CLAIMS:

1. A high temperature superconducting, HTS, field coil, the HTS field coil comprising:

a plurality of turns comprising HTS material and metallic stabilizer;

a partially insulating layer separating the turns, such that current can be shared between turns via the partially insulating layer;

the partially insulating layer comprising:

an electrically conducting layer coated on one side with a first insulating layer and on the other side with a second insulating layer;

each insulating layer having one or more windows through which electrical contact can be made between the turns and the electrically conducting layer;

wherein the windows in the first insulating layer are offset in the plane of the electrically conducting strip from the windows in the second insulating layer.

2. An HTS field coil according to any preceding claim, wherein the electrically conducting layer is a continuous electrically conducting strip.

3. An HTS field coil according to ~~any preceding~~ claim 1, wherein the electrically conducting layer comprises a plurality of regions, each region electrically connecting a respective first window in the first insulating layer to a respective second window in the second insulating layer, and each region being electrically insulated in the plane of the electrically conducting layer from the other regions.

4. An HTS field coil according to claim 3, wherein each region comprises a track between the first and second window, a length of the track between the first and second window being at least twice a width of the track measured perpendicular to the length.

5. An HTS field coil according to claim 4, wherein each track is non-linear.

6. An HTS field coil according to any preceding claim, wherein the windows in the second layer are each a part of a respective via extending through the first insulating layer, the second insulating layer, and the electrically conductive layer, the partially

insulating layer further comprising an insulating cap on each via at the end proximate to the first insulating layer.

7. An HTS field coil according to any preceding claim, ~~wherein the electrically conducting layer comprises a metal.~~

~~8. An HTS field coil according to claim 7, wherein the metal is one of:~~
~~copper;~~
~~brass;~~
~~steel;~~
~~stainless steel;~~
~~Hastelloy; and~~
~~nickel.~~

~~9. An HTS field coil according to any preceding claim, wherein the partially insulating layer and the turns are continuously wound.~~

~~10. An HTS field coil according to any preceding claim,~~ wherein the offset distance between each window on one layer and the closest window on the other layer is greater than a thickness of the electrically conducting layer, and/or~~.~~

~~11. An HTS field coil according to any preceding claim,~~ wherein the offset distance between each window on one layer and the closest window on the other layer is less than 1/5 of the length of a turn of the HTS field coil, more preferably less than 1/10, more preferably less than 1/50.

8~~12~~. An HTS field coil according to any preceding claim, wherein each insulating layer comprises a plurality of windows offset along a length of the partially insulating layer.

9~~13~~. An HTS field coil according to ~~any preceding~~ claim 8, wherein the windows on each insulating layer are regularly spaced with a spacing that is the same for both insulating layers, and wherein each window has the same area, and/or~~.~~

~~14. An HTS field coil according to any preceding claim,~~ wherein the windows on one insulating layer are offset from those in the opposing insulating layer such that each window on one insulating layer is equidistant from the two closest windows of the opposing insulating layer.

10~~15~~. An HTS field coil according to ~~any preceding~~ claim 8 or 9, wherein the insulating layers are formed by:

helically wrapping an insulating tape around the electrically conducting layer; or

helically wrapping an insulating tape around the turns;

such that gaps in the helical winding form the windows.

11~~16~~. An HTS field coil according to any of claims 1 to 7~~11~~, wherein each insulating layer comprises a single window extending along the length of the insulating layer, and the window on one insulating layer is offset along a width of the partially insulating layer from the window in the other insulating layer.

12~~17~~. An HTS field coil according to claim 11~~16~~, wherein the electrically conducting layer is bent such that the portion of the electrically conducting layer exposed by each window lies in the plane of the respective insulating layer.

13~~18~~. An HTS field coil according to any preceding claim, wherein each insulating layer extends beyond the electrically conducting layer on at least one side.

14~~19~~. An HTS field coil according to any preceding claim, wherein~~-~~:

the partially insulating layer comprises electrically conducting inserts in the or each window;

each window is plated with an electrically conducting material; and/or

the electrically conducting layer comprises electrically conducting protrusions which extend into the or each window;~~-~~

and wherein:

~~20. An HTS field coil according to claim 19, wherein~~ the electrically conducting inserts or protrusions fill the respective window; or~~-~~

~~21. An HTS field coil according to claim 19, wherein~~ the electrically conducting inserts or protrusions fill only a portion of the respective window, and electrical contact

between the electrically conducting layer and the turns through the window is only via the electrically conducting inserts.

1522. An HTS field coil according to any preceding claim, wherein the partially insulating layer comprises electrically conducting connection strips located outside the insulating layers and electrically connected to the electrically conducting strip via the windows, wherein the electrically conducting connection strips are electrically connected to the adjacent turns.

~~23. An HTS field coil according to any preceding claim, wherein the HTS field coil is solder potted.~~

1624. An HTS field coil according to any preceding claim, wherein the partially insulating layer comprises a plurality of sections connected by butt joints.

1725. A method of manufacturing an HTS field coil, the method comprising:

providing an HTS cable, the HTS cable comprising HTS material and metallic stabiliser;

providing a partially insulating layer, the partially insulating layer comprising:

an electrically conducting layer coated on one side with a first insulating layer and on the other side with a second insulating layer;

each insulating layer having one or more windows through which electrical contact can be made between the turns and the electrically conducting layer;

wherein the windows in the first insulating layer are offset in the plane of the electrically conducting layer from the windows in the second insulating layer;

assembling the HTS cable and the partially insulating layer together to form an HTS field coil, such that current can be shared between turns of the HTS cable via the partially insulating layer.

1826. A method according to claim 1725, wherein providing the partially insulating layer comprises separately providing each of the electrically conducting layer and, insulating layers, and forming the partially insulating layer during winding of the HTS coil.

1927. A method according to claim 1826, wherein forming the partially insulating layer during winding of the coil comprises attaching the insulating layers to the electrically conducting layer with epoxy and curing the epoxy by the use of heated pressure rollers immediately before winding the partially insulating layer into the coil.

2028. A method according to claim 1725, wherein providing the partially insulating layer comprises:

bonding the insulating layers to the electrically conducting layer by adhesive;

etching the insulating layers to form the windows.

~~29. A method according to claim 25 or 28, wherein providing the partially insulating layer comprises providing a plurality of sections of partially insulating layer and connecting the sections by butt joints.~~

2130. A method according to any of claims 1725 to 2029, wherein providing the partially insulating layer comprises:

providing a first insulating layer;

coating a surface of the first insulating layer with the electrically conductive layer;

attaching a second insulating layer to the electrically conducting layer;

drilling the windows in the first and second insulating layer.

~~31. A method according to claim 30, wherein drilling the windows in the second insulating layer comprises drilling vias through the first insulating layer, electrically conducting layer, and second insulating layer, and applying an insulating cap to an end of each via proximate to the first insulating layer.~~

~~32. A method according to claim 30 or 31, wherein providing the partially insulating layer further comprises:~~

~~for each of the first and second insulating layer, coating a surface of the insulating layer opposite to the electrically conducting layer with an electrically conducting connection layer, and wherein the electrically conducting connection layer is in contact with or soldered to the HTS cable following winding of the coil.~~

~~33. A method according to claim 32, and comprising lining each window with an electrically conductive material in order to electrically connect the electrically conducting layer and the respective metal layer.~~

~~34. A method according to any of claims 30 to 33, and comprising etching the electrically conductive layer to form a plurality of regions, such that when the partially insulating layer is assembled, each region electrically connects a respective first window in the first insulating layer to a respective second window in the second insulating layer, and each region is electrically insulated in the plane of the electrically conducting layer from the other regions.~~

2235. A method according to any of claims 1725 to 2134, and comprising solder potting the HTS field coil.

2336. A method according to claim 2235, wherein at least one of the partially insulating layers has an overhang which extends beyond the electrically conducting layer on at least one side, and comprising, following the step of solder potting, machining that side of the HTS coil to a level such that at least a portion of the overhang is removed.

~~37. A method according to claim 35 or 36, and comprising epoxy potting the HTS field coil following the step of solder potting.~~

2438. A method according to any of claims 2235 to 2337, and comprising, prior to solder potting, applying a removable mask to one side of the HTS coil, and removing the mask following solder potting.

~~39. A method according to any of claims 25 to 38, wherein providing an HTS cable comprises providing a plurality of HTS tapes, each comprising HTS material, and connecting the HTS tapes to form a cable.~~

~~40. A method according to claim 39, wherein the step of connecting the HTS tapes together to form a table is performed during winding of the HTS field coil.~~

~~41. A method according to claim 40, wherein the step of connecting the HTS tapes together comprises:~~

~~coating each tape in solder;~~

~~passing the HTS tapes together through a heated roller immediately prior to winding the HTS field coil.~~

~~42. A high temperature superconducting, HTS, field coil having a radius greater than 50cm, the HTS field coil having a plurality of turns comprising HTS material, wherein the turns are arranged such that current can be shared between turns via a resistive material.~~

~~43. An HTS field coil according to claim 42, wherein the resistive material is a semiconductor.~~

~~44. An HTS field coil according to claim 43, wherein the resistive material is germanium.~~

~~45. An HTS field coil according to any one of claims 1 to 24 and 42 to 44, wherein each turn comprises a plurality of HTS tapes, and wherein a resistance between HTS tapes in each turn is less than a resistance between turns.~~

~~46. A high temperature superconducting, HTS, field coil having a radius greater than 50cm, the HTS field coil having turns comprising HTS material, wherein the turns are separated by a metal-insulator transition material which has a first resistivity at a first temperature which is less than a peak critical temperature of the HTS, and a second, lower resistivity at a second temperature higher than the first temperature.~~

~~47. An HTS field coil according to claim 46, wherein the second resistivity is less than one tenth of the first resistivity.~~

25~~48~~. A tokamak fusion reactor comprising an HTS field coil according to any one of claims 1 to 16~~24 and 42 to 47~~, wherein the HTS field coil is one of a toroidal field coil or a poloidal field coil.

2649. A proton beam therapy, PBT, device comprising an HTS field coil according to any one of claims 1 to 1624 and 42 to 47, wherein the HTS field coil is one of:

a field coil of an accelerator of the PBT device;

a dipole or quadrupole magnet of a proton beam steering system of the PBT device.