CLAIMS

1. An apparatus, comprising:

a first pair of opposing electrode arrangements configured to confine ions received between the first pair opposing electrode arrangements in a confinement volume portion of a confinement volume inwardly laterally in a first confinement direction with respect to a longitudinal ion propagation direction, each opposing electrode arrangement of the first pair including an arrangement of RF electrodes configured to receive an RF voltage having an alternate phase between adjacent RF electrodes of the arrangement of RF electrodes of the opposing electrode arrangement of the first pair and to confine received ions between the first pair of opposing electrode arrangements; and

a second pair of opposing electrode arrangements separate from the first pair of opposing electrode arrangements and configured to confine ions received between the second pair of opposing electrode arrangements in the confinement volume inwardly laterally in a second confinement direction that complements the first confinement direction, each opposing electrode arrangement of the second pair including an arrangement of RF electrodes configured to receive an RF voltage having an alternate phase between adjacent RF electrodes of the arrangement of RF electrodes of the opposing electrode arrangement of the second pair;

a first traveling wave electrode arrangement situated between adjacent RF electrodes of the first pair of opposing electrode arrangements and that includes a plurality of traveling wave electrodes extending in a longitudinal sequence in the ion propagation direction, in which the traveling wave electrodes are configured to receive a variable DC voltage and to produce a corresponding traveling wave configured to manipulate movement of the ions within the confinement volume.

2. An apparatus according to Claim 1, in which the first and second ion confinement directions are mutually perpendicular to the ion propagation direction.

3. An apparatus according to Claim 1, in which the first and second pairs of opposing electrode arrangements are configured to confine ions of opposite polarities.

4. An apparatus according to Claim 1, in which the first and second pairs of opposing electrode arrangements are configured to laterally separate, with respect to the ion propagation

direction, received ions of different polarity into non-overlapping ion groups in the confinement volume portion.

5. An apparatus according to Claim 1, in which RF electrodes of each arrangement of RF electrodes of the second pair of opposing electrode arrangements are stacked in the second confinement direction, and in which the RF electrodes of the second pair of opposing electrode arrangements extend longitudinally in the ion propagation direction and provide confinement of received ions in the second confinement direction.

6. An apparatus according to Claim 5, in which each of the stacked RF electrodes includes one or more substantially planar surfaces extending laterally in the second confinement direction.

7. An apparatus according to Claim 5, in which the RF electrodes are wire electrodes.

8. An apparatus according to Claim 5, in which a portion of at least two RF electrodes of the second pair of opposing electrode arrangements extend into the confinement volume portion by different amounts to provide a non-rectangular confinement cross-section of the confinement volume portion .

9. An apparatus according to Claim 1, in which each opposing electrode arrangement of the second pair includes a second traveling wave electrode arrangement configured to confine ions received in the confinement volume in the second confinement direction.

10. An apparatus according to Claim 9, in which each second traveling wave electrode arrangement includes a plurality of traveling wave electrodes extending longitudinally in the ion propagation direction and spaced apart from each other in the second confinement direction, in which the plurality of traveling wave electrodes of the second traveling wave electrode arrangement are configured to receive a variable DC voltage and to produce a corresponding traveling wave to confine ions within the confinement volume in the second confinement direction inward.

11. An apparatus according to Claim 9, in which the second traveling wave electrode arrangements are configured to confine received ions in an extended confinement volume portion of the confinement volume that is laterally adjacent to the confinement volume portion of the first pair of opposing electrode arrangements with respect to the ion propagation direction.

12. An apparatus according to Claim 10, in which the RF electrodes of the second pair of opposing electrode arrangements extend longitudinally in the ion propagation direction and are spaced apart from each other in the second confinement direction.

13. An apparatus according to Claim 12, in which the traveling wave electrodes of the second pair of opposing electrode arrangements are situated between adjacent RF electrodes of the second pair of opposing electrode arrangements.

14. An apparatus according to Claim 11, in which the first and second pairs of opposing electrode arrangements are situated on a pair of opposing surfaces defining an electrodeless gap that includes the confinement volume portion and the extended confinement volume portion.

15. An apparatus according to Claim 1, in which the confinement volume defines a first ion conduit and the apparatus further comprises a second ion conduit separate and laterally spaced apart from the first ion conduit and in which the second ion conduit includes a plurality of electrode arrangements and at least one of the electrode arrangements of the second ion conduit is an opposing electrode arrangement of the first or second pairs of opposing electrode arrangements of the first ion conduit.

16. An apparatus according to Claim 1, in which the alternate phase between adjacent RF electrodes of the arrangement of RF electrodes of the opposing electrode arrangement of each of the first pair and the second pair is 180 degrees out of phase.

17. An apparatus according to Claim 1, in which the confinement volume is curved or tapered.

18. A method, comprising:

receiving ions in a confinement volume defined between a first pair of opposing electrode arrangements, each of the first pair of opposing electrode arrangements including a first arrangement of RF electrodes and a first arrangement of traveling wave electrodes situated between adjacent RF electrodes of the first arrangement of RF electrodes, in which the first traveling wave electrodes extend in a longitudinal sequence with respect to a longitudinal ion propagation direction;

moving the received ions along the longitudinal ion propagation direction in response to receipt of a variable DC voltage by the traveling wave electrodes of the first traveling wave electrode arrangement;

providing a first RF field in response to receipt of a first RF voltage by the RF electrodes of the first RF electrode arrangement;

confining, by the first RF field, the received ions in the confinement volume in a first lateral inward direction between the first pair of opposing electrode arrangements with respect to the ion longitudinal propagation direction;

providing a second RF field in response to receipt of a second RF voltage by RF electrodes of a second RF electrode arrangement of a second pair of opposing arrangement of electrodes; and

confining, by the second RF field, the ions in the confinement volume in a second lateral inward direction with respect to the ion longitudinal propagation direction that complements the first inward direction.

19. A method according to Claim 18, in which the RF electrodes of each second RF electrode arrangement forms a stack with adjacent RF electrodes of the stack configured to receive the RF voltage having an alternate phase, and in which each RF electrode of each second RF electrode arrangement extends longitudinally along the confinement volume.

20. A method according to Claim 18, in which:

the first pair of opposing electrode arrangements are spaced apart across a center confinement volume portion of the confinement volume;

the second pair of opposing arrangement of electrodes are spaced apart across an extended confinement region of the confinement volume adjacent to the center confinement volume portion;

a first electrode arrangement of the first pair of opposing electrode arrangements and a first electrode arrangement of the second pair of opposing electrode arrangements are associated with a first common surface; and

a second electrode arrangement of the first pair of opposing electrode arrangements and a second electrode arrangement of the second pair of opposing electrode arrangements are associated with a second common surface.

21. A method according to Claim 20, in which the second pair of opposing arrangements of electrodes includes a second arrangement of traveling wave electrodes that are alternatingly arranged between RF electrodes of the second arrangement of RF electrodes, and in which the confining of the received ions in the second lateral inward direction includes confining the received ions in the extended confinement region in the second lateral inward direction in response to receipt of a variable DC voltage to the traveling wave electrodes of the second arrangement of traveling wave electrodes.

22. A method according to Claim 18, in which the received and confined ions have opposite polarities.