TUNING, CONDITIONING, AND DARK CURRENT MEASUREMENTS OF A NEW GUN CAVITY AT PITZ*

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Abstract

In December 2005, a new gun cavity for the Photo Injector Test Facility at DESY in Zeuthen (PITZ) was tuned with the help of a specially designed tuning device. The tuning procedure and its results as well as RF measurements will be presented. Meanwhile, the cavity was installed in the PITZ facility and conditioned. Dark current measurements with different cathodes were performed and are described. Comparisons to former measurements are made.

INTRODUCTION

The photo injector test facility at DESY in Zeuthen (PITZ) was built in order to test and optimize electron sources for Free Electron Lasers and Linear Colliders. One of the main tasks is to prepare gun cavities for subsequent use at FLASH and XFEL. Up to now, three gun cavities have been built by DESY and another one is in production. They are designed for a peak power of 4.5 MW and an average heat load of 50 kW [1]. In order to reach higher power levels, two further guns with improved cooling will be built towards the end of 2006.

After the production of the first gun cavity, prototype No.1, a water-to-vacuum leak was found. It was figured out that the used copper did not fulfill the specifications. The leak was repaired with a kind of glue, but an installation at FLASH was not recommended. Therefore, this gun was used for high power tests at PITZ after the commissioning of a 10 MW multi beam klystron in June 2005 [2]. The conditioning towards higher peak and average power ended suddenly with the break-up of the old water-to-vacuum leak which appeared at a gradient of about 57 MV/m [3]. Meanwhile, the cavity was again repaired and is available for further tests.

Frequency measurements after the gun production showed a frequency difference from the goal frequency of 1.3 GHz (detuning) of 615 kHz, see Table 1. This detuning is caused by the brazing and cannot be calculated. Thus, the gun was mechanically tuned and the dimensions of the cells have been corrected in the design of the next gun cavity.

Gun cavity prototype No.2 was nevertheless showing a large detuning, probably due to the different copper quality. The gun was used in the PITZ1 phase until Nov.2003 and was installed at FLASH after a complete characterization at PITZ [4] where it is in operation since February 2004.

Gun cavity prototype No.	1	2	3.1
Frequency detuning (kHz)	616	1207	632
Field flatness E_{half}/E_{full}	0.90	0.97	0.94
Mode spacing 0-π-mode (MHz)	5.3	5.2	5.2

Table 1: RF measurements results of all three existing DESY cavities before tuning. The detuning was calculated for an operation temperature of 43°C under vacuum (measurement at 23°C in air).

The third gun cavity (prototype No.3.1) has been built in 2003. In order to avoid the complicated tuning procedure that was necessary for the previous guns, the cell's dimensions have been corrected again. In addition, the gun has special tuning knobs that allow modifying the resonance

Figure 1: Photograph of gun cavity prototype No.3.1.

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frequency by up to 300 kHz. However, after some first rf measurements of the resonance frequency in September 2004, it became clear that the tuning knobs cannot be used: the measured detuning was too large (Table 1).

TUNING OF THE NEW GUN CAVITY

In order to shift the frequency and to correct the field profile, a new tuning device has been developed. It consists of a stable girder on which the gun is placed, and two tools for deforming the cavity walls: a tuning stamp for pushing the cathode wall at the cathode plane, and a tuning clamp for pulling the coupler-facing wall of the full cell. For frequency measurements a small tapered coupler has been built by BESSY. Thus the system became much easier to handle compared to the large and heavy coaxial coupler used in the beamline installation. A bead pull setup for field profil measurements can be easily mounted to the tuning device. Figure 2 shows a photograph of the complete setup.

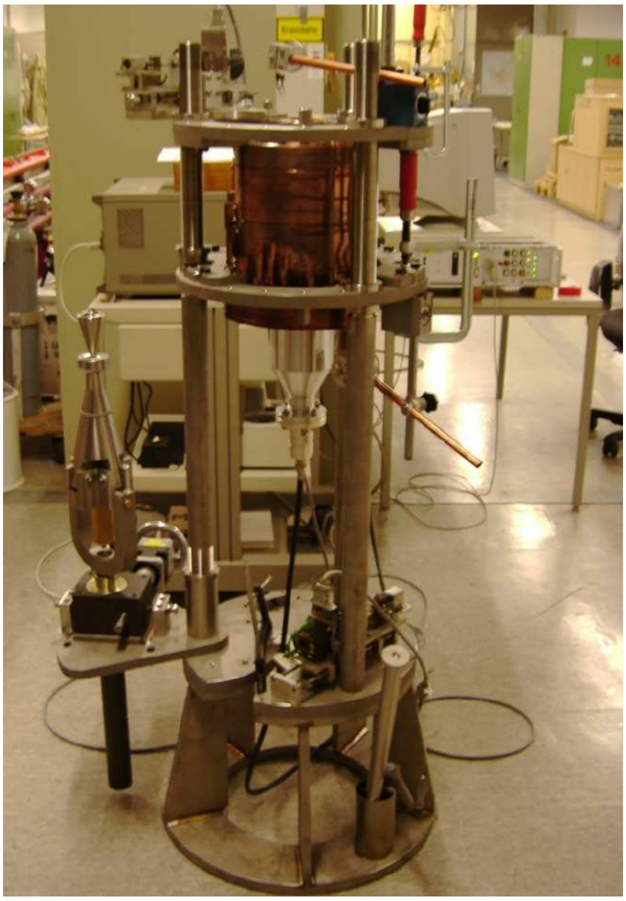

Figure 2: Photograph of the tuning device with the gun cavity, the BESSY test coupler, the bead pull setup, and the tuning tools: the clamp (mounted) and the stamp.

In November 2005, the new tuning device was used for the first time. Gun cavity No.3.1 was tuned in several consequent steps. Each time the cavity walls were pushed or pulled some ten microns and the deformation was surveyed. The use of the tuning tools left partly visible signatures in the material, but mostly not to recognize when touching. Figure 3 shows an example of the marks from both tuning tools.

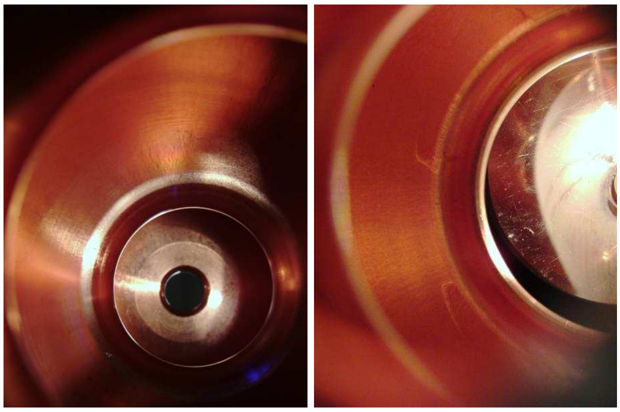

Figure 3: Marks in the copper material from the tuning stamp (left; a circular mark around the cathode hole) and from the tuning clamp (right; two imprints in the coupler-side wall).

As result of the tuning, the resonance frequency is reached at the design operation temperature of 54°C, while the field flatness E_{half}/E_{full} was measured to be about 1.06, see Figure 4. This means, the field at the cathode is 6% higher than in the full cell. According to simulations, this is a good compromise between high average accelerating

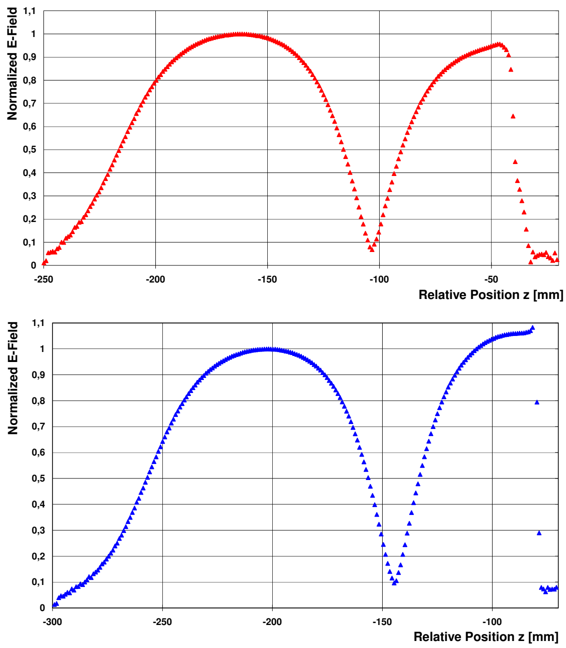

Figure 4: Field distribution in the gun before (top) and after (bottom) tuning. The cathode field is finally 6% higher than the field in the full cell.

gradient and maximum gradient at the cathode for space charge compensation. The quality factor of the cavity was also determined: Q_0= 24200.
Using the new tuning device, the tuning procedure was very smooth and comfortable. Therefore, it was decided to do a re-tuning of cavity No.1 which was tuned in 2001 for an operation temperature of 35°C. But during the high power tests in 2005 it was found that the lower temperature limit of the cooling water system limits the reachable average power at such a low operation temperature. The goal of the tuning was thus to increase the operation temperature. As a result of the re-tuning, an operation temperature of 50°C was obtained while keeping the field flatness constant at a value of about 1.05.

DARK CURRENT STUDIES

After the tuning, the new gun cavity was installed in the PITZ beamline and conditioned up to the full FLASH specifications: 3.5 MW peak power, 900 μs pulse duration, and 10 Hz repetition rate, corresponding to an average power of 31.5 kW [3].
Extensive dark current studies started in April 2006 and continued during the summer. The measurements were done for one Cs_2Te cathode (used for beam operation in 2005 and 2006), and for four Mo cathodes (with optical polished surface, used for gun conditioning). One of the Mo cathodes (cathode 80.1) has a hole pattern on its surface [5]. It was foreseen to serve for dark current generation studies but the corresponding pattern was not found in the dark current images. An example of such an image is displayed in Figure 5: it shows the YAG screen signal of dark current emitted by this specially prepared cathode 80.1.

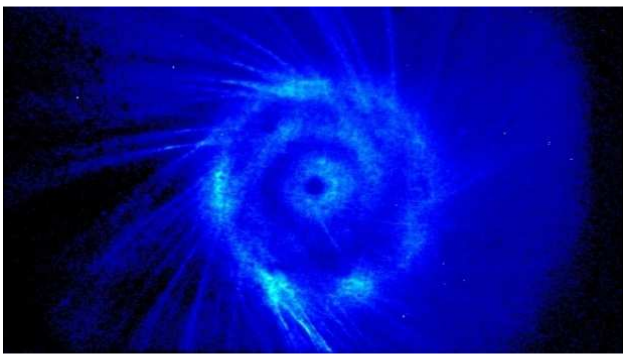

Figure 5: Dark current from cathode 80.1 on a YAG screen.

Figure 6 displays a photograph of the cathode 80.1 as well as a picture of cathode 58.1 (Cs_2Te).
Figure 7 shows the measured dark current level without solenoid magnets ($I_{main} = I_{bucking} = 0$ A) as function of the gradient at the cathode for two different guns: cavity prototype No.2 (data from 2002) and cavity prototype No.3.1 (data from 2006). For each gun, one distribution is shown for Mo and one for Cs_2Te. The dark current level

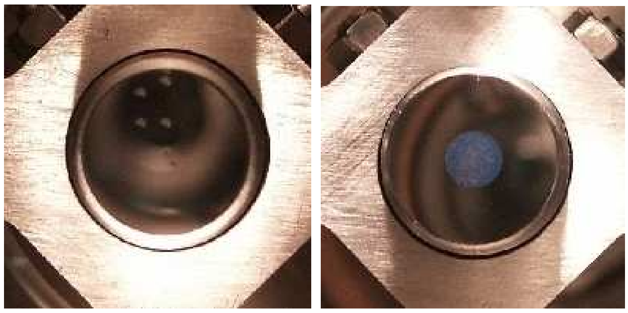

Figure 6: Topview of two of cathodes in the cathode chamber: Mo cathode 80.1 with the special hole pattern (left) and Cs_2Te cathode 58.1 (right).

produced 2002 without magnets is higher than the currently measured level. In order to understand the origin of this difference - the cavity or the photo cathodes or both - more detailed studies are necessary. One possible reason is a difference in the emitted dark current spectrum, as presented in [3]. At fixed magnet settings it can lead to a different effective aperture (due to the gun itself, the coupler, and the following beamline) and thus to a different detected dark current level downstream the gun.

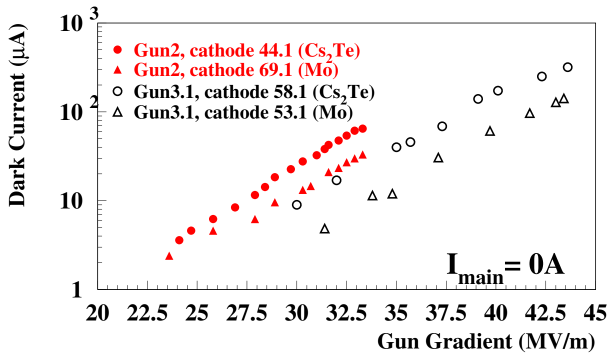

Figure 7: Dark current without solenoids produced with two gun cavities for different cathodes at PITZ.

Dark current measurements at different gradients have been performed as function of the currents in the main and the bucking solenoids. Examples for such 2D dark current measurements are shown in Figure 8: the dark current emitted by cathode 75.1 (Mo) was recorded for all combinations of I_{main} and $I_{bucking}$ at three different gradients.
Taking the maximum entry in such a 2D dark current distribution, one obtains the maximum dark current level emitted by a certain cathode at a defined gradient. Figure 9 shows the resulting distribution for gun cavity No.3.1 with cathode 53.1 (Mo) and cathode 58.1 (Cs_2Te). In addition to the data from 2006, an old result from the PITZ1 phase (spring 2003) when using gun cavity No.2 is drawn for comparison. The level of the emitted dark current is approximately equal, at least for the Cs_2Te cathode.
Finally, the maximum dark current of all Mo cathodes used in gun cavity No.3.1 is shown in Figure 10. The maxi-

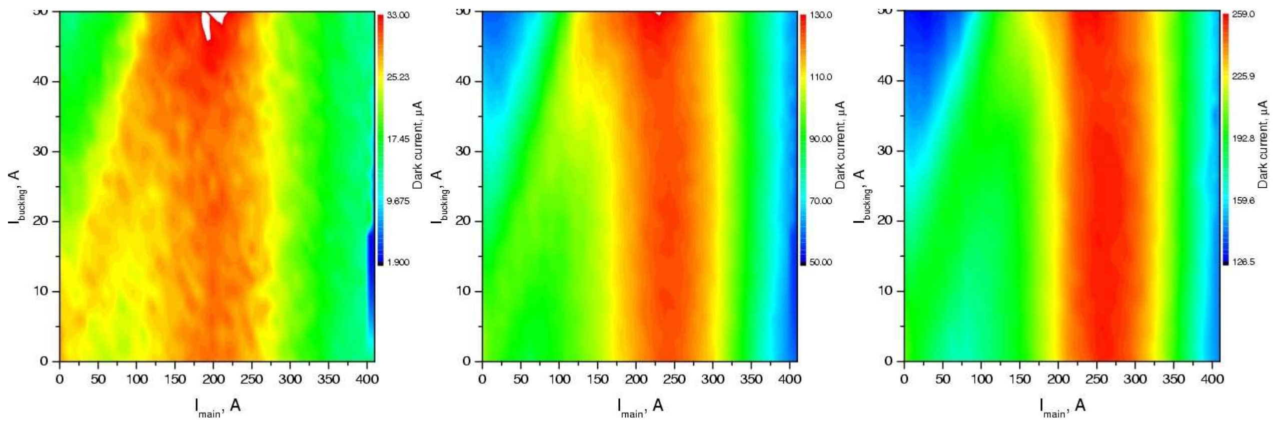

Figure 8: 2D scans of dark current emitted by Mo cathode 75.1 for all combinations of I_{main} and $I_{bucking}$ at different gradients: 35 MV/m, 40 MV/m, and 3543 MV/m (from left to right). Note the different color coded scale.

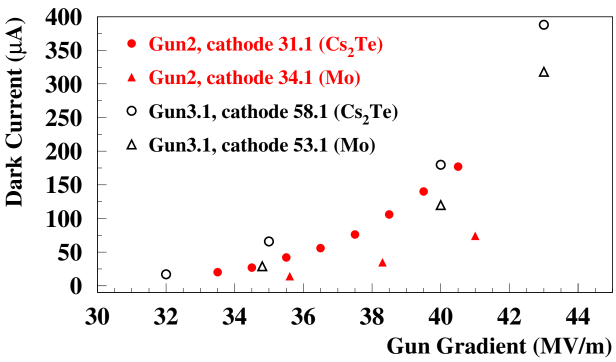

Figure 9: Maximum emitted dark current with two gun cavities for different cathodes.

mum amount of dark current is comparable for the analyzed cathodes, even if the emitted spectrum was different, as reported in [3].

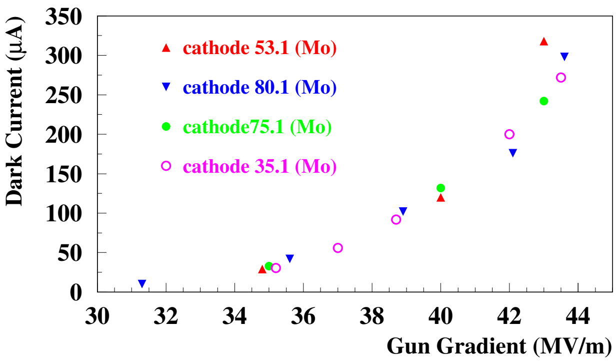

Figure 10: Maximum emitted dark current from the Mo cathodes used in gun cavity No.3.1.

From all dark current studies done with the new gun cavity it can be concluded that this cavity produces about the same amount of dark current as the former used cavity (prototype No.2). This means that there is no influence on the dark current from the tuning marks which have been produced by using the new tuning device. Therefore, the device can be also used for the tuning of further new cavities which are planned to be used at PITZ.

Nevertheless, the dark current level produced by the cathodes needs to be further decreased. In order to do so, more detailed studies of the dark current emission are necessary as well as improvements on the photo cathodes themselves.

SUMMARY AND OUTLOOK

A new gun cavity (prototype No.3.1) has been built, tuned, and commissioned at PITZ. The results of the tuning and extensive dark current measurements have been presented in this paper. Comparisons with formerly taken data was done. The gun is currently used for beam measurements at PITZ. After its full characterization, it will be dismounted from the beamline in autumn 2006 in order to be available as spare gun for the FLASH user facility. For PITZ, a new gun is currently in preparation (prototype No.3.2).

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