DIRECT DETECTION OF THE ELECTRON CLOUD AT ANKA

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Abstract

Low energy electrons generated by the interaction of high energy particles with the beam pipe surface can be detrimental for accelerators performances increasing the vacuum pressure, the heat load and eventually producing beam instabilities. The low energy electrons accumulating in the beam pipe are often referred to as electron cloud. In this presentation we report on the direct evidence of the electron cloud in the electron storage ring of the synchrotron light source ANKA (ANgstrom source KArlsruhe).

INTRODUCTION

Preliminary studies performed with the cold bore superconducting undulator installed in the ANKA storage ring suggest that the beam heat load is mainly due to the electron wall bombardment [1]. The beam heat load due to the electron cloud $P_{\rm el}$ is roughly given by:

$$P_{\rm el} = \Delta W \cdot \dot{N}, \qquad (1)$$

where ΔW is the energy increase of one electron due to the kick by a bunch and $\dot{N}$ is the number of electrons hitting the wall per unit time. A direct measurement of the total beam heat load P and of the electron cloud flux $\dot{N}$ and energy ΔW to the walls of a vacuum chamber at cryogenic temperatures would give useful informations to understand electron bombardment as heating mechanism to a cold vacuum chamber. Performing this measurement is not straightforward; to this end we plan to build a dedicated cold vacuum chamber for diagnostics to measure the electron energy and flux of the electrons bombarding the wall, the heat load, the pressure, and the gas composition [2]. In this contribution we report on measurements performed in the room temperature region of the ring proving the existence of low energy electrons bombarding the wall of the room temperature vacuum chamber in the ANKA storage ring using as a pick up a clearing electrode. First simulations using the ECLOUD code [3] adapted to an electron beam are also presented.

EXPERIMENTAL SETUP

In the upper part of Fig. 1 is shown the position of the clearing electrode in the ANKA storage ring. Of relevance

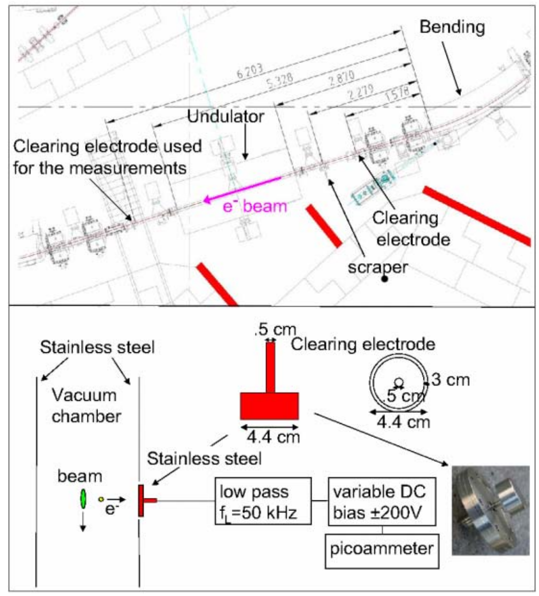

Figure 1: **Top**: Location of the clearing electrode used to detect the low energy electrons in the storage ring ANKA. **Bottom**: Experimental set up used to detect the low energy electrons filling the room temperature region of the beam pipe.

for the results presented in the following is that it is located after the superconducting undulator. The experimental set up is sketched in the lower part of Fig. 1. The low pass filter with cutoff frequency $f_L = 50$ kHz is used to suppress the high frequency signal coming from the beam time structure (revolution frequency = 2.7 MHz, bunch spacing=2 ns corresponding to 500 MHz). The clearing electrode is made of stainless steel and is electrically isolated from the rest of the beam pipe. The DC Voltage supply (ISEG module) allows to bias the electrode between -200 V and +200 V. The picoammeter (Keithley) is used to read the current flowing through the electrode.

RESULTS

Biasing the electrode with negative bias the electrons are repelled from it, while biasing it with positive bias the low energy electrons filling the beam pipe are collected. This

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is demonstrated in Fig. 2. Figure 3 shows the importance

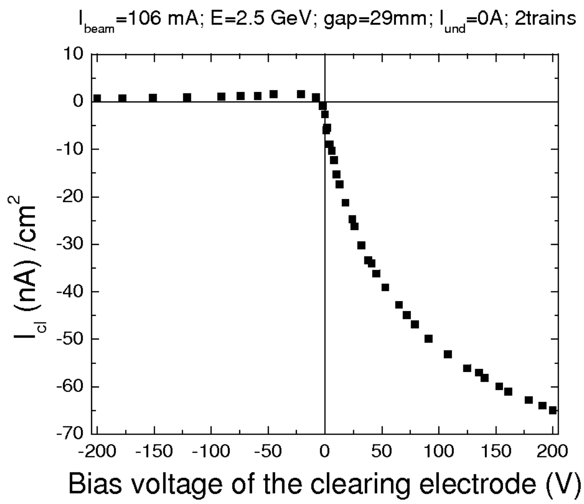

Figure 2: Clearing electrode current per cm^2 as a function of the bias voltage.

of photoelectrons to the clearing electrode current. In order to screen the superconducting undulator from the synchrotron radiation produced by the upstrem bending magnet a scraper is moved in during the energy ramp. The scraper position is also reported as a function of beam energy in Fig. 3. The area of the beam vacuum chamber at the clearing electrode position marked in orange in the inset is shadowed when the scraper horizontal position is smaller than 14.2 mm: when this happens the flux of electrons collected by the clearing electrode decreases by more than one order of magnitude. Figure 4a) reports the elec-

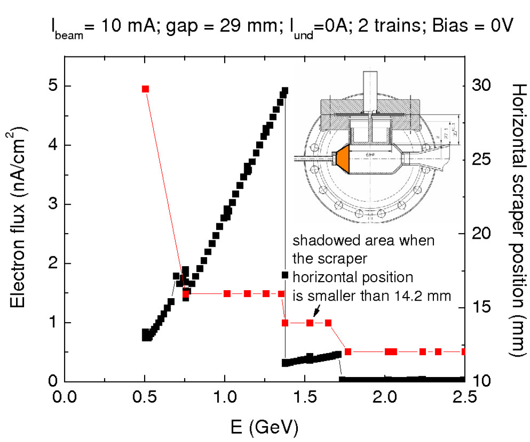

Figure 3: Electron flux as a function of the electron beam energy.

tron flux dependence on the average electron beam current. The lower current measured at bias 0 V in Fig. 3 at 2.5 GeV and 10 mA with respect to the one reported in Fig. 4a) is to be attributed to a lower illumination of the vacuum cham-

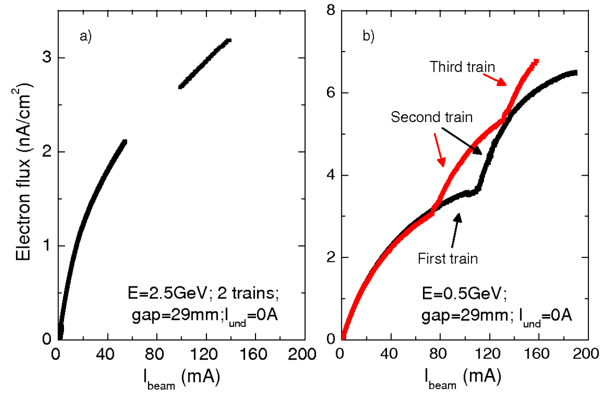

Figure 4: **a)**: Electron flux as a function of the electron beam current. **b)**: Electron flux as a function of the electron beam current during injection at a beam energy of 0.5 GeV.

ber due to a change in the orbit. The (low energy) electron current depends non linearly on the beam intensity, see Fig. 4a). In case we would only deal with photoelectrons we would expect no dependence on the filling pattern. In Fig. 4b) is reported the low energy electrons current during injection at a beam energy of 0.5 GeV. ANKA can be filled with one bunch train consisting of 32 bunches with a bunch spacing of 2 ns, or two or three bunch trains separated by 120 ns. The injection is done filling first the first train, then the second and eventually the third. Here the dependence of the electron flux on the filling pattern is evident. At 2.5 GeV the electron flux is slightly higher (about 5%) for the fill with two trains with respect to the one with three trains, so for a higher bunch current. More investigations are needed to study the dependence of the low energy electron flux to the wall on the bunch current.

ECLOUD SIMULATIONS

We have performed several computer simulations using the program ECLOUD [3] to crosscheck the experimental results. Reproducing the bunch pattern with two trains, we have scanned the beam intensity (through the bunch intensity). Table 1 lists the parameters used in the simulations. The evolution of the electron density as a function of time is shown in Fig. 5 for different beam intensities. An interesting behaviour found using the ECLOUD simulations is that the electron density does not reach a saturated level after 5 turns, but it keeps slowly increasing from turn 1 to turn 5. This behaviour is currently under study.

The average electron density at turn 5 as a function of the beam intensity is shown in Fig. 6 (red points). The linear dependence behaviour, and the absence of any onset suggesting an electron avalanche effect is an indication that no multipacting takes place at the clearing electrode location, and that the electron flux is due to the accumulation of photoelectrons produced by synchrotron radiation.

Figure 6 (blue triangles) shows the flux hitting an elec-

Table 1: Input parameters used in the ECLOUD simulations to scan the beam intensity between 10 and 150 mA in a two trains bunch pattern.

Parameter	value
# of bunches / turn	64
particle beam energy, E[GeV]	2.5
# parts per bunch, N_b [e-/bunch]	[0.35 - 5.4] e9
bunch spacing, sb [m]	0.6
bunch length, σ_z [mm]	12
hor / ver rms beam size, mm	.840 / .063
hor / ver chamber aperture, mm	80 / 29
secondary emission yield, $\delta_{\max}$	2.0
energy for max SEY, $E_{\max}$ [eV]	290.
primary ph-e emission yield	0.005
energy ph-e, position of peak [eV]	7.
energy ph-e, sigma distrb. [eV]	5.
energy sec. e-, sigma distrb. [eV]	1.8

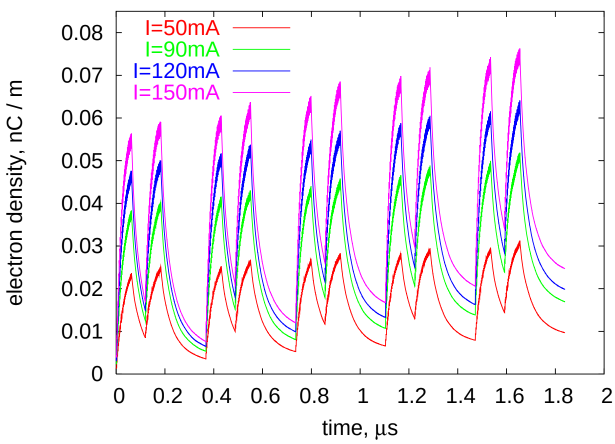

Figure 5: Evolution of the electron density as a function of time during 5 turns for different beam intensities.

trode of radius 2 cm located at the center of the rectangular vacuum chamber. Photoemitted electrons grow linearly with the beam current, while the blue triangles in Fig. 6 describe a square root behaviour attributed to the space charge effects, which repel the electrons away from the center of the chamber – similar to the behaviour observed in Fig. 4b). The flux is slightly smaller in the simulations than in the experimental results, but the difference is not significantly large.

OUTLOOK

To measure the flux and spectrum of the low energy electrons bombarding the wall we plan to use in house developed retarding field analysers, that are cheap and can be easily implemented in the cold vacuum chamber. To have a reference for the quality of the in house developed retarding field analyzer we have bought an electron energy

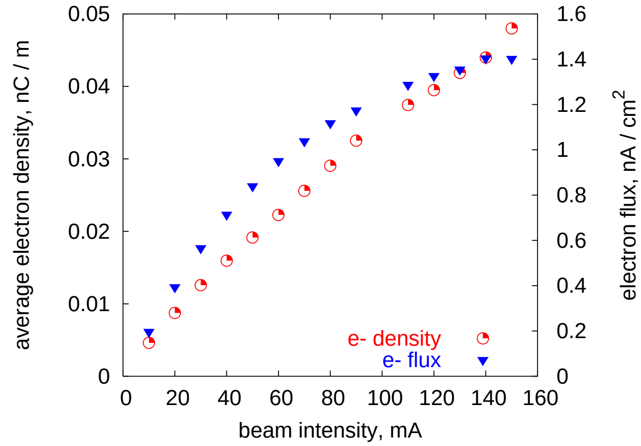

Figure 6: Average electron density as a function of the electron beam current (red points), while the blue triangles show the flux hitting an electrode of radius 2 cm located at the center of the rectangular vacuum chamber as a function of the electron beam current.

analyzer, which permits to measure with high accuracy the energy spectrum of the low energy electrons bombarding the wall in the room temperature region of the beam pipe. Concerning the simulations we plan to study the effect of long simulations (more than 6 turns) and the effect of the initial location of the photoelectrons, which will help us to study the effect of the scraper.

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