Title
Closing Remarks

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CLOSING REMARKS*

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Abstract

I present my impressions on the talks presented at the ECLOUD'04 Workshop. The list is is incomplete, and reflects my points of view.

SUMMARY

We had 59 attendees from many institutions around the world. Most attendees were also speakers, who gave excellent presentations on a broad spectrum of topics related to the electron-cloud effects. I regret the absence of 4 participants who did not attend on account of problems with the new entry requirements into the US.

There has been great progress since the ECLOUD'02 workshop (CERN, April 2002). The "crash program" initiated at CERN some 6 years ago keeps yielding valuable new results, both experimental and simulated, particularly from the SPS when operated with LHC-style beams. This program will provide essential expertise for the commissioning of the LHC vis-à-vis the electron-cloud effect. We have also seen the rise of new constituencies from intense hadron storage rings. The electron-cloud phenomenon at the PSR is now firmly established and well understood in most aspects. Based on the PSR experience, the SNS is preparing for an electron cloud and taking steps to mitigate it by coating the vacuum chamber with TiN. The existence of the electron cloud at RHIC is now firmly established in the room-temperature sections; it is inferred to exist in the cold regions, although there are no direct observations in this case. The electron cloud is anticipated to play a significant role in heavy-ion fusion drivers. As a result, a program of simulations and bench measurements has been set up at LBNL. Our community is thus enriched by the experience brought in by practitioners with long-standing expertise in 3D simulations of space-charge dominated beams and ion-surface interactions.

A new generation of simulations is emerging, involving 3D parallel PIC codes. These hold the promise of more detailed and precise calculations, although the predictive power of such tools is likely to remain limited by the uncertainties in the input quantities required by the simulations. In particular, electronic surface properties are critical, as the average electron-cloud density depends sensitively on them in most practical cases. Unfortunately, these properties are hard to measure in the regime of practical interest. Furthermore, the secondary emission yield is sensitive to the treatment, conditioning state, and history of the surface. Detailed bench measurements obtained at CERN on copper samples show that the true secondary component of the secondary electron emission yield conditions nicely with electron bombardment, but not not so the reflected component at low energy. These measurements are consistent with operational experience at the PSR, which has a stainless steel chamber. The electron-cloud effect, therefore, is self-conditioning and time-dependent.

At the SPS, a strong conditioning effect has been observed that significantly reduces the electron cloud intensity over a time scale of hours to days. The conditioning of the LHC vacuum chamber surface, however, will probably be more subtle than at the SPS. In the LHC there will be substantial synchrotron radiation striking the surface at top beam energy, but the surface will be cold. Generally speaking, the conditioning effect proceeds faster for intense beams of closely-spaced bunches. Such beam configurations will be impossible or impractical in the LHC, where one must balance the conditioning requirements against the need to avoid quenches and beam dumps. Therefore, it remains of paramount importance to specify an optimal conditioning protocol for the LHC commissioning.

In spite of all the progress, something seems to be still missing, namely a practical synthesis of the electron-cloud effect. Such a synthesis might take the form of a few rules of thumb that would give an approximate quantitative answer to the intensity and other characteristics of the electron cloud for a given machine. Perhaps it is premature to expect such a synthesis, although it seems important to achieve it to prove the practical value of our research by providing quick and reliable guidance for the commissioning of several new machines over the next 5 years or so (LHC, SNS, JPARC, BEPCII and, possibly, the upgraded KEKB and PEP-II, etc.). For example, we might attempt to identify the most relevant variables for each machine and concentrate our efforts on them, either as simulation inputs (that should be reliably measured) or output (that should be computed).

A qualitatively new approach to the electron-cloud buildup was presented by U. Iriso. The approach is based on a simple nonlinear map that relates the average cloud density at time t to its value at time $t-\Delta t$, where Δt is typically one bunch spacing. The simplest form of the map that yields good results is characterized by three coefficients a_1, a_2 and a_3, whose values were obtained by empirical fits to more standard build-up simulation results carried out for RHIC. After a few bunch passages, the results for the electron-cloud density from the map technique are in startling agreement with those from standard simulations,

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and are obtained at a tiny fraction of the computational cost of the latter. This agreement seems to imply an underlying simplicity of the electron-cloud dynamics which may be one aspect of the hoped-for synthesis mentioned above. This conclusion would be considerably strengthened if the above results prove to be valid in a wider context than the one in which they were obtained. Reaching an understanding of such underlying simplicity merits high priority. A first goal should be the computation of the a_i's in terms of physical (beam and chamber) parameters, even if approximately.

For the reasons mentioned above, the more detailed and precise numerical simulations that are possible by the advent of large, massively parallel computers, carry an intrinsic risk: owing to the increase in the complexity of the physical model typically embodied by such simulation programs, parametric studies will take more and more human time and effort, despite the increase in CPU power, which is expected to grow by two orders of magnitude over the next 5 years. Therefore, unless sensible judgment is used in the choice of simulation cases, the increase in raw computer power may lead to an intractably large number of simulation results which might be impossible to distill into knowledge useful for the operation of real machines. Theoretical understanding from analytic theory, and from simplified calculations such as those provided by the map technique, ought to proceed in parallel with high-power simulations in order to develop a fruitful program of practical value.

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