DESIGN AND MEASUREMENTS OF A TEST STAND FOR THE SEM-GRID SYSTEM OF THE ESS-BILBAO

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Abstract

In the framework of the ESS-Bilbao accelerator, a test stand for the development of Secondary Electron EMission grid (SEM-Grid) has been designed and manufactured as a part of the diagnostics system for beam profile measurements. This test stand is a vacuum system based on an EQ 22/35 electron source from SPECS used as a beam injector. This electron source has an energy range from 0 to 5 KeV and a maximum beam current up to 200 μA. Although we have thought in a SEM-Grid of 40 wires (20 wires in each X and Y direction), two prototypes of 16 wires (8x8) of 250 μm diameter and spaced 1 and 2 mm, respectively, have been developed due to its easier implementation and tested in the test stand. In order to develop an electronics readout system for the SEM-Grid, first studies of the prototype signals have been done. The secondary emission current of each wire will be integrated and amplified to provide a significant voltage signal that can be measured by our acquisition system. A description of the SEM-Grid test stand and the measurements developed is given here.

INTRODUCTION

In the framework of the new ESS-Bilbao (ESSB) [1] accelerator facility and in collaboration with the Department of Electricity and Electronics of the University of the Basque Country (UPV-EHU), the SEM-Grid project is one of the open design lines within the development of the diagnostic systems. The most important typical parameters of the ESSB beam and the prototype SEM-Grids are shown in Table 1.

In accelerator physics, beam profiles are the density distributions of particles over the two transverse coordinates X and Y. The beam profile can be influenced by quadrupole magnets installed in all accelerators, therefore continuous monitoring is important to control the beam shape and to optimize operating parameters. Different types of devices, depending on the kinds of particles, intensity and energy, can be classified into non-destructive (SEM grids) and destructive (Faraday cups) [2]. Beam profiles may be measured via secondary electron emission (SEE) [3]. When particles hit a surface, secondary electrons are liberated, escaping from the surface [4]. For the profile determination, individual wires interact with the beam; this is called Secondary Electron EMission grid (SEM-Grid) [4] or harp grids. They are widely used as an electronic alternative to get a very large dynamic range, where each wire is read out using an independent electronic channel.

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Table 1: Main Parameters of the Future ESS-Bilbao Proton Linac and Profile SEM-Grids

Beam Parameters	
Max. proton current	90 mA
Max. final energy	300 MeV
Max. beam power	75 kW
Max. repetition rate	50 Hz
Pulse length	1.5 ms
Bunch frequency	352.2 MHz
Profile SEM-Grids	
Number of Wires	16-40
Diameter of Wires	250 μm
Length of Wires	20 mm
Spacing between Wires	1-2 mm
Signal Wires	Kapton® isolated

The beam shape is inflluenced by the magnet settings and the beam emittance ϵ [4]. Knowing the lattice, i.e., the $\beta(s)$ function and the dispersion $D(s)$ at the monitor location s, the measured beam width $\sigma(s)$ is given by

$$\sigma_x^2(s) = \epsilon_x\beta_x(s) + \left(D(s)\frac{\Delta p}{p}\right), \qquad \sigma_y^2(s) = \epsilon_y\beta_y(s) \qquad (1)$$

In a synchrotron the lattice functions are known or can be measured separately. If in addition, the momentum spread $\Delta p/p$ is known, the input emittance can be calculated because in the vertical plane the dispersion is zero in most cases (only horizontal bending magnets are used). Nevertheless, the dispersion is important to interpretate the beam width. In a LINAC, the lattice functions are not so precisely fixed due to the variable emittance orientation, leading to a less stringent relation between profile width and emittance.

This document resumes the current status of this diagnostic project, focusing on the test stand required to develop a SEM grid system, including its electronics.

SYSTEM DESCRIPTION

In order to develop a beam profile SEM grid system and other ESSB diagnostics devices, a vacuum test stand has been designed and manufactured. The test stand is currently being used to test a prototype of SEM grid, that will allow for the development of its corresponding signal conditioning electronics.

Vacuum Test Stand

Figure 1 shows the 3D CAD design of the vacuum test stand. This test stand is a vacuum system that allows the

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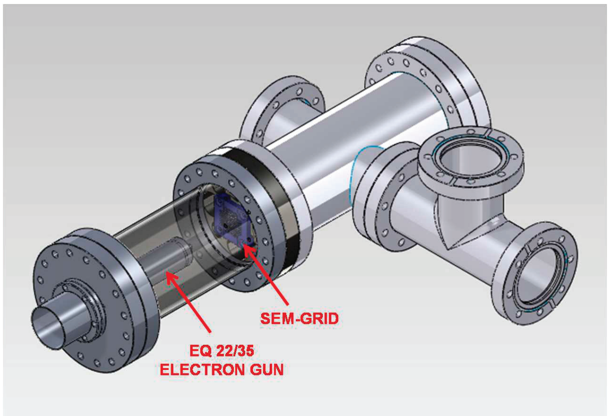

Figure 1: 3D CAD design of the vacuum test stand, showing the position of the SEM-Grid and the electron gun.

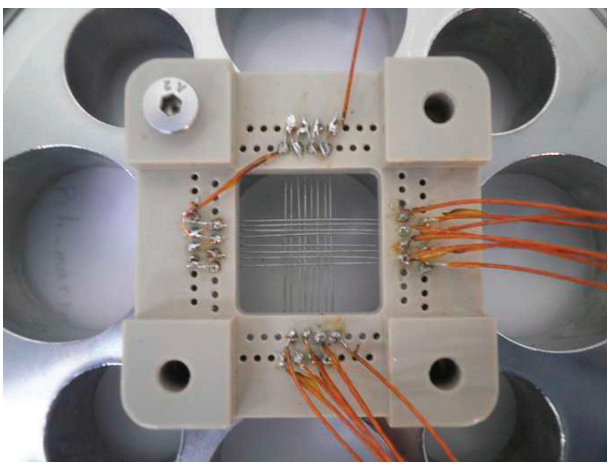

Figure 2: Picture of the first ESSB SEM-Grid prototype, assembled on its support, with the wires in common mode.

use of a comercial electron source EQ 22/35 with its power supply (PU-EQ 22/35 from SPECS) [5] as a beam injector. This electron source has an energy range from 0 to 5 KeV and a maximum beam current of 200 μA, and allows for the beam to be deflected ±5 mm from the initial position. Additionally, a beam chopper also from SPECS is generating beam pulses of up to 50 μs length. A phosphor screen is used in the test stand to visualize the electron beam possition (see Fig. 3-right). The vacuum is obtained using a turbo pump from Pfeiffer Vacuum.

A prototype of a SEM grid is placed in the test stand, and the electron beam is focused on its wires. Fig. 3 shows the system after assembly and in opperation.

SEM-Grid Design

Table 1 shows the key parameters of the SEM grid: number, length, diameter and spacing between the wires [2].

The baseline design for the ESSB SEM-Grid system calls for 40 Titanium (Ti) wires, 20 in horizontal direction and 20 in vertical one, spaced 1 mm from center to center, and an extra strip for grounding or bias voltage. Each

Figure 3: Left: internal view of the test stand, showing the SEM-Grid and the electron gun at the back. Right: beam spot impacting over one of the wires of the grid.

wire is 250 μm thick and will be mounted on a ceramic support. When electrons pass through the wires, secondary electrons are emitted and the current induced on the wire will be detected using an integrator amplifier. The ratio diameter-to-spacing of the wires determines the attenuation of the beam current [6] (and also the signal strength on the individual wires). Typically only 10% of the beam area is covered by the wires and in this sense the profile measurement is nearly non-destructive.

First Prototypes of the SEM-Grid

Although the baseline design calls for 40 wires, for the first tests a 16-wire prototype was assembled because our available acquisition cards are limited to that number of channels. Figure 2 shows a picture of the first prototype. The support is made of Polyether ether ketone, a vacuum compatible plastic (down to 10^{-7} mbar). It has 8 horizontal and 8 vertical, 250 μm diameter wires with a 1 mm pitch.

The wires are from Titanium (Ti), being tightened as much as the design allows. The grids to be used in the accelerator will be different and will require more thorough engineering. Ti was used as the active medium just because the loss of SEE signal from other materials after prolonged exposure in the beam [4, 6]. For long exposures to a centered beam a signal loss results, the meassured beam centroid magnitude decreases and beam tails are artificially enhanced. Ti suffers less from the loss of SEE signal.

Connections to the grid wires are made using Kapton® isolated copper wires from Kurt J. Lesker, connected to each end of the wires, and soldered to the copper pieces that clamp Titanium wires in place. Figure 2 shows the connections made in the prototype. The copper wires are connected on the other end to a 41-pin vacuum feedthrough on the test stand. Half of the wires will be connected to a single electronic channel and the other half are connected to a common. The current signals of the wires will be integrated and amplified to provide a significant voltage signal that can be measured by our acquisition system.

This first prototype is already assembled and tested in our vacuum test stand. Figure 3 shows the system working, the beam spot and the shadow of one of the wires of the first SEM grid prototype is shown on the picture of the right.

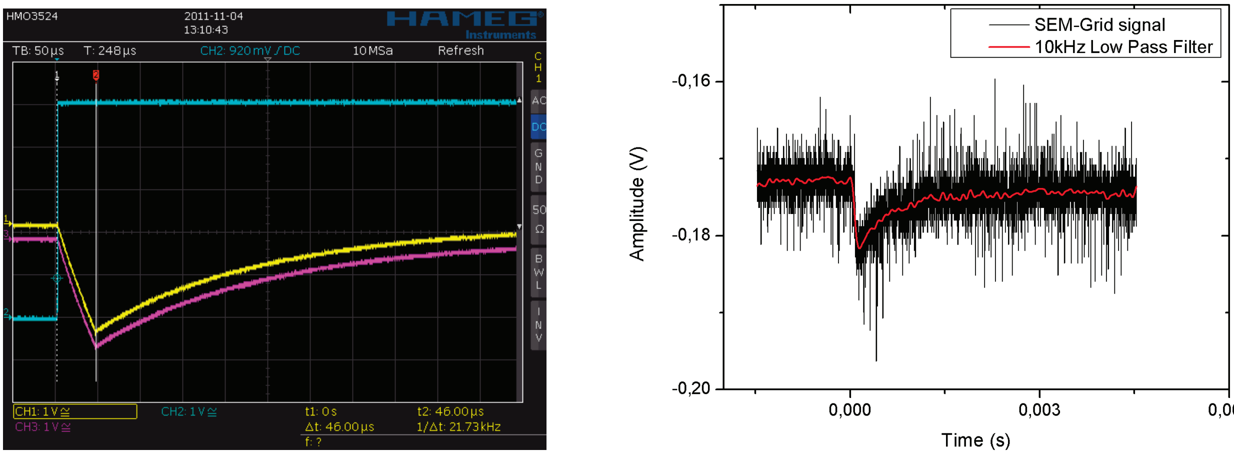

Figure 4: Left: pulse mode respone showing both the rise time (~50 μs) and the fall time (~500 μs). Right: 10 kHz low pass filter applied over a typical grid signal using OriginLab®.

To study the influence of the separation between wires, a second grid prototype was assembled. In this case the half of the 250 μm diameter wires were 1 mm apart, and the other half 2 mm appart. All else was the same as the first prototype. This prototype will be tested in the near future.

SEM-Grid Electronics System

The design of an electronics system for the SEM grid is the most important issue under development. The electronics will be based on a wide dynamic range integrator using a low noise op amp and a gain amplifier in order to provide a voltage signal that can be measured by the acquisition system. After the tests we must decide the integration time, the amplifier gain and the bias voltage required to avoid the electrons jump to neighbor wires (low bias voltage is required if we increase the distance between wires).

SIGNALS MEASUREMENTS

The ESSB SEM grid diagnostic system has been tested using the described test stand. Several tests have been carried out in order to measure and characterize the typical signals of the grid and to develop the electronics system.

Different types of beam conditions were selected in our test stand. The energy of the EQ 22/35 [5] was adjusted between 3 and 5 keV, being the current variable up to 200 μA. Both continuous (CW) and pulse (PM) modes were used in our measurements, using the Beam Chopper [5] for pulse mode. All the wires of the grid were connected to a feedthrough 41-pin Amphenol connector in the test stand, reading one side of each wire using a resistor to obtain a voltage signal and being the other side connected to ground.

Figure 4 presents an example of the signals measured with the first prototype of the SEM grid. The left-hand side of the Fig. 4 shows the response of the first SEM grid prototype to a PM beam measured between signal and ground. This figure shows both the rise time of the response signal (~50 μs) and also the fall time (~500 μs). The noise level of the wire signal is ~30 mV peak to peak. The right-hand side of the Fig. 4 shows a typical PM signal, applying a 10 kHz low pass filter using OriginLab®. This filter is implemented in our electronics we are already developing. Other filters were applied over these signals.

As it was explained in the previous section, a second SEM grid prototype is already assembled and it will be tested in our vacuum test stand in order to investigate the influence of the spacing between wires and the way to readout the wires. In this prototype, all the wires are connected to a single electronic channel. This means all the wires will be read in a differential mode.

SUMMARY AND CONCLUSIONS

With the objective of developing a SEM grid and the corresponding electronics system for the future ESS-Bilbao linac, a vacuum test stand and two grids prototypes have been developed. Several tests were performed to characterize our typical grid signals. The study of these kind of signals is useful in order to design an electronics acquisition system for the SEM grids that is under developing.

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