

RF power measurement at AMTF.

A joint development of a commercial company and DESY

More than 100 accelerator modules for the European XFEL have to be conditioned and tested in the Accelerator Module Test Facility (AMTF) at DESY. Besides a large high- and low-power RF, vacuum and cryogenic infrastructure, complex RF testing equipment is necessary to accomplish this task. To ensure simple measurement procedures and reliable results in a cost-conscious way, optimized power measurement devices have been developed by the company D.A.R.E!! Instruments together with DESY. When the test facility will start operating in spring 2013, about 150 of these devices will be in use for the next two to three years.

Major components of the European XFEL are the superconducting accelerator cavities working at 1.3 GHz. Eight such cavities are assembled together with RF high-power couplers, tuners and other accessories in one module. Prior to their installation in the linear accelerator of the European XFEL, all modules are subject to a performance test on a module test stand. For these tests, DESY has built a new test facility, the AMTF.

To reach the highest possible accelerating fields in the cavities, RF components such as the RF power couplers have to be conditioned accordingly. This conditioning is done through a slow increase of the RF power and pulse length over time, which “cleans” the RF vacuum components to later ensure a stable operation. A well-proven conditioning procedure that has been used at DESY for many years is as follows: The RF power starts with a pulse length of 20 μ s and a power rise up to a maximum power of 1 MW. Then the pulse length is successively increased (50 μ s, 100 μ s ... 1.3 ms), and again a power rise is performed. The repetition rate is 2 Hz to allow a sufficient recovery of the vacuum in the RF components.

The whole conditioning procedure is controlled by sophisticated software, and many different signals are monitored to ensure that the components are not harmed or destroyed. The most important signals during this conditioning are the different RF power values. The power measurements have to deliver actual power values at any time – wrong values can lead to unexpectedly high RF power on the components and bear the risk of performance degradation or damage of the components.

After the RF components have been conditioned, the transmitted power of the cavity has to be calibrated to the accelerating field of the cavity. For every cavity, five different power values are measured during the test (P forward, P reflected, P transmitted, PHOM1, PHOM2). Every module contains eight cavities, and

there are three module test stands at the AMTF. For the whole test facility, we thus have to be able to measure 120 calibrated RF power values simultaneously (Fig. 1).

The process described above entails the following RF power measurement requirements:

- > Peak RF power measurement for short pulses: 2 μ s to 2 ms
- > Repetition rates of 100 ms to 1 s
- > High dynamic (> 55 dB): calibration at P forward \leq 1 kW and conditioning up to \geq 1 MW
- > Very high reliability (no dependency on external trigger signals)
- > No new adjustment for different operating modes to ensure error-free measurements
- > Open interface for the data acquisition system
- > Because of the high channel density: low cost

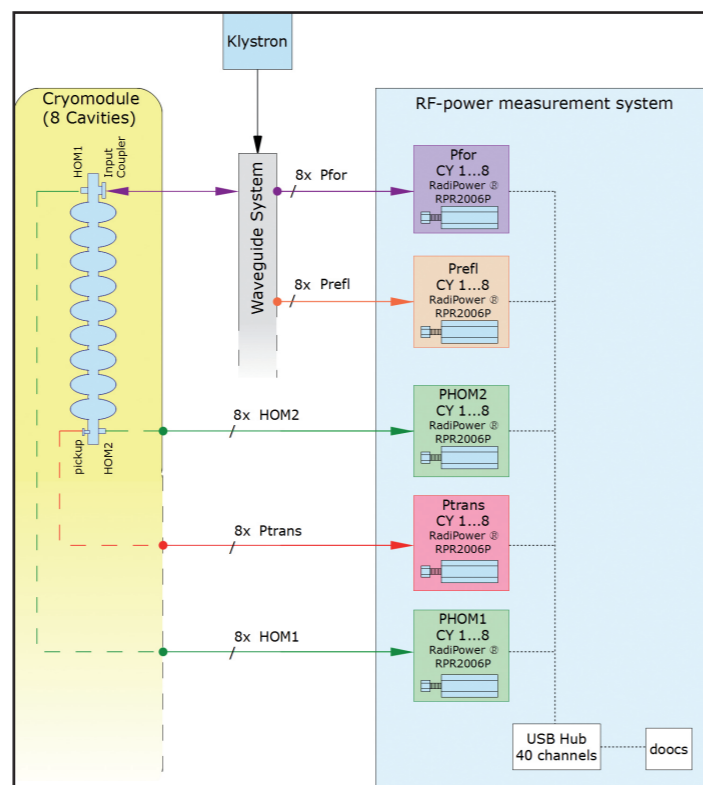


Figure 1 Block diagram of the power measurement at the module test stands at AMTF



Figure 2 Array of 10 RadiPower power measurement heads for the module test stands at AMTF

A continuous market analysis proved that many good products were available. But it also showed that, in many cases, the power measuring devices were too complicated, too special (hand adjustment necessary) or too costly.

Three years ago, the company emv GmbH in Taufkirchen, Germany, called our attention to the RadiPower power measurement devices (with USB interface) from D.A.R.E!! Instruments in Woerden, the Netherlands (Fig. 2). We asked them for a simple and safe measurement procedure: permanent

RF power measurement with a high detection rate of the maximum value. By readout of the peak value from the measurement device, the held value will be reset and a new maximum value can be measured and held. A server reads the value and stores the maximum power as a history.

D.A.R.E!! Instruments adapted the RF power measuring heads hardware and the firmware to our requirements, and we tested the devices in a module test stand and in the accelerator environment at FLASH.

The devices are also able to measure a calibrated power curve of the RF pulse with a dynamic > 65 dB. This allows us to simplify the complex and costly power trace measurement (down-converter and ADCs) and use only one device for both functions (Fig. 3).

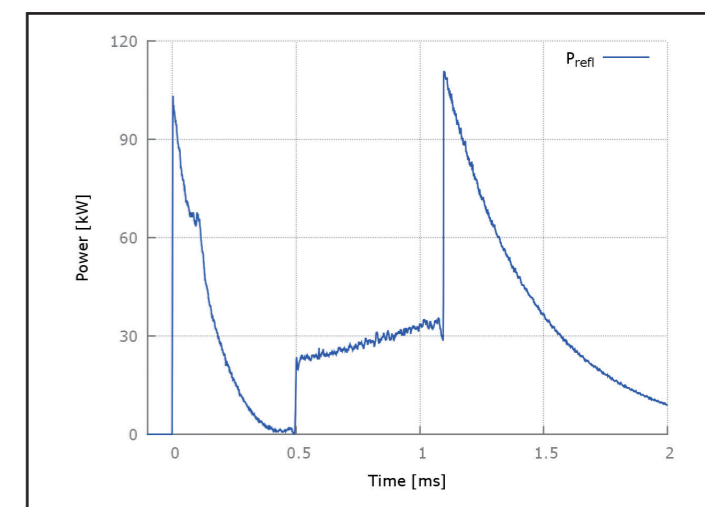


Figure 3 Trace of the reflected power at a FLASH cavity during operation

In addition to the safe and simple peak power measurement, the server now also uses the trace measurement. Usually the repetition rate during the conditioning of the cavities and couplers is \geq 1 Hz, therefore the peak power searching time has a minimum of 1 s. After this, the device automatically measures a new power trace.

For one module test stand, 40 devices are connected to one USB hub (6*7-channel USB hub with three power supplies), which provides the LINUX server with the data. The power meter is now integrated into the DOOCS control system and the measurement software can access the power values and traces.

After some iterations of the hard- and software as well as many tests at DESY, we have ordered and received 150 RadiPower RF power measurement devices (RPR2006P) for all the DESY module test stands.

We would like to thank the company D.A.R.E!! Instruments and all their personnel for the fruitful and professional collaboration.

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