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(54) **CORE FOR AN ELECTRIC SHUNT REACTOR**

(57) It is proposed a core (2) for an electric shunt reactor (30), the core (2) comprising: a first and a second yoke (4, 6); and a column assembly (10, 20) arranged along a respective longitudinal column axis (11, 21). The column assembly (10, 20) comprises an intermediate section (12, 22) and at least two distal column elements (14, 16; 24, 26). The column assemblies (10, 20) connect the first and second yoke (4, 6) in order to establish a magnetic path (8). A duct (18; 28) extends along the longitudinal column axis (11; 21) through the column assembly (10; 20) and through the *first* and second yokes (4, 6). The duct (18; 28) inters with the magnetic path (8). The distal column element (14; 16; 24; 26) has a lamination pattern differing from a lamination pattern of the intermediate section and differing from a lamination pattern of the neighboring yoke (4; 6) in order to mitigate the interference of the duct (18; 28).

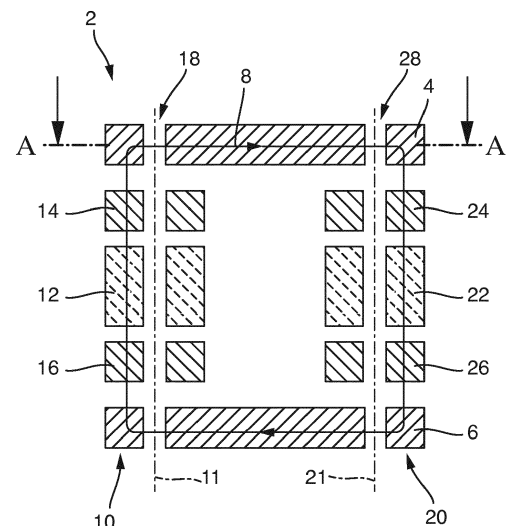
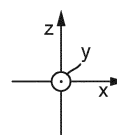


Fig. 1



Description

FIELD OF THE INVENTION

[0001] The present invention relates to a core of an electric shunt reactor.

BACKGROUND

[0002] Electric shunt reactors improve the stability and efficiency in medium and high-voltage networks. More specifically, electric shunt reactors compensate for a capacitive reactive power and reduce over voltages.

SUMMARY

[0003] In view of the prior art, it is an object of the present disclosure to improve the core for an electric shunt reactor. The core comprises: a first and a second yoke; and at least one column assembly arranged along a respective longitudinal column axis. The column assembly comprises an intermediate section and at least two distal column elements. The column assembly connects the first and second yoke in order to establish a magnetic path. A duct extends along the longitudinal column axis through the column assembly and through the first and second yokes, wherein the duct interferes with the magnetic path. The distal column element has a lamination pattern differing from a lamination pattern of the intermediate section and differing from a lamination pattern of the neighboring yoke in order to mitigate the interference of the duct.

[0004] The differing lamination pattern of the distal column element allows that the magnetic flux can change its direction along the orientation of the laminations. Consequently, the proposed core has the advantage that an over-excitation in the yoke is avoided. This over-excitation caused by unwanted magnetic flux distributions which may occur at a certain phase angles is avoided. Consequently, noise emission of the electric shunt reactor is reduced, power efficiency is increased and damages are avoided.

[0005] Besides these advantages a centrally-clamped configuration of the core has also constructional advantages. Centrally clamped configurations allow an easy pressing of the columns due to central tie rods. The comparably cheap centrally-clamped configuration benefits in the sense that the centrally clamped configuration allows an avoidance of further tie rods arranged around the column assemblies. Moreover, the distal column elements allow an avoidance of return limbs which result in a compact and cheap core design. As a result a compact, reliable and cheap core is provided.

[0006] According to an advantageous embodiment a strip-like portion of the distal column element extends essentially parallel to a longitudinal yoke axis and is delimited by the duct. The strip-like portion has the differing lamination pattern. The different lamination pattern in the

strip-like portion increases the field forming effect and therefore provides the avoidance of the unwanted magnetic flux distribution.

[0007] According to an advantageous embodiment the differing lamination pattern of the distal column element comprises an orientation of laminations perpendicular to an orientation of laminations of the neighboring yoke. This also increases the effect of the elimination of unwanted magnetic flux.

[0008] According to an advantageous embodiment the duct receives a tie rod of a clamping structure. Advantageously, a clamping structure is provided.

[0009] According to an advantageous embodiment the laminations of the distal column element extend parallel to each other. A cheap embodiment for the distal column element is provided.

[0010] According to an advantageous embodiment the laminations of the distal column element extend annularly around the longitudinal column axis, and wherein each lamination has an interruption in circumference direction. Advantageously, an envelope of the column assembly in the sense of a cylinder can be maintained with this embodiment of the distal column element.

[0011] According to an advantageous embodiment the distal column element comprises an outward layer with a lower electrical resistivity than one of the laminations of the distal column elements. Advantageously, the outward layer reduces unwanted flux leakage.

[0012] According to an advantageous embodiment the distal column element is arranged between the neighboring yoke and the intermediate section. This allows advantageously the forming of the magnetic flux in a transition zone between the yoke and the intermediate section.

[0013] According to an advantageous embodiment the yoke comprises a first yoke section and a second yoke section, wherein the yoke sections leave out a yoke gap, the yoke gap being part of the ducts. In this embodiment the yoke provides a recess without material to avoid the unfavorable magnetic flux distribution.

[0014] According to an advantageous embodiment each yoke section comprises an inward layer with a lower electrical resistivity than one of the laminations of the yoke section. Advantageously, the inward layers reduce unwanted flux leakage.

[0015] According to an advantageous embodiment the yoke is arranged between the distal column element and the intermediate section. This embodiment allows that the constructional changes of the core are reduced to a minimum as the area between the yoke and the intermediate section may remain unaffected, i.e. the mechanical changes between the yoke and the intermediate section can be reduced to a minimum.

[0016] According to an advantageous embodiment the yoke comprises a recess to receive the distal column element. This allows a more compact design of the core.

[0017] Further advantageous embodiments and features are shown and described the relationship with the

following figures. The same reference signs are used even for different embodiments.

BRIEF DESCRIPTION OF THE FIGURES

[0018]

- Figure 1 shows a schematic sectional view of a core;
- Figure 2 shows a schematic sectional view of the electric shunt reactor;
- Figure 3 shows schematically a sectional view of figure 1;
- Figure 4 shows schematically a view of the core of figure 3 toward an x-direction;
- Figure 5 shows schematically a view of the core of figure 1 toward the x-direction.
- Figures 6 to 10 show a schematic perspective view of the core, respectively.

DESCRIPTION OF THE EMBODIMENTS

[0019] Figure 1 shows a schematic sectional view of a core 2 for an electric shunt reactor. The core 2 comprises a first yoke 4 and a second yoke 6. The yokes 4 and 6 are mechanically and magnetically connected by at least two column assemblies 10 and 20, wherein each column assembly 10, 20 comprises an intermediate section 12, 22 and distal column elements 14, 16, 24, 26. Each column assembly 10, 20 connects the yokes 4 and 6 mechanically and magnetically in the sense of a single column. The distal column elements 14 and 24 are arranged nearby the first yoke 4. The distal column elements 16 and 26 are arranged nearby the second yoke 6. Therefore, the distal column elements 14, 24, 16, 26 are distally arranged with respect to the column assembly 10, 20, respectively.

[0020] The column assemblies 10 and 20 extend along a respective longitudinal column axis 11 and 21. The column assemblies 10 and 20 connect the first and second yokes 4 and 6 mechanically in order to establish a magnetic path 8. For each column assembly 10, 20 a duct 18, 28 extends along the respective longitudinal column axis 11, 21 through the first yoke 4, the respective distal column element 14, 24, the respective intermediate section 12, 22, the respective distal column element 16, 26, and the second yoke 6. The intermediate section 12, 22 comprise a plurality of stacked laminated column elements. The ducts 18, 28 are intended to receive a tie rod of a clamping structure. The ducts 18, 28 interfere with the magnetic path 8 as the ducts 18, 28 constitute a central cutout in the respective material. This interference is explained in connection with the figures 3, 4 and 5. To

mitigate the interference of the ducts 18 and 28 the distal column elements 14, 16, 24 and 26 have a lamination pattern differing from a lamination pattern of the intermediate section 12, 22 and differing from a lamination pattern of the neighboring yoke 4, 6. Of course further column assemblies can be arranged between the shown column assemblies 10 and 20. Also reactor cores 2 with return limbs can be realized using this principle. A lamination pattern in general comprises the geometrical arrangement of the lamination sheets inside an element, for example the yoke, distal column element and column elements of the intermediate section. Neighboring laminations are insulated by an insulation material between the laminations. Of course, a core 2 may comprise only one column assembly 10 and return limbs arranged between the yokes 4, 6, wherein the return limbs do not comprise a gap.

[0021] Figure 2 shows a schematic sectional view of the electric shunt reactor 30 comprising the core 2. The electric shunt reactor 30 comprises a casing 32 filled with insulation fluid 34 like mineral oil. Of course, also a dry-type shunt reactor is feasible, therefore not comprising the insulation fluid 34. The clamping structure comprises a first clamping support 36 and second clamping support 38. Tie rods 40 and 42 of the clamping structure extend along the respective longitudinal column axes 11 and 21 through the ducts 18 and 28, respectively. Windings 44 and 46 are arranged around the intermediate sections 12 and 22, respectively. Not shown clamping elements are arranged between the clamping support 36, 38 and the core 2 and/or a between the clamping support 36, 38 and the winding 44, 46, respectively. These clamping elements exert a clamping force on the core 2 and/or on the windings 44 and 46.

[0022] Figure 3 shows schematically a sectional view A-A of a core 2. In contrast to figure 1 the core 2 is not equipped with the distal column elements 14, 24, 16, and 26. Moreover, the shown core 2 comprises three column assemblies 10, 20 and 50. The shown schematic magnetic flux distribution 60 occurs for the left-hand side column assembly 10 with phase state $+\Phi$, the right-hand side column assembly 20 in a phase state $-\Phi$ and the middle column assembly 50 in the phase state $\Phi=0$. Due to the omitted material in the ducts 18 the yoke 4 comprises areas 62a to 62h with the magnetic flux perpendicular to a longitudinal yoke axis 64. Therefore, the magnetic flux is forced to change from one magnetic sheet to the adjacent magnetic shield in the sense of the laminations. As the laminations of the yoke 4 are oriented parallel to an xz-plane, the shown magnetic flux orthogonal to longitudinal the yoke axis 62 will produce eddy currents in the laminations of the yoke 4. These eddy currents result in increased power losses.

[0023] Figure 4 shows schematically a view of the core 2 of figure 3 toward the x-direction. The yoke 4 comprises the section 62a and 62b with the critical magnetic flux which has the orientation orthogonal to the longitudinal axis 64. The column assembly of the core 2 of the figures

3 and 4 comprises laminated column elements 66 with radially extending laminations. Neighboring laminated column elements 66 are spaced apart by spacers 68 to provide air gaps between the laminated column elements 66. Therefore the core 2 can be also termed gapped core.

[0024] Figure 5 shows schematically a view of the core 2 of figure 1 toward the x-direction. The distal column element 14 is arranged between the yoke 4 and the intermediate section 12. The distal column element 14 is surrounded by electrically insulating spacers 17. At least a central portion 70 of the distal column element 14 comprises laminations with a lamination pattern different from a lamination pattern of laminations of the yoke 4 and neighboring laminated column element 66a of the intermediate section 12. As shown the magnetic flux is formed by the distal column element 14 in a way so that orthogonal flux distributions along the magnetic path 8 are avoided in the yoke 4 or at least reduced.

[0025] Figure 6 shows a schematic perspective view of the core 2 according to an embodiment. The distal column elements 14 and 16 are arranged between the intermediate section 12 and the yokes 4 and 6, respectively, and are rectangular block shaped. The yokes 4 and 6 comprise laminations, which are planar metal sheets, having an orientation parallel to an xz-plane. Neighboring laminations are electrically insulated to each other. Therefore the yokes 4 and 6 exhibit the first lamination pattern.

[0026] The distal column elements 14 and 16 comprise laminations with an orientation parallel to an yz-plane. The laminations of the distal column element 14 have an orientation parallel to each other. Therefore the distal column elements 14 and 16 have laminations with an orientation orthogonal to the laminations of the yokes 4 and 6. The distal column elements 14 and 16 exhibit the second lamination pattern.

[0027] The distal column elements 14 and 16 comprise the portion 70 which is a strip-like volume of the distal column element 14, extending essentially parallel to the longitudinal yoke axis 64 and being delimited by the duct 18 extending through the distal column element 14. At least the portion 70 has the second lamination pattern. The laminations of the column elements 14, 16, 24 and 26 are preferably made of a material comprising iron.

[0028] According to an embodiment, the distal column elements 14, 16, 24 and 26 are limited by outward layers 71, 73, respectively. The outward layers 71, 73 extend essentially parallel to the laminations of the distal column element 14, 16, respectively. The outward layers 71, 73 have a lower electrical resistivity than a single one of the laminations enclosed by the outward layers 71, 73. The outward layers 71, 73 are preferably made of a material comprising copper and/or aluminum.

[0029] According to a further embodiment, the yokes 4 and 6 are limited by lateral layers 75, 77, respectively. The outward lateral layers 75, 77 extend essentially parallel to the laminations of the yokes 4 and 6, respectively. The lateral layers 75, 77 have a lower electrical resistivity

than a single one of the laminations enclosed by the lateral layers 75, 77. The lateral layers 75, 77 are preferably made of a material comprising copper and/or aluminum.

[0030] The laminated column elements 66 of the intermediate section 12 comprise laminations which have an orientation along the z-axis and are oriented radially from the column axis 11. The laminated column elements 66 of the intermediate section 12 have the third lamination pattern.

[0031] Figure 7 shows a schematic perspective view of the core 2 according to an embodiment. In contrast to figure 6 the yokes 4, 6 comprise a first yoke section 4a, 6a and a second yoke section 4b and 6b. Therefore the yokes 4, 6 comprise an omission of material in the area between the yoke sections 4a and 4b, 6a and 6b through which the longitudinal column axis 11, 21 passes.

[0032] According to an embodiment the yoke sections 4a, 4b are limited by facing inward layers 79, 81, respectively. The inward layers 79, 81 extend essentially parallel to the laminations of the yoke sections 4a and 4b, respectively. The inward layers 79, 81 have a lower electrical resistivity than a single one of the laminations of the yokes sections 4a, 4b. The inward layers 79, 81 are preferably made of a material comprising copper and/or aluminum. The yoke sections 6a and 6b also comprise inward layers 79, 81.

[0033] Figure 8 shows a schematic perspective view of the core 2 according to an embodiment. In contrast to figure 6 the distal column elements 14 and 16 of the column assembly 10 enclose the yokes 4 and 6. The intermediate section 22 is arranged between the yokes 4 and 6.

[0034] Figure 9 shows a schematic perspective view of the yoke 4. The distal column elements 14, 24 are arranged in corresponding recesses 74, 76, respectively.

[0035] Figure 10 shows a schematic perspective view of the core 2 according to an embodiment. In contrast to the core 2 according to figures 6 the column assemblies 10, 20 are different with respect to the distal column elements 14, 16. The distal column elements 14, 16 have laminations extending annularly around the longitudinal column axis 11. Each lamination is interrupted for example by providing a gap 80. Of course, the distal column elements 14, 16 may comprise more than one gap 80, therefore being provided as a plurality of sub-elements. The distal column elements 14, 16 comprise the portion 70, in which the laminations are oriented parallel to the zy-plane. Therefore, also the radially laminated distal column elements 14, 16 according to this embodiment provide the second lamination pattern in the portion 70 which differs from the lamination pattern in the neighboring portion of the yoke 6 and from the lamination pattern in the neighboring portion of the column element 66a.

[0036] According to an embodiment, the distal column elements 14 and 16 comprise an outward layer 83, respectively. The outward layer 83 surrounds the laminations of the distal column element 14, 16, respectively. The outward layer 83 has a lower electrical resistivity

than a single one of the laminations enclosed by the outward layer 83. The outward layer 83 is preferably made of a material comprising copper and/or aluminum.

Claims

1. A core (2) for an electric shunt reactor (30), the core (2) comprising: a first and a second yoke (4, 6); and at least one column assembly (10; 20) arranged along a respective longitudinal column axis (11; 21), wherein the column assembly (10; 20) comprises an intermediate section (12; 22) and at least two distal column elements (14, 16; 24, 26); wherein the column assembly (10; 20) connects the first and second yoke (4, 6) in order to establish a magnetic path (8); wherein a duct (18; 28) extends along the longitudinal column axis (11; 21) through the column assembly (10; 20) and through the first and second yokes (4, 6), the duct (18; 28) interfering with the magnetic path (8); and wherein the distal column element (14; 16; 24; 26) has a lamination pattern differing from a lamination pattern of the intermediate section (12; 22) and differing from a lamination pattern of the neighboring yoke (4; 6) in order to mitigate the interference of the duct (18; 28).
2. The core (2) according to claim 1, wherein a strip-like portion (70) of the distal column element (14; 16; 24; 26) extends essentially parallel to a longitudinal yoke axis (64) and is delimited by the duct (18; 28), and wherein the strip-like portion (70) has the differing lamination pattern.
3. The core (2) according to claim 1 or 2, wherein the differing lamination pattern of the distal column element (14; 16; 24; 26) comprises an orientation of laminations perpendicular to an orientation of laminations of the neighboring yoke (4; 6).
4. The core (2) according to one of the preceding claims, wherein the duct (18; 28) receives a tie rod (40; 42) of a clamping structure.
5. The core (2) according to one of the preceding claims, wherein the laminations of the distal column element (14; 16; 24; 26) extend parallel to each other.
6. The core (2) according to one of the claims 1 to 4, wherein the laminations of the distal column element (14; 16; 24; 26) extend annularly around the longitudinal column axis (11; 21), and wherein each lamination has an interruption (80) in circumference direction.
7. The core (2) according to one of the preceding claims, wherein the distal column element (14; 16) comprises an outward layer (71; 73; 83) with a lower electrical resistivity than one of the laminations of the distal column elements (14; 16).
8. The core (2) according to one of the preceding claims, wherein the distal column element (14; 16; 24; 26) is arranged between the neighboring yoke (4; 6) and the intermediate section (12; 22).
9. The core (2) according to one of the preceding claims, wherein the yoke (4; 6) comprises a first yoke section (4a; 6a) and a second yoke section (4b; 6b), wherein the yoke sections (4a, 4b; 6a, 6b) leave out a yoke gap, the yoke gap being part of the ducts (18, 28).
10. The core (2) according to claim 9, wherein each yoke section (4a, 4b, 6a, 6b) comprises an inward layer (79, 81) with a lower electrical resistivity than one of the laminations of the yoke section (4a, 4b, 6a, 6b).
11. The core (2) according to one of the preceding claims, wherein the yoke (4; 6) is arranged between the distal column element (14; 16; 24; 26) and the intermediate section (12).
12. The core (2) according to one of the preceding claims, wherein the yoke (4; 6) comprises a recess (74; 76) to receive the distal column element (14; 16; 24; 26).
13. An electric shunt reactor (30) comprising the core (2) according to one of the preceding claims.

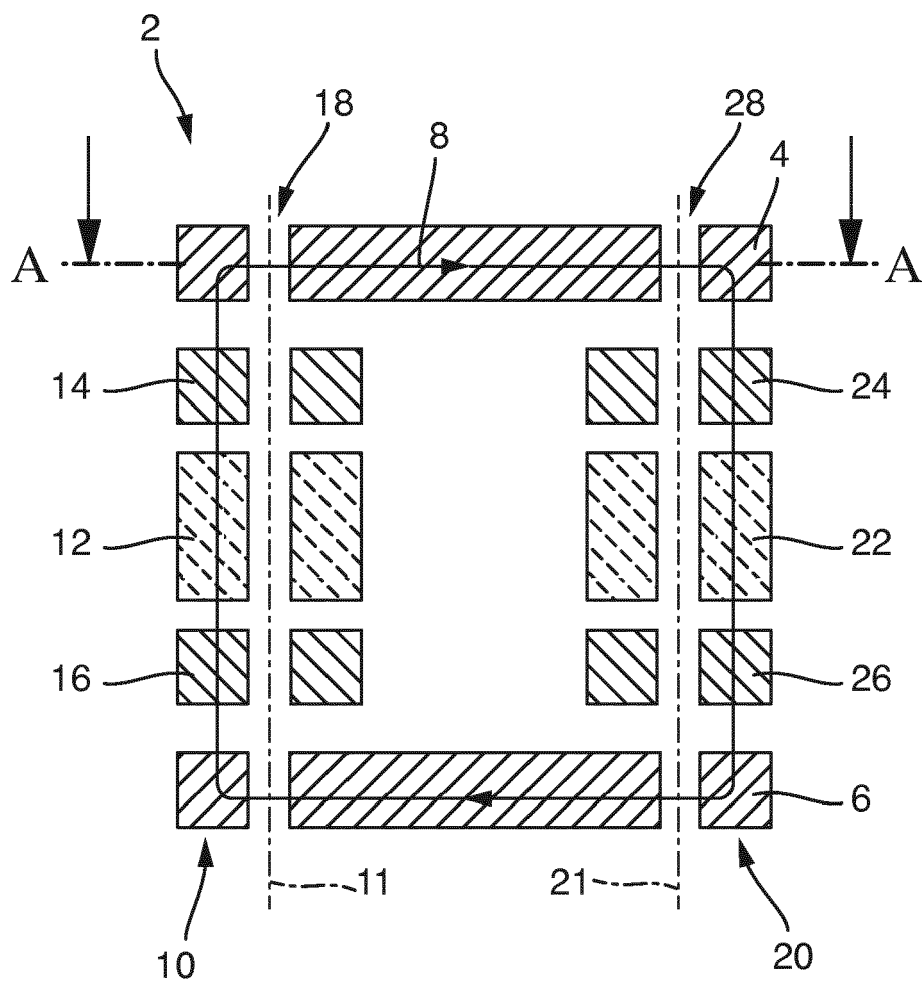
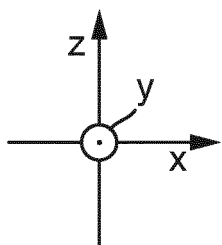


Fig. 1



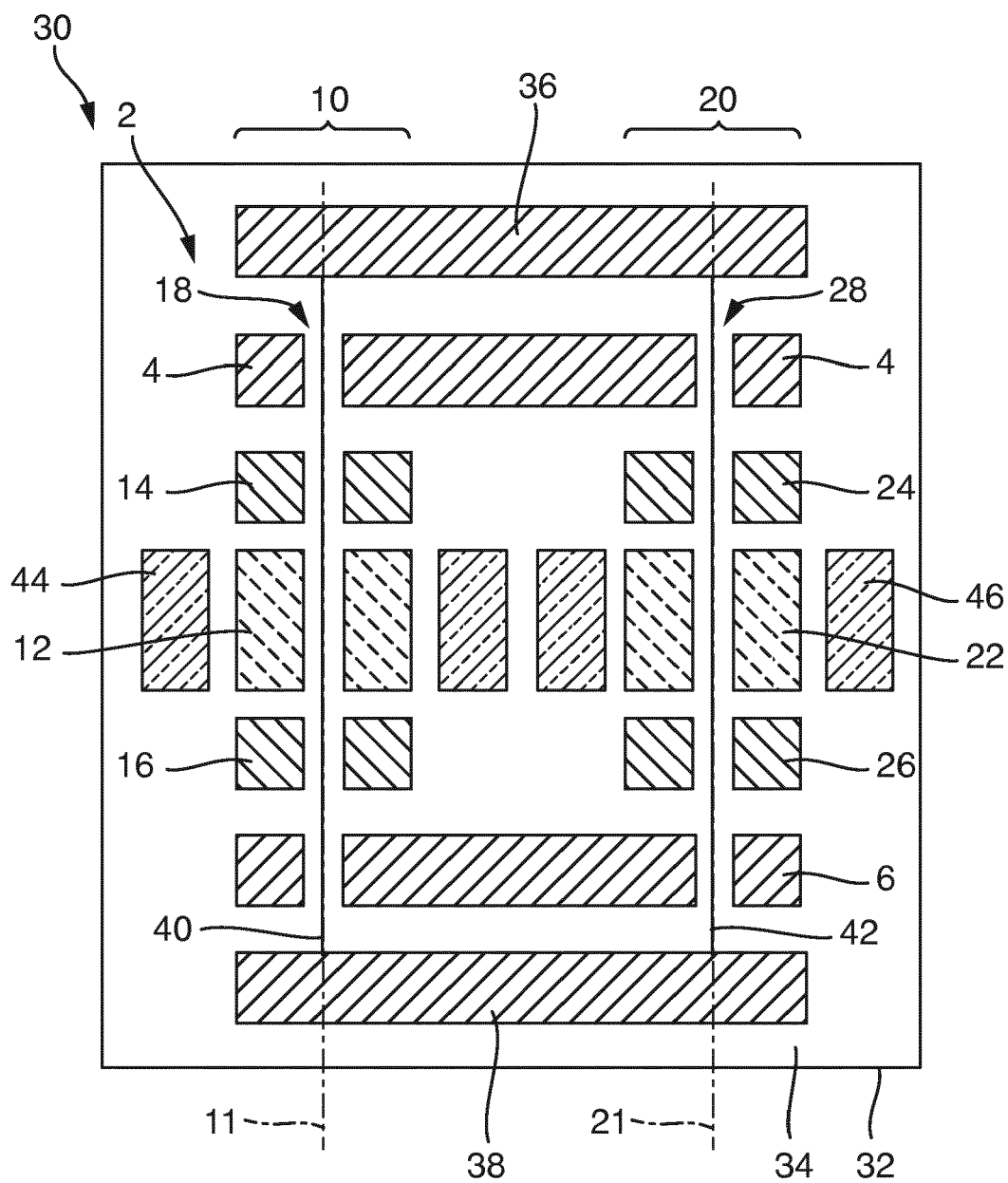
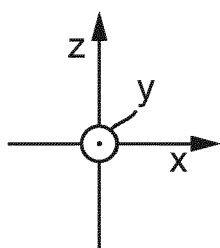
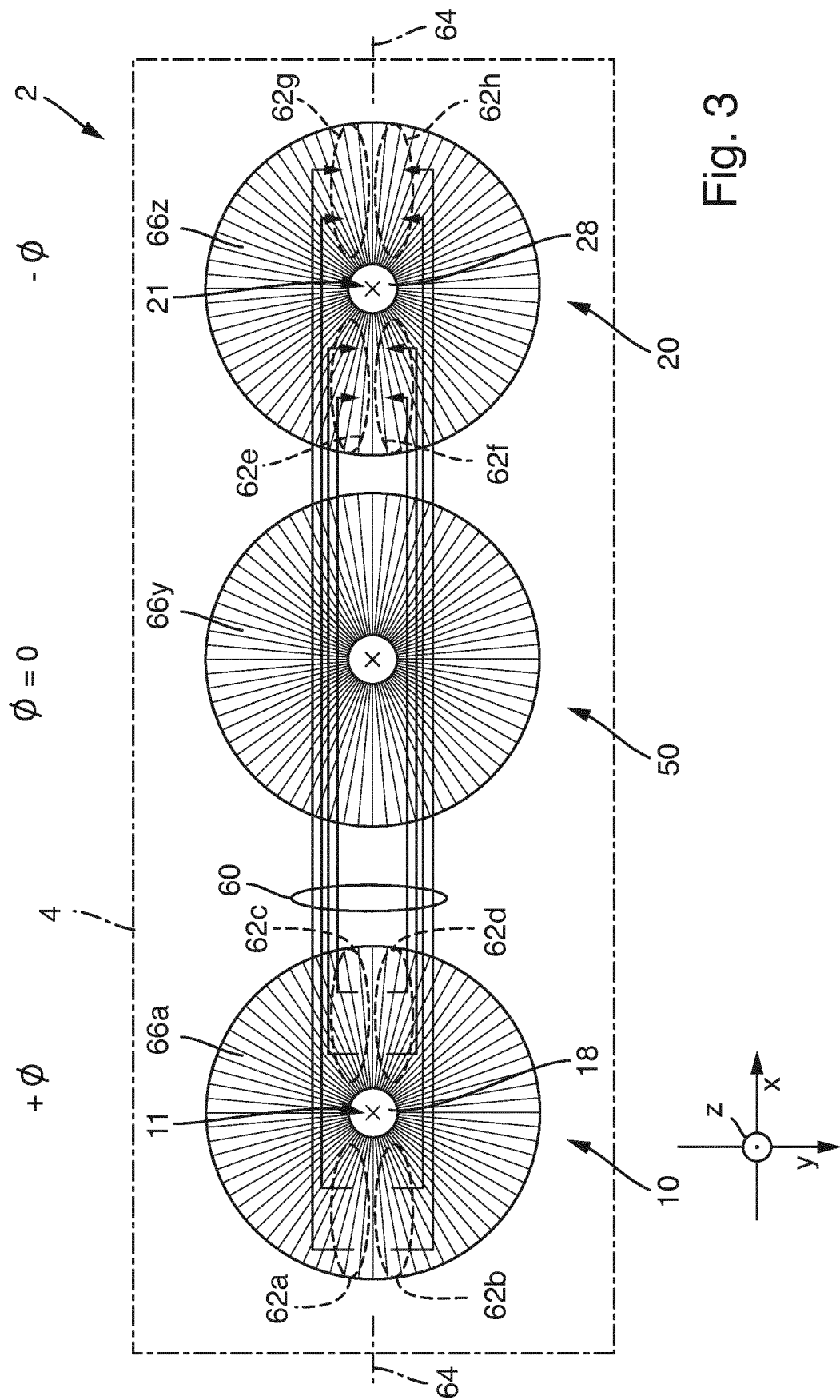


Fig. 2





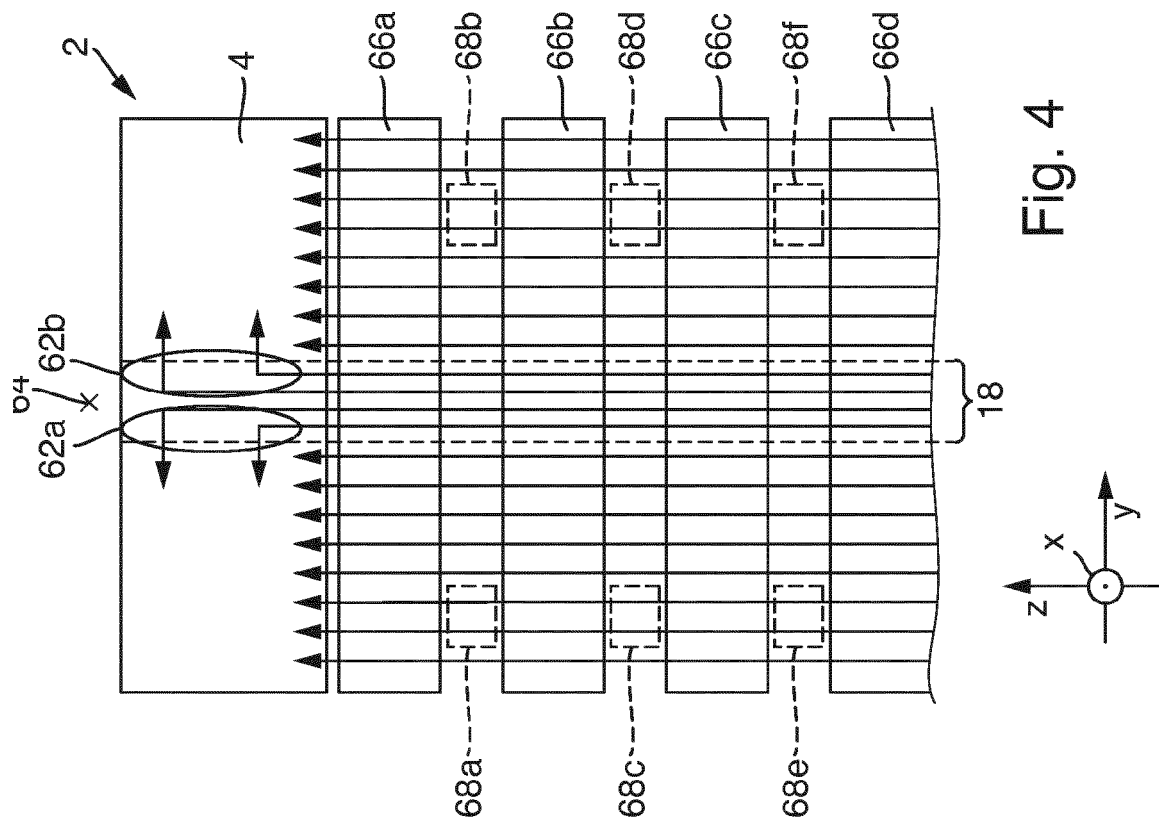


Fig. 4

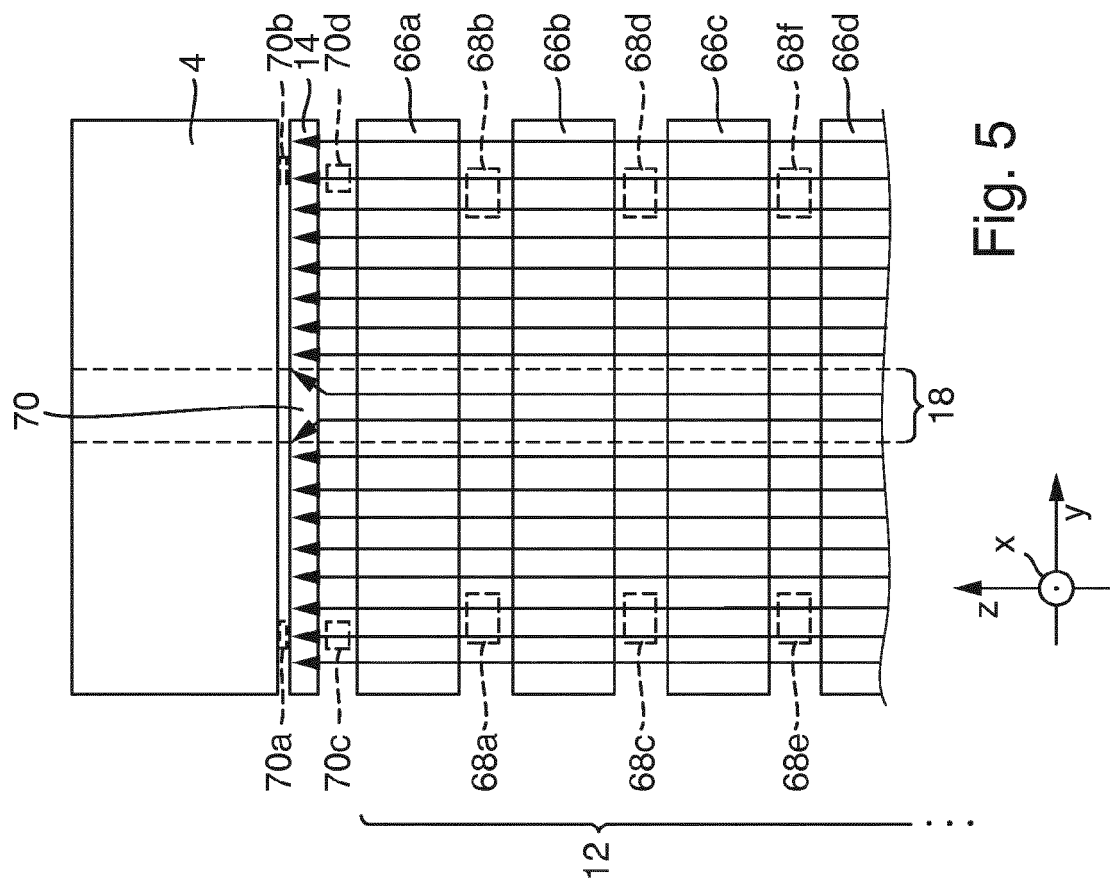
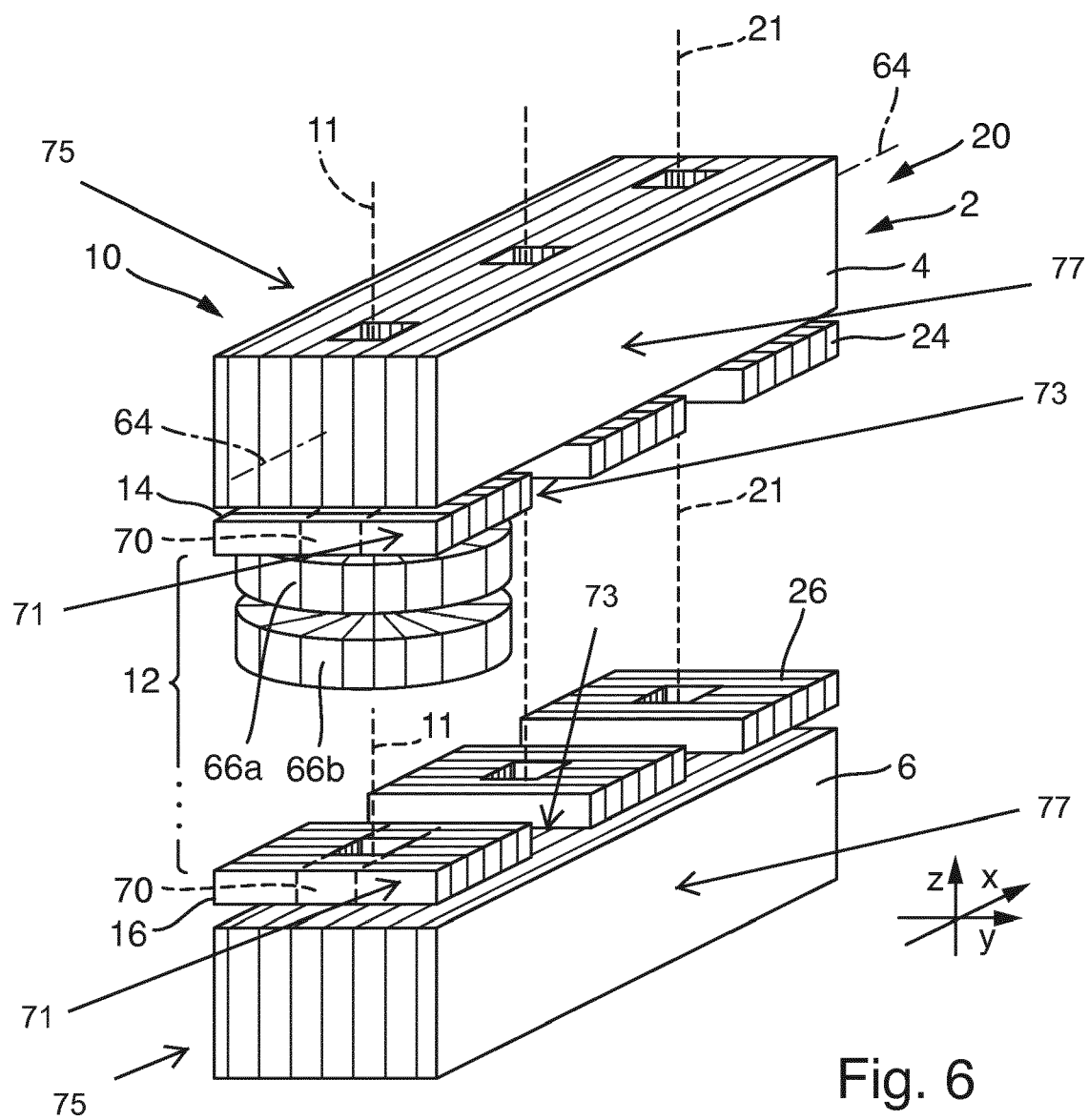


Fig. 5



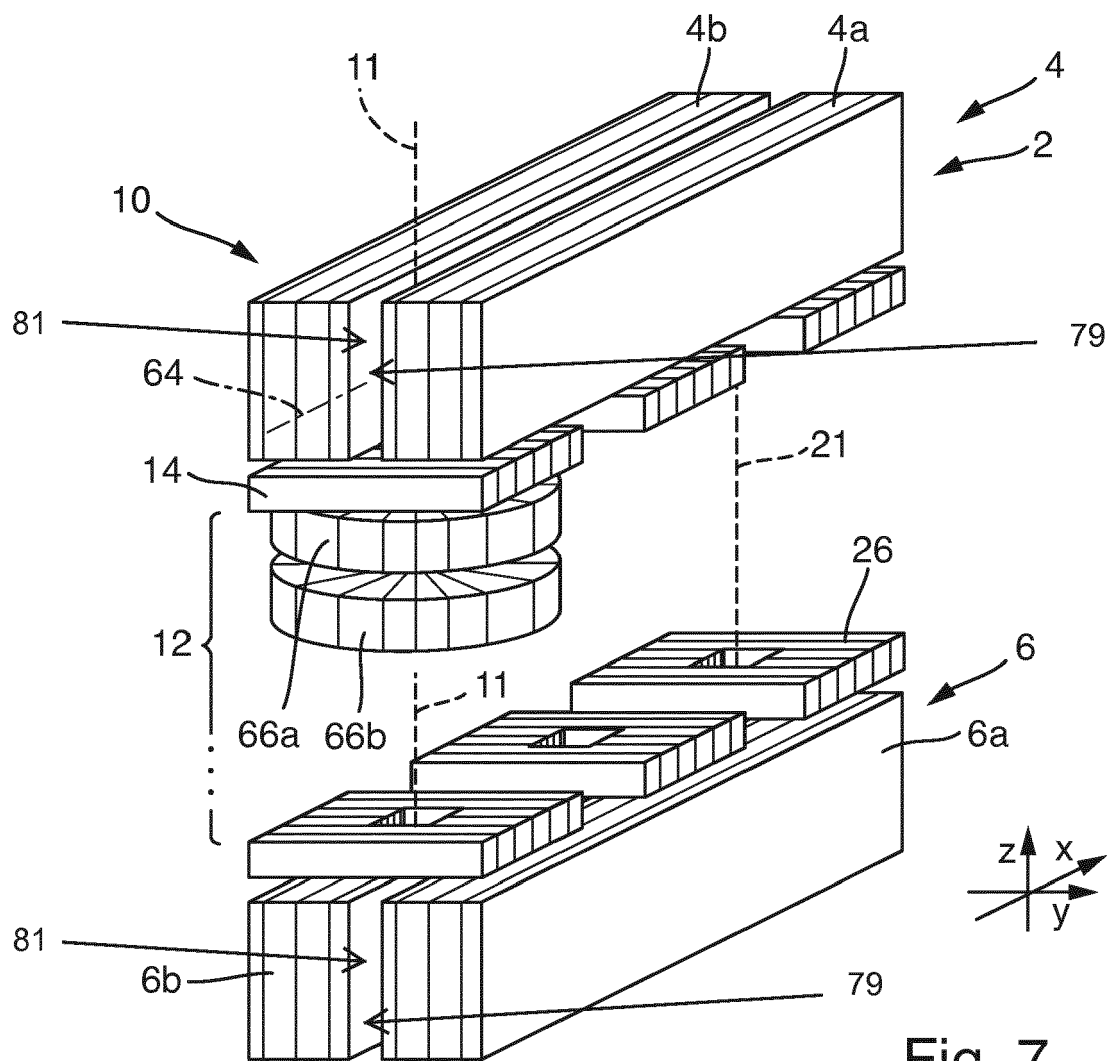
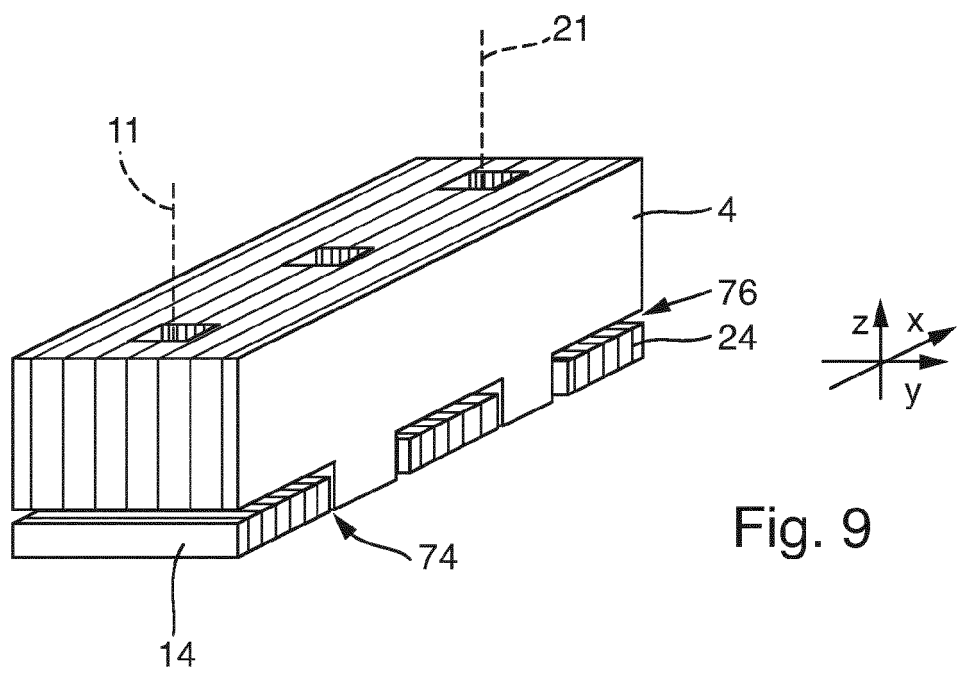
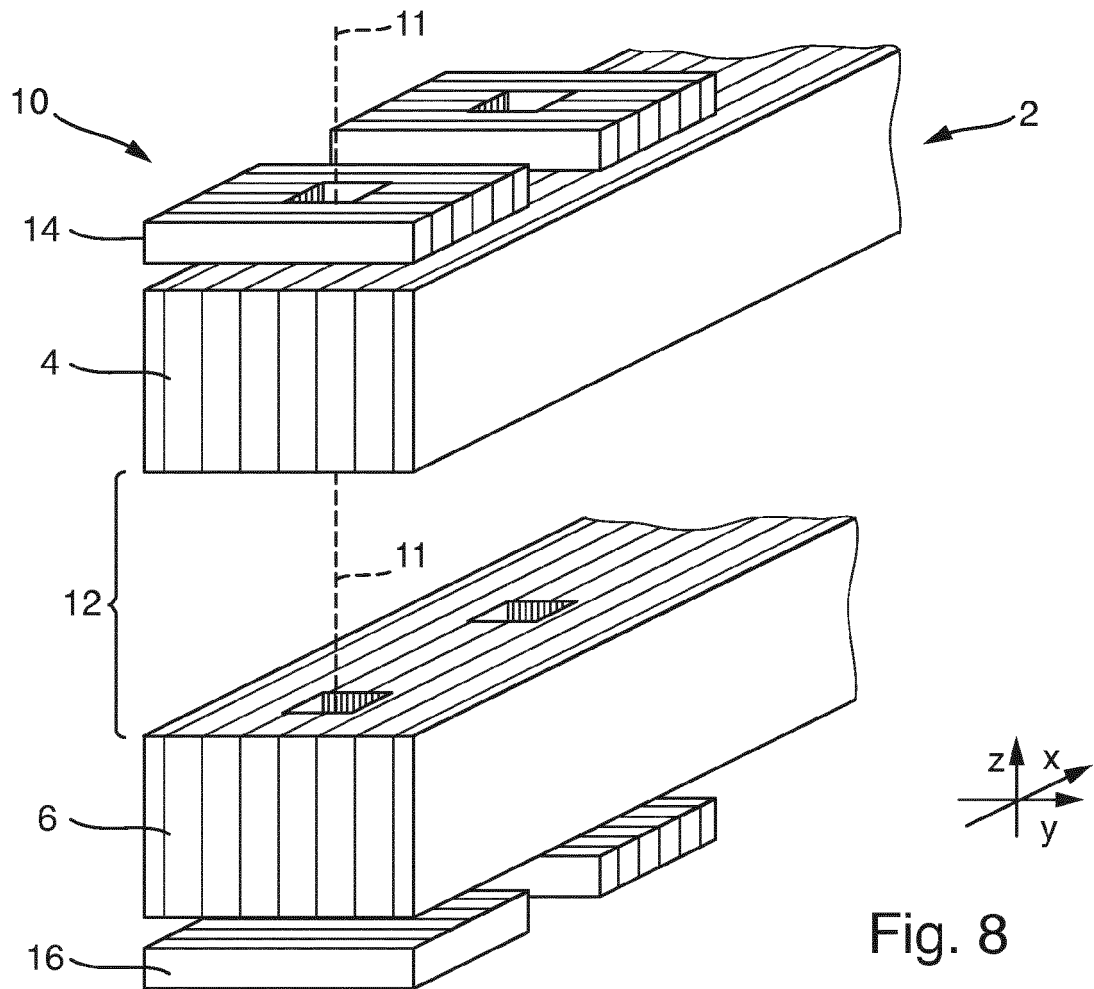
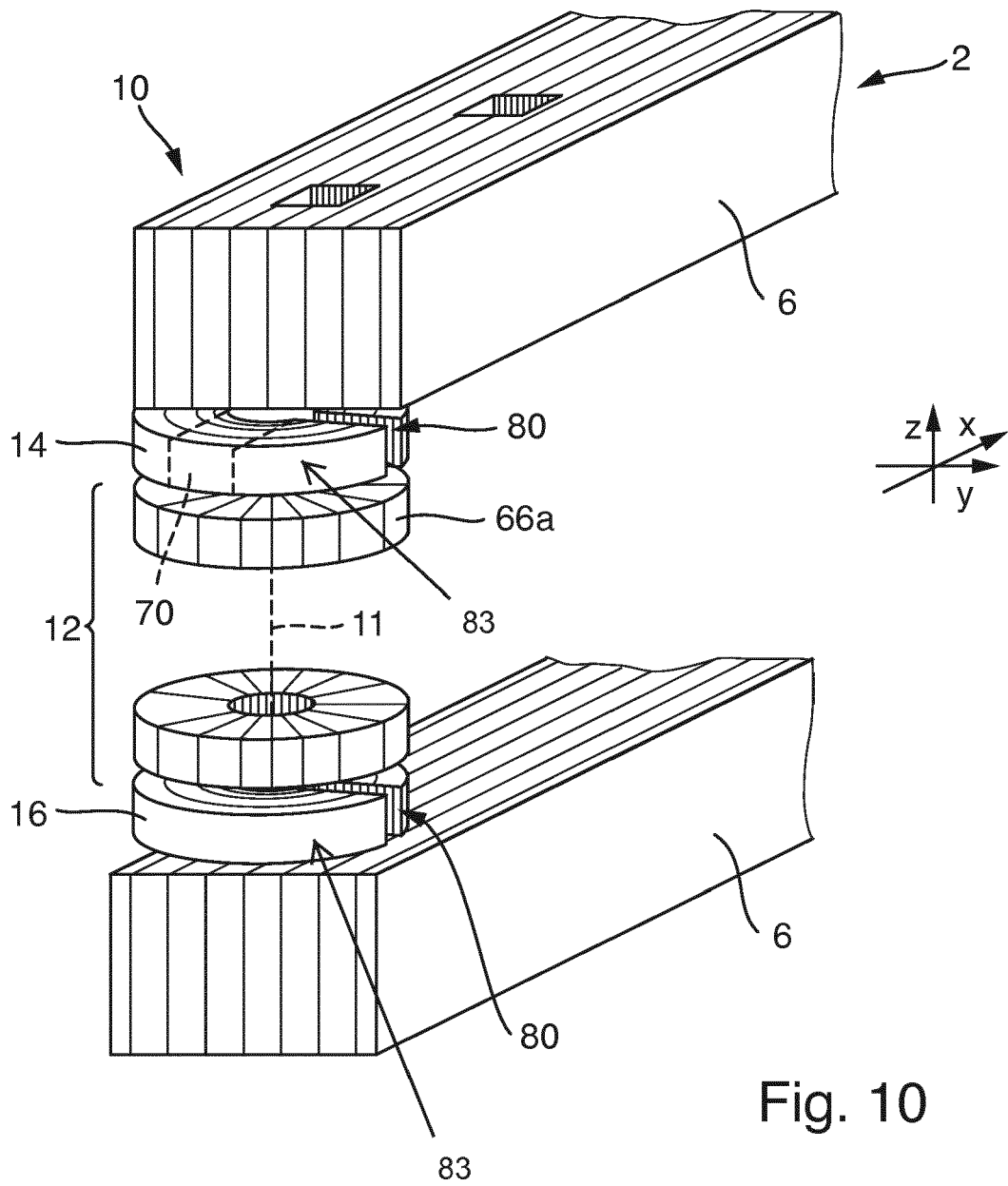


Fig. 7







EUROPEAN SEARCH REPORT

Application Number
EP 17 15 1850

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 4 May 2017	Examiner Winkelman, André
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