7.3 A and a maximum RF power of about 160 kW good for 40 mA beam current. In a later stage all transmitters will be equipped to full power.

REFERENCES

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