Progress in Development of a Resonant Structure as a Heavy Ion Position Detector for Coasting Beam

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Problem

The information about the beam position in an accelerator has always been of the utmost interest, not only for machine operators as an important beam tuning parameter, but also for experimenters as a main reflection of particles' kinematics. For example, the proposed mass measurements of short-lived nuclei in the CR storage ring at FAIR require accurate determinations of transverse positions of stored ions, in order to apply fine corrections for the errors. Moreover due to the poor production rates of the secondary beams, a satisfactory heavy ion position detector should also be sensitive enough, hopefully to single ions.

Solution

The utilization of resonant structures in the design of beam position monitor (BPM) to enhance the sensitivity has a history of more than half a century. Nowadays cavity-based BPMs are commonly employed in most radioactive research facilities around the world [1]. A group of beam-diagnostics experts in GSI have successfully developed a pillbox-shaped Schottky pickup for the ESR not so long ago. Its capability of observing the dynamic cooling processes of single ions was demonstrated during an experiment in 2011 [2].

Glossary

When it comes to a cavity, three figures of merit are usually adopted to characterize its properties [3].

Resonant Frequency f_0 Because of a finite volume, only some EM fields with certain frequencies that form standing waves can remain in a cavity. They are fixed by the cavity shape, and thus called (eigen-)modes.

Quality Factor Q In the real world, power loss of a cavity is inevitable. $Q = \omega_0 W / P_l$ is introduced to parametrize the ability of preserving the EM field in a certain mode.

Shunt Impedance R Analogous to the resistor in a damped resonant circuit, R indicates the dissipated power from a cavity merely via heat conversion. In most circumstances R/Q, which is material independent, is used instead.

References

[1] X. Chen, "History of cavity beam position monitors". *GSI-Report-2014-3*, GSI, Darmstadt (2014).

[2] F. Nolden, P. Hülsmann *et al.*, "A fast and sensitive resonant Schottky pick-up for heavy ion storage rings". *Nucl. Instrum. Meth. A*, **659** (2011) 69.

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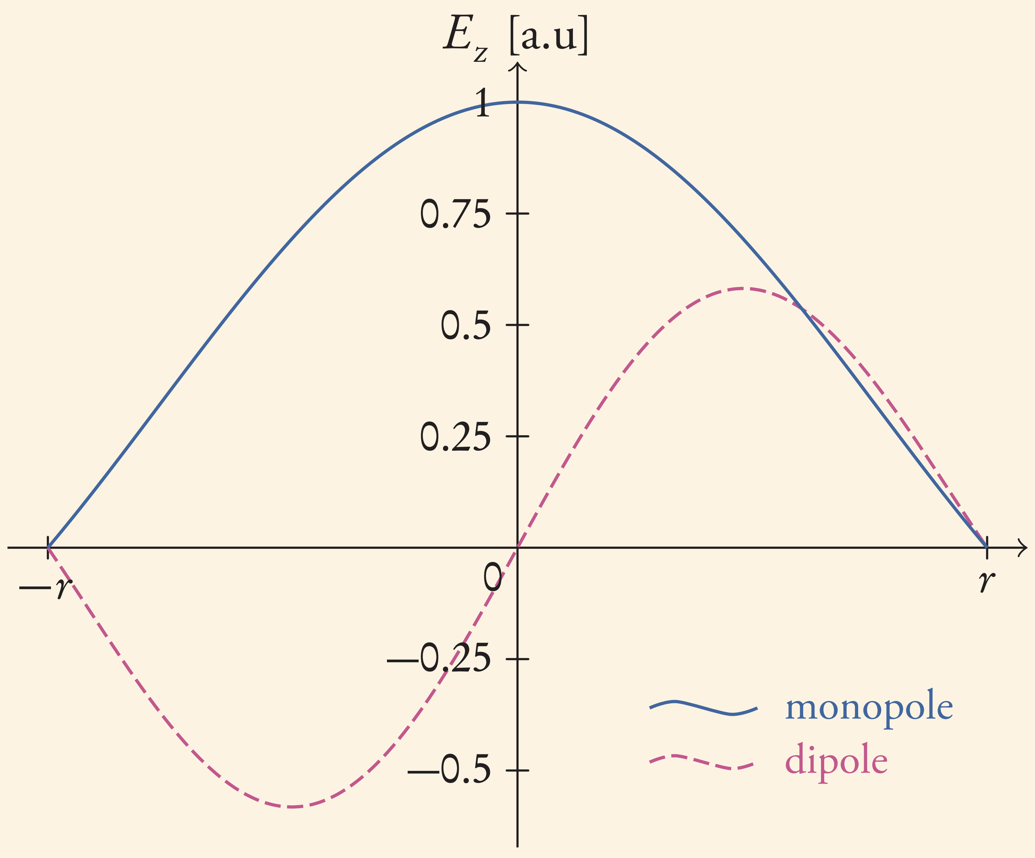
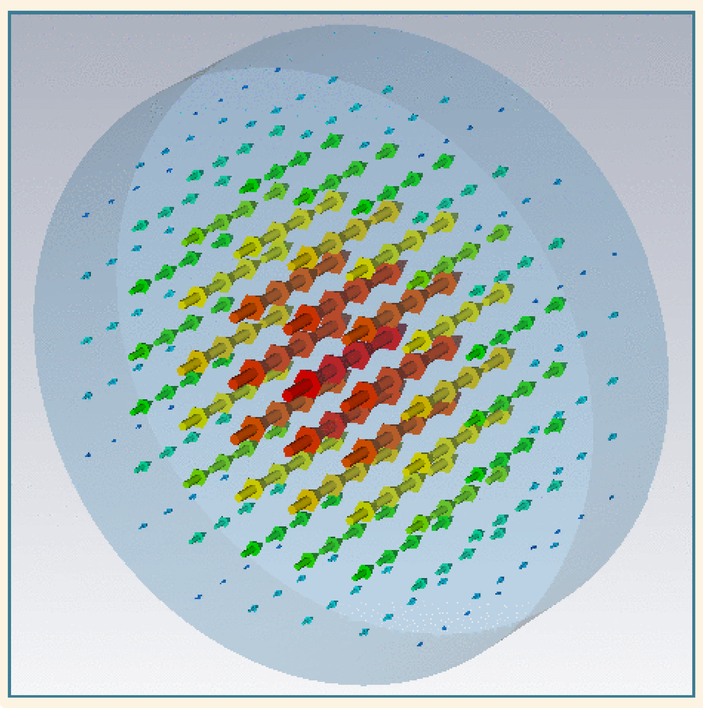
Design

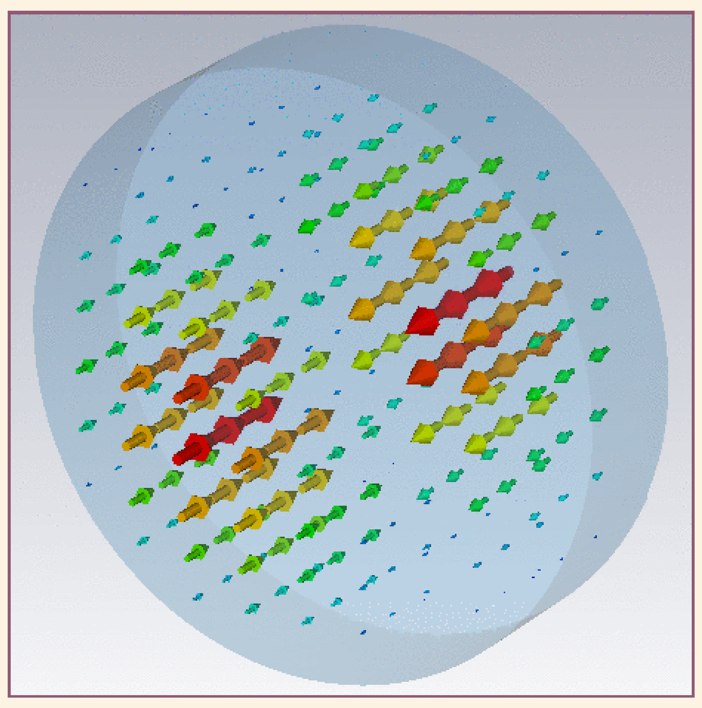


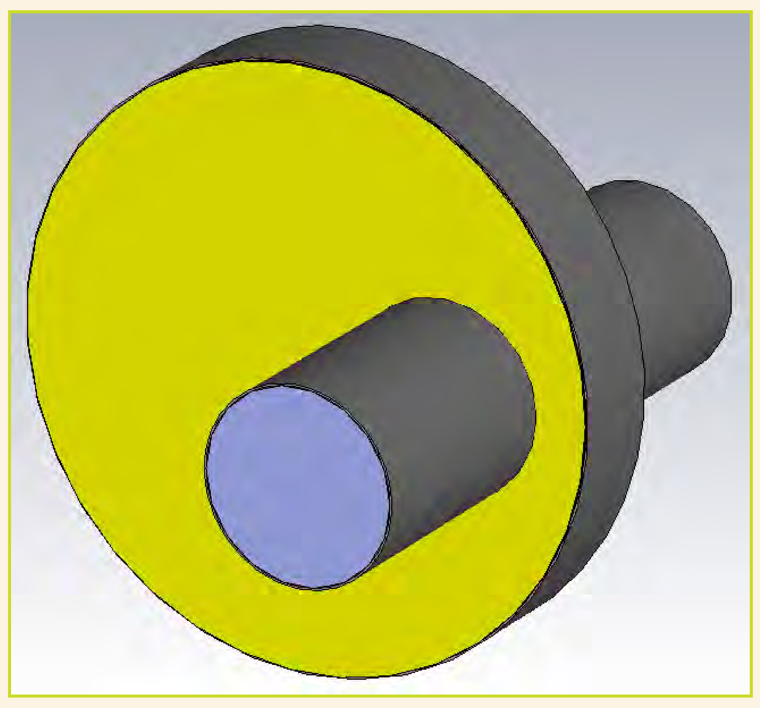
Enhancing the sensitivity of a cavity is equivalent to increasing the coupling between the cavity and the beam. Higher coupling strength means higher shunt impedance, which in turn requires stronger electric field projection on the axial direction. Additionally in order to distinguish the beam position, shunt impedance should manifest a large variety within the opening of the beam pipe. By investigating the behavior of the two simplest modes in a circular cavity, it is easy to conclude two generic design schemes:

- dipole mode with beam pipe placed in the centre,
- **monopole mode with beam pipe placed off-centred.**

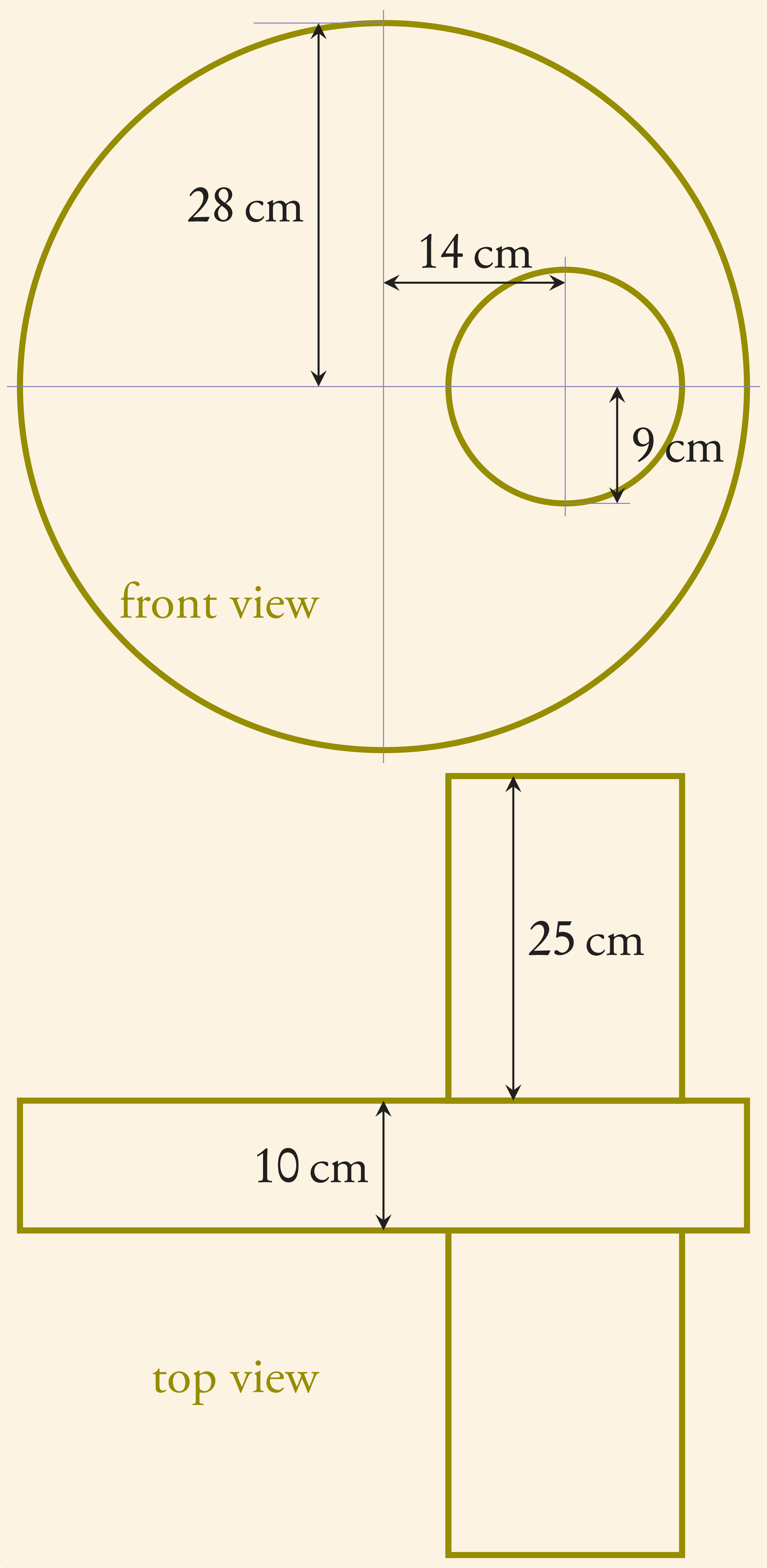
The latter is more preferable in our case to cope with low-current beams, taking advantage of much higher field strength in monopole mode while still benefiting from the ascending regime of field distribution.







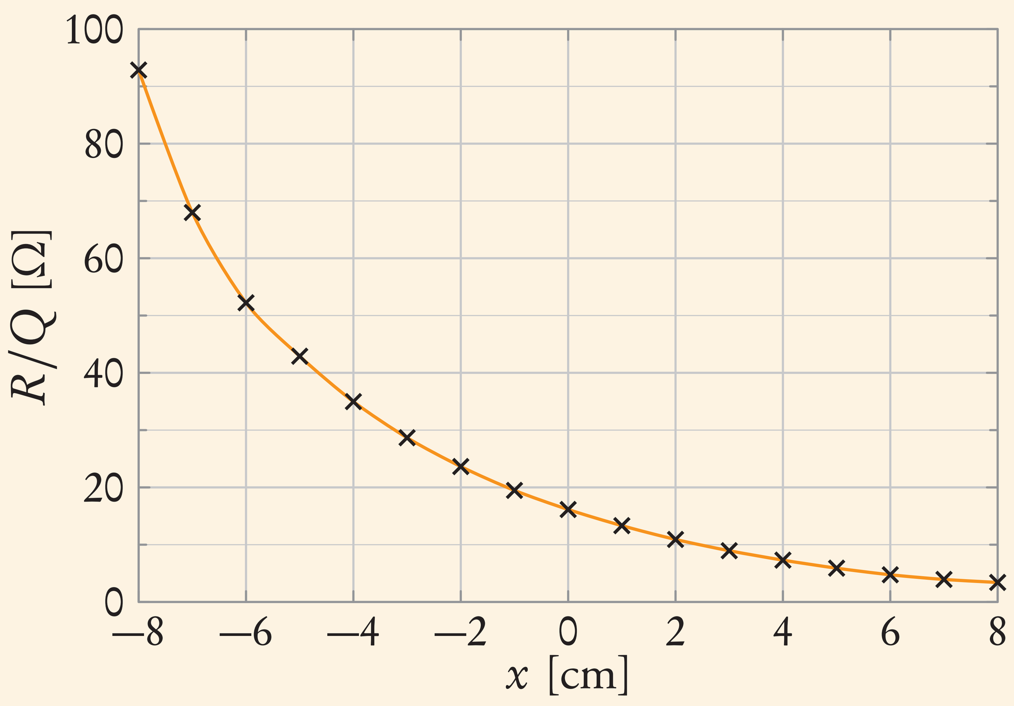
Simulation



CST MICROWAVE STUDIO is used to study the RF properties of such a model cavity. The beam pipe is offset halfway from the cavity centre with a radius of 9 cm, which is a fairly wide opening. In addition to the geometric modeling, some lossy materials, like stainless steel and aluminium, are also taken into account in the computer simulation. Using the *Eigenmode Solver*, EM fields are calculated in the monopole mode. Afterwards quality factor and shunt impedance are deduced by the *Template Based Post Processing*.

- $f_0 = 409.77$ MHz
- $Q = 13\,673$
- R/Q plot shows an average decrement of 5.6 Ω/cm

However the drop-off trend on the right side, equivalently lateral region, slows down significantly owing to the large pipe, which will reduce the position resolving ability. Possible solutions are being sought to minimize this kind of effect.



Acknowledgments

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