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RF POWER WAVEGUIDE DISTRIBUTION FOR THE RF GUN OF THE EUROPEAN XFEL AT DESY

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Abstract

The first section of the European XFEL provides the 43 m long injector. The injector consists of a 1.3 GHz RF gun, a 1.3 GHz cryomodule, a 3.9 GHz cryomodule and an extensive diagnostic section. The RF gun operates with a maximum RF peak power up to 6.5 MW, 10 Hz repetition rate and up to 650 µs pulse length. The starting point in the 1.5 cell normal conducting L-Band cavity of the RF gun is a Cs2Te photocathode, which produces electron bunches, which are injected into the superconducting accelerating section of the European XFEL. The RF power is generated by a 10 MW multi beam klystron and distributed to the RF gun through a RF power waveguide distribution system. In order to enhance the reliability of the distribution system, the peak power is minimized in every section of the system by splitting the power in different branches. The RF power reaches its maximum just in front of the RF gun after combination of all branches. An additional air pressure system decreases the break down level in the waveguides of the distribution.

We present the layout of the waveguide distribution system for the XFEL RF gun at Desy and report on first operation experiences.

REQUIREMENTS FOR THE WAVEGUIDE DISTRIBUTION FOR THE RF GUN

The main requirement is to feed the gun at the 7th underground floor in the XFEL tunnel with a klystron located at the 3rd underground floor with high reliability [1]. Therefore the connecting waveguide distribution has been designed and installed in a narrow shaft with high precision and high accuracy. The connecting waveguide distribution, as shown in Fig. 1, compensates the mechanical misaligment, the thermal expansion and the weight of the waveguide distribution due to flexible waveguides and a customized support system, which consists of several hanging units to stabilize the waveguide system from upper, lateral and lower sides.

To create a system as reliable as possible the two klystron outputs are splitted into four branches, which lead the RF power to unique developed isolators each at the end of the shaft. Through power combiners those branches are connected and the RF power is transferred to the RF gun window.

The Figure 1 shows the Connecting Waveguide Distribution with all four branches, which extend from the 3rd to the 7th underground floor.

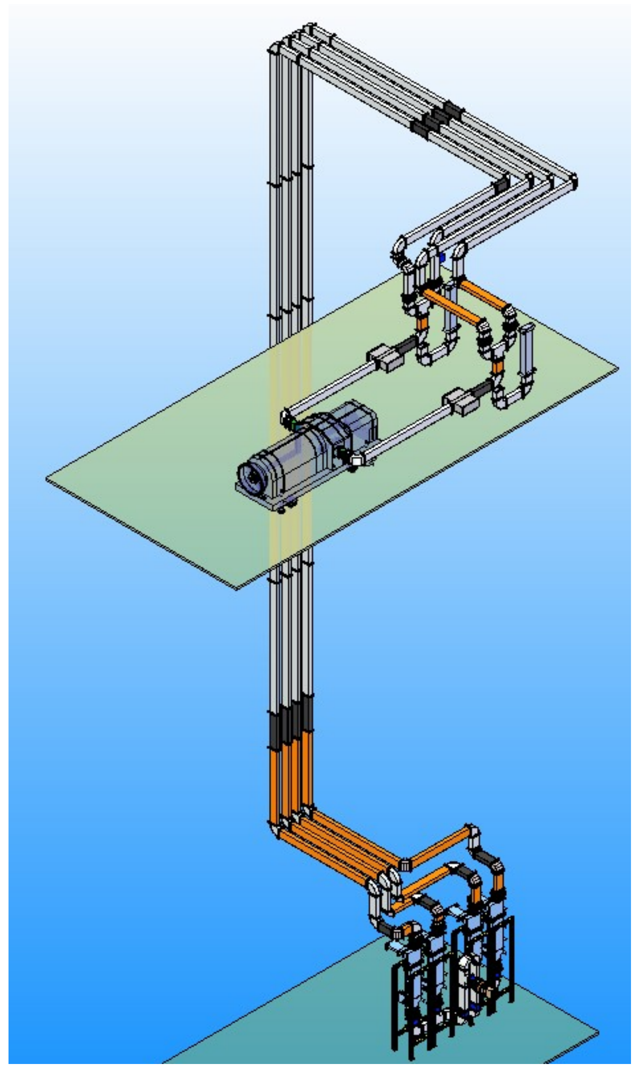

Figure 1: Connecting waveguide distribution for the RF gun.

WAVEGUIDE DISTRIBUTION FOR THE RF GUN

The complex waveguide distribution system for the RF gun consists of 236 parts both standard type WR650 and specific waveguide components [2]. To manage the distance in the injector shaft of approximately 25 m between the 10 MW klystron and the individual gun waveguide distribution, straight waveguides, H – bends as well as flexible waveguides are used and assembled with a support system only developed for this purpose. Several special bearings with springs compensate the waveguide weight over the entire length between the 3rd and 7th

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underground floor. To avoid phase changes during the gun operation, the upper and lower ends of the waveguide section in the shaft are fixed and therefore 800 mm flexible waveguides are used to compensate thermal expansions of the waveguide distribution. The installation of such kind long system has completed with a special setup, which provides an adjustment accuracy level of ±0.1 mm and ±0.15 degrees. This allows the installation of the waveguide distribution and connection to the gun window without any stress. Monitoring and fastening of the waveguide distribution system in the shaft is carried out regulary.

In order to supply the gun with up to 8 MW RF power with high reliability three sections of different air pressures are realized for the waveguide distribution system.

Four specific 2.5 MW pulse power isolators each with 1.5 bar air pressure were developed by Ferrite, St. Petersburg, and installed in front of the gun window, as shown in Fig. 2. Since non-gas-tight waveguide distributions are used, small air leaks are compensated by the air flow machines. A major benefit of using pressurized waveguides is the resulting change of the waveguide shape, which leads to a phase shift; therefore no movable parts inside the waveguides are necessary.

The installed flanges of the waveguide distribution are standard Desy-type UDR14D flanges, which increase the reliability of the RF contact and decrease air losses caused by small leaks.

To separate the air pressure additionally, ten 5 MW air-air windows are installed at the RF waveguide distribution, four in front of the isolators, two in front of the power combiner and four at the two outputs of the klystron, as shown in Fig. 1 and Fig. 2.

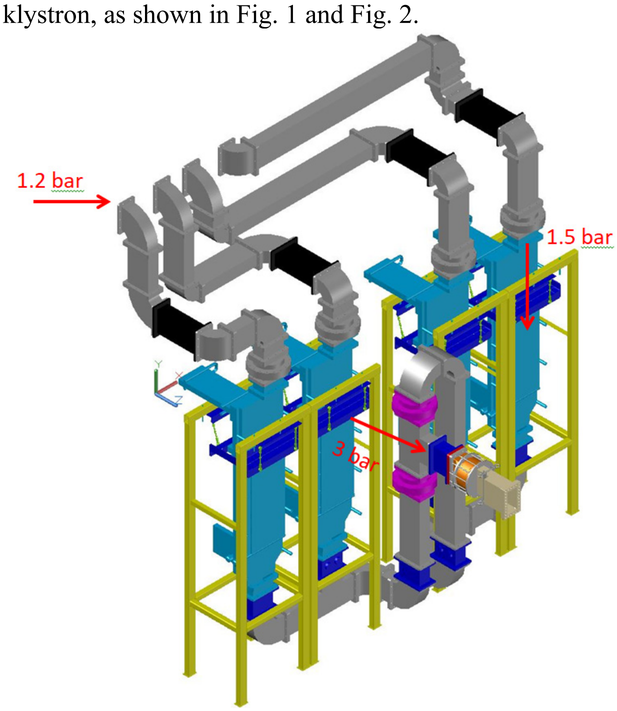

Figure 2: Waveguide distribution for the RF gun with different sections of pressure.

To increase the accuracy of power measurements for the RF gun a specific directional coupler with a high directivity of more than 40 dB is installed in front of the gun window, which is produced by Ferrite St. Petersburg, as shown in Fig. 3. By means of power sensors, which are connected to the directional coupler directly, the power level can be determined precisely without any complicated cable calibration. The power sensors are connected by an USB cable to a computer, which is shielded from radiation, to measure the RF power to the RF gun. From individual power measurements the measurement error is evaluated as ±0.1 dB both for forward and reflected signal.

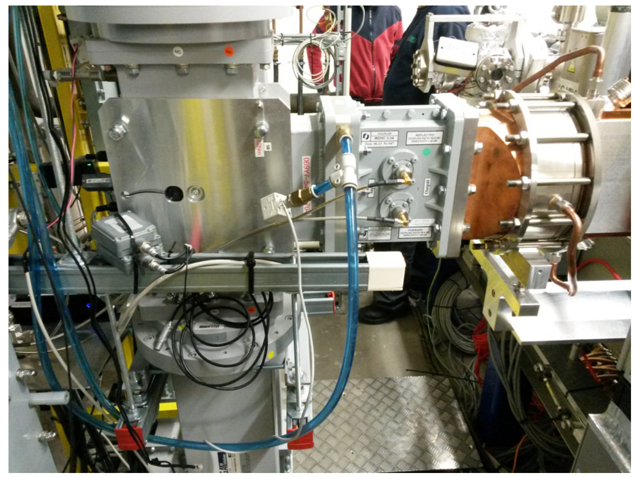

Figure 3: Directional coupler in front of the RF gun window in the XFEL injector.

AIR FLOW SYSTEM FOR THE WAVEGUIDE DISTRIBUTION FOR THE RF GUN

The air flow system for the waveguide distribution for the RF gun consists of two air flow machines, which have been developed to decrease the probability of breakdown and for phase tuning. By changing the air pressure in the waveguides the size of the waveguide changes and therefore the RF phase advance.

Starting at the 3rd underground floor the air flow system supplies an air pressure of 1.2 bar inside the four branches of the waveguides. To set the phase in these four sections independently 5 MW air-air windows have been installed. Each waveguide branch is followed by a 2.5 MW isolator. In order to increase the air spark breakdown limit of these isolators the operating pressure is increased to 1.5 bar. The main reason of using four isolators is to reduce the RF power in each isolator and by this to ensure a highly reliable system.

In order to reach only one waveguide path and thus to supply the maximum RF power to the RF gun with the same phase, all branches are combined by means of three waveguide combiners [3]. To increase the reliability only non-movable waveguide components have been used; any mechanical phase shifters have been avoided. To operate the RF gun as stable as possible an air pressure up to

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3 bar is applied in the waveguide section in front of the RF gun.

To control such a complex airflow system, which increases the performance of the waveguide distribution, a Programmable Logic Controller (PLC) with individual software is needed. The installed controller is called BC9000 and the software has been written by Structured Text (ST).

The airflow system is included in the control system of the XFEL. The software enables the operators on the one hand to modify desired parameters quickly and directly, on the other hand it has a feature of an automatic self-diagnosis, which alerts the operator in case of an error.

WAVEGUIDE DISTRIBUTION FOR THE 1.3 GHz INJECTOR CRYOMODULE

The subsequent 1.3 GHz superconducting injector cryomodule, as shown in Fig. 4, is supplied by a klystron and an unique waveguide distribution system, which has a different design in comparison to the other waveguide distributions in the XFEL tunnel.

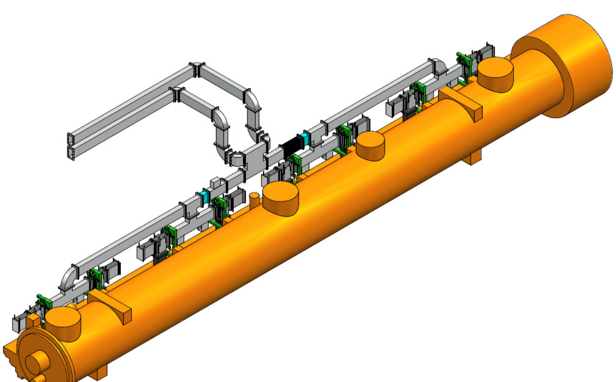

Figure 4: Waveguide distribution for the 1.3 GHz injector cryomodule.

The 10 MW klystron is located in the 3rd underground floor and feeds RF power up to 3 MW with a pulse length of 1.37 ms and a repetition rate of 10 Hz. The RF power between both outputs is tunable due to an additional phase shifter. A connecting waveguide distribution transfers the RF power from the klystron to the waveguide distribution of the cryomodule at 7th underground floor, as shown in Fig. 5.

To operate with the maximum energy for the injector cryomodule, it is necessary to supply individual power to each cavity. Using a 3 dB hybrid each klystron output is feeding four cavities. Due to requirements of beam dynamics the power distribution of the injector cryomodule must be considered as two independent power distributions, since the maximum gradients of the cavities 1-4 and 5-8 show a significant difference. By using specific tuned power splitters and binary cells the power losses are decreased as much as possible [3] [4]. The Fig. 5 shows the waveguide distribution for the injector complex, including the gun waveguide distribution and the connecting waveguide distribution system.

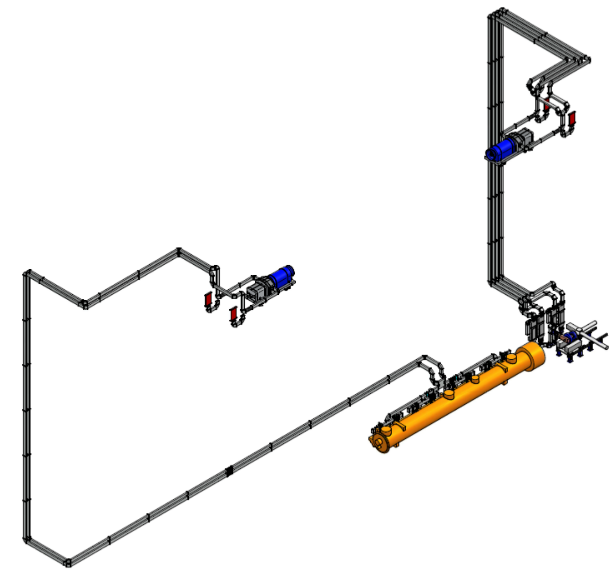

Figure 5: Waveguide distribution for the injector complex.

SUMMARY

The waveguide distribution for the injector of the European XFEL, which consists of several waveguide components, has been successfully installed in the XFEL tunnel. The waveguide distribution for the RF gun has been tuned and tested up to full power. According to experience the RF waveguide distribution shows a high reliable performance.

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