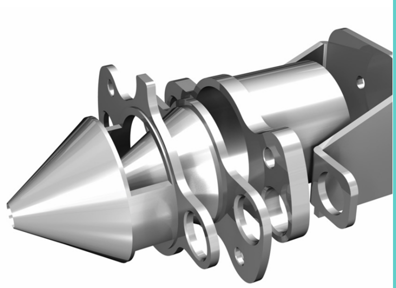

Ion Lens Design

Agilent ICP-MS technology brief

Benefits of Agilent off-axis ion lens:

High ion transmission

The combination of twin extraction lenses and the "Omega" off axis ion lens provides exceptionally high ion transmission and low background. This allows Agilent ICP-MS systems to use an optimum configuration of:

- Very robust (low CeO) plasma conditions giving good matrix tolerance, high ionization, and low interferences.
- Small interface cone orifices that limit the transfer of matrix contaminants into the high vacuum region. This improves stability and reduces maintenance.

Minimal mass bias

Using a low voltage to deflect the ions keeps the ion beam focused throughout the instrument. This reduces the mass bias (loss of low mass sensitivity) that is typical of other ion lens designs such as photon stop or 90° deflector.

Robust and easy to maintain

The Agilent extract and off axis lens unit is mounted on the skimmer cone base plate. The lens is in front of the "gate valve" so is not under vacuum when the ICP-MS is in standby mode. This means the lens is very quick and easy to access for routine maintenance—there is no need to switch off the vacuum to clean the lens.

Principles of ICP-MS ion lens design

ICP-MS instruments use ion "lenses"—metal plates with voltages applied to them—to deflect the ions as they pass through the vacuum system.

The ion lens of an ICP-MS has two main functions:

First, to focus the ions and "steer" them efficiently from the skimmer cone to the entrance aperture of the collision/reaction cell (CRC). In a triple quadrupole ICP-MS, the ions are steered from the skimmer cone to the first quadrupole (Q1). Ion focusing is more critical with ICP-QQQ since the entrance aperture for a Q1 chamber is smaller than for a CRC, as Q1 requires a better vacuum.

Second, to prevent photons and neutrals from the plasma from reaching the electron multiplier (EM) detector and increasing background count rates.

These two functions are somewhat conflicting, as the ion transmission would be highest with a straight path from the skimmer to the CRC (or Q1) entrance. But a straight path would pass the highest number of photons and neutrals, leading to extremely high background. The challenge is to design an ion lens that blocks photons and neutrals while efficiently transmitting ions.

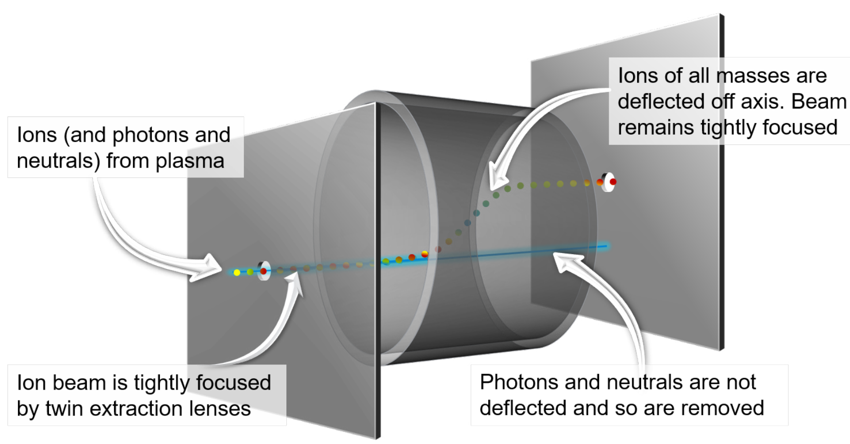

Figure 1. Agilent off-axis Omega lens provides high transmission for all masses and good rejection of photons and neutrals. This gives high sensitivity and low background.

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Alternative ion lens designs used in ICP-MS

Most early ICP-MS systems used an ion lens design based on one of two alternative configurations:

1. A photon stop or shadow stop—a metal disk is placed between the skimmer cone aperture and the entrance of the high vacuum region. Ions are bent around the metal disk, while photons and neutrals—which are uncharged and so travel in straight lines—are blocked from reaching the detector by the photon/shadow stop. This design is no longer used in commercial ICP-MS.
2. A quadrupole deflector (Q Def)—a multi-electrode lens is used to bend the ion beam through 90° between the skimmer cone and the analyzer chamber entrance (*1-3*). This type of lens has been revived in some recent instruments (*4*), but the design originated almost 30 years ago.

Both of these traditional lens designs have the limitation that the ions are bent through a sharp angle, which requires a strong electrostatic field. The amount of deflection is dependent on the kinetic energy of the ion, which is proportional to its mass. As a result, these lenses bend light ions more than heavy ions. This effect causes mass bias, where one region of the mass range (usually the low masses) is transmitted less efficiently than another.

ICP-MS is a multielement technique, so mass bias is generally an unwanted, negative characteristic. Figure 2 illustrates schematically how mass bias is introduced in a 90° quadrupole deflector ion lens.

Different ion lens designs vary significantly in their mass response performance. Figure 3 shows how the Agilent off-axis lens provides more uniform ion transmission across the mass range, minimizing mass bias and delivering consistent, low detection limits for all analytes.

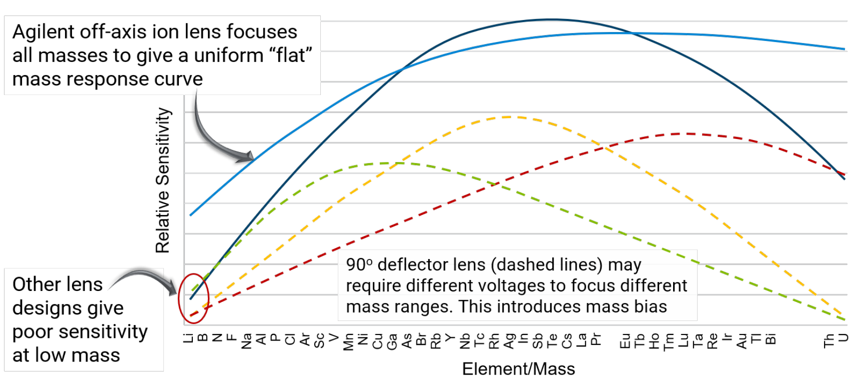

Figure 3. Mass response curves for different ion lens designs. The dashed lines show the response curves for a 90° deflector lens that requires different settings to focus low (green), mid (yellow), and high (red) masses. With this lens type, tuning to maximize signal for one mass region reduces sensitivity for the other masses.

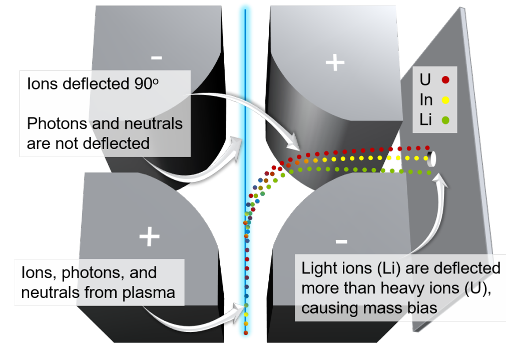

Figure 2. Right angle (90°) deflection lens bends the ions through a sharp curve. Heavy ions have more kinetic energy and so are deflected less than light ions. Mass-dependent deflection introduces mass bias.

What's in a name? The term "quadrupole" is misleading when applied to a 4-electrode deflector lens. To function as a quadrupole mass filter, the ions must travel axially (parallel to the rods), through RF fields created in the central space between the rods. The schematic in Figure 2 shows that a deflector lens does not meet these requirements. The ions travel perpendicular to the axis of the rods and the four electrodes have DC (not RF) voltages applied to them, so no mass filtering occurs.

Conclusion

The Agilent off axis ion lens focuses all masses, minimizing mass bias and providing high sensitivity and low detection limits for elements across the mass range. The lens is also simple to optimize and provides excellent matrix tolerance and stability.

References

1. Seiko patent JPB 3188794, September 10, 1993, accessed April 2021. Search "3188794" at link
2. Seiko patent US 5,559,337, September 24, 1996, accessed April 2021. link
3. Hitachi patent US 6,423,965 B1, July. 23, 2002, accessed April 2021. link
4. Kroukamp, E. and Abou-Shakra, F. *Spectroscopy* 35 (9), **2020**

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DE44313.3058449074

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Published in the USA, May 17, 2021
5994-3527EN

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