Dark current at TTFL rf-gun

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During the last run, dark current measurements have been routinely done at TTFL rf-gun. Effects on beam performance and linac operation are presented.

1. Introduction

The TESLA Test Facility Linac (TTFL)[1] uses an RF photoinjector and a superconducting linac to accelerate electrons for the TTF free electron laser (TTF-FEL)[2]. The photoinjector is based on an RF gun operated at 35 MV/m, 100 μs rf flat top pulse length. The electron source is a Cs_2Te photocathodes illuminated by UV laser light. The 4^{th} harmonic (λ= 262 nm) of a Nd:YLF laser[3]is used. Usually a train of bunches, with bunch charge between 1 nC and 8 nC, is generated. The bunch spacing in the train is 1 μs. Dark current is produced along the rf pulse. A possible source of dark current are tips or needles on surfaces exposed to high electric field. The current density due to this field emission is given by the Fowler-Nordheim relation [4]:

$$j \propto (\beta E)^{\frac{5}{2}} exp(-\frac{B}{\beta E}) \qquad (1)$$

where E is the electric field amplitude, β is an enhancement factor due to the geometry of the source and B is a material dependent parameter. The dark current is source of undesired beam halo and radiation along the linac. Therefore is important to understand dark current sources in order to reduce them as much as possible.

2. Measurements

The dark current is measured with a Faraday cup that can be inserted at the gun exit. The signal from the Faraday cup is detected with an oscilloscope. A typical signal is reported in Fig. 1. The rising and falling edge of the rf pulse are

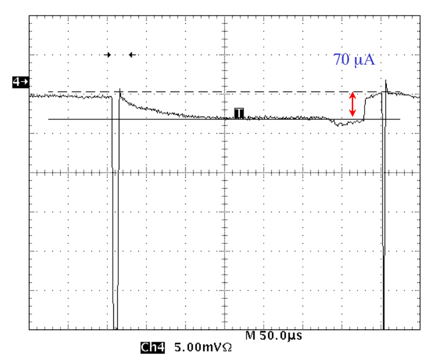

Figure 1. Oscilloscope trace used for dark current measurement. The spikes at the begin and at the end are due to multipactoring during Rf start and stop. The pedestal is due to dark current.

clearly visible as spikes at the beginning and at the end of the pulse. They are due to multipactoring during rise and fall of rf. In between the spikes, a pedestal is visible that grows along the pulse. This pedestal is due to the dark current produced during the Rf pulse. We measure the dark current by measuring the height of the pedestal at the end of the pulse, before the rf stop signal as shown in Fig. 1. From simulations, the source of the dark current is the gun backplane and mainly the region around the cathode. The Rf contact between the cathode and the body of the gun is assured by a CuBe spring. It is possible to image the dark current on a screen downstream from the gun and resolve the spring convolutions. The contribution to the dark current from the photoemissive material is lower than the Faraday Cup sensitivity. The dark current history for the cathodes used is reported in Fig. 2 [5]. The typical initial value of the dark current is below 100 μA after the cathode insertion in the gun. The dark current then rises slowly. Often an abrupt increase is observed that can reach also some mA. Reused cathodes have always an initial dark current value higher than their fresh value and the current rise is earlier and faster. On the contrary, degradation of quantum efficiency has not been observed. The experimental evidences collected till now can be summerized as follows:

- Removing the cathode from the gun and pumping the cathode region lowers the dark current but only for short time.
- The dark current value after the cathode insertion depends on the pumping time.
- Reused cathodes have an earlier and faster dark current rise than new cathodes.
- No clear indication of dark current from the photoemissive area has been collected.

The main effect related to dark current during linac operation is radiation losses in the linac components. In addition, beam jumps were observed. These were due to dark current induced charging of the dielectric mirrors used to point the laser to the cathode. The problem has been solved replacing them with mirror having a metallic bulk material.

3. Conclusions

Measurements and induced effects of dark current have been reported. Studies are in progress in order to find and eliminate the dark current sources. New materials and coatings for the spring are investigated. An activity is in progress also for studying new finishing of the Molybdenum cathode plug.

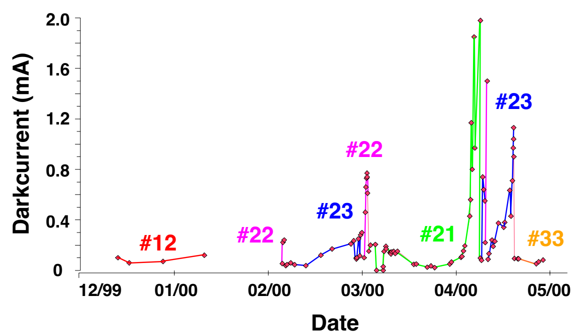

Figure 2. Dark current history for the cathodes used in the gun during the last run. Different cathodes are rappresented by different colors. Note that some cathodes have been used more than once.

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Photo Injector Test Facility under Construction at DESY Zeuthen*

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A **P**hoto **I**njector **T**est Facility is under construction at DESY **Z**euthen (PITZ) within a cooperation of BESSY, DESY, MBI, and TUD. The aim is to develop and operate an optimized photo injector for future free electron lasers and linear accelerators. First operation of the rf-gun is planned for late autumn 2000. In this paper we want to outline the scientific goals, the planned and existing hardware, the status of the project and new developments.

1. Goals

The scientific goal of the project is to operate a test facility for rf-guns and photo injectors in order to optimize injectors for different applications like free electron lasers, production of flat beams for linear colliders and polarized electron sources. We will make comparisons of detailed experimental results with simulations and theoretical predictions. At the beginning we will concentrate on the development of an optimized photo injector for the subsequent operation at the TESLA Test Facility - Free Electron Laser (TTF-FEL) [1]. This also includes the test of new developed components like the laser, cathodes and beam diagnostics under realistic conditions. After the installation of a booster cavity we will be able to test new concepts for the production of flat beams[2]. On a longer term basis we plan to investigate the design of polarized electron sources.

2. Setup

The experimental setup is shown in figure 1. In the future, the teststand will be complemented by more diagnostics, beam optical components and a booster cavity.

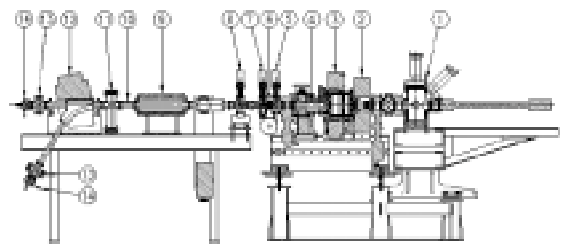

Figure 1. Experimental setup of PITZ in the start-up phase: 1. cathode system, 2. bucking solenoid, 3. main solenoid, 4. coaxial coupler, 5. laser input port, 6. beam position monitor, 7. Faraday cup + view screen, 8. emittance measurement system (slits + pepper pot), 9. quadrupole triplet, 10. wall gap monitor, 11.+13. view screen, 12. dipole, 14. Faraday cup.

3. Schedule and Status

In September 1999 it was decided to built the test facility in DESY Zeuthen. Now the raw construction work is mainly finished and soon we will start the installation of the test stand itself and all the other equipment. We plan to have the first rf inside the gun cavity in November and the first photoelectrons are scheduled for January 2001. A major upgrade of the test stand will take place mid 2002 when a booster cavity will be installed.

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4. Laser Development

The Max-Born-Institute develops the photocathode laser for PITZ. Besides the former requirements for the TTF photocathode laser system [3] a new request on the logitudinal shape of the micropulses will be realized by the MBI: the micropulses should have a flat-top profile, 5-20 ps FWHM, with rising and trailing edges shorter than 1 ps. This requires a new laser concept which is shown in figure 2. The key element is the optical-parametric amplifier (OPA). It provides large amplification bandwidth and therefore allows for the amplification of pulses with sharp edges. A grating combination will be used for programming the shape of the micropulses. Wave front deformations will be corrected by computer-controlled optics. An extended version of the field tested TTF photocathode laser will serve as a pump laser for the OPA. In the beginning it will be used to produce the first photoelectrons. Then a continual upgrade to the full laser system follows.

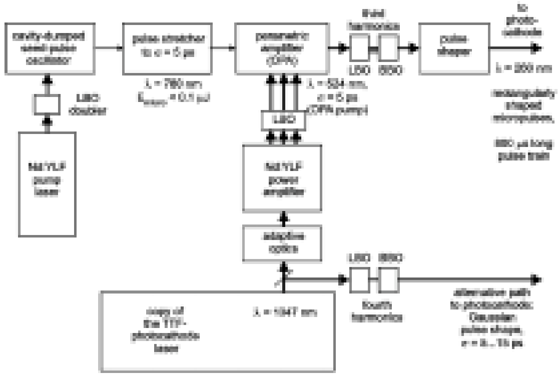

Figure 2. Scheme of the photocathode laser for the generation of micropulses with variable shape.

5. Simulations

One goal of TEMF at TU Darmstadt is the numerical study of the minimum attainable transverse and longitudinal emittance as a function of rf-gun parameters. Figure 3 presents a simulation that takes into account space charge and nonlinear rf forces. It shows that the main part of the transverse emittance is caused by the emission process and that the evolution of the emittance for the first and the second half of the bunch is opposite. The behaviour of the projected emittance seems to be a result of the rf field effects and MAFIA TS2 and ASTRA[4] are shown to be in good agreement. An other topic for TEMF is the development and installation of an on-line simulation program (V-code) [5] that is based on a model of ensembles. It will help to obtain an online understanding of the dynamics of the beam. At DESY an ASTRA simulation with a cutted disk structure booster cavity was performed. This cavity provides an average gradient of $\approx$ 12.6 MV/m and boosts the beam up to about 30 MeV. According to that simulation emittances in the sub-mm-mrd regime can be obtained.

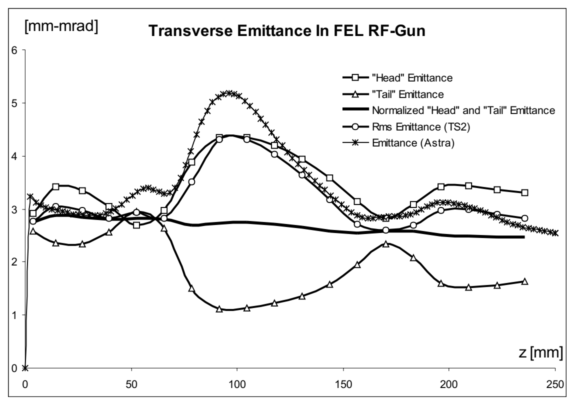

Figure 3. Development of transverse emittance in the rf-gun.

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