EXPERIMENTAL DETERMINATION OF E-CLOUD SIMULATION INPUT PARAMETERS FOR DAΦNE*

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Abstract

DAΦNE is an electron-positron collider with 1.02 GeV center of mass energy. For each circulating beam the maximum design current is 5 A. Preliminary simulations predicted e-cloud induced beam instabilities in the positron ring. Such calculations were based on literature results on aluminum reflectivity, photon yield, etc., not directly measured from the actual DAΦNE chamber wall material. Here we show how calculations strongly depend on the assumed reflectivity and photon yield values. These two quantities have been measured using synchrotron radiation on samples prepared and made of the same aluminum alloy (Al 5083) used for the storage ring of DAΦNE. The obtained experimental results are implemented in the calculations.

INTRODUCTION

Low-energy background electrons in particle accelerators can interfere with the correct operation of the machine itself; there are operating conditions that can lead to large amplification of the electronic cloud. The electrons can be produced directly by ionization of the residual gas molecules or by irradiation of the vacuum chamber surfaces by synchrotron radiation, ions, beam particles, or electrons themselves. If the cloud density becomes sufficiently large, the beam-cloud interaction can degrade the particle beam. In positive charged particle rings, the electron cloud can oscillate synchronously with the particle bunches, giving rise to an exponentially growth of the electron density. This phenomenon, called *multipacting*, is manifested by an anomalous vacuum pressure rise and can produce beam instabilities. In order to predict, and possibly prevent these problems, some simulations must be performed on the formation and development of the electron cloud in accelerator rings.

These arguments apply also to the case of the DAΦNE Φ-Factory[1,2,3,4]: it is a twin ring 510 MeV electron-positron collider facility at INFN-LNF Frascati National Laboratories (Italy). The collider consists of two symmetric and concentric main rings, about 100m long, laying in the same horizontal plane, sharing two interaction regions (IR), in which the electron/positron beams cross at a small tunable angle of ±12.5 mrad. The luminosity peak value is given by:

$$L_{peak} \propto \frac{I^+ I^-}{4\pi\sigma_x\sigma_y}$$

where I^+ and I^- are the colliding beam total currents and σ_x and σ_y are the beam sizes in the collision point. Any effect that prevents the above quantities to reach their design values has to be studied and counteracted, as it is the case of the e-cloud buildup that limits the maximum positron current in the storage ring, as explained above.

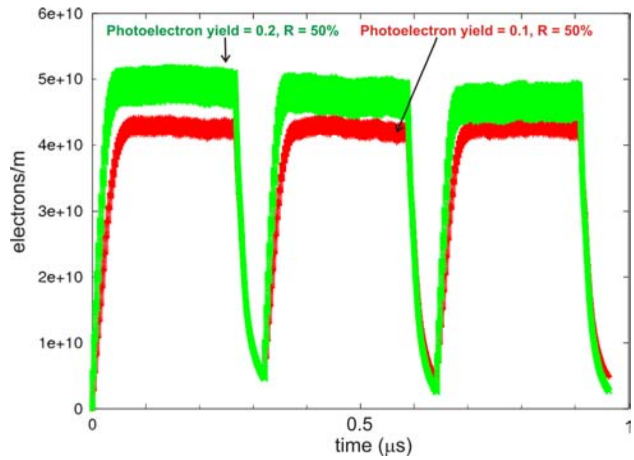

Figure 1: mean e-cloud linear density in the storage ring calculated for two different photoelectron yield values (0.2 and 0.1) with a reflectivity of 50%.

CALCULATIONS

Several codes are available to evaluate e-cloud density around the circulating beam, but most of the parameters are strictly dependent upon the vacuum chamber geometry, the material choice, and its surface finishing.

Here we concentrate on the relevance of photon reflectivity and photon yield on the simulated e-cloud build up. The ECLOUD code [5] has been used to simulate the average e-cloud linear density as a function of reflectivity and photoelectron yield. This is shown Fig 1-2 where it is clear the importance of using the appropriate parameters. In Fig. 1 the e-cloud linear density is reported for two different photoelectron yield values, while in Fig 2 the electron density is plotted changing the reflectivity. The effect on the electron density is relevant for both the two cases and shows how much is important the exact knowledge of these parameters in order to obtain a reliable estimation of the e-cloud effect impact on the collider performance and its remedy efficiency.

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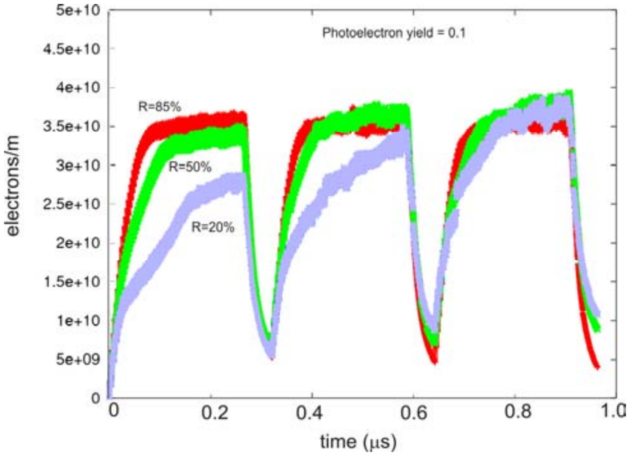

Figure 2: mean e-cloud linear density plotted changing the value of the reflectivity (85%, 50%, and 20%) with a photoelectron yield of 0.1.

EXPERIMENTAL RESULTS

The reflectivity $R(\omega)$ and the photoelectron yield $Y(\omega)$ have been measured at the BEAR beamline at Elettra (Trieste, Italy) [6] in the photon energy range from 10 to 1000 eV, using a calibrated photodiode (AXUV100 by the IRD Inc.) [7] and a picoammeter for the measure of the drain current. The sample is made of the material used for the vacuum vessel (an aluminum alloy Al 5083-H321). The six degrees of freedom of the spectroscopy chamber of the beamline [8] allowed us to measure the specularly reflected light impinging onto the sample at three different incidence angles (85°, 45°, and 5°), and the diffused light setting the photodiode far from the specular direction. A tungsten mesh, absorbing about 10% of the incoming flux, calibrated with the directly illuminated photon detector, was used to constantly monitor the incoming flux. The results are presented in Fig 3 and 4 for the specular reflectivity. The diffused light was also measured and was negligible in all cases. We can calculate the total light intensity reflected by the DAΦNE walls. It is given by:

$$I_r = \int_0^\infty d\omega I(\omega) R(\omega)$$

where $I(\omega)$ is the synchrotron radiation photon flux produced in the bending sections of DAΦNE with a ring current of 1 A. The integrated reflectivity I_r/I ($I = \int_0^\infty d\omega I(\omega)$) calculated for the incidence angles 85°, 45°, and 5° is reported in the following table.

θ_i	I_r / I
85°	27%
45°	0.2%
5°	0.1%

Fig 5 shows the number of photons reflected by the DAΦNE walls as function of the incident photon energy.

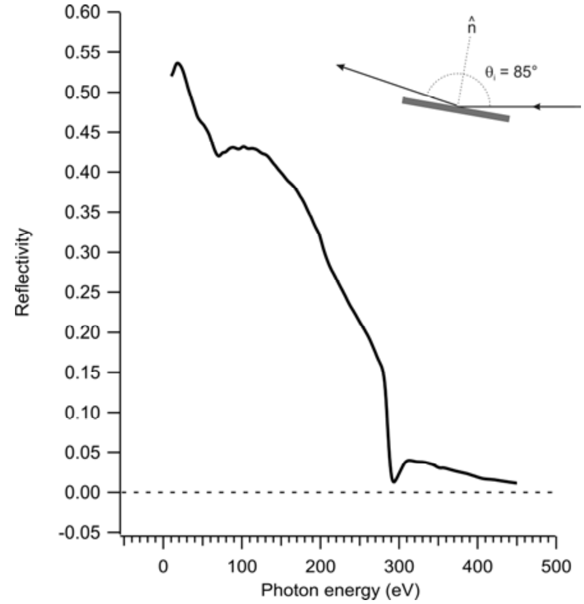

Figure 3: Reflectivity measurement with an incidence angle of 85°.

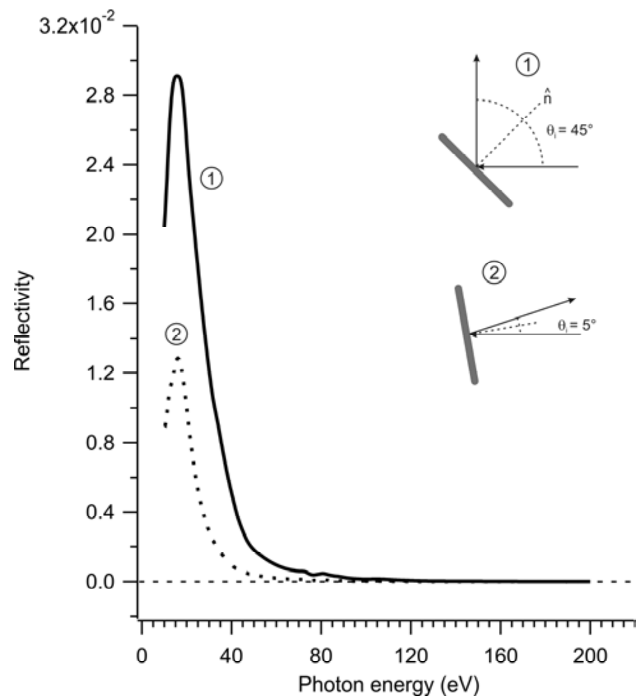

Figure 4: Reflectivity measurement with an incidence angle of 45° (1) and 5° (2).

The used experimental apparatus permits us to determine the photoelectron yield (PY), i.e. the number of electrons produced by an incident photon. The number of electrons emitted by the material is determined measuring the current I_{sample} drained by the sample when it is illuminated by the photon flux. The calculated photoelectron yield values are plotted in Fig 6.

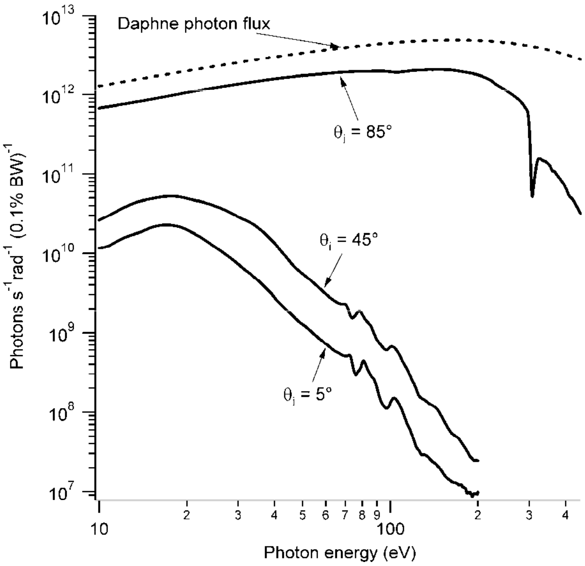

Figure 5: Number of reflected photons obtained by the reflectivity curves at incidence angle θ_I = 85°, 45°, 5°.

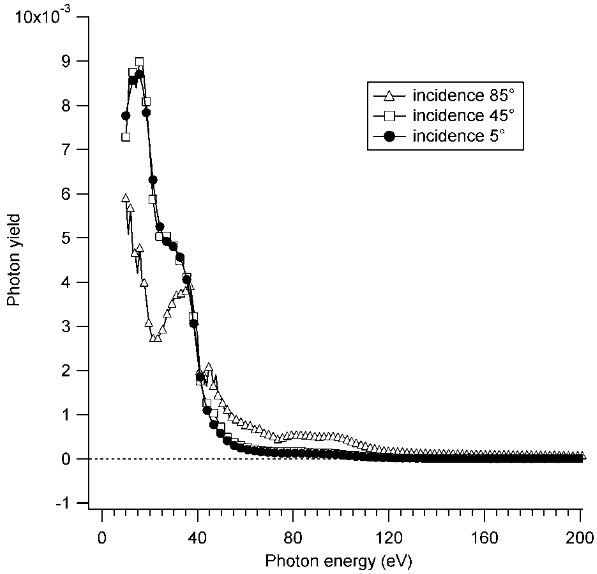

Figure 6: Photoelectron yield of the Al sample measured at incidence angles 85°, 45°, and 5°.

The total PY is calculated by integration of the plot and it gives the total number of electrons produced by the material when it is illuminated by photons in the range 10-1000 eV. The total PY is about 0.2 in all three cases even though the shape of the three curves are slightly different. For grazing incidence (85°) the PY is higher than that measured at 45° and 5° for photon energies greater than about 40 eV, while at smaller incidence angles the PY is much more significant at lower energies. The PY curves for incidence 45° and 5° are almost the same at low energies (between 10 eV and 100 eV).

CONCLUSIONS

Electron cloud simulations have been performed to study the dependence of the obtained results from the values of reflectivity and photoelectron yield used to perform the simulations. The results suggest the need of using experimentally determined values to be able to extract reliable predictions of e-cloud build up. Synchrotron radiation studies showed that the parameters used so far in the simulations are different from the experimental data obtained from the Al samples representative of the DAΦNE vacuum chamber. The code has been implemented with the measured values. This suggests the need to extract experimental values for reflectivity and photoelectron yield of the material used in other accelerator machines where electron cloud simulations are required.

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* This work is partly supported by the Commission of the European Communities under the 6th Framework Programme "Structuring the European Research Area", contract number RIDS-011899.

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