SERIES PRODUCTION OF THE RF POWER DISTRIBUTION FOR THE EUROPEAN XFEL

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Abstract

The RF power distribution for the European XFEL allows for individual RF power for the 808 superconducting cavities of the European XFEL. It consists of a number of elements, not only waveguide components, but also girders, cables or cooling systems. The production of the RF distribution consists of several tasks. In order to deal with the schedule of the entire project a detailed planning, organization and monitoring of the series production of the RF power distribution was required. This paper describes the RF power distribution layout and the series production process.

RF SYSTEM LAYOUT

Figure 1 shows the RF waveguide distribution of one RF station for 4 cryogenic accelerator modules. The klystron has two output waveguides (blue) and generates up to 10MW RF power, 2 times 5MW, at 1.4ms and 10Hz repetition rate. The output power can be absorbed in RF loads (red) during test of the RF station or can be transmitted by waveguides (orange) to the accelerator modules (yellow) during accelerator operation. The output power of each arm is split again to 2 module waveguide distributions (grey).

The module waveguide distribution is shown magnified. In the linear part RF power is branched off by asymmetric shunt tees for a pair of cavities and then split again. In front of each cavity an isolator is installed, which protects the klystron from reflected power. Within the module waveguide distribution the phase is adjusted by fixed phase shifters and controlled for each individual cavity by adjustable phase shifters. The phase between the modules can be adjusted by additional adjustable phase shifters if required. In the first layout the shunt tees between modules and for a pair of cavities were assumed to be 3 dB shunt tees, whereas the asymmetric shunt tees in the linear part of the distribution are 3 dB, 4.77 dB and 6 dB. With this design all cavities would be supplied by the same RF power. The advantage of this layout is that uses the same type of components for all waveguide distributions and allows for preproduction independent of the accelerator module production status. The disadvantage is that the weakest cavity with lowest achievable gradient determines the input power for all cavities connected to this power station and thus limits even stronger and better cavities.

Therefore it was assumed that during production of the cavities pre-sorting with respect to maximum achievable gradient and grouping them appropriately in modules will be possible. It was assumed that 2 cavities with the same maximum achievable gradient could be grouped into a pair [1, 2]. By changing the coupling ratios of the asymmetric

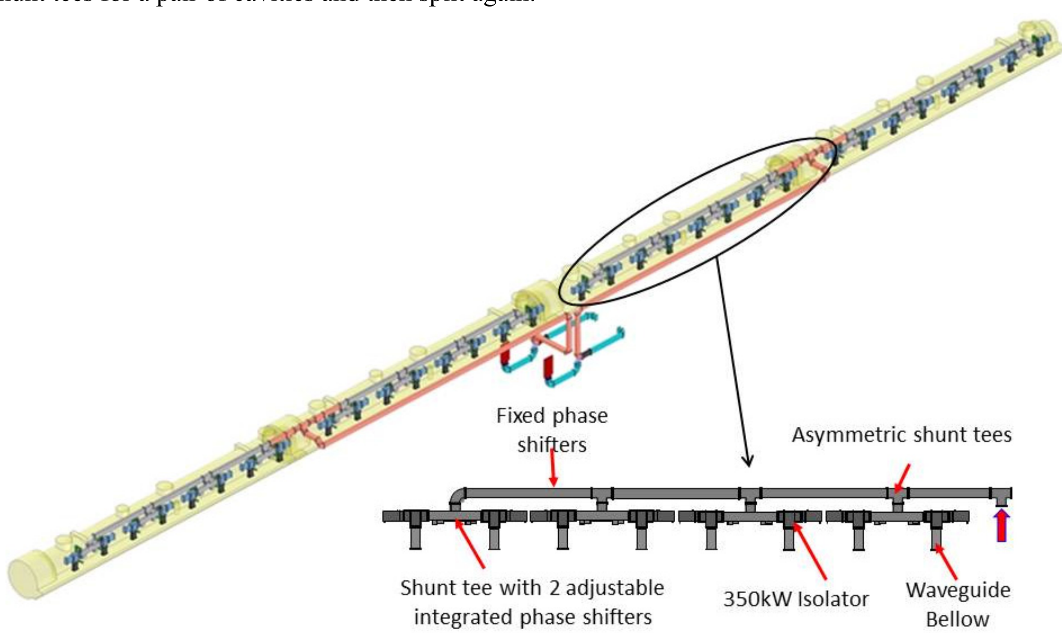

Figure 1: RF waveguide distribution layout for one RF station.

shunt tees it would be possible to provide the appropriate power for a pair of cavities. The advantage of this intermediate layout would be that there would be no limitation by the weakest cavity and production of module distribution could already start after selection of cavities for a specific cryogenic module. All components of the distributions could be of same type with the exception of the asymmetric shunt tees between a pair of cavities.

SERIES PRODUCTION

During production of the accelerator modules it turned out that many cavities degrade when installed in the accelerator modules. Therefore it was necessary to change the layout of the RF waveguide distribution further in order to allow for individual power for each cavity. All shunt tees between two cavities and between modules have to be asymmetric shunt tees with individual coupling ratio. Since the adjustment of the coupling ratios changes the phase advance too, some fixed shifters have to be modified and the adjustable phase shifters have to be tuned near to the edges of their tuning range in order to compensate for this phase change. The advantage of this solution is that it allows for maximum achievable gradient in a module (Fig. 2).

The disadvantage is that most of the waveguide components are now individual components, which makes the entire production and tuning process much more complicated, time consuming and expensive. In addition production of the module distributions is only possible after a full test of the accelerator modules. The adjustment and tuning of all components between the klystron and the module distribution is more difficult and time consuming.

The tailoring of the module waveguide distributions increases the maximum achievable gradient of each accelerator module and therefore of the maximum electron beam energy of the XFEL linac. In some cases it was possible to reach the gradient which could only be reached by 5 untailored standard module distributions with only 4 tailored distributions.

In addition to the waveguides the water cooling system and the RF and control cables have been installed, tested and calibrated during the installation process. After final test each module waveguide distribution together with the cooling system and the cables has been transported and connected to the associated accelerator module. In order to avoid mechanical stress to the input coupler of the module it was necessary to align the distribution with a precession of 1.5 mm. Since this is difficult to achieve with a 12 m long distribution special fixtures and girders have been developed. In addition to these fixtures and girders additional tools, fixtures, girders and software have been developed for acceptance test of individual components, assembly, and for low level and high power RF test. The software allowed to a high degree automatic test of distributions and record of data in a data base. With all these measures and an increase of personnel it was possible to reach the average production rate of about 1 module waveguide distribution per week, up to a maximum of 1.5 distributions per week while preserving individual tailoring for each module.

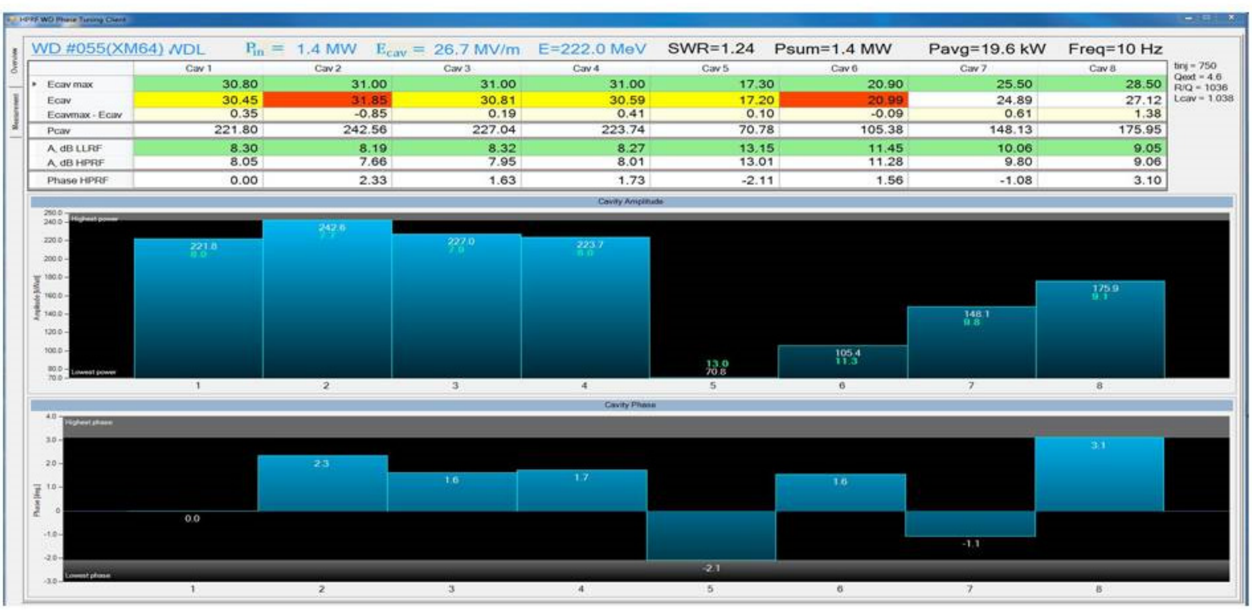

Figure 2: Example: Layout and tailoring of module waveguide distribution WD55 for accelerator module XM64 at WATF. The table shows the desired maximum achievable gradients of the cavities, actual achievable gradients and the required RF input power. In addition the relative phases of the cavities are measured. The columns show the input power to the cavities (zero suppressed) and the relative phases. Measurements were done at the WATF high power test stand. By individual tailoring additional 78 MeV (about 50% more) of beam energy gained by this module compared with a module with equal power distribution are possible. WD55 is preliminary phase tuned for beam acceleration with+/-3 degree between cavities.

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STATUS AND SUMMARY

During the last three years 98 individual module waveguide distributions have been designed, assembled, tuned, measured, tested at full power and installed on the accelerator modules at the waveguide assembly and test facility (WATF) (see Fig. 3). Another 4 module distributions have been prepared for later tuning.

Figure 3: Five assembled module waveguide distributions at WATF.

The average production rate was about 1 module distributions per week. This rate has been increased to 1.5 module distributions per week after about one third of the total production. This was only possible by refinement and optimization of the all single steps during the production of a distribution and by increasing the personnel working on the tasks. Figure 4 shows one module distribution connected to one cryogenic accelerator module.

In addition installation, tuning and measurement of waveguide components between the klystrons and the module waveguide distributions has been performed in the XFEL tunnel. Only five of twenty-six RF stations are waiting for the last steps of installation, all other RF stations are commissioned. Two stations for the injector are already in operation for more than one year.

By tailoring the waveguide distributions it was possible to reach and even surpass the target average gradient of 23.6 MV/m. The total maximum beam energy which finally will be reached might be 3-4 GeV higher than the target energy of 17.5 GeV.

Figure 4: Module waveguide distribution connected to one accelerator module.

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