SECONDARY EMISSION GRIDS FOR LOW AND HIGH ENERGY ELECTRON BEAMS

M. Bernard, R. Chehab, T. Garvey, B. Jacquemard, O. Jouniaux, P. Roudier, J-L. Saury, A. Variola

Laboratoire de l'Accélérateur Linéaire IN2P3 - CNRS
et Université de Paris-Sud, 91405 Orsay Cedex, France

Y. Lussignol, M. Jablonka
CEA/DSM/DAPNIA Saclay, France

Abstract

In the framework of the TESLA test facility (TTF) project, transverse beam profile monitors using secondary electron emission grids have been studied and constructed. For the low energy beam (250 keV), implying short stopping ranges and high deposition in the grid material, titanium strips of only 12 micrometers thickness have been chosen. An SEM-Grid with 32 strips of 300 micrometers width and 400 micrometers separation has been put on the first part of the TTF injector. Secondary emission current is integrated and digitized. Data treatment done with standard VME provides beam profiles with the corresponding widths (FWHM, RMS, ...) which are sent to an EPICS data base in order to determine the beam emittance. The latter can be analyzed within the macropulse through a 100 ns step gating system. Other SEM-Grids designed for energy dispersion measurements at 10 and 500 MeV have been constructed. Two grids made of 40 wires of 20 micrometers diameter and 2 and 0.75 mm spacing respectively are provided with the same readout system as for the low energy grid. A description of the SEM-Grids with their electronic readout system is given here. Emphasis is put on heating and transparency problems which are very crucial for low energy beams. First results with the 250 keV beam obtained at Saclay are also presented.

1 INTRODUCTION

A test facility for the TESLA linear collider project (TTF) is being built at DESY-Hamburg. This 500 MeV linac has a high duty cycle (800 microseconds, 10 Hz repetition rate) with a peak intensity of 8 mA. Such intensity induces severe constraints on the destructive monitors dedicated to beam profile measurements. Various types have been developed for use with the pulsed beam of TTF. Many of them concerns secondary emission multigrids (SEM-Grids) and Transition Radiation in the Optical range (OTR) [1]. This note contains a presentation of different SEM-Grids to be used throughout the whole linac. The injector is made of a 250 keV electron source, a superconducting RF "capture cavity" to bunch and accelerate the incoming beam to energies of 8 to 14 MeV and a beam analysis station to measure the properties of the accelerated beam. SEM-Grids are used to measure the 250 keV beam profile from which the transverse emittance is derived. The energy dispersion of the 8-14 MeV beam is also measured with an appropriate SEM-Grid; a third grid, with a slightly different geometry is placed on the 500 MeV analysis line. A description of the SEM-Grids with their electronic readout system is given below. Results on the 250 keV beam profiles and emittance are presented.

2 BEAM PROFILES FOR LOW ENERGY BEAMS

An SEM-Grid is placed between the subharmonic buncher and the "capture cavity" to measure the vertical beam profile at 250 keV. This low energy beam implies short stopping ranges and high rate of energy deposition in the grid material. A comparison between different materials (Tungsten, Carbon, Beryllium, Titanium) led to the choice of titanium. Stopping range is about 130 microns; multiple scattering average angle is 0.7 rad for a 12 micron thick strip. The use of this grid is destructive for the beam and avoids any other measurement after it.

2.1 Heating problems

Ionization losses induce consequent heating in the material during the pulse duration or in the average regime.

2.2 Heating during pulse duration

The temperature rise during the pulse duration is given by:

$$\Delta T = \frac{\Delta U}{V.\delta.Csp} \tag{1}$$

where ΔU, represent the energy deposited in the strip,
V, the volume concerned by the beam impact,
δ, the material density,
C_{sp}, the specific heat. A 250 keV electron deposits an amount of energy per unit length of:

$$\frac{\Delta E}{\Delta S} = 3MeV/g\,cm^{-2} \tag{2}$$

This gives an amount of 13.6 MeV cm^{-1} for the titanium; temperature rise is less than 70^0 on the central strip for a gaussian beam distribution of $\sigma_x = \sigma_y$ = 2.5 mm and for a 800 μs pulse. Such heating can be tolerated even for smaller beam dimensions provided the total number of impinging electrons is decreased via pulse width reduction.

2.3 Average heating

For a large number of pulses, heat is dissipated by conductivity and radiation leading to an equilibrium:

$$\Delta E_p = \Delta E_d + \Delta E_r \tag{3}$$

Where ΔE_p, ΔE_d, ΔE_r represent the deposited energy and the energies dissipated by conductivity and radiation respectively. We get the following expressions: for the energies deposited/dissipated per unit time:

$$\frac{\Delta E_p}{\Delta t} = f \frac{\Delta N}{\Delta X} \cdot \frac{\Delta E}{\Delta S} \; L \cdot \ell$$

$$\frac{\Delta Ed}{\Delta t} = 2kL \cdot \ell \frac{\Delta T}{Y_o} \tag{4}$$

$$\frac{\Delta E_r}{\Delta t} = \sigma\epsilon[0.4LY_o][T_1^4 - T_2^4]$$

where, f represent the repetition frequency
$\frac{\Delta N}{\Delta x}$, the number of particles intercepted by the strip,
L and ℓ the width and thickness of the strip, respectively,
Y_o the strip length,
k, the thermal conductivity,
ΔT, the temperature increase $(T_1 - T_2)$ w.r.t the ambient,
σ, the Stefan-Boltzmann constant,
ϵ, emissivity factor of the material. A reasonable working regime, so as to limit the equilibrium temperature to 400^0 is to use 10 μs pulses 8 mA peak at 10 Hz repetition frequency for a titanium multigrid with $(L = 300\mu, \ell = 12\mu, Y_o = 5$ cms) and for a beam with 1 mm width rms.

2.4 Description of the multigrid

The multigrid is made of 32 titanium strips of 12 μm thickness; strip width of 300 μm and separation of 400 μm. The titanium multigrid is fixed on a ceramic support on which photolithography and engraving of the electrical patterns have been previously realised. An electrolytic gold layer (10 microns) has been deposited on the engraved pattern. The strips are obtained through chemical cutting on the titanium foil. The latter is then fitted on a frame applied on the engraved pattern; the strips are then stretched and electrically welded. A stainless steel grid, obtained by photolithography, is provided and put a few mm after the titanium grid: a bias voltage of 50 volts is put on the former.

2.5 Electronic readout

The SEM-Grid VME board was developped at LAL. Integrators with LF 356 OP-amps are connected to the strips. An adjustable gain amplifier is added in each channel. Digitisation is realised via a MAX 255 circuit. Each of these modules has 8 sample-and-holds with a multiplexer, an 8 bit ADC and an 8 bit x 8 channel memory. Data treatment is done on a Motorola MVME 162 LX board running Vx Works and the EPICS database system from LANL and ANL. The following specific tasks are performed:

- Measurement and averaging of profiles
- noise substraction
- Timing through a 100 ns gating system which allows profile analysis inside the macropulse
- calculation of beam area, mean and widths (RMS, FWHM, width for 90% of the intensity)
- storage of profiles and calculated data on Unix system files

The profile and the calculated data are stored in the EPICS database and may be seen on Unix displays with the EPICS MEDM tool. The displays allow to control the measurement parameters (amplifier gain, noise substraction, timing) and to save the data on files.

2.6 Emittance Determination

For each setting of the magnetic lenses preceeding the monitor, n profiles are taken, averaged and the corresponding widths (RMS, FWHM, ...) determined. The magnetic lenses setting values and the widths are then stored on a UNIX system file. The measurement process and the file storage are controlled from a display. At 250 keV, due to space charge effects, an appropriate procedure is needed for the emittance calculation. It uses the integration of the Kapchinsky- Vladiminsky envelope equation[2]:

$$R'' + \frac{K}{m_o} R - \frac{\epsilon^2}{R^3} - \frac{qI}{2\pi\epsilon_o mo(\beta\gamma c)^3 R} = 0 \tag{5}$$

where we take for R twice the RMS value and for I, the total intensity: This equation is integrated successively for n different settings of the magnetic lens placed before the SEM-Grid. The calculated radii are then compared to the measured ones and a least square fit method allows the value of the emittance, the radius and divergence of the beam upstream of the magnet to be determined. The Twiss coefficients are then derived and the ellipse constructed and displayed.

3 BEAM PROFILES FOR HIGH ENERGY ELECTRON BEAMS [10 MEV, 500 MEV]

Multigrids are made of 40 tungsten wires with 20 μm diameter and 2 or 0.75 mm separation. As for the titanium multigrid, a polarized grid (50 volts) is put 5 mm after the multigrid in order to capture the secondary electrons. Except for the wires, the technology used is similar to that of the titanium grid. The electronics readout is the same as well as the procedure for width determination. However the application is here, different. These grids are dedicated to the energy dispersion measurement at 10 and 500 MeV and are placed in the horizontal focal plane of the analyzing magnet. The dispersion coefficient is 16 mm/% at 10 MeV and 12 mm/% at 500 MeV. The expected resolution is 10^{-3}. The gating system will allow energy dispersion analysis inside the macropulse (800 μs).

4 EXPERIMENTAL RESULTS ON THE TTF INJECTOR

Measurements have been performed on the first part of the injector at 250 keV. The SEM-Grid provided beam profiles: examples are presented on figure 2. Following the method described above the beam emittance has been derived. A set of beam dimension (2 σ) vs the intensity in the magnetic lens is represented on figure 3. The normalized emittance found is 12 mm mrad which agrees with a preceeding measurement previously done at Saclay with a 3-wire monitor [3].

5 SUMMARY AND CONCLUSIONS

SEM-Grids with different materials and geometries are used on TTF injector. They provide good resolution, (much less than 1 mm), excellent signal to noise ratio. The first results, obtained at low energy, showed also good reliability and behaviour with intense beams (5.10^{11} e^-/pulse).

6 REFERENCES

[1] A Variola et al, this Conference

[2] B. Aune et al, “A device for gun emittance measurement” - IEEE Trans. Nucl NS -32 (1985) 1896

[3] M. Jablonka et al, this Conference

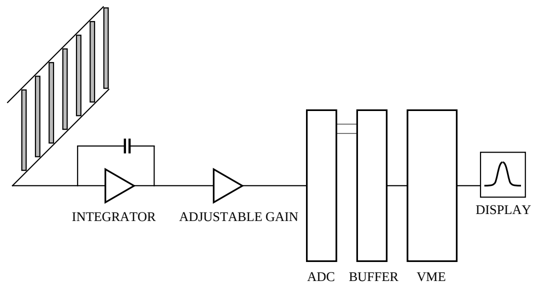

Figure 1: Block diagram of the SEM-Grid Electronics

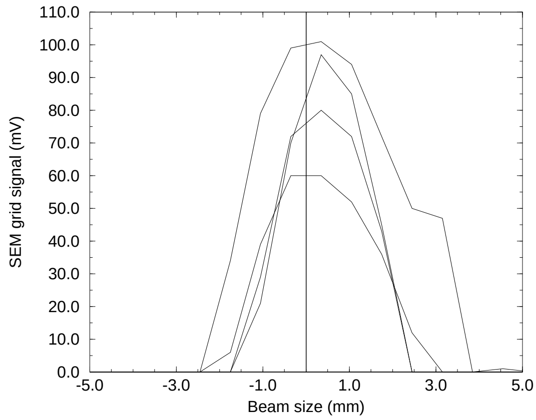

Figure 2: Beam Profiles

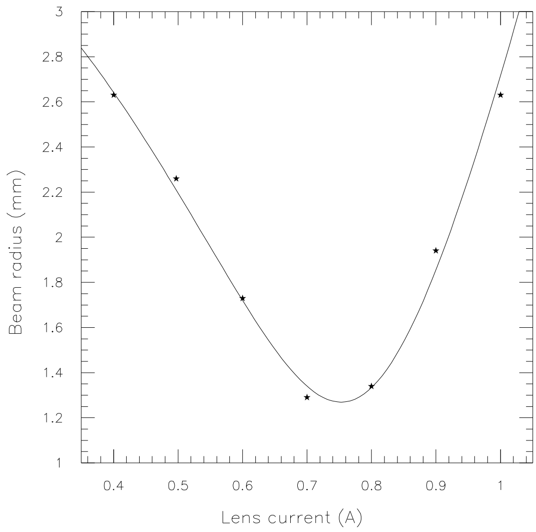

Figure 3: Beam dimensions vs lens intensity