CLAIMS

What is claimed is:

1. A device for spatial confinement, guidance, or focusing of ions in gases, comprising:

a plurality of electrode elements having microscopic gaps therebetween that produce a Dehmelt pseudopotential due to an oscillatory electric field created by an alternating voltage applied to said elements, wherein field intensity required for effective confinement or focusing under the operational gas pressure is precluded by electrical breakdown through the gas in macroscopic gaps but permitted in microscopic gaps having a higher breakdown threshold.

2. The device of Claim 1, wherein said gas pressure is the ambient atmospheric pressure; or a pressure ranging from 50 Torr (6.67 kPa) to about 1 atm (101.3 kPa); or a pressure ranging from about 1 atm (101.3 kPa) to 5 atm (506.6 kPa).

3. The device of Claim 1, wherein said microscopic gaps range in width from 10 μm to 200 μm; or from 20 μm to 100 μm.

4. The device of Claim 1, wherein said electrode elements have microscopic thicknesses that range from 10 μm to 200 μm; or that range from 20 μm to 100 μm.

5. The device of Claim 4, wherein the electrode elements have microscopic thicknesses that range from 1/3 times to 3 times the width of gaps between the electrode elements; or the thicknesses are equal to the width of the gaps between the electrode elements.

6. The device of Claim 1, wherein the frequency of said oscillatory field ranges from 10 MHz to 150 MHz; or from 25 MHz to 60 MHz.

7. The device of Claim 1, wherein the electrode elements are plates having internal apertures of any geometry arranged in a stack that conveys ions through said apertures sequentially across the stack while repelling ions inside from the aperture circumference by the Dehmelt pseudoforce.

8. The device of Claim 7, wherein neighboring plates carry opposite phases of an alternating voltage.

9. The device of Claim 8, wherein ions are propelled along the stack by a time-independent longitudinal electric field derived from a ladder of fixed voltages applied to said plates in superposition with the alternating voltage.

10. The device of Claim 7, wherein ions are propelled along the stack by a gas flow resulting from vacuum suction into a following instrument stage maintained at a lower gas pressure selected from: a mass spectrometer, an ion mobility spectrometer, a photoelectron spectrometer, a photodissociation spectrometer, and combinations thereof.

11. The device of Claim 7, wherein said apertures have essentially the same geometry and cross-sectional area, defining an ion-guiding tunnel.

12. The device of Claim 7, wherein said apertures have homologous shapes and cross-sectional areas that decrease along the stack, defining a funnel that focuses ion beams entering the stack through an entrance aperture into tighter beams exiting through a smaller terminal aperture.

13. The device of Claim 7, wherein said apertures have homologous shapes and cross-sectional areas that increase in preselected segments and decrease in other preselected segments along the stack, defining an hourglass ion funnel or a double hourglass ion funnel, wherein regions of said funnels having wider apertures for ion storage are spaced between, or separated by, regions of narrower apertures that provide ion focusing.

14. The device of Claim 1, wherein the electrode elements are built on, or attached to, a preselected surface forming a periodic grating, such that the Dehmelt pseudoforce repels ions from said preselected surface.

15. The device of Claim 14, wherein the preselected surface of the electrode elements is composed of a metal or other electrically-conductive material disposed on an insulating substrate forming the body of the electrode elements.

16. The device of Claim 14, wherein ions are further moved along said preselected surface by a longitudinal electric field derived from a ladder of

fixed voltages applied to the electrode elements in superposition with alternating voltages.

17. The device of Claim 14, wherein at least two of said surfaces are disposed at an angle, forming a wedge with an open slit at the apex thereof which compresses a beam of ions entering an open base of the wedge in one dimension, forming a narrower belt-shaped beam exiting through said slit.

18. The device of Claim 17, wherein ions are propelled through said wedge toward the exit by: a longitudinal electric field derived from a ladder of fixed voltages applied to the elements on said surfaces in superposition with alternating voltages, a gas flow resulting from vacuum suction into a following instrument stage, or a combination thereof.

19. The device of Claim 18, wherein said following stage is selected from the group consisting of: a mass spectrometer, an ion mobility spectrometer, a photoelectron spectrometer, a photodissociation spectrometer, and combinations thereof.

20. The device of Claim 17, wherein said device is disposed to receive ions from a linear or elongated rectangular array of elementary sources selected from: an electrospray (ESI) emitter array, or a plate for matrix-assisted laser desorption ionization (MALDI).

21. The device of Claim 17, wherein said device is disposed at or after the terminus of an ion mobility spectrometry (IMS) analyzer to compress ion

packets exiting therefrom into a parallelepiped geometry for injection into another instrument stage.

22. The device of Claim 17, wherein said device is disposed at or after the terminus of a differential mobility analyzer (DMA), a differential mobility spectrometry (DMS), or a field asymmetric waveform ion mobility spectrometry (FAIMS) analyzer having a planar or transverse-cylindrical gap geometry to compress the belt-shaped ion beam exiting therefrom for injection into another instrument stage.

23. The device of Claim 17, wherein said belt-shaped ion beam is refocused into a circular or a different cross-sectional shape using a following electrodynamic ion funnel with a gas pressure lower than that inside said wedge.

24. The device of Claim 17, wherein said belt-shaped ion beam is introduced into a subsequent ion mobility spectrometry (IMS) stage in a continuous or pulsed mode, and separated or filtered therein while retaining a rectangular cross section.

25. The device of Claim 24, wherein said IMS stage operates in a mode selected from the group consisting of: drift-tube IMS, traveling-wave IMS, DMA, DMS, FAIMS, and combinations thereof.

26. The device of Claim 24, wherein said device receives ions from a source of linear or elongated-rectangular shape.

27. The device of Claim 24, wherein said belt-shaped beam is further extracted from said IMS stage with compression that retains its rectangular cross section with another device selected from the group consisting of: ion mobility spectrometers, photoelectron spectrometers, photodissociation spectrometers, and combinations thereof.

28. The device of Claim 17, wherein said belt-shaped beam is injected into a subsequent mass spectrometry (MS) stage, in a continuous or pulsed mode, and analyzed therein while retaining a rectangular cross section.

29. The device of Claim 28, wherein said MS stage is a time-of-flight (ToF) mass spectrometer, and the lateral span of said belt-shaped beam is orthogonal to both the directions of ion velocity in MS analysis and ion injection into the ToF instrument.

30. The device of Claim 28, wherein said device receives ions from a source of linear or elongated-rectangular shape.

31. The device of Claim 30, wherein said belt-shaped beam is further injected into a subsequent mass spectrometry (MS) stage and analyzed therein while retaining the rectangular cross section such that the whole IMS/MS separation is performed on a planar ion beam.

32. The device of Claim 31, wherein said MS stage is a time-of-flight (ToF) mass spectrometer, and the lateral span of said belt-shaped beam is orthogonal to

both the ion velocity vector in MS analysis and the direction of ion injection into the ToF instrument.

What is claimed is:

1. A device for spatial confinement, guidance, or focusing of ions in gases, comprising:

a plurality of electrode elements having microscopic gaps therebetween that produce a Dehmelt pseudopotential due to an oscillatory electric field created by an alternating voltage applied to said elements, wherein field intensity required for effective confinement or focusing under the operational gas pressure is precluded by electrical breakdown through the gas in macroscopic gaps but permitted in microscopic gaps having a higher breakdown threshold.

2. The device of claim 1, wherein said gas pressure is the ambient atmospheric pressure; or a pressure ranging from 50 Torr to about 1 atm; or a pressure ranging from about 1 atm to 5 atm.

3. The device of claim 1, wherein said microscopic gaps range in width from 10 μm to 200 μm; or from 20 μm to 100 μm.

4. The device of claim 1, wherein said electrode elements have microscopic thicknesses that range from 10 μm to 200 μm; or that range from 20 μm to 100 μm.

5. The device of claim 4, wherein the electrode elements have microscopic thicknesses that range from ⅓ times to 3 times the width of gaps between the electrode elements; or the thicknesses are equal to the width of the gaps between the electrode elements.

6. The device of claim 1, wherein the frequency of said oscillatory field ranges from 10 MHz to 150 MHz; or from 25 MHz to 60 MHz.

7. The device of claim 1, wherein the electrode elements are plates having internal apertures of any geometry arranged in a stack that conveys ions through said apertures sequentially across the stack while repelling ions inside from the aperture circumference by the Dehmelt pseudoforce.

8. The device of claim 7, wherein neighboring plates carry opposite phases of an alternating voltage.

9. The device of claim 8, wherein ions are propelled along the stack by a time-independent longitudinal electric field derived from a ladder of fixed voltages applied to said plates in superposition with the alternating voltage.

10. The device of claim 7, wherein ions are propelled along the stack by a gas flow resulting from vacuum suction into a following instrument stage maintained at a lower gas pressure selected from: a mass spectrometer, an ion mobility spectrometer, a photoelectron spectrometer, a photodissociation spectrometer, and combinations thereof.

11. The device of claim 7, wherein said apertures have essentially the same geometry and cross-sectional area, defining an ion-guiding tunnel.

12. The device of claim 7, wherein said apertures have homologous shapes and cross-sectional areas that decrease along the stack, defining a funnel that focuses ion beams entering the stack through an entrance aperture into tighter beams exiting through a smaller terminal aperture.

13. The device of claim 7, wherein said apertures have homologous shapes and cross-sectional areas that increase in preselected segments and decrease in other preselected segments along the stack, defining an hourglass ion funnel or a double hourglass ion funnel, wherein regions of said funnels having wider apertures for ion storage are spaced between, or separated by, regions of narrower apertures that provide ion focusing.

14. The device of claim 1, wherein the electrode elements are built on, or attached to, a preselected surface forming a periodic grating, such that the Dehmelt pseudoforce repels ions from said preselected surface.

15. The device of claim 14, wherein the preselected surface of the electrode elements is composed of a metal or other electrically-conductive material disposed on an insulating substrate forming the body of the electrode elements.

16. The device of claim 14, wherein ions are further moved along said preselected surface by a longitudinal electric field derived from a ladder of fixed voltages applied to the electrode elements in superposition with alternating voltages.

17. The device of claim 14, wherein at least two of said surfaces are disposed at an angle, forming a wedge with an open slit at the apex thereof which compresses a beam of ions entering an open base of the wedge in one dimension, forming a narrower belt-shaped beam exiting through said slit.

18. The device of claim **17**, wherein ions are propelled through said wedge toward the exit by: a longitudinal electric field derived from a ladder of fixed voltages applied to the elements on said surfaces in superposition with alternating voltages, a gas flow resulting from vacuum suction into a following instrument stage, or a combination thereof.

19. The device of claim **18**, wherein said following stage is selected from the group consisting of: a mass spectrometer, an ion mobility spectrometer, a photoelectron spectrometer, a photodissociation spectrometer, and combinations thereof.

20. The device of claim **17**, wherein said device is disposed to receive ions from a linear or elongated rectangular array of elementary sources selected from: an electrospray (ESI) emitter array, or a plate for matrix-assisted laser desorption ionization (MALDI).

21. The device of claim **17**, wherein said device is disposed at or after the terminus of an ion mobility spectrometry (IMS) analyzer to compress ion packets exiting therefrom into a parallelepiped geometry for injection into another instrument stage.

22. The device of claim **17**, wherein said device is disposed at or after the terminus of a differential mobility analyzer (DMA), a differential mobility spectrometry (DMS), or a field asymmetric waveform ion mobility spectrometry (FAIMS) analyzer having a planar or transverse-cylindrical gap geometry to compress the belt-shaped ion beam exiting therefrom for injection into another instrument stage.

23. The device of claim **17**, wherein said belt-shaped ion beam is refocused into a circular or a different cross-sectional shape using a following electrodynamic ion funnel with a gas pressure lower than that inside said wedge.

24. The device of claim **17**, wherein said belt-shaped ion beam is introduced into a subsequent ion mobility spectrometry (IMS) stage in a continuous or pulsed mode, and separated or filtered therein while retaining a rectangular cross section.

25. The device of claim **24**, wherein said IMS stage operates in a mode selected from the group consisting of: drift-tube IMS, traveling-wave IMS, DMA, DMS, FAIMS, and combinations thereof.

26. The device of claim **24**, wherein said device receives ions from a source of linear or elongated-rectangular shape.

27. The device of claim **24**, wherein said belt-shaped beam is further extracted from said IMS stage with compression that retains its rectangular cross section with another device selected from the group consisting of: ion mobility spectrometers, photoelectron spectrometers, photodissociation spectrometers, and combinations thereof.

28. The device of claim **17**, wherein said belt-shaped beam is injected into a subsequent mass spectrometry (MS) stage, in a continuous or pulsed mode, and analyzed therein while retaining a rectangular cross section.

29. The device of claim **28**, wherein said MS stage is a time-of-flight (ToF) mass spectrometer, and the lateral span of said belt-shaped beam is orthogonal to both the directions of ion velocity in MS analysis and ion injection into the ToF instrument.

30. The device of claim **28**, wherein said device receives ions from a source of linear or elongated-rectangular shape.

31. The device of claim **30**, wherein said belt-shaped beam is further injected into a subsequent mass spectrometry (MS) stage and analyzed therein while retaining the rectangular cross section such that the whole IMS/MS separation is performed on a planar ion be.

32. The device of claim **31**, wherein said MS stage is a time-of-flight (ToF) mass spectrometer, and the lateral span of said belt-shaped beam is orthogonal to both the ion velocity vector in MS analysis and the direction of ion injection into the ToF instrument.