Current & Future Q-pole/Ionizer Improvements

Part I Quadrupole Mass Spectrometers— an Overview about High End Q-poles

Applications, Integration into analytical machines

Part II Optimisations of the Q-pole at Balzers

Ion Source:
Magnets
Emission Current
Compact Ion Source

Deflection Unit:
Lower Deflection Voltage at higher resolution
Other deflection unit?

Part III Future Q-pole/Ionizer Improvements

Discussion
Quadrupole Mass Spectrometer Development

1962

Start of QMG development based on license from Siemens

1967 QMG 101 First useful QMG on the market

1971 QMG 111 Low-cost unit

1972 QMG 511 First digital controlled Quadrupole

1973 QMG 311 Low-cost analog unit

1980 QMG 112 New control unit

1982 QMG 064 First QMG with push button RGA (<= 8 components)

1986 QMG 420 New control unit
new RF-generator
No tubes anymore

1989 QMG 420-C Black box concept for RGA
QMG 125 Screen Control unit for RGA

1992 Quad Link QMG 421-C "all" detection methods
QMG 421 integrated (FC/SEM,Counting)
state of the art electronic

1994 Prisma New concept

1997 QMG 422 New electrometer preamplifier
and autoranging

1993 Merger of Leybold and Balzers

1996 Business Unit Balzers and Leybold Instrumentation
2000 New name : Inficon
IPO November 2000

Inficon Syracuse was developing quadrupole mass spectrometers since decades too.
The analytical mass spectrometers are continued in Liechtenstein and Syracuse develops manufactures and markets mass spectrometers for the electronic industries.
Principle of a Quadrupole-Mass-Spectrometer

Pressure in the Mass-Spectrometer $< 10^{-5}$ mbar
Ion Sources

Ion-Optics Energy Filters

Mass-Filters

Detectors

Gas-Inlet Systems: one stage two stage Molecular Beam Inlet, Membrane etc.
<table>
<thead>
<tr>
<th></th>
<th>6.0</th>
<th>8.0</th>
<th>15.8</th>
<th>100</th>
<th>200</th>
<th>300</th>
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<tbody>
<tr>
<td>Rod diam.</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Rod length</td>
<td>mm</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Capacity</td>
<td>pF</td>
<td>19.5</td>
<td>34.5</td>
<td>49.5</td>
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<table>
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<tr>
<th></th>
<th>1 - 100</th>
<th>1 - 200</th>
<th>1 - 512</th>
<th>1 - 128</th>
<th>1 - 340</th>
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<tbody>
<tr>
<td>Mass range</td>
<td>amu</td>
<td></td>
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<tr>
<td>Frequency</td>
<td>MHz</td>
<td>2.46</td>
<td>2</td>
<td>2.25</td>
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<tr>
<td>Reactive power</td>
<td>kVA</td>
<td>0.08</td>
<td>0.1</td>
<td>9</td>
<td>7</td>
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<tr>
<td>Volts/amu</td>
<td>V</td>
<td>6.08</td>
<td>4.02</td>
<td>9.04</td>
<td>20.2</td>
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<tr>
<td>Analyzer</td>
<td>QMA</td>
<td>200</td>
<td></td>
<td>400</td>
<td></td>
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<tr>
<td>RF generator</td>
<td>QMH 200</td>
<td>1</td>
<td>200-2</td>
<td>400-5</td>
<td>400-1</td>
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<tr>
<td>Transmission</td>
<td>%</td>
<td></td>
<td>10</td>
<td>35</td>
<td></td>
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<tr>
<td>for Xe</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Contribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>to the neighbour mass</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>He to 3 amu</td>
<td>10 ppm</td>
<td>20 ppm</td>
<td>10 ppb</td>
<td>&lt;1 ppb</td>
<td>10 ppb</td>
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<tr>
<td>Resolution He / D₂</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Xe in air</td>
<td></td>
<td>yes</td>
<td>yes</td>
<td></td>
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**Mass-Filter and Applications**

<table>
<thead>
<tr>
<th>6 mm rod diameter</th>
<th>8 mm rod diameter</th>
<th>16 mm rod diameter</th>
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</thead>
<tbody>
<tr>
<td>100 and 200 amu</td>
<td>512, 1024 and 2048 amu</td>
<td>128 and 340 amu</td>
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- **6 mm rod diameter**:
  - Leak Detectors
  - Sputter Process Monitoring
  - TDS-Systems
  - Thermostat Omnistar
  - "noble" RGA

- **8 mm rod diameter**:  
  - SIMS SNMS
  - Detection of external generated ions
  - Environmental analysis
  - Gas Analytics
  - R&D applications
  - Plasma Diagnostics
  - OEMS

- **16 mm rod diameter**:  
  - Environmental analysis
  - R&D applications separation of isotopes
  - Detection of external generated ions: OEM
  - possible further applications:
    - *
    - *

- **ICP-MS**
Optimisation of the Q-pole
(used in Aerodyne's Machine)

Mass Resolution, Stability, so far not an issue (to be improved)

increase the sensitivity in the machine!

Cross-Beam Ion Source

Mass-Filter

SEM

deflection unit

Sensitivity:
0.8 - 1.0 x 10^-4 A/mbar
(measured for argon and the 16 mm system)

1) Higher Ionisation Efficiency:
   a) Magnets to enlarge the electrons' path
   b) Increase the Emission Current

2) Adapt the geometry to the experimental set-up
   ---> compact ion source

16 mm rod system with about 50% Transmission (Xe)
or an
8 mm rod system with about 35% Transmission (Xe)

Field Axis Technology
Transmission and Precision of the rod system

discrete 17 dynode SEM manufactured in house
90° inflection to improve signal/noise

1) Conversion Efficiency of the SEM Current-Amplification?
2) Optimisations of the deflection unit
   a) Voltage and voltage resolution
   b) Geometrical design
Sensitivity increased by a factor of 4 to 6 compared to 1 mA. At about 8 mA SCLC and/or saturation starts; (20 mA possible from the power supply). The price we have to pay for this is a reduced filament lifetime.
Quadrupole rod system

Entrance aperture

Focus

Grounded electrode

Extraction

Formation chamber

Filament

Wehnelt
Cross Beam Ion Source

Flight paths of electrons

Quadrupole rod system

Entrance aperture

Focus

Grounded electrode

Extraction

Formation chamber

Filament

Wehnelt
**Deflection Unit** at the moment:

Pair of two concentric plates, no spherical shape in the direction perpendicular ions are injected with a few eV into the deflection units.

Experimentally: Set of lower voltages \( \Delta V \) results in an increased sensitivity theoretically only the difference between the two voltages determines the electrical field between the plates, however SIMION-Simulations also suggest that improved focusing onto the dynode occurs at low deflection voltages.

Idea: To adapt an Ion-Inflection Unit (spherical device) which is used for 90° inflection with an endpoint detector:

Preliminary stopped because it turned out to be rather difficult to incorporate the spherical device into the existing 90° set-up.

**In-Line Version?**

Increased signal of course however noise will rise too

Under Discussion no real progress at the moment
"Fiel-Axis-Voltage" and electrically isolated Analyzers

Electrons can impact onto the chamber-walls --- desorption

Electrons can only impact onto the Anode well defined surface

Case screens the Q-Pole etc.

Ions cross fringing fields with high energy low disturbance

Background and electrically Interferences reduced

Ideal Injection into the rods system High Transmission peak-form
Quadstar 422

Software-Situation Quadstar

Quadstar 422:
32bit-version

end of 2002

All 32-bit operation systems from Microsoft
exception of Windows 95 and Windows ME

Quadstar 422: will be tested as english
version!

Windows 98 2nd edition
Windows NT 4.0 service pack 6
Windows 2000 professional
Windows XP professional

Arcnet PCMCIA
ISA-card
RS 232

Data compatible
with older versions

No updates from 16 bit to 32 bit
Only as New-Installation

Quadstar 6.10

Only for PCMCIA
no additional features
compared to previous versions
Optimisation of the Q-pole
(used in Aerodyne's Machine)

Results till October 2002

Cross-Beam Ion Source

Mass-Filter

SEM

Increased Emission: factor of 4-6

"No idea" what could be improved

Compact Ion Source factor 2

If everything is optimised 100%

theoretically factor 2

Magnets

no improvement???

Lower deflection voltage factor of 2

Other deflection unit??????

factor of 2-3 ???

About one order of magnitude increased sensitivity
1) Adapt a Magnet onto the Ion Source:

Larger path of the electrons through the formation chamber will cause a higher ionisation efficiency

Result: No improvement
Tested by: Aerodyne

Experience: Factor of four to five with normal gas analysis.
Not complete understood (G.Peter)

2) Compact Ion Source:

Optimise the distance between the oven and the active volume of the Ion Source.

Result: about a factor of two more sensitivity
Tested by: Aerodyne

3) Increase the Emission Current:

Higher Ionisation Efficiency

Result: factor of 4-6
Tested by: Inficon in Balzers

Combination of 1) and 2) could result in a factor of about 10 however we do not know up to now how the compact Ion Source does at higher emission current