Status of the 10MW MBKs during commissioning of the European XFEL in DESY.

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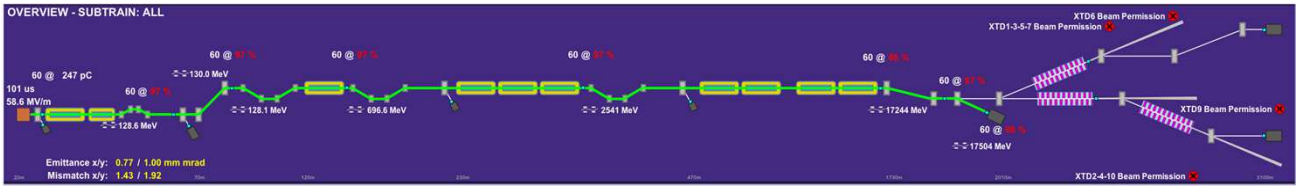
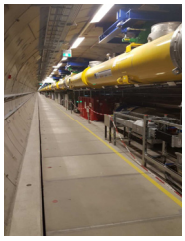
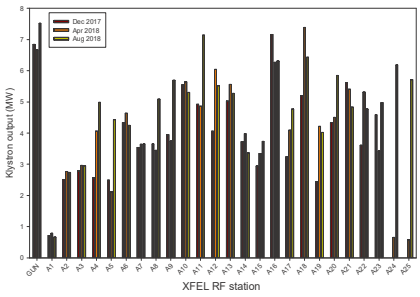
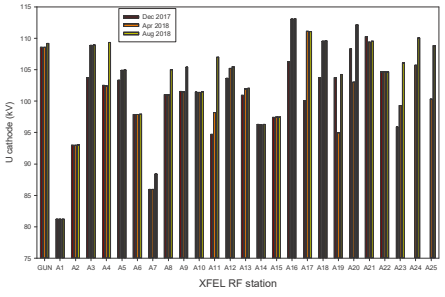
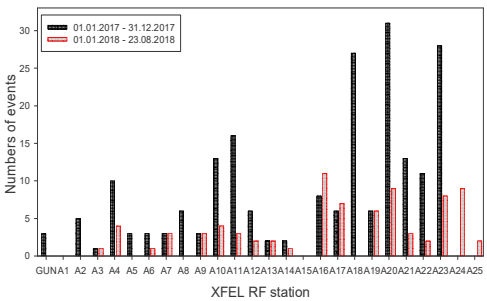
At present 26 RF stations for European XFEL are in operation. Each of the RF stations consists of a HV modulator located in a separate building on the DESY campus, up to 1600 m long 10 kV HV cables that connect the modulator and the HV pulse transformer located in the underground tunnel, 120kV, 3 m long HV cable connecting the HV pulse transformer and the connection module (CM) of the horizontal multi-beam klystron (MBK). The klystron can produce RF power up to 10 MW, at a RF frequency of 1.3 GHz, 1.5 ms pulse length and 10 Hz repetition rate. Two RF stations of the injector have already achieved about 24000 hours of operation, RF stations of the XFEL bunch compressor area have operated up to 13000 hours and the klystrons in the XFEL main linac already have about 11000 hours of operation (Status August 2018). To increase the lifetime of the klystrons, we use a fast protection system (KLM) that is based on the comparison of the actual RF shape and the expected RF shape. In the case of a difference exceeding a certain margin, for example, in the case of RF breakdown in a klystron or RF breakdown in a waveguide system (WGS), the KLM quickly, shorter than 800 ns, switches off the input RF signal. Thus, it does prevents the vacuum level in the klystron worsen too much or it minimizes the RF overvoltage time at the output windows of the klystron in case of breakdown in WGS. In this article we will give a summary of the present klystron status including the numbers of HV klystron gun and RF arcs in the klystrons.



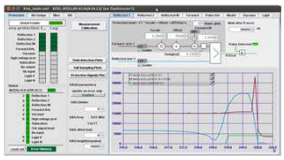






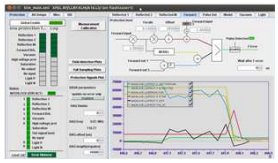


Klystron Life Time Management System (KLM)

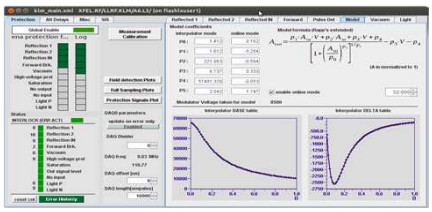


RF breakdown in WG system of ARM1, RF station A24.L3

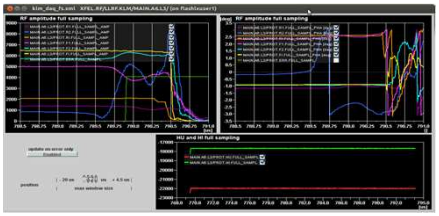
RF breakdown inside klystron, RF station A13.L3



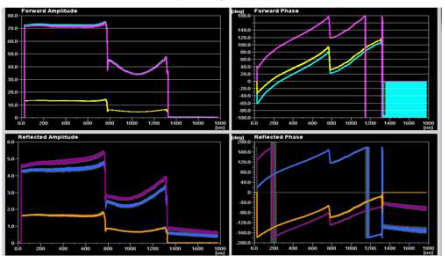
~800 nS between detection and RF stopping, RF station A16.L3



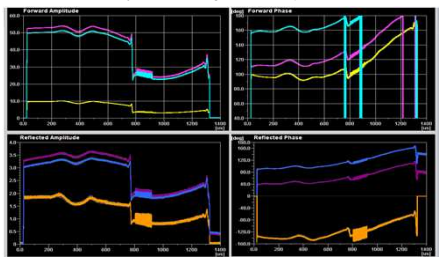
Model for estimation of expected klystron power, RF station A6.L3



RF breakdown in WG system of ARM2, high resolution shapes, RF station A6.L3



Output forward and reflection amplitudes and phases in case of using the phase modulation, RF station A6.L3 Gradient 760 MV

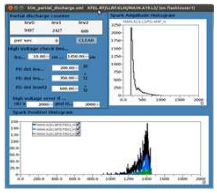


Output forward and reflection amplitudes and phases, without the phase modulation, RF station A10.L3 Gradient 770 MV, 160 bunches

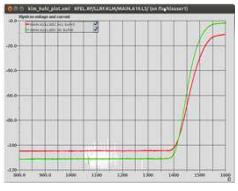
Connection Module (CM-600)

Mains parameters of CM and HFPS

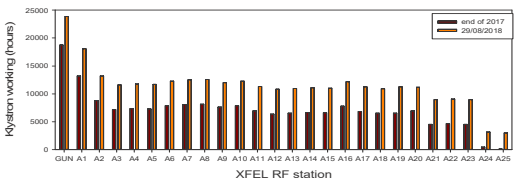
1.	Working frequency	1.6 kHz
2.	Power	up to 840 W
3.	Stability of power	+/- 0.3%
4.	Oil volume in CM	< 30 litres
5.	Max electrical field strength	< 35 kV/cm
6.	Accuracy for current measurement	+/-0.1%



Partial discharges distribution for the time position and amplitude, A19.L3

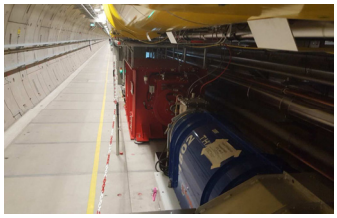


Partial discharges on HV waveform, A19.L3



Conclusion

In February 2008 the first prototype of MBK for XFEL had been installed on the MBK test stand DESY. Since August 2012 we have started a test and conditioning of the first one from 27th serial MBKs for XFEL. The klystrons were tested together with connection modules (CM) and with different types of HV cables. To increase the lifetime of klystron a special fast protection system (KLM) was designed and tested. In March 2015 we started the installation of MBK to the XFEL tunnel. In July 2018 XFEL reached the design energy of 17.5 GeV. For the moment 26 XFEL RF stations produced in total 124.6 MW impulse power, 4.87 MW in average, the average cathode voltage is 104.5 kV, RF and HV breakdown rate for the MBK during last 8 months is 0.443 breakdowns per day for all of XFEL klystrons.



XFEL tunnel view

Front side connection of MBK

Collector side connection of MBK