Tutorial Wien filter

Introduction

Generally, Wien filters are used for separating charged particle beams by velocity using orthogonally superimposed magnetic and electric fields. Their greatest advantages are low weight and compact size compared to other systems used for particle separation, e.g. quadrupole filters or dipole magnets.

A Wien filter allows for separation of the following particles:

- ions of different velocities, masses or charge states
- multiply charged ions and molecules
- charged clusters

Design and functional principle

In a Wien filter, electrical charged particles are forwarded through a plate capacitor, which is positioned in a homogeneous magnetic field. The directional parameters (electric field E, magnetic field B and the charged particle's path) are perpendicular to each other in that arrangement. Figure 1 visualizes this principle. The charged particles enter the setup through the aperture on the left side and pass the superimposed fields.
The magnetic field causes a downward deflection, whereas the electric field causes an upward deflection of the ions path. If the Lorentz force equals the Coulomb force

$$F_C = F_L \,,$$

the resulting force equals zero and the ion passes the fields without any deflection.
The equilibrium of forces leads to

$$qE = qvB \quad \text{with} \quad E = \frac{U}{d}$$

and

$$\frac{U}{d} = vB$$
$$\Rightarrow \; v = \frac{U}{Bd} = \frac{E}{B}$$

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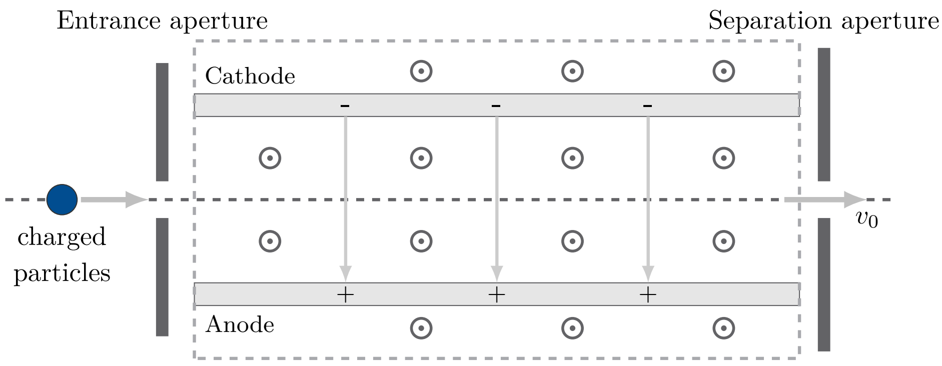

Figure 1: Wien filter's functional principle

with an applied voltage U, plate separation d, ion charge state q and ion velocity v. Using the vector product, the ion motion in the field can be described with

$$\begin{aligned} m\dot{\vec{v}} &= m\vec{a} \\ &= q \cdot \left(\vec{E} + \vec{v} \times \vec{B}\right) . \end{aligned}$$

Zero deflection is required

$$m\vec{a} = 0 \,,$$

leading to

$$q\vec{E} = -q \cdot \left(\vec{v} \times \vec{B}\right) .$$

If the velocity, the electric and the magnetic field are perpendicular to each other, the following applies:

$$v = \frac{|\vec{E}|}{|\vec{B}|}$$

Only ions with a specific velocity remain on a rectilinear path, while slower or faster ions are deflected and suppressed by the separation aperture.

In order to choose between different ion species and thus different charge-to-mass ratios, one of the two superimposed fields must be variable. In most applications the electric field can be varied by adjusting the supplied voltage. For a distinctive ion species

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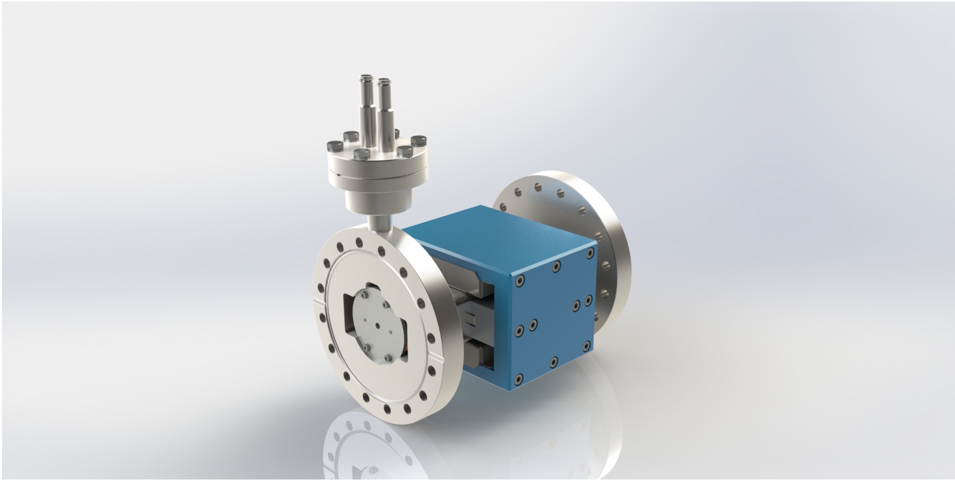

Figure 2: Technical realization of a Wien filter by D.I.S Germany

the following formula for the Wien filter voltage applies:

$$U_{WF} = \sqrt{\frac{2qe(U_0 - U_a)B^2d^2}{m}}$$

The entrance and separation apertures must be adapted according to the intended range of application as well.

Range of application

Velocity filters (Wien filters) are often used in various particle accelerators and, together with other electrostatic and magnetic filters, form a complex system for selecting particles of certain mass, charge state and velocity.
Depending on the ion species of interest and the energy range involved, the required field strengths must be carefully determined in order to achieve sufficient resolution and transmission.
Figure 2 shows the technical realization of a Wien filter based on a DN100 CF flange for operation with high power, large diameter beams of light ions.

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