SPECTRUM OF THE LOW ENERGY ELECTRONS BOMBARDING THE WALL IN THE ANKA STORANGE RING

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Abstract

Recent investigations with the cold bore superconducting undulator installed at ANKA indicate that the main contribution to the beam heat load is caused by electron bombardment [1], [2]. For a quantitative understanding of the problem a cold vacuum chamber for diagnostics (COLDDIAG) is in the design phase [3]. In this contribution we report on the first measurements of the spectrum of the low energy electrons bombarding the wall of the cold vacuum chamber in a room temperature region of the ANKA storage ring performed using a in house developed retarding field analyzer (RFA). The calibration of the RFA performed at the national laboratories of Frascati is also described.

INTRODUCTION

Superconducting insertion devices (IDs) have higher fields for a given gap and period length compared with the state of the art technology of permanent magnets. This technological solution is very interesting for synchrotron light sources since it permits to increase the brilliance and/or the photon energy at moderate costs. One of the key issues for the development of superconducting IDs is the understanding of the beam heat load to the cold vacuum chamber. Possible beam heat load sources are, synchrotron radiation, resistive wall heating, other RF effects and electron and/or ion bombardment. Both, synchrotron radiation and resistive wall heating losses can be computed [1], [4]. The values according to these effects have been calculated and compared for the different cold vacuum chambers with the measured values. The difference between beam heat load measured and calculated is not understood. Two factors are influencing the electron accumulation, that is the beam and the chamber surface characteristics [1].

RETRADING FIELD ANALYZER (RFA)

The RFA is an integrating device that transmits electrons with energy greater than the retarding grid voltage. In principle, the derivative of the collector current with respect to the grid voltage is proportional to the electron energy spectrum. The in house developed RFA is shown in Fig. 1. The detector is mounted behind a vacuum penetration slotted disc. On the left and right of the beam axis are left 5 mm of solid material to reduce RF effects. As shown in Fig. 2 the slotted disc is grounded to present a uniform field to the incoming electrons, so that the electrons inside the vacuum chamber do not see an effective electric field from the RFA which would spoil the measurement. The electrons travel through the slotted disc with their kinetic momentum and are then decelerated by the grid voltage. The retarding grid is biased at a retarding potential V_r such that only electrons with kinetic energies greater than $W_{kin} = e \cdot V_r$ are transmitted to the collector. The collector is biased with a positive voltage to attract all the electrons transmitted through the grid. The collector current (i.e. electron flux) is measured with a picoamperemeter. The electron energy spectrum is proportional to the derivative of the measured collector current with respect to the grid bias.

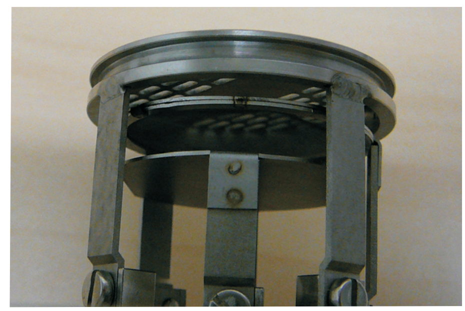

Figure 1: Picture of the in house developed retarding field analyzer.

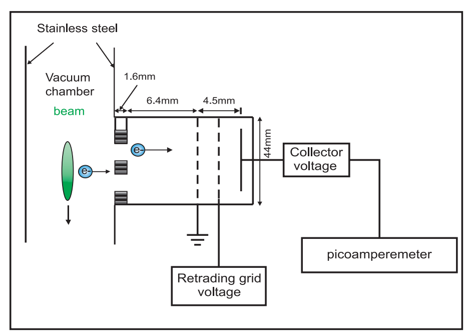

Figure 2: Sketch of the experimental set up of the RFA.

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CALIBRATION OF THE RFA

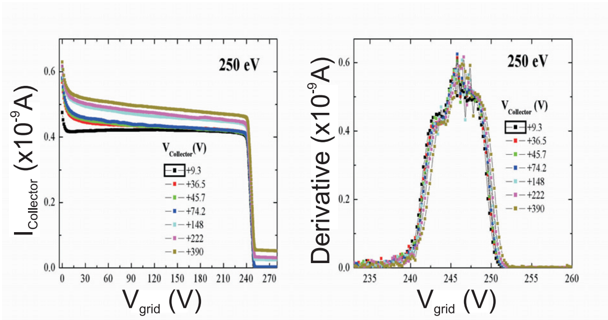

Figure 3: Results of the calibration for 250eV beam energy. Left plot: collector current over grid voltage. On right: correspondent derivative in the region when the beam energy equals the grid voltage.

The calibration has been performed at LNF (Frascati) in a UHV chamber with a vacuum better than 10^{-10} Torr after bake-out. In a first set up the beam was generated by an electron gun (OMICRON) which allows a stable operation for beam currents with energies between 10 eV to 250 eV. The current was in the order of nA and was measured with a Faraday cup. The gun was mounted in front of the detector. It was possible to study its response to the variation of the energy of beams from 10 eV to 250 eV. The data were acquired with a customized LABVIEW program which allows to scan the negative voltage of the grid from the lowest to the highest value and to acquire consequently the current on the collector. Both operations were performed by using a Keithley amperemeter and voltage source (model 6487 controlled by LABVIEW). Residual noise was minimized by using a NIM power supply for the grid. Signals could be acquired also at low energies, for a low current of the incident beam. The collector was positively biased with floating batteries which do not introduce noise in the measured current. Fig. 3 shows the result for an electron beam energy of 250 eV. A characteristic step in the collector current can be observed when the beam energy equals the grid voltage. The correspondent derivative at the area of the step voltage represents the sensitivity of the RFA. The collector voltage was varied from +9V to +390 V in order to understand the effect of different voltages on the shape of the curves. The measurements reveal that at different electron beam energies the shape and the width of the step is independent from the applied voltage of the collector. The accuracy of the RFA is shown in table 1, where the full width at half maximum (FWHM) of the derived peaks with corresponding collector voltage is listed.

Additional tests are still underway. The goal of this second phase of calibration is to study how the RFA is able to acquire electrons emitted from a Cu sample bombarded with electron beams at various energies. Therefore the sample is mounted isolated from ground in order to apply on it different negative bias and to read the current of sample generated by beams [5]. The first results indicate that in this case such a simple analyzer as the RFA, detects mainly the low energy electrons which are created at its grids and not the real energy distribution curves produced by the sample. This call for a more careful analysis of the data obtained, and the need of using better analyzer to finally certify the energy spectrum of low kinetic electrons in a storage ring.

Table 1: Full width at half maximum (FWHM) of the derived peaks (s. Fig. 3 below) at the corresponding electron energy and collector voltage.

Energy [eV]	$V_{Collector}$ [V]	Δ_{FWHM} [V]
250	+74.2	7.6
200	+74.2	8.3
180	+45.7	3.9
150	+45.7	5.8
100	+74.2	4.3
80	+148	3.3
70	+148	2.5
60	+45.7	3.1
50	+74.2	2.1
40	+36.5	2.7
30	+45.7	2.1
20	+9.3	1.4
10	+74.2	1.6

EXPERIMENTAL SETUP

The RFA was successfully implemented in the ANKA storage ring. It is located about 1 m after the superconducting undulator. The experimental setup can be seen in Fig. 2. In order to suppress the high frequency signal coming from the beam time structure (revolution frequency = 2.7 MHz, 2 ns bunch spacing corresponding to 500 MHz) low pass filter with cut off frequency $f_L = 50$ kHz is used between the collector and the picoamperemeter. The two channel DC voltage supply (ISEG module) allows biasing the grid and the collector between -200 V and +200 V. A picoamperemeter (Keithley) is used to read the collector current.

RESULTS

Fig. 4 shows the collector current $I_{collector}$ against the grid voltage U_{grid} and the correspondent derivative. $I_{collector}$ decreases almost 80% by changing the grid bias from 0 V to 20 V. This is evidence that the biggest contribution of $I_{collector}$ is due to low energy electrons. The main contribution of the signal comes from low kinetic electrons with energies below 20 eV. The maximum of the electron energy distribution N(E) is at around 5 eV. The electron energy spectra are plotted with the error bars as derived from the calibration of the RFA in the laboratory. Measurements were performed at different collector voltages to investigate its possible influence on the energy spectra. The plot

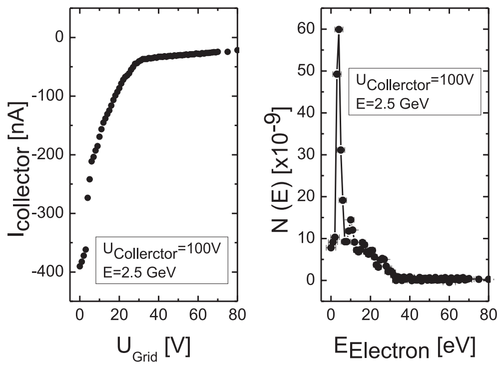

Figure 4: Measurements at the ANKA storage (beam energy 2.5 GeV, beam current approx. 110 mA, grid voltage 100 V). Left plot: $I_{collector}$ against U_{grid}. On the right: correspondent derivative.

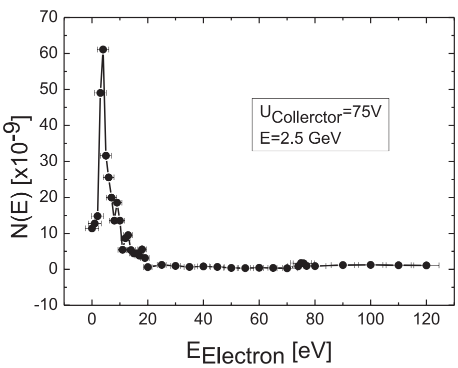

Figure 5: Electron energy spectrum at 2.5 GeV and a grid voltage of 75 V.

of the spectrum of the kinetic electrons in Fig. 5 was obtained with similar parameters as that in figure 4: Only the collector voltage was changed from 50 V to 75 V The beam energy was 2.5 GeV and the beam current was at about 110 mA. As expected there is no observable effect on the spectrum. In contrast the beam energy has an influence on the shape of the spectrum. This becomes evident by comparing

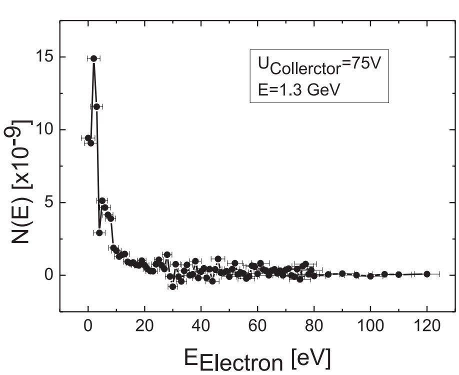

Figure 6: Electron energy spectrum at 1.3 GeV and a grid voltage of 75 V.

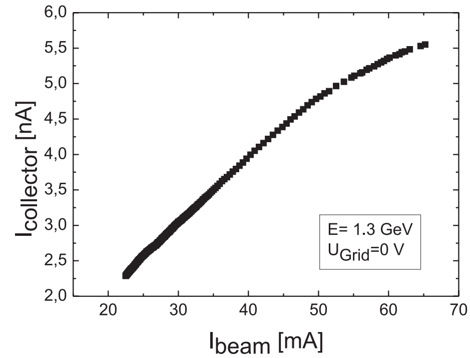

Figure 7: Collector current as a function of the electron beam current at 1.3 GeV with $U_{collector}$ = 50 V and U_{grid} = 0V.

the spectra in Fig. 5 with a beam energy of 2.5 GeV and Fig. 6 6 with 1.3 GeV. The maximum is shifted to lower energies and also the collector current seems to decrease more (i.e. almost 80% of the signal decays by changing the grid bias from 0 V to 15 V). In order to study the dependence of the amount of electrons impinging the wall as a function of the beam current the grid voltage was set to 0 volts and the collector voltage was set to a value of 50 V. The result is shown in Fig. 7. Clearly a divergence of a linear dependence can be observed.

SUMMARY AND OUTLOOK

The presented investigations verify the existence of low energy electrons which bombard the wall of the room temperature vacuum chamber in the ANKA storage ring. It was possible to determine energy spectra of low energy electrons which are claimed as one source for the heat load to the cold bore of superconducting undulators Resent RFA calibration measurements in the laboratory at LNF (Frascati) reveal that the acquired data might to be interpreted more carefully. The values of the flux and energy of the electrons bombarding the wall measured with the RFA have to certified with a better analyzer. Therefore a cylindrical sector field analyzer will be used. This will allow us to calibrate the RFA and eventually modify its design to improve its performance for this particular application.

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