

EUROPEAN XFEL RF GUN COMMISSIONING AND LLRF LINAC INSTALLATION

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Abstract

The European x-ray free electron laser (XFEL) is based on a 17.5 GeV super conducting pulsed linac and is scheduled to deliver its first beam in 2016. The first component of its accelerator chain, the RF gun, was installed in fall of 2013 and its commissioning is underway. This contribution gives an update on the low level radio frequency (LLRF) system development and installation for the XFEL. In particular, the installation, performance and conditioning results of the RF gun are presented. The subsequent steps toward LLRF components mass-production, testing and installation for the XFEL linac are also explained.

INTRODUCTION

The low level radio frequency (LLRF) system for the European XFEL was presented in [1–3]. The emphasis was given on the architecture of the LLRF system for the main linac and on its design based on the MTCA [4,5] technology. The XFEL injector however constitutes a special case. It begins with an RF gun, followed by the first accelerating super conducting module (A1), followed by a third harmonic cryomodule (AH1). In November 2013, the first component of the XFEL injector was installed, the RF gun, along with the entire RF power chain required for its operation. Because the gun had already been pre-conditioned, the goal of this task was to commission the gun installation and infrastructure rather than re-condition the gun itself. The remaining components of the injector, A1, AH1, the warm beam line and the injector dump will be installed and ready for cold commissioning next year. The next milestone is the installation of the first RF station (four cryomodules) at the front end of the accelerator. This paper first presents the LLRF installation for the 2013 RF gun commissioning. In a second part, the preparation of components and steps towards mass-production for the main linac installation is explained.

RF GUN AND LLRF

The RF gun and its LLRF system are located on the lowest floor (seventh underground floor: UG7) of the injector building (XTIN). The klystron however, is located four floors above, in the so-called injector klystron gallery (UG3). The master oscillator providing the RF reference and the master timing system are located on the fifth floor of XTIN (UG5). RF waveguides, RF cables and optical fibers linking these three different subsystems are distributed over two main shafts, connecting all floors of the injector building. To distribute the RF power from the klystron to the gun itself, the waveguide structure is divided into 4: each of the two klystron's arm subsequently splits into two waveguides. The 4 parts are then recombined on the seventh floor, at the RF window, just before the RF gun, as depicted in Fig. 1.

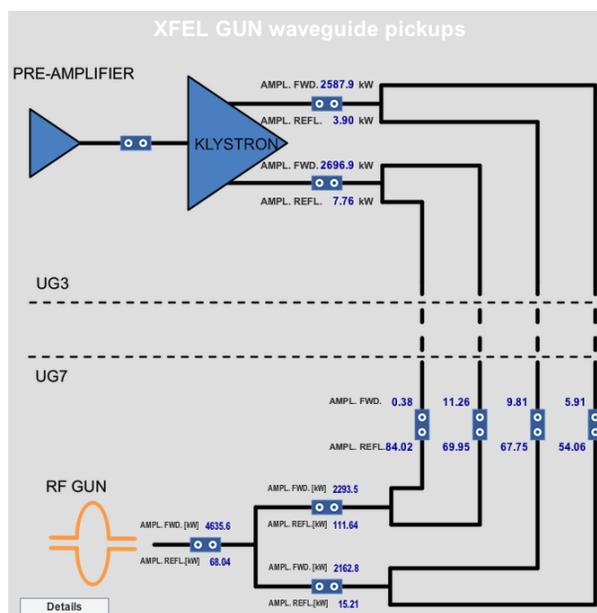


Figure 1: Gun RF distribution scheme and measurement points.

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The LLRF system is installed in a compact form factor two rack-unit MTCA crate. It comprises a power module (uPM), a MCH (management unit), a CPU, a timing module, and three front-rear MTCA pairs, to perform klystron drive control, signal monitoring and machine protection functionality. The block diagram of Fig. 2 illustrates the internal organization of the MTCA crate. One of the two digitizers (uADC) is matched with an 8-channel down-converter 1-channel up-converter (DRTM-DWC8VM1) [6]. It monitors the last six forward and reflected power signals from the waveguide chain, and uses the last two (gun PFWD and gun PREFL) to compute a virtual probe (PROBE = PFWD - PREFL) used for regulation. The other digitizer is paired with a stan-

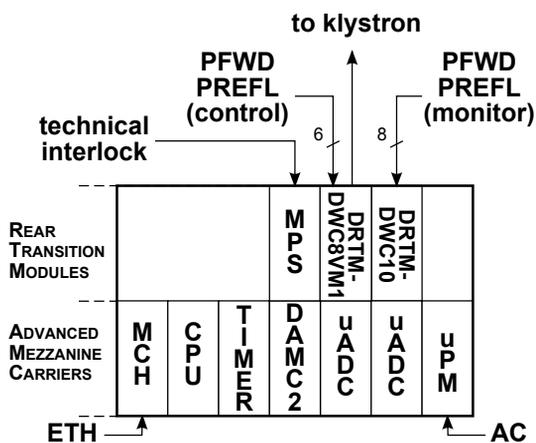


Figure 2: Schematic layout of the LLRF MTCA modules.

ard 10 channel down-converter module (DRTM-DWC10), used to monitor the other eight forward and reflected power signal picked-up from the four directional power couplers before recombination of the waveguides. These signals are not used for gun regulation but provide important amplitude and phase information about the RF transmission from the klystron (UG3) down to the gun (UG7). On the third underground floor, the pre-amplifier and klystron output forward and reflected power are monitored by power meters, used for signal level calibration. In the final installation, a MTCA crate will also be installed in UG3 to monitor these signals. It was not yet available at the time of the gun commissioning.

The machine protection system (MPS) consists of a rear module gathering the signals from the technical interlock sub-system (klystron, coupler, vacuum, etc...), paired with an FPGA front carrier board (DAMC02). The MPS and timing module provide respectively an RF permit and an RF gate signal on the backplane shared by all MTCA modules. The LLRF drive signal is framed by the RF gate and interlocked by the RF permit. The timing module also provides a trigger to the LLRF system (UG7), synchronized to the master timing system (UG5) and to the trigger used in UG3 for the pulse transformer and the klystron.

Figure 3 shows the LLRF system installed inside the injector rack. The cabinet cooling unit, power supply for external modules (PSM), drift compensation module (DCM), local oscillator and clock generation module (LOGM), and MTCA

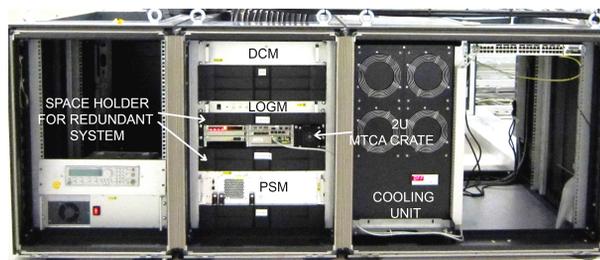


Figure 3: LLRF modules for the RF gun installed in the injector racks.

crate are visible. The redundant LLRF system for the complete injector will occupy two sets of three racks. After commissioning of the entire signal chain on a water-cooled load, the gun was connected and re-commissioned over the duration of a month (Fig. 4), up to 7 MW for short pulse lengths (50 usec) and up to 5 MW for the full 650 usec pulse length. The gun was intentionally not pushed to the full XFEL specifications (6.5 MW, 650 usec) to avoid damaging the RF window.

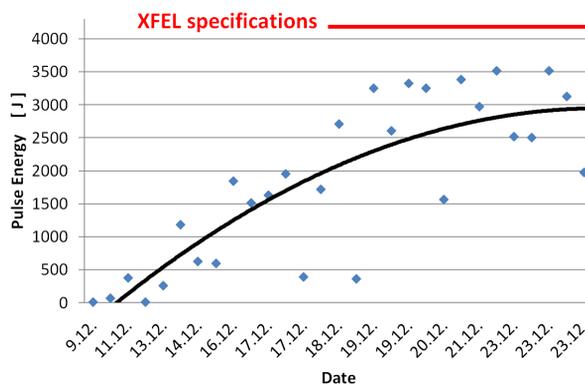


Figure 4: Gun conditioning energy over time.

LINAC INSTALLATION

Despite initial delays in procurement and assembly, the cryomodule production rate is now ramping up and the first four cryomodules of the first linac (L1) are currently being tested in the accelerating module test facility (AMTF). Preliminary results of the cryomodule prototypes and pre-series is reported in [7]. After validation of the modules, the waveguide distribution is tailored to the cavity performance and fixed onto the cryomodules. The first RF station (4 cryomodules) is then ready to be assembled in the XFEL tunnel (Linac 1).

The LLRF racks must be prepared in advanced. This task starts with the incoming inspection of all LLRF components, following a similar procedure for MTCA boards or external modules. First, the modules are visually inspected, the results from the tests performed by the vendor are reviewed, verified for randomly selected devices (5%) and archived. At this stage, all devices are also labelled with a sticker showing the device name, inventory number and a scannable 2D bar

code, linking to their entry in the database system (KDS [8]). An example is shown in Fig. 5



Figure 5: Standard LLRF label, with scannable 2D bar code.

Some devices are then placed in a test stand where more advanced functionality is tested. Then, the complete MTCA crate is assembled, the operating system is installed, drivers are loaded, servers are configured, boards are programmed with the operation firmware and the integration of the MTCA crate is verified.

The next step is the complete rack installation. This task takes place in a dedicated space inside the XTIN, the rack assembly and test area (RATA), where the racks are first prepared (installation of power strips, patch panels, supporting rails, etc..) before all the LLRF components are installed. Inner rack cabling then takes place (RF cables, AC power, Ethernet links). The complete assembly is documented in KDS, as illustrated in Fig. 6, showing a DCM, LOGM, and MTCA crate. The ID of the installed down-converters is saved for every crate slot, hence documenting the installed hardware configuration. One should also emphasize that the MTCA boards are also equipped with a unique electronic tag, readable by the MCH, so that the exact location of the device can also be cross checked on-line.

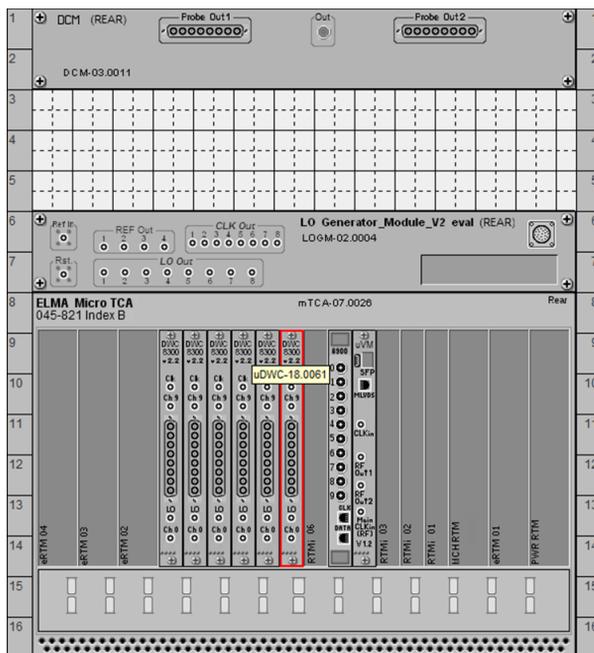


Figure 6: KDS snapshot of a LLRF installation.

Once their assembly is complete, the racks are temporary connected to the mains, in order to perform a system-level

integration check. This is a necessary step as troubleshooting becomes more complicated once the racks are installed in the tunnel.

Once the cryomodule installation inside the tunnel is finished, the equipped racks are placed underneath the modules, RF cabling between the modules and the racks is performed, connection to mains, cooling water and Ethernet is then taking place, after which, the warm commissioning of the complete RF station can start.

The racks preparation for L1 is currently on-going. The tunnel installation of the four cryomodules of L1 is scheduled for summer 2014.

CONCLUSION

This contribution gives an update on the installation progress for the LLRF system of the European XFEL. The first milestone was achieved in December 2013, when the RF gun was successfully installed and commissioned in the injector building on the seventh underground level. The next RF gun test is scheduled for July 2014, which will be the first time with beam.

The second part of this contribution gives an overview of the quality control steps and installation sequence for the XFEL LLRF system. Testing components at an early stage is essential, as the schedule constraints dictate a very short commissioning time. The second crucial point of such a large scale installation is documentation and device tracking. State of the art labeling systems and on-line device identification are two powerful tools essential to a successful installation. The complete installation of the first linac of the XFEL accelerator chain is scheduled for the coming months; its warm commissioning should take place soon after.

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