CLAIMS

1. A particle beam irradiation apparatus for charged particle cancer therapy of a tumor of a patient using a charged particle beam, comprising:

a synchrotron configured to accelerate the charged particle beam;

a respiration sensor configured to generate a respiration signal, the respiration signal monitoring a breathing cycle of the patient during use;

a rotatable platform configured to hold the patient, wherein said rotatable platform rotates through about three hundred sixty degrees during an irradiation period of the patient;

an injection system configured to inject protons into said synchrotron, wherein said injection system comprises any of:

a negative ion source configured to generate negative ions;

an ion beam focusing system configured to focus the negative ions along the a negative ion beam path inside a vacuum tube;

a tandem accelerator; and

a partial vacuum system,

wherein said synchrotron uses the respiration signal to deliver the charged particle beam to the tumor at a set point in the breathing cycle,

wherein said delivery of the charged particle beam at said set point of the breathing cycle occurs in greater than five rotation positions of said rotatable platform, and

wherein said tandem accelerator comprises a carbon foil in said negative ion beam path, wherein during use the negative ions that transmit through said carbon foil convert to protons along a proton beam path, wherein said carbon foil mechanically couples to walls circumferentially surrounding the negative ion beam to yield a vacuum barrier between a negative ion beam side of said carbon foil and a proton beam side of said carbon foil.

2. The apparatus of Claim 1, wherein said respiration sensor comprises a force meter replaceably attached to the patient’s chest.

3. The apparatus of Claim 1, wherein said respiration sensor comprises:

a first thermal resistor positioned proximate the patient's nose;

a second thermal resistor positioned both out of an exhalation path of the patient and in the same local room environment as said rotatable platform,

wherein said respiration signal is generated using differences between readings from said first thermal resistor and said second thermal resistor.

4. The apparatus of Claim 1, further comprising:

a display screen connected to an upper portion of said rotatable platform, said display screen displaying breath control commands to the patient.

5. The apparatus of Claim 4, wherein said respiration signal is used in generating said breath control commands and wherein said breath control commands comprise a visual countdown on said display screen to when the patient's breath is to be held.

6. The apparatus of Claim 1, wherein said delivery of said charged particle beam at said set point of said breathing cycle occurs in greater than twenty rotation positions of said rotatable platform, wherein ingress energy of said charged particle beam is circumferentially distributed about the tumor.

7. The apparatus of Claim 6, wherein said delivery of said charged particle beam delivers none of said ingress energy to the patient's spinal cord or eye.

8. The apparatus of Claim 1, wherein said negative ion source comprises:

a high temperature plasma chamber;

a magnetic material within said high temperature plasma chamber, wherein said magnetic material provides a magnetic field barrier between said high temperature plasma chamber and a low temperature plasma region.

9. The apparatus of Claim 1, wherein said ion beam focusing system comprises:

a first electrode circumferentially surrounding said negative ion beam path; and

a second electrode partially obstructing said negative ion beam path with a conductive mesh,

wherein electric field lines run between said conductive mesh and said first electrode,

wherein said electric field lines focus said negative ions along said negative ion beam path.

10. The apparatus of Claim 1, wherein said partial vacuum system comprises:

a turbo molecular pump pumping air out of said vacuum tube into a holding volume;

a pressure sensor sensing a pressure in said holding volume;

a controller receiving said pressure from said pressure sensor, wherein said controller instructs an actuator to open a valve when said pressure crosses a threshold; and

a semi-continuously operating pump removing pressure from said holding volume, wherein said semi-continuously operating pump operates in coordination with said actuator opening and shutting said valve.

11. The apparatus of Claim 1, wherein said synchrotron comprises four turning sections, wherein each of said turning sections turns said charged particle beam about ninety degrees.

12. The apparatus of Claim 11, wherein each of said four turning sections comprises four main bending magnets.

13. The apparatus of Claim 12, wherein each of said main bending magnets comprises two beveled edges, wherein each of said two beveled edges focus said charged particle beam.

14. The apparatus of Claim 1, wherein said synchrotron comprises no quadrupole magnets about a circulating path of said charged particle beam in said synchrotron.

15. The apparatus of Claim 1, wherein said synchrotron comprises a circumference of less than sixty meters and at least thirty edge focusing surfaces, wherein an edge focusing surface comprises a beveled edge of a main bending magnet.

16. The apparatus of Claim 1, wherein said synchrotron comprises only four turning sections, wherein each turning section comprises at least four bending magnets, and wherein each bending magnet comprises at least one focusing edge.

17. The apparatus of Claim 1, wherein said synchrotron comprises:

exactly four turning sections; and

no quadrupoles about a circulating path of said charged particle beam in said synchrotron.

18. A method for charged particle beam irradiation of a tumor of a patient, comprising the steps of:

accelerating a charged particle beam with a synchrotron;

monitoring a breathing cycle with a respiration sensor, said respiration sensor generating a respiration signal corresponding to the patient’s breathing cycle;

rotating a platform holding the patient,

wherein said platform rotates through about three hundred sixty degrees during an irradiation period of the patient,

using the respiration signal, delivering said charged particle beam to the tumor at a set point in the breathing cycle, wherein said step of delivering said charged particle beam at said set point of said breathing cycle occurs in greater than four rotation positions of said rotatable platform;

injecting protons into said synchrotron with an injection system, wherein said injection system comprises a negative ion source, an ion beam focusing system, a tandem accelerator, and a partial vacuum system;

generating negative ions with said negative ion source;

focusing said negative ions along a negative ion beam path inside a vacuum tube using said ion beam focusing system; and

converting said negative ions into protons inside said tandem accelerator; and

in said negative ion source, providing a magnetic field barrier between a high temperature plasma chamber and a low temperature plasma region using a magnetic material located inside said high temperature plasma chamber.

19. The method of Claim 18, wherein said step of monitoring comprises use of a force meter strapped to the patient's chest to generate said respiration signal.

20. The method of Claim 18, wherein said step of monitoring comprises:

sensing patient breathing with a first thermal resistor positioned proximate the patient's nose;

sensing room temperature using a second thermal resistor positioned both out of an exhalation path of the patient and in the same local room environment as the platform,

wherein said respiration signal is generated using differences between readings from said first thermal resistor and said second thermal resistor.

21. The method of Claim 18, further comprising the step of:

displaying breath control commands on a display screen mounted on an upper element of said platform.

22. The method of Claim 18, further comprising the step of:

delivering said charged particle beam at said set point of said breathing cycle in greater than twenty rotation positions of said rotatable platform, wherein ingress energy of said charged particle beam is circumferentially distributed about the tumor.

23. The method of Claim 18, wherein said step of delivering said charged particle beam delivers none of said ingress energy to the patient's spinal cord or eye.

24. The method of Claim 18, further comprising the step of:

focusing said negative ions along said negative ion beam path using electric field lines within said ion beam focusing system,

wherein a first electrode circumferentially surrounds said negative ion beam path; and

wherein, a second electrode partially obstructs said negative ion beam path with a conductive mesh,

wherein said electric field lines run between said conductive mesh and said first electrode.

25. An apparatus for focusing negative ions in a negative ion beam having a cross-sectional area as part of a charged particle irradiation device, comprising:

a first focusing electrode circumferentially surrounding the negative ion beam;

a second focusing electrode comprising conductive paths at least partially blocking the negative ion beam;

wherein first electric field lines run between said first focusing electrode and said second focusing electrode,

wherein the negative ions encounter force vectors running up said first electric field lines that focus the negative ion beam.

26. The apparatus of Claim 25, wherein said first focusing electrode comprises a negative charge, wherein said second focusing electrode comprises a positive charge.

27. The apparatus of Claim 26, wherein said conductive paths comprise any of:

a series of conductive lines running substantially in parallel across the negative ion beam;

a conductive grid crossing the negative ion beam; and

a foil crossing the negative ion beam, said foil having holes with combined areas of at least ninety percent of the cross-sectional area of the negative ion beam.

28. The apparatus of Claim 27, wherein said conductive paths block less than ten percent of the cross-sectional area of the negative ion beam.

29. The apparatus of Claim 28, further comprising:

a third focusing electrode circumferentially surrounding the negative ion beam, wherein said second focusing electrode comprises a position between said first focusing electrode and said third focusing electrode,

wherein said third focusing electrode comprises a negative charge,

wherein second electric field lines run between said third focusing electrode and said second focusing electrode,

wherein the negative ions encounter force vectors running up said second electric field lines that focus the negative ion beam.

30. The apparatus of Claim 25, further comprising:

a negative ion source comprising:

a magnetic material; and

a high temperature plasma chamber substantially encompassing said magnetic material;

wherein said high temperature plasma chamber comprises: a first ion generation electrode at a first end of said high temperature plasma chamber, a second ion generation electrode at a second end of said high temperature plasma chamber, and a magnetic field carrying outer wall;

wherein application of a first high voltage pulse across said first ion generation electrode and said second ion generation electrode breaks hydrogen in said high temperature plasma chamber into component parts;

wherein said magnetic material yields a magnetic field loop running through said first ion generation electrode, through said magnetic field carrying outer wall, through said second ion generation electrode, across a gap, and through said magnetic material;

wherein said magnetic field loop yields a magnetic barrier across said gap between said high temperature plasma chamber and a low temperature plasma region, said magnetic barrier passing a subset of said component parts;

wherein low energy electrons interact with atomic hydrogen to create hydrogen anions in said low temperature plasma region;

wherein application of a second high voltage pulse across said second ion generation electrode and a third ion generation electrode extracts negative ions from said negative ion source into the negative ion beam.

31. The apparatus of Claim 30, further comprising:

a synchrotron,

wherein the negative ion beam is converted into a proton beam using a beryllium carbon film, wherein said carbon film comprises a thickness of about 30 to 200 microns thickness;

wherein the proton beam is injected into said synchrotron;

wherein said synchrotron comprises:

four turning sections, wherein each of said turning sections turns the proton beam about ninety degrees;

no quadrupole magnet about a circulating path of the proton beam in said synchrotron.

32. An apparatus for accelerating charged particles, comprising:

a synchrotron, comprising:

exactly four turning sections, wherein each of said turning sections turns the charged particle beam about ninety degrees;

wherein said synchrotron comprises no quadrupole magnet about a circulating path of the charged particle beam in said synchrotron.

33. The apparatus of Claim 32, wherein each of said four turning sections comprises four main bending magnets.

34. The apparatus of Claim 33, wherein each of said main bending magnets comprises two beveled edges, wherein each of said two beveled edges focus the charged particle beam.

35. The apparatus of Claim 32, wherein said synchrotron comprises:

a circumference of less than sixty meters; and

at least thirty edge focusing surfaces, wherein an edge focusing surface comprises a beveled edge of a main bending magnet.

36. The apparatus of Claim 32, wherein said synchrotron comprises exactly four turning sections, wherein each turning section comprises at least four bending magnets, and wherein each bending magnet comprises at least one focusing edge.

37. The apparatus of Claim 32, further comprising:

a negative ion source comprising:

a magnetic material; and

a high temperature plasma chamber substantially encompassing said magnetic material;

wherein said high temperature plasma chamber comprises: a first ion generation electrode at a first end of said high temperature plasma chamber, a second ion generation electrode at a second end of said high temperature plasma chamber, and a magnetic field carrying outer wall;

wherein application of a first high voltage pulse across said first ion generation electrode and said second ion generation electrode breaks hydrogen in said high temperature plasma chamber into component parts;

wherein said magnetic material yields a magnetic field loop running through said first ion generation electrode, through said magnetic field carrying outer wall, through said second ion generation electrode, across a gap, and through said magnetic material;

wherein said magnetic field loop yields a magnetic barrier across said gap between said high temperature plasma chamber and a low temperature plasma region, said magnetic barrier passing a subset of said component parts;

wherein low energy electrons interact with atomic hydrogen to create hydrogen anions in said low temperature plasma region;

wherein application of a second high voltage pulse across said second ion generation electrode and a third ion generation electrode extracts negative ions from said negative ion source into the negative ion beam;

wherein the negative ion beam is converted to the charged particle beam and injected into said synchrotron.

38. The apparatus of Claim 37, further comprising a focusing system for the negative ion beam, comprising:

a first focusing electrode circumferentially surrounding the negative ion beam;

a second focusing electrode comprising conductive paths at least partially blocking the negative ion beam;

wherein electric field lines run between said first focusing electrode and said second focusing electrode,

wherein the negative ions encounter force vectors running up said electric field lines that focus the negative ion beam.

39. The apparatus of Claim 32, further comprising a negative ion beam focusing system, comprising:

a first focusing electrode circumferentially surrounding the negative ion beam;

a second focusing electrode comprising conductive paths at least partially blocking the negative ion beam;

wherein first electric field lines run between said first focusing electrode and said second focusing electrode,

wherein the negative ions encounter force vectors running up the electric field lines that focus the negative ion beam,

wherein the negative ion beam is converted into a proton beam using a beryllium carbon film, wherein said carbon film comprises a thickness of about 30 to 200 microns thickness,

wherein said charged particle beam comprises the proton beam, wherein the proton beam is injected into said synchrotron.

40. The apparatus of Claim 39, wherein said first focusing electrode comprises a negative charge, wherein said second focusing electrode comprises a positive charge.

41. The apparatus of Claim 40, wherein said conductive paths comprise any of:

a series of conductive lines running substantially in parallel across the negative ion beam;

a conductive grid crossing the negative ion beam; and

a foil crossing the negative ion beam, said foil having holes with combined areas of at least ninety percent of the cross-sectional area of the negative ion beam.

42. The apparatus of Claim 41, wherein said conductive paths block less than ten percent of the cross-sectional area of the negative ion beam.