Electromagnetic non-destructive detectors for storage rings

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Synopsis Electromagnetic detectors are essential tools for the accelerator physicist. They can as well be designed to meet specific needs for performing precision atomic and nuclear physics experiments with stored highly-charged ions in storage rings. In this work we report on our ongoing detector developments at GSI.

The passage of particles through non-destructive electromagnetic detectors in storage rings induces a periodic signal that can be related to the particle's mass through its revolution frequency. Additionally the recorded signal can deliver information on the lifetime of the unstable nuclei if the data is processed through short time Fourier analysis. Furthermore, these so called Schottky signals deliver information on general properties of the particle beam such as momentum spread [1] and can even be used to observe stability of other elements in the storage ring such as the electron cooler [2] and power supplies.

Resonant cavity detectors

Electromagnetic detectors designed for the detection of Schottky signals are based on a variety of geometries with their respective advantages and disadvantages for each application [3]. Of particular interest for precise determination of particle frequencies and intensities in storage rings are resonant cavities. Due to their high Q value, they can achieve high sensitivities, albeit at the cost of lower operation bandwidth. The usually large eigenmode frequency also allows for higher frequency and hence higher mass resolution power. An example of such a detector has been developed for the ESR storage ring at GSI facility [4] and its single ion sensitivity has been demonstrated [5].

Currently a R&D prototype of a similar longitudinal detector is under construction and is planned for test in the ESR as well as the future HESR and CR facilities of FAIR. The new detector will allow for variation of sensitivity during the operation. This feature would extend the scope of application of resonant cavity detectors in future storage ring experiments.

Designs based on resonant cavity structure are also suitable for detection of trasnversal displacement of the ion beams (please refer to [6] for a review). Here the electric dipole field is used to discern the beam position relative to the electric axis. Although this approach is successful in most cases, the small amplitude of the electric dipole field at the vicinity of the center of very large beam pipes (such as those found in the CR storage ring at FAIR) causes a low coupling amplitude and therefore low sensitivity. In order to overcome this issue, a design based on the monopole mode of a cavity with an elliptical cross section was proposed [7] and further investigated in [8]. Combined with an isochronous ion optical setting inside the storage ring, it is possible then to use the position information as an additional correction for Schottky mass measurements [9]. Currently R&D prototypes are planned to be tested in collaboration with S-DALINAC facility in Darmstadt before final designs are approved for the future CR at FAIR.

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Slow wave detectors

One of the inherent shortcomings of cavity based electromagnetic detectors is their rapid loss of sensitivity for low energy beams (i.e. very slow particles) due to the effect of transit time factor. However, there is a growing interest for experiments at lower energies motivated by precision studies in atomic, nuclear structures and astrophysics. A common practice is to use the so called slow or traveling wave detectors that allow for lower phase velocities [3]. A detector based on this approach is currently under developement for the newly installed CRYRING [10] facility at GSI.

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