High Average RF Power Tests with 2 RF vacuum windows at PITZ.

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Abstract

The Photo Injector Test facility at DESY, Zeuthen site (PITZ), was built with the aim to develop and characterize electron sources for future usage at FLASH and at the European XFEL.

Recently, the main focus at PITZ has been the study of gun reliability and photoinjector performance at high average power.

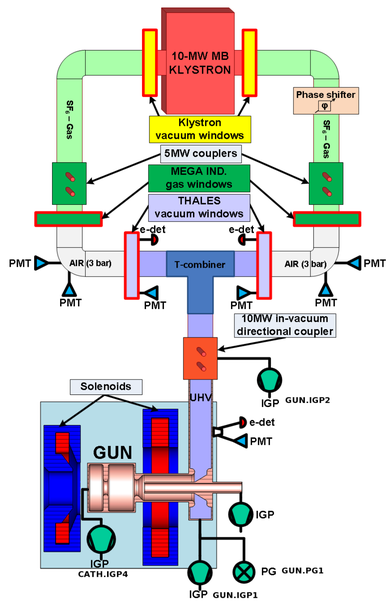
The goal is to get stable and reliable operation with 6.4 MW peak power in the gun at 650us RF pulse length and 10 Hz repetition rate.

To achieve this, a new RF feed system with two RF windows was installed at PITZ in 2014. During this test, the old gun 4.2 with a modified back-plane design for better cathode contact has been used.

In this contribution the results of the RF conditioning of gun 4.2 with a detailed interlock analysis will be reported as well as results from recent electron beam characterization.

New RF spring design: gold then rhodium coated contact stripes. Used together with electro-polished cathodes to improve contact.

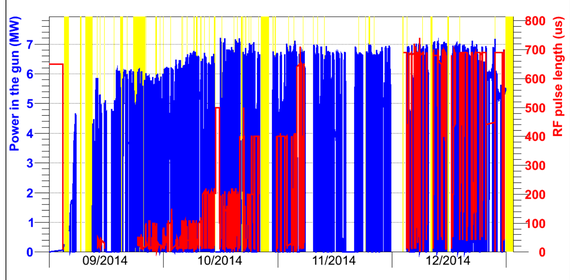
RF feed system with two RF windows



RF feed system used for gun 4.2 with 2 vacuum RF windows.

Main interlock (IL) systems:
> Photomultipliers (PMTs).
> Electron detectors.
> Reflection amplitude given by directional couplers.
> Vacuum pressure.

Conditioning procedure



Power and pulse length history during gun 4.2 conditioning (04/09/2014 to 31/12/2014).

The standard procedure applied for the conditioning of the RF guns is detailed starts with a RF pulse as short as possible (typically 10 us RF flattop).
> Step 1: from the lowest power, increase the power until the maximum.
> Step 2: once the maximum is reached, go to step 1. with an increased RF pulse length.

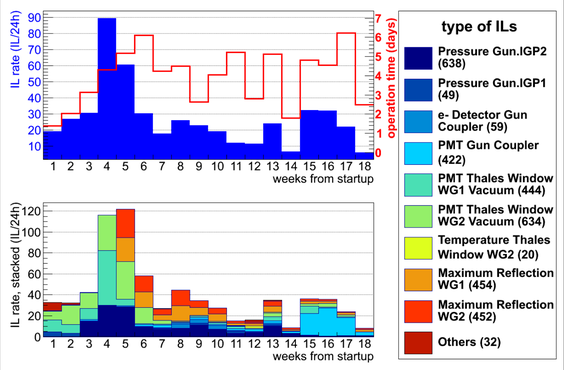
RF pulse lengths steps are 10 us, 50 us, 100 us, 200 us, 400 us and 650 us.

Conditioning is started with a 5 Hz repetition rate. Once the maximum power with 200 us RF pulse length is reached, the repetition rate is changed definitively 10 Hz.

If an interlock happens, ramping is started from minimum power keeping the same RF pulse length.

If the vacuum pressure has increased above 10^{-7} mbar during the IL, the ramping is started from 10us RF pulse length.

Conditioning of gun 4.2



Rate and type of ILs during gun 4.2 conditioning (04/09/2014 to 31/12/2014).

Mainly ILs from PMTs looking at the vacuum windows were interrupting the operation during the first five weeks.

From the 6th week of conditioning on, mainly maximum reflection ILs, gun coupler PMT ILs and vacuum ILs interrupted the conditioning.

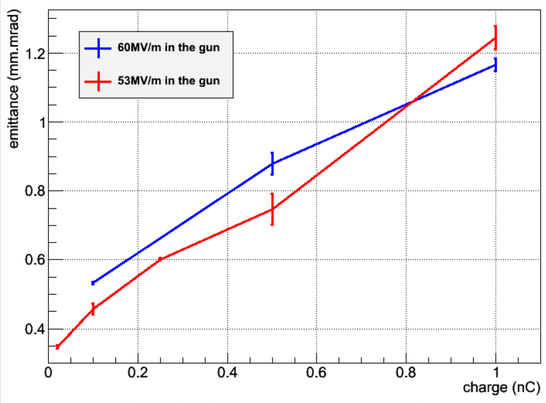
From the 15th week, the gun coupler PMT IL threshold was decreased to prevent vacuum ILs. The vacuum trips were successfully prevented, but the threshold was readjusted on the 18th week (to an intermediate value) due to the large number of gun PMT coupler ILs.

Percentage of weekly gun 4.2 operation time spent at different RF pulse lengths and power levels.

Emittance measurement

The projected emittance of the electron beam produced by gun 4.2 has been measured using the slit scan technique, with a longitudinally Gaussian laser (FWHM ~11.5ps).

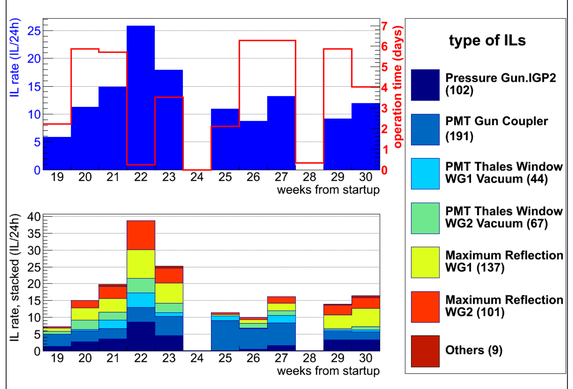
For each charge, the laser diameter, the solenoid current and the RF gun phase have been optimized.



Minimum emittance function of the bunch charge with a gradient of 60 MV/m (corresponding to a power of ~6.4 MW) and with 53 MV/m (~5MW).

The measured emittance numbers for 53MV/m are below the specifications for the commissioning at the European XFEL. The projected emittance numbers for 60MV/m are larger than for 53MV/m due to the usage of Gaussian temporal laser shapes and that the mismatch of the slices is much larger at 60 MV/m than at 53 MV/m, although the slice emittances is smaller at 60 MV/m than at 53 MV/m.

Operation at 6.4 MW and 650 us RF pulse length

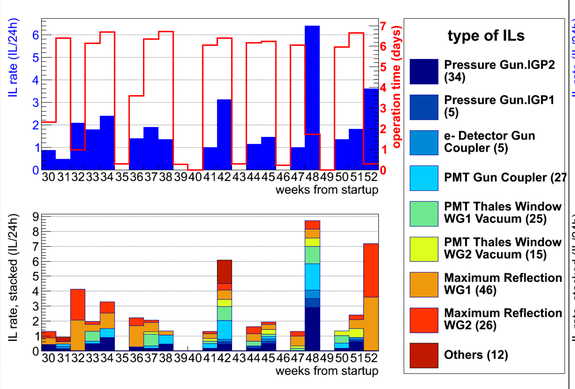


Rate and type of ILs during operation a 60MV/m and 650 us RF pulse length (05/01/2015 to 27/03/2015).

The goal was to get stable operation at 60MV/m (~6.4 MW) and 650 us RF pulse length. However, due to ILs (average of 12 ILs per day), that was only possible for ~50% of the operation time.

The threshold for the PMT gun coupler IL was reduced from the 25th week to the 27th week, which reduced the number of vacuum interlock, but increased the number of gun coupler PMT interlocks. The threshold value was then restored.

Operation at 5 MW and 650 us RF pulse length

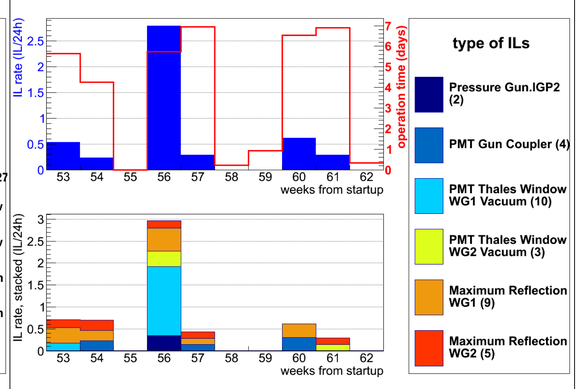


Rate and type of ILs during operation a 53MV/m and 650 us RF pulse length (05/01/2015 to 27/03/2015).

The rate of ILs (average of 1.6 ILs per day) is reduced considerably compared to the 6.4 MW run and there are much less vacuum trips as well.

Also the percentage of operation time spent at more than 4.8MW reaches up to 96%.

Operation at 6.4 MW and 250 us RF pulse length



Rate and type of ILs during operation a 60MV/m and 250 us RF pulse length (27/03/2015 to 01/11/2015).

The rate of ILs (average of 0.75 ILs per day) for that operation mode is the lowest, but still above the admissible rate for FLASH or the European XFEL (1 IL per week of operation).

However, recent developments of a fast gun recovery tool allow to recover after an IL in a few minutes instead of ~1h, which reduces ILs impact on the operation very significantly.

The integration of this fast gun recovery tool in standard operation is ongoing.

Conclusion and Prospects

Following the established conditioning procedure, gun 4.2 reached specification (60 MV/m, 650us RF pulse length and 10 Hz repetition rate) within 3-4 months of conditioning, the first month was mainly RF window conditioning, the last two for the gun. Then, despite 4 months of run at more than 6 MW and 650 us RF pulse length, stable operation was not possible with these parameters, probably because of the ~9 years long history of the gun 4.2 with heavy use at PITZ and FLASH and the subsequent re-machining of the cathode backplane.

However operation at 5MW with 650 us RF pulse length and at 6.4 MW 250 us RF pulse length was much more stable. In addition, a fast gun recovery tool will help to reduce the downtime down to an acceptable level for an FEL user facility.

The measured emittances are within specifications for the commissioning of the European XFEL.

After the first months of conditioning of gun 4.2, there were no problems anymore with the RF windows, proving that the 2 windows solution works. Also the vacuum pressure was very low and no damage could be observed on the new cathode spring design, which demonstrates that the new gold-coated cathode spring with corresponding cathode plugs works as well..

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