# CONDITIONING OF THE RF GUN AT THE PHOTO INJECTOR TEST FACILITY AT DESY ZEUTHEN

I. Bohnet, V. Djordjadze, F. Stephan, M. Winde, DESY, 15738 Zeuthen, Germany
K. Flöttmann, R. Ischebeck, C. Lackas, DESY, 22603 Hamburg, Germany

*Abstract*

A photo injector test facility is being commissioned at DESY Zeuthen. The aim is to develop and operate an optimized photo injector for future free electron lasers and linear accelerators which require extraordinary beam properties. First operation of the rf gun was done in December 2001. In order to get higher gradients in the rf gun than achieved today in similar normal conducting cavities, extensive conditioning work on the rf gun needs to be done. To increase the efficiency and safety aspects of the conditioning work an Automatic Conditioning Program (ACP) is developed. A deeper analysis of the ACP data is enabled by a Data Aquisition system (DAQ). Specific information about diagnostic elements at the rf gun are given and the requirements in order to simplify the conditioning work are outlined. The events which happened during conditioning so far are briefly described.

## 1 INTRODUCTION

A photo injector test facility is being commissioned at DESY Zeuthen in order to optimize injectors for applications which require extraordinary beam properties [1]. The heart of the facility, the rf gun, consists of a 1.5 cell L-band copper cavity with coaxial rf coupler, two solenoids for space charge compensation and a $Cs_2Te$ cathode. First operation of the facility was achieved in December 2001 [2, 3]. An extensive rf commissioning was done to get high gradients in the rf gun which will be described in the following.

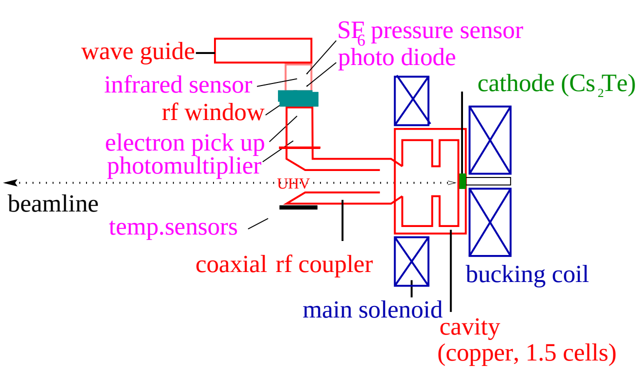


Figure 1: Sketch of the rf gun and the diagnostics elements for the conditioning.

## 2 AUTOMATIC CONDITIONING PROGRAM AND DIAGNOSTICS

RF conditioning of a cavity is a time consuming work in which different effects like field emission of electrons from protrusions on the surface, multipacting or sparks can destroy the rf gun or the rf window [4]. Therefore, the $Cs_2Te$ cathode is replaced by a Mo cathode during the rf conditioning. A gun interlock consisting of different detectors is installed (see Figure 1) to switch off the rf power in case of these events. An Automatic Conditioning Program (ACP) has been developed to increase the efficiency and the safety of the conditioning work. The aim is to get even higher gradients ($> 35$ MV/m) in the rf gun than achieved today in similar normal conducting cavities. The ACP controls the rf power and reacts appropriately on interlock signals. Fast signals from photomultipliers interrupt the rf power within an rf pulse so that the conditioning can be continued with the next rf pulse. Interruptions of slow signals from temperature or vacuum pressure sensors offer a recovering time for the rf gun. After resetting an interlock the program increases the power rapidly or slowly, depending on certain rf power thresholds. A first version of the ACP program was written in MATLAB [5]. An improved version is under development. It is a C++ program running under SunOS [6]. Its graphical user interface runs as a collection of Labview [7] virtual instruments. Using the rich set of graphical possibilities of Labview, we want to achieve a quicker and more clever control of the conditioning process in connection with an online analysis.

## 3 DATA ACQUISITION AND ANALYSIS

The regular conditioning data of ACP as vacuum pressure, settings, interlocks, etc. are recorded frequently. A guntrip-logbook records special comments during parameter changes or interlock events. However, a deeper analysis of what's going on during conditioning is realized by an event recorder of ACP. The ADC signals of the fast gun interlock detectors as well as the rf signals are dumped with a sampling rate of 1-9 MHz into a ring buffer. This buffer is stopped just after an interlock event happened which allows to read out the data stored during the last rf pulse trains. But also for the normal run of the facility it is important to know the behaviour of the whole system and its parts as well as the correlation between different components. Therefore a Data Aquisition system (DAQ) has been established which enables a deeper analysis of the commissioning results [8]. This program was developed in the

ROOT framework, which supplies an object-oriented data base as well as multiple analysis tools. It uses DOOCS servers to get access to the elements of the facility. The program runs simultaneously on three Sun SPARC workstations and uses a common timing system, which allows to relate different detectors recorded by different computers in different database files. Recorded data are analysed by means of tools developed in the frame of ROOT and MATLAB utilities. This analysis allows to observe the behaviour of single subsystems and possible deviations from their normal functionality and serves to avoid problems in the set-up operation.

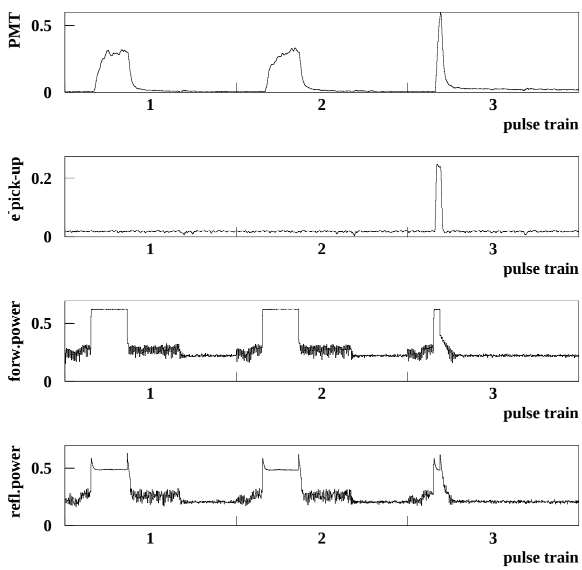


Figure 2: Fast ADC signals in arb. units during the last three pulse trains of an photomultiplier + electron pick-up interlock event.

## 4 RF COMMISSIONING

In the beginning of the conditioning process it was important to find out very carefully the achievable rf settings and to clarify which rf power was already able to be put into the cavity. In December 2001, we started with a low average power corresponding to short rf pulse lengths ($50 - 100\,\mu$s) and a low repetition rate (1 Hz). The solenoids were switched off in the beginning. The gun interlock thresholds have been checked and readjusted. The resonance frequency of the cavity was re-tuned with the cooling water system. For higher repetition rates corresponding to higher average power the gun can be significantly detuned which increases the reflected power. After getting an overview of the rf limits we configured ACP to achieve higher gradients. The current of the solenoids were swept within a small range which was extended step by step up to the full range of 0–400 A. Based on the fact that

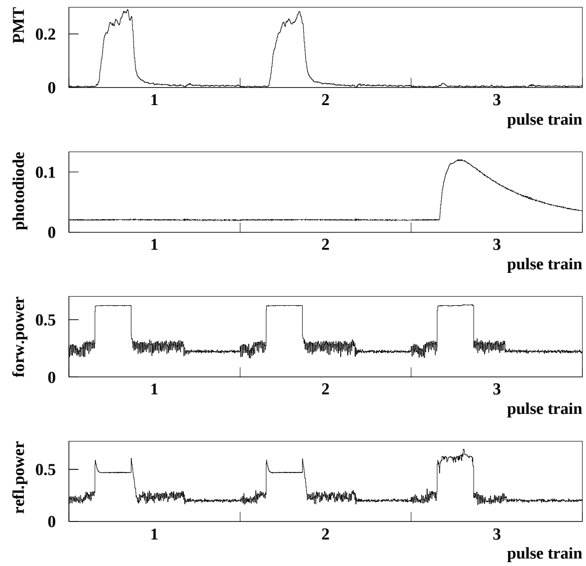


Figure 3: Fast ADC signals in arb. units during the last three pulse trains of an photodiode interlock event.

the present gun had been partially conditioned at DESY in Hamburg before the first conditioning work was very smoothly. First photo electrons were produced in January 2002. A mechanical damage of the rf window in March 2002 resulted in a small vacuum leackage, so that the rf vacuum window had to be exchanged by a new one which never was in use before. Meanwhile the repetition rate of the rf pulse trains was increased from 1 Hz to 5 Hz for stability reasons of the rf power supply. The following conditioning work was more challenging and events like sparks occured more often than during the first running period. Figure 2 displays the signals of the photomultiplier and the electron pick-up (top diagrams) and the forwarded and the reflected power of the gun (bottom diagrams) during the last three rf pulses of a length of $100\,\mu$s before the gun interlock switched off the rf. The photomultplier usually shows a background signal during each rf pulse train which is visible in pulse train 1 and 2 in the top diagram. One clearly sees the peak of the photomultiplier during the last rf pulse train in coincidence with a peak signal of the electron pick-up. The photomultiplier is directly connected to the rf system, so that after passing a threshold the rf pulse is switched off within some microseconds. Figure 3 shows the signals of the photomultiplier and the photodiode (top diagrams) as well as the forwarded and the reflected power of the gun (bottom diagrams) during the last three rf pulses before an interlock event. An increase of reflected power is visible in the 3rd pulse, so that the photomultiplier does not see anymore a signal. But the photodiode, which is located in front of the rf window outside the vacuum measures a spark. This interlock event has been accompanied by a bang in the wave guides. Figure 4 shows the vacuum pressure versus the current of the main solenoid in the

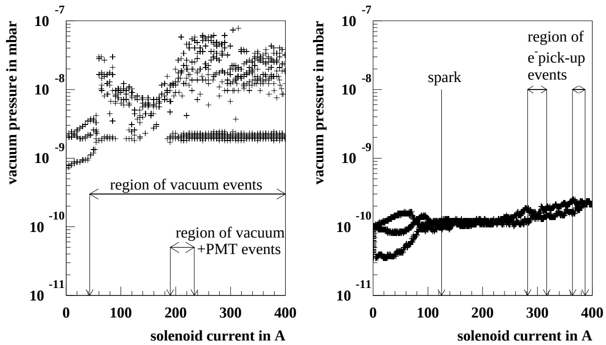


Figure 4: Vacuum pressure as a function of the main solenoid current in the beginning (left diagram) and at the end (right diagram) of the rf window conditioning.

beginning (left diagram) and at the end (right diagram) of the rf window conditioning. The time in between was two weeks. These diagrams display a big improvement. In the beginning the gradient on the cathode was limited to about 20 MV/m whereas at the end the gradient was swept within 20 to 34 MV/m. The vacuum pressure was reduced within this time by almost three orders as well as the number of interlock events. The number of gun interlock events which happened within this time is shown in Figure 5. It is obvious that one has to distinguish the gun interlock events into groups. Vacuum events are mostly produced by multipacting characterized due to the dependence on the solenoidal field. Pure photomultiplier events are not fully understood as well as electron pick-up events which are mostly observed in connection with an increase of vacuum pressure and of the photomultiplier signal. An event of the photodiode occurs usually alone, it seems to be a flashover in the $SF_6$ section of the waveguide (in front of the rf vacuum window). Such a spark occured at a solenoid current of 110 A shown in the right diagram of Figure 4.

## 5 CONCLUSIONS

The conditioning procedure with ACP obtained a stable operation for rf pulses up to a length of 400 $\mu$s at a repetition rate of 5 Hz including a solenoidal field between 0 and 0.25 T with a compensated field a the position of the cathode. The maximum gradient was 34 MV/m which was limited by the present high voltage power supply of the rf system which will be upgraded soon.

## 6 ACKNOWLEDGEMENTS

We want to thank the shift crews and the rf group of the photo injector test facility at DESY Zeuthen (PITZ) for the intensive and time consuming help during the gun conditioning.

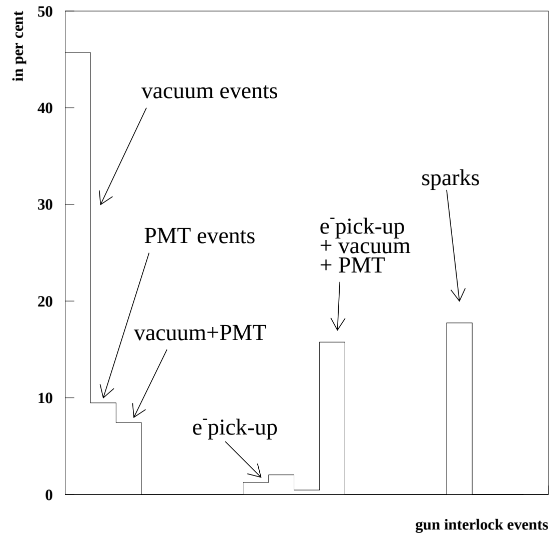


Figure 5: Gun interlock events in per cent during the rf window conditioning.

## REFERENCES

[1] F. Stephan et al., "Photo Injector Test Facility under Construction at DESY", FEL 2000, Durham.

[2] R. Bakker et al., "First Measurements at the Photo Injector Test Facility at DESY Zeuthen", Proc. EPAC2002, Paris, June 2002.

[3] http://desyntwww.desy.de/pitz/

[4] I. Bohnet, J. Baehr, K. Floettmann, D. Lipka, F. Stephan, M. Winde, Q. Zhao, "Photo Injector Test Facility in the Commissioning Phase at DESY Zeuthen", Contributions to the FEL2001 Conference, 20th to 24th August 2001, Darmstadt, Germany.

[5] http://www.mathworks.com

[6] http://www.sun.com

[7] http://www.natinst.com

[8] http://tesla.desy.de/doocs/extprograms/daq/index.html