UPGRADE OF THE 1.3GHz SYSTEM AT FLASH

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Abstract

The FLASH RF system consists of several RF stations, which provide RF power up to 10MW at 1.3GHz, 1.3ms and 10Hz repetition rate, each, for the superconducting cavities and the RF gun of the FLASH linear accelerator. During the last upgrade of the FLASH facility several modifications were made to the RF system. The oldest RF stations, constructed and manufactured by FNAL more than 15 years ago, were replaced. Since one additional superconducting accelerator module was added and one superconducting module and the RF gun were replaced, modification and rearrangement of the RF waveguide distributions were required. An XFEL type waveguide distribution for the new accelerator module ACC7 and a distribution without individual phase shifters for the exchanged module ACC1 were installed. A new waveguide distribution for the RF gun allows phase tuning by changing the gas pressure in the waveguides. It will also allow supplying the RF gun by a 10MW multi beam klystron instead of the currently used 5MW single beam klystron at a later point of time.

This paper describes the exchanged and recently installed RF stations and the layout of the waveguide distribution system.

INTRODUCTION

FLASH is based on the TESLA Test Facility at DESY which began construction in the early 1990s with the idea of testing all components required to construct a linear collider using superconducting cavity technology. Over the years the test facility has undergone many changes in order to meet the demands of different test options and operation conditions. Today FLASH serves as a user facility for synchrotron radiation research as well as a test facility for the European XFEL and for ILC studies.

FLASH accelerates an electron beam of 1nC bunches up to 1GeV which is used to generate laser light in the VUV regime. The electrons are produced in a RF gun and are accelerated in fifty-six superconducting nine-cell niobium cavities which are grouped in seven cryogenic modules. The cavities are operated in a range between 18MV/m and 35MV/m. The RF power required by the RF gun and the cavities is generated by four 5MW klystrons and one 10MW multi beam klystron. The RF power distribution based on WR650 type waveguide distributes the power between the RF sources and the RF gun or the superconducting cavities. Due to various requirements and the current state of the art at any given point in time a number of waveguide components and layouts have had to be developed, installed and operated over the years.

RF STATION LAYOUT

Each FLASH RF station consists of a HV pulse modulator with pulse transformer, a high power klystron, which generates the power required by the RF gun and the cavities, as well as a number of additional components. The HV pulses modulator converts AC line voltage to pulsed high voltage up to 130kV at a pulse duration of 1.5ms and 10Hz repetition rate. The klystrons convert pulsed power into pulsed RF power by amplifying an input RF drive power of 200W to the 5MW or 10MW output level with pulse durations up to 1.3ms of which 500us are required to fill the cavities with RF power and 800us to accelerate the beam. More detailed information of the RF station layout can be found in [1].

RF DISTRIBUTION LAYOUT

General FLASH RF Distribution Layout

Figure 1 shows the RF distribution after upgrade. Five RF stations have been installed at FLASH and are labelled by #2 to #6. The station #3 provides RF power to the RF gun of FLASH and #2 to the first cryogenic module ACC1 with eight cavities.

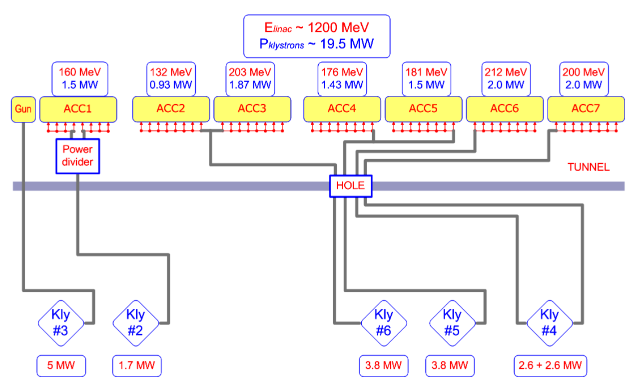

Figure 1: FLASH RF System.

Station #6 has been added during the upgrade and supplies RF power to the modules ACC2 and ACC3. Station #5 supplies ACC4 and ACC5 and station #4 ACC6 and ACC7, which has been added during upgrade. The total length of the FLASH waveguide system is about 300m with 80% linear waveguide.

Existing RF Station Waveguide Distribution

The waveguide distributions between the klystrons and the accelerator modules ACC2-5 (modified slightly during the upgrade) are to be found in the following. A 2-meter section between the klystron window and an additional window with an interior circulator (filled with

1.2bar SF6), a module distribution for eight cavities at the cryogenic module, and several meters of WR650 waveguide filled with air at atmospheric pressure between these two sections. The typical power loss in the circulators and long waveguides between the klystron and the cavity is on the order of 25%. The module distribution is of linear type. Here equal amounts of power are branched off by hybrids and the operation gradient of these modules is limited by the maximum gradient of the weakest cavity in the module.

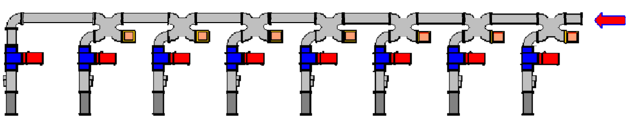

Figure 2: Linear RF waveguide distribution.

Distribution for Cryogenic Module ACC6/ACC7

The module distributions for ACC6 and ACC7 are of combined type with asymmetric shunt tees and symmetric shunt tees with integrated phase shifters. By adjusting the position of the tuning posts in the asymmetric shunt tees the coupling ratio could be optimized for maximum possible gradient for a pair of cavities and therefore improves the limitations of the weak cavity limit.

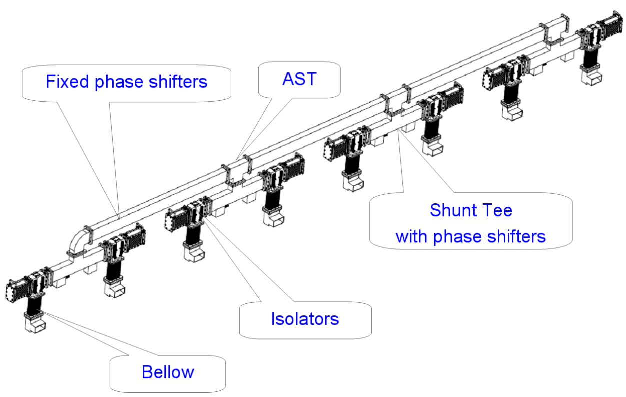

Figure 3: XFEL type distribution ACC6/7.

The distribution for ACC6 serves as a prototype for the XFEL as does the module distribution for ACC7. It was tuned outside the FLASH tunnel, tested and then mounted together with the water cooling system to the module. For the installation of ACC7 the whole unit was transported to the FLASH tunnel.

Figure 4: Transport of ACC7 including distribution.

Distribution for the Cryogenic Module ACC1

The RF station #2, equipped with a 5MW vertical THALES TH2104C klystron, provides about 1.5MW to the module distribution of the replaced ACC1. This distribution meets a specific beam dynamics requirement for the RF power distribution of the eight superconducting cavities. At present the first four cavities need to be operated at a gradient of 20MV/m and the second four cavities at 25MV/m. Therefore the RF power between the first and second four cavities is split unequally by a combination of two 3dB hybrids and phase shifter. Within each group of four cavities the power is equally distributed. The phase advance has been adjusted by fixed phase shifter and choosing the proper geometry of the different waveguide elements. Therefore movable phase shifters are no longer needed during operation of the module. The total accelerating voltage of ACC1 after the FLASH upgrade increases from 128MeV to 160MeV.

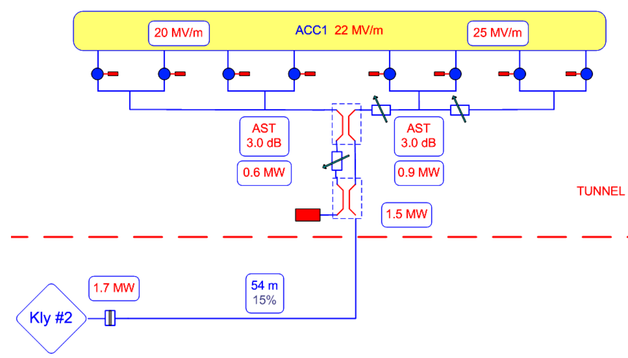

Figure 5: ACC1 waveguide distribution.

Waveguide Distribution for the RF Gun

RF station #3, also equipped with a 5MW TH2104C, generates RF power of about 4.3MW for the one-and-a-half-cell normal conducting RF gun. To provide a reliable waveguide distribution with the shortest possible length, and consequently power losses, the modulator was turned by 180 degree, and a new type of distribution was installed, which allows phase tuning by changing the gas pressure in the waveguides. It consists of 2 strings of waveguides. These will allow using a 10MW multi beam klystron at a later point of time. Since the klystron requires SF6 at the klystron window a short section of about 1.5m length between the klystron window and the two additional windows in front of the strings is filled with SF6, typically at 1.4 bar. A second 3-meter section containing two four-port circulators and a combiner in the tunnel between the RF gun window and the additional windows at the end of the waveguide strings is likewise filled with SF6 at 1.1 bar. This is in order to protect the RF gun window and to enhance the power capability of the circulators. The waveguide length between the klystron and the RF gun is about 30m. The strings are fixed at the beginning, the end and at every turn of direction with bellows mounted in between these points. This gives a stable length of the waveguide strings over temperature. By applying a constant air flow with an overpressure of 0.07bar and a humidity of 20 to 30% in one string, while applying an airflow to the other string of maximum 0.3bar a phase tuning of -15.8degree/m/bar could be achieved. The use of low humidity air and of only standard waveguide components gives a higher power capability of the waveguide strings. Critical components like phase shifters are no longer needed. Since the airflow is about 10 l/min only the resulting phase for the RF gun is changing slow relatively to the phase changes by the LLRF system. Because of very small losses of the new waveguide distribution and the circulators about 4.3MW of power are reaching the RF gun. More detailed information about the different module distributions can be found in [2-5]. Figure 6 shows the modified RF gun distribution.

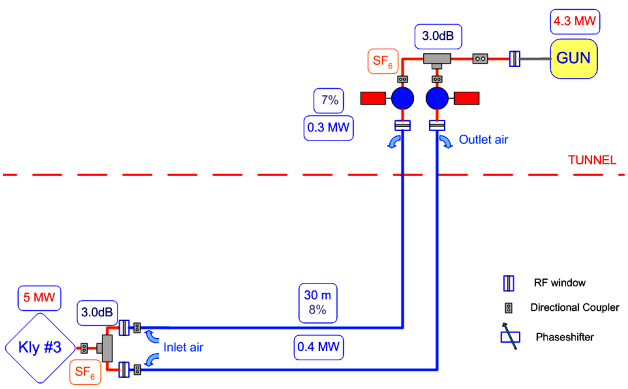

Figure 6: RF gun distribution.

MODULATORS

The two oldest RF stations operated at FLASH were constructed and manufactured by FNAL more than 15 years ago. Since it was becoming more and more difficult to maintain these older stations as well as to order spare components it was decided to replace them during the last upgrade by stations almost identical to the latest stations and to reuse them for test facilities for the European XFEL.

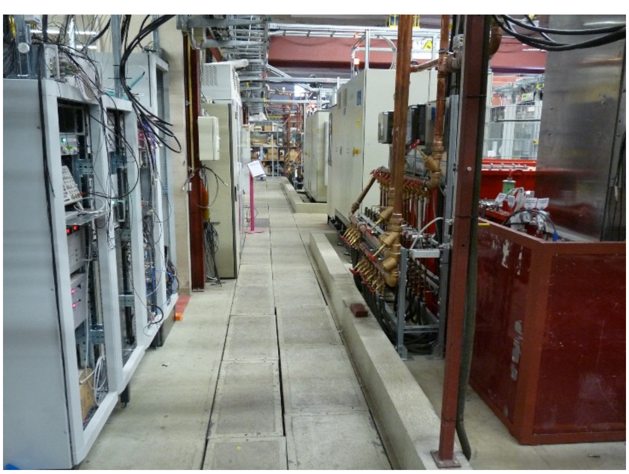

Figure 7: New RF station 3 with control racks.

The later stations have been assembled at DESY from components made by industrial companies. Figure 7 shows one of the new RF stations. They are capable of providing pulsed power for multi beam klystrons with an output power of 10MW at a repetition rate of 10Hz.

OUTLOOK AND SUMMARY

During the last shutdown the FLASH RF system was upgraded. Two RF stations were replaced and another upgraded. One accelerator module waveguide distribution was added and new distributions for the first accelerator module and the RF gun were installed. In addition, several improvements were made. Following the technical commissioning, the RF system has been operated successfully both during beam commissioning and during accelerator studies. Successful operation of the RF system will hopefully continue during operation of FLASH as a user facility, which will start in September 2010.

ACKNOWLEDGEMENTS

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REFERENCES

[1] S. Choroba., "Design and Status of the XFEL RF System", Proceedings of PAC07, Albuquerque, New Mexico, USA, June 25-29, 2007, p. 841.

[2] V. Katalev, S. Choroba, "RF Power Distributing Waveguide System for TESLA", Proceedings of the Russian Particle Accelerator Conference, Rupac 2002, Obninsk, Russia, October 1-4, 2002, p 79.

[3] V. Katalev, S. Choroba, "Tuning of External Q and Phase for the Cavities of a Superconducting Linear Accelerator", Proceedings of the XXII International Linear Accelerator Conference, Linac 2004, Lübeck, Germany, August 16-20, 2004, p 724.

[4] V. Katalev, S. Choroba, "Compact Waveguide Distribution with Asymmetric Shunt Tees for the European XFEL", Proceedings of the 22nd Particle Accelerator Conference, PAC07, Albuquerque, USA, June 25-29, 2007, p. 176.

[5] S. Choroba et al., "Operation experience with the FLASH RF waveguide distribution system at DESY", Proceedings of the XXIV Linear Accelerator Conference, LINAC08, Victoria, BC, Canada, September 29 - October 3, 2008, p. 978.

[6] V. Katalev, S. Choroba, "Waveguide Distribution for FLASH", Sixth CW and High Average Power RF Workshop, CWRF2010, Barcelona, SPAIN, May 4-7, 2010, http://cwrf2010.cells.es/