A NEW TYPE OF WAVEGUIDE DISTRIBUTION FOR THE ACCELERATOR MODULE TEST FACILITY OF THE EUROPEAN XFEL

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Abstract

In order to test 100 superconducting accelerator modules within two years three test benches have been created in the accelerator module test facility (AMTF) to achieve the rate of one cryomodule per week. Each RF station of the test facility consists of a 5 MW RF station, at 1.3 GHz, 1.37 ms pulse width and 10 Hz repetition rate, with a waveguide distribution system. Each waveguide distribution supplies RF power to eight cavities, four times a pair of cavities. The distribution allows for a maximum power of 1 MW per cavity when the distribution is switched to a mode supplying power to only four cavities. A new type of 1 MW isolator and a new compact 5 MW power divider have been developed to achieve that goal.

Several cryomodules have been already successfully tested with this setup. We present the waveguide distribution for this test stand and describe the performance of the different elements.

REQUIREMENTS FOR THE AMTF WAVEGUIDE DISTRIBUTION

The AMTF [1] waveguide distribution should meet several specific sometimes conflicting requirements. On one side the distribution should have a compact size since there is only limited space in the AMTF shielding tunnel. On the other side it should supply high pulse RF power to the individual cryomodule cavities with high flexibility by only one power klystron. In addition the waveguide distribution has to protect the klystron against reflected power from superconducting cavities.

The three basic requirements are:

- Power per cavity:
  1 MW max pulse power
  2.2 kW max average power
- One 5 MW klystron as RF power source
- The waveguide distribution layout must allow for a free access to the cavity couplers for local clean room installation.

In order to satisfy these conditions specific waveguide components, such as a 1 MW isolator and a 5 MW power divider have been developed and integrated in the waveguide distribution. A 3D-view of the AMTF waveguide distribution is shown in Fig.1.

During maintenance of RF station the klystron has to be connected to two dummy loads. Therefore a mechanical waveguide switch is installed which allows for quick connection of the klystron and the loads.

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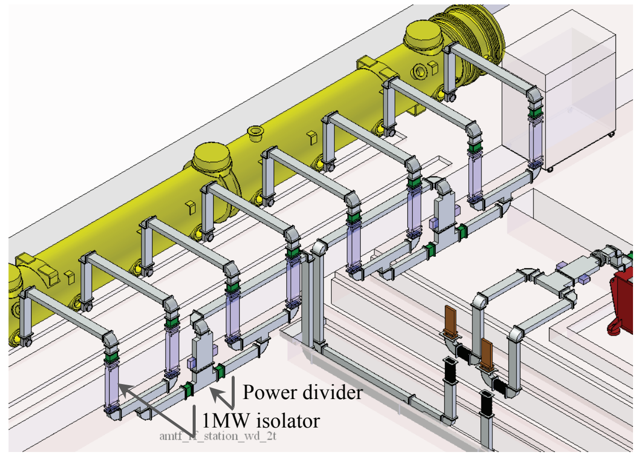

Figure 1: 3D-view of the AMTF waveguide distribution.

1 MW ISOLATOR

In order to protect the klystrons in the XFEL tunnel against reflected power the Y-junction circulators with matched and four port phase shift circulators with two matched load are used. For the AMTF waveguide distribution the isolators could not be used since the Y-junction circulators are limited in power and phase shift circulators are too big. Therefore a new type of a 1 MW isolator has been developed by the Company "FERRITE" from St. Petersburg, Russia. The new FWHI3-27A type isolator uses the nonreciprocal energy absorption in the ferrite elements by ferromagnetic resonance for waves with circular polarization. An overview of the device (without magnetic system) is shown in Fig.2.

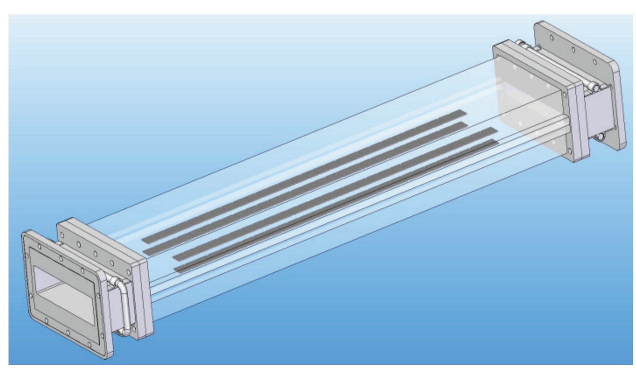

Figure 2: View of the S.P.A.FERRITE 1 MW isolator.

In this device the reflected power is absorbed in the ferrite material itself and not in an external matched load. The special type of the ferrite, its shape and location as well as the design of water cooling system allows to increase the average power. The magnet system uses a

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high-performance permanent Fe-Nd-B magnet. To decrease the weight and size of the device the waveguide height has been reduced by three times compared with a standard WR650. But due to a specific configuration and tuning of the magnetic system the power capability of device has been saved.

After test of the first prototype at DESY and further improvement more than 30 isolators have been produced meeting the following specifications:

- Pulse power, max 1 MW
- Average power, max 2.2 kW
- Input SWR, max 1.15 (at full reflection)
- Isolation, min 30 dB
- Insertion loss, max 0.5 dB
- Full reflection any phase
- Length 950 mm
- Height 1/3 of WR650
- Flange UDR-14D

All isolators have been successfully tested up to 1.15 MW input power.

5 MW COMPACT POWER DIVIDER

The 5 MW power divider has been developed in cooperation with MicroPlus-Apostolov Company, Sofia, Bulgaria. The device is designed in accordance with a classical scheme: shunt tee, two phase shifters and hybrid with integrated H bends. Each waveguide component has been designed especially for this power divider. Simulation results of the device with CST Microwave Studio (MWS) is shown in Fig.3.

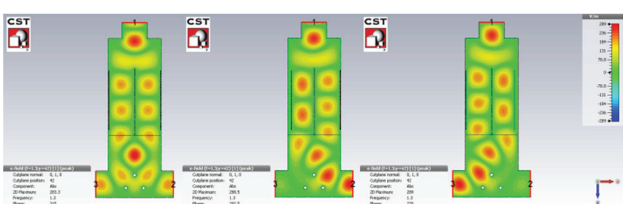

Figure 3: RF power distribution depending on the phase shifter piston position

Depending on the phase shifter position the RF power is distributed between the two outputs ports. The integrated phase shifter is similar to the phase shifter for waveguide distribution in the XFEL tunnel [2]. A piston is driven by a linear positioning system with stepping motors. The linear positional accuracy is better than 0.1 mm. The phase shifter has a compact construction with possibility to operate with overpressure of the gas in the waveguide. To reduce an impact of the mounting errors and thermal deformation during operation the design of the phase shifter meets the principle of the kinematic design [3].

To decrease the size of the power divider a new type of hybrid junction with integrated - bends has been also developed. It allows reducing the device length of the 5MW divider down to 700 mm.

The 5MW power divider parameters are:

- Pulse power, max 5 MW
- Average power, max 50 kW
- Input SWR, max 1.2
- Isolation, min 27 dB
- Length 700 mm
- Width 550 mm
- Flange UDR-14D
- Overpressure, max 0.5 bar.

The combination of these power dividers allows distributing the RF power from the 5 MW klystron with high flexibility to any pair of the cavities with a maximum power up to 1 MW for each cavity.

WAVEGUIDE DISTRIBUTION FOR AMTF RF STATION

The AMTF contains 3 RF test stands to test cryomodules for the XFEL. This allows a test rate of one cryomodule per week. Each RF station consists of a 5 MW RF station and the specific waveguide distribution which supplies a cryomodule. The schematic of the waveguide distributing system is shown in Fig. 4. Each pair of cavities is supplied through a shunt tee which divides the RF power equally to the two cavities. For two pairs of cavities a 5 MW power divider is installed. It allows to distribute the RF power between two pairs. Another 5 MW power divider which is installed after the klystron distributes RF power between two halves of the cryomodule.

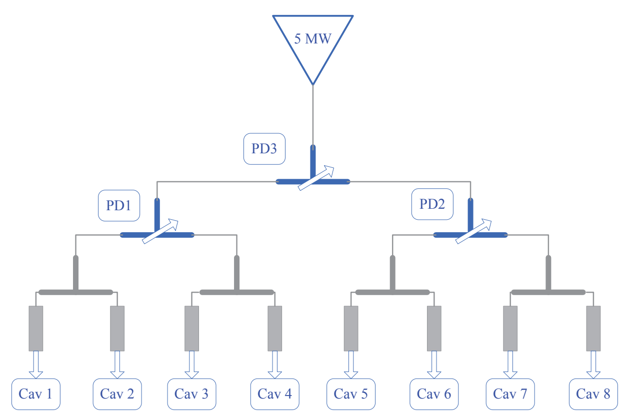

Figure 4: Schematic of the power distribution system.

Table 1 summarizes typical operation conditions of the AMTF waveguide distribution. The power generated by the klystrons is more than the sum of the power supplied to the cavities since losses in the distribution have to be taken into account. 1MW is the maximum pulse power which can be accepted by one cavity and its input coupler.

The waveguide distribution contains 15 directional couplers with high directivity (more than 40 dB) to measure and control the distribution of RF power.

For RF station conditioning two manual RF switches are provided. The RF switch allows for connection of the klystron to the dummy loads. The RF switch consists of a standardized H-bend and a flexible waveguide that allows to avoid electrical field breakdown and to compensate for mechanical deviations of waveguide components. The RF switch has contacts for a personnel interlock.

Table 1: Power distribution possibilities for the cavities at AMTF RF Station.

N	Pkly, MW	Pcavity, MW							
		1	2	3	4	5	6	7	8
1	4,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
2	4,5	1	1	1	1	0	0	0	0
3	4,5	1	1	0	0	1	1	0	0
4	4,5	1	1	0	0	0	0	1	1
5	4,5	0	0	1	1	1	1	0	0
6	4,5	0	0	1	1	0	0	1	1
7	4,5	0	0	0	0	1	1	1	1
8	2,2	1	1	0	0	0	0	0	0
9	2,2	0	0	1	1	0	0	0	0
10	2,2	0	0	0	0	1	1	0	0
11	2,2	0	0	0	0	0	0	1	1

To avoid any mechanical stress to the cavity input couplers and to compensate a thermal expansion during operation the waveguide system is attached to tunable six degree of freedom support frame. The support frame allows also for precise adjustment of the mounting position for each individual waveguide component. The waveguide distribution with support frame in the AMTF shielding tunnel is shown in Fig.5.

Figure 5: Waveguide distribution connected to a cryomodule in the AMTF shielding tunnel.

The two basic components of the waveguide distribution in AMTF shielding tunnel, one 5 MW power divider and one 1 MW isolator are shown in Fig.6.

Figure 6: 5 MW power divider and 1 MW isolator in the AMTF shielding tunnel.

The waveguide components and the entire distribution have been successfully tested up to full RF power of 5 MW.

SUMMARY

Three RF stations have been successfully installed at AMTF. The waveguide distribution system for each station has been tuned and tested up to full power. Since the end of 2013 several cryomodules were tested and prepared for installation in XFEL tunnel.

ACKNOWLEDGEMENT

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