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(54) Title: HEATSINK CELL WITH MICROCHANNELS

(57) Abstract: A heatsink cell includes a first set of microchannels, a second set of microchannels, an inlet slot to fluidically couple the first set of microchannels and the second set of microchannels at an inner side of the heatsink cell, a first outlet slot to fluidically couple the first set of microchannels at a first outer side of the heatsink cell, and a second outlet slot to fluidically couple the second set of microchannels at a second outer side of the heatsink cell. The first set of microchannels is to receive first coolant from the inlet slot of the heatsink cell and output the first coolant through the first outlet slot, and the second set of microchannels is to receive second coolant from the inlet slot of the heatsink cell and output the second coolant through the second outlet slot.

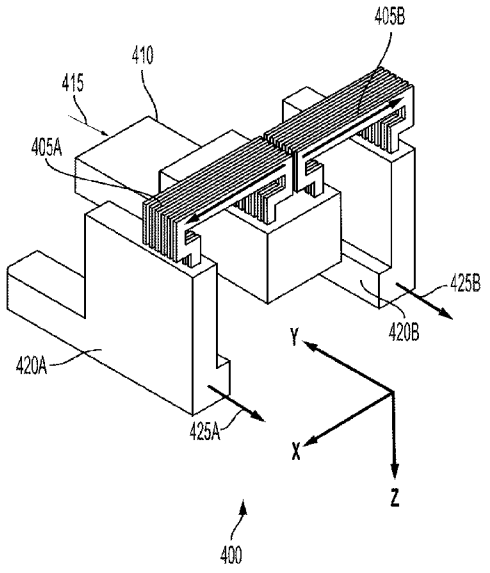


FIG. 4A

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HEATSINK CELL WITH MICROCHANNELS

BACKGROUND

[0001] A heatsink may include microchannels through which coolant flows. The heatsink can couple with a heat generating device and remove heat therefrom by circulating the coolant.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Non-limiting examples of the present disclosure are described by way of example with reference to the accompanying figures, which are schematic and are not intended to be drawn to scale. Unless indicated as representing the background art, the figures represent aspects of the disclosure. For purposes of clarity, not every component may be labeled in every drawing. In the drawings:

[0003] FIG. 1 is a block diagram of an example heatsink system including heatsink cells and a manifold.

[0004] FIG. 2 is a schematic diagram of an example heatsink system including heatsink cells and a manifold.

[0005] FIG. 3A is a schematic diagram of example heatsink cells. FIG. 3B is a schematic diagram of an example of a cell shown in FIG. 3A.

[0006] FIG. 4A is a schematic diagram of a portion of an example heatsink cell. FIG. 4B is a cross-sectional view of the example heatsink cell shown in FIG. 4A.

[0007] FIG. 5 is a schematic diagram of a portion of an example heatsink cell.

[0008] FIG. 6A is a schematic diagram of an example layered component. FIG. 6B is a top view of the layered component shown in FIG. 6A.

[0009] FIG. 7A is a schematic diagram of an example layered component. FIG. 7B is a top view of the layered component shown in FIG. 7A.

[0010] FIG. 8A is a schematic diagram of an example layered component. FIG. 8B is a top view of the layered component shown in FIG. 8A.

[0011] FIG. 9A is a schematic diagram (top view) of an example layered component. FIG. 9B is a schematic diagram (bottom view) of the layered component shown in FIG. 9A.

[0012] FIG. 10 is a block diagram of an example system for operating the heatsink system shown in FIG. 1.

DETAILED DESCRIPTION

[0013] A heatsink may include microchannels, in which coolant can flow to remove heat from a heat generating device thermally coupled to the heatsink. With rapid growth in the fields of high performance devices (e.g., high-powered silicon devices, graphics processing unit (GPU), central processing unit (CPU), processors for artificial intelligence (AI) data centers, etc.) and device modules for various applications (e.g., a printhead, chips therein, etc.), there is a need for more efficient and reliable cooling techniques.

[0014] A heatsink system can drive coolant through microchannels at a rate high enough to provide efficient cooling. However, sustaining such a high rate often increases drive pressures, putting stress on the system and potentially leading to failures in the system (e.g., a leak). Furthermore, in a heatsink system, coolant enters each microchannel at a lower temperature and exits at a higher temperature, resulting in less efficient cooling at the exit side of the microchannel. This non-uniformity in cooling can impact the device performance.

[0015] One aspect of techniques disclosed herein is directed to a system. The system can include an inlet, an outlet, a plurality of heatsink cells, including a first heatsink cell and a second heatsink cell, and a manifold structure to fluidically couple the plurality of heatsink cells with the inlet and the outlet. The manifold structure can include an inlet fluid connector to receive coolant from the inlet and direct the coolant into the plurality of heatsink cells, the inlet fluid connector including a first inlet pathway fluidically coupled with the first heatsink cell and a second inlet pathway fluidically coupled with the second heatsink cell, and an outlet fluid connector to receive the coolant from the plurality of heatsink cells and direct the coolant into the outlet, the outlet fluid connector including a first outlet pathway fluidically coupled with the first heatsink cell and a second outlet pathway fluidically coupled with the second heatsink cell.

[0016] Another aspect of the techniques disclosed herein is directed to a heatsink cell. The heatsink cell can include a first set of microchannels, a second set of microchannels, an inlet slot to fluidically couple the first set of microchannels and the second set of microchannels at an inner side of the heatsink cell, a first outlet slot to fluidically couple the first set of microchannels at a first outer side of the heatsink cell, and a second outlet slot to fluidically couple the second set of microchannels at a second outer side of the heatsink cell. The first set of microchannels is to receive first coolant from the inlet slot of the heatsink cell and output the first coolant through the first outlet slot, and the second set of microchannels is to receive second coolant from the inlet slot of the heatsink cell and output the second coolant through the second outlet slot.

[0017] The techniques disclosed herein can reduce a fluid path length of the coolant, thereby reducing the drive pressure and providing efficient and uniform cooling. Furthermore, this allows for reliable operation of the heat generating device as well as the heatsink system itself. In addition, a dimension, an arrangement, etc. of the heatsink system and/or the heatsink cells can be designed to accommodate a wide range of device sizes, multiple devices, and/or various cooling needs within a device. For example, by dividing the coolant into the first pathway and the second pathway and individually controlling the coolant therein, the techniques disclosed herein can provide solutions to meet various cooling needs within a device.

[0018] FIG. 1 is a block diagram of an example heatsink system 100 including heatsink cells 130 and a manifold 120. The heatsink system 100 can be a cooling module to thermally couple with a device from which heat is removed. Such a device (referred to as "heat generating device," hereinafter) may be or include high performance devices (e.g., high-powered silicon devices, GPU, CPU, processors for AI data centers, etc.) and device modules for various applications (e.g., a printhead, chips therein, etc.). The heatsink system 100 can include an inlet 105, an outlet 110, the manifold 120, and the heatsink cells 130.

[0019] Each of the heatsink cells 130 can include microchannels 135. In some examples, the heatsink cells 130 may be or include a substrate including the microchannels 135. The heatsink cells 130 and/or the microchannels 135 can thermally couple with a heat generating device to remove heat therefrom. In some examples, the heatsink cells 130 may include a first set (e.g., column, array, etc.) of microchannels and a second set (e.g., column, array, etc.) of microchannels. In some examples, the heatsink cells 130 may include a

plurality of sets of heatsink cells. For example, the heatsink cells 130 may include an array of heatsink cells.

[0020] The heatsink system 100 can receive coolant (e.g., fluid, water, etc.) through the inlet 105. The inlet 105 may be an entry point or opening through which the coolant enters the heatsink system 100. In some examples, the inlet 105 may include a valve or other control mechanisms to control and/or regulate the flow of the coolant into the heatsink system 100.

[0021] The heatsink system 100 can direct the coolant into the heatsink cells 130 (e.g., the microchannels 135 therein) through the manifold 120. The manifold 120 may be or include a device, a component, or a structure to fluidically couple the inlet 105 and the heatsink cells 130. The manifold 120 can receive the coolant from the inlet 105 and direct the coolant into the heatsink cells 130. In some examples, the manifold 120 can include an inlet fluid connector to receive the coolant from the inlet 105 and direct the coolant into the heatsink cells 130. In some examples, when the heatsink cells 130 includes a plurality of sets of heatsink cells, the inlet fluid connector can include a first inlet pathway fluidically coupled with a first heatsink cell of the heatsink cells 130 and a second inlet pathway fluidically coupled with a second heatsink cell of the heatsink cells 130. In some examples, a first portion of the coolant can be directed from the inlet 105 into a first set of the heatsink cells 130 through the first inlet pathway, and a second portion of the coolant can be directed from the inlet 105 into a second set of the heatsink cells 130 through the second inlet pathway. In some examples, the manifold 120 can direct the first portion of the coolant through the first inlet pathway into the first heatsink cell at a first rate, and to direct the second portion of the coolant through the second inlet pathway into the second heatsink cell at a second rate. In some examples, the second rate can be higher than the first rate.

[0022] The microchannels 135 may be or include a coolant passage or any structure through which the coolant can flow. In some examples, the microchannels 135 may be or include an elongated passage. In some examples, the microchannels 135 may have various structural features, including, but not limited to, a zigzag pattern, a porous structure, or any symmetric/uniform shape. As discussed in greater detail below, the microchannels 135 may include various features to fluidically couple with the manifold 120, the inlet 105, the outlet 110, or any component within the heatsink system 100. In some examples, the microchannels 135 may include a first set of microchannels 135 and a second set of

microchannels 135, which can share a same dimension in one of width, length, or depth. In some examples, a first channel of the microchannels 135 and a second channel of microchannels 135 share a same dimension in one of width, length, or depth. In some examples, the microchannels 135 may be formed such that the microchannels are symmetrical and/or uniform (or substantially) within the heatsink cells 130, thereby providing a symmetric and/or uniform flow rate of coolant within the microchannels 135. For example, the microchannels are substantially uniform, differing in a dimension by, for example, less than 10 %.

[0023] The microchannels 135 of the heatsink cells 130 can receive the coolant from the inlet 105 (e.g., through the manifold 120). In some examples, the heatsink cells 130 can include various features to receive the coolant from the manifold 120 and direct the coolant into the microchannels 135. The heatsink cells 130 can include an inlet slot to fluidically couple the manifold 120 and the microchannels 135. The inlet slot can receive the coolant from the manifold 120 and direct the coolant into the microchannels 135. In some examples, when the heatsink cells 130 includes a plurality of sets of heatsink cells, the heatsink cells 130 can include a plurality of inlet slots, and each of the inlet slots can be fluidically coupled to a respective one of the heatsink cells 130. For example, the heatsink cells 130 can include an array of heatsink cells, and each of the array can be fluidically coupled to a respective inlet slot. For example, each of the inlet slot can receive a respective portion of the coolant and direct the respective portion into a respective heatsink cell of the array.

[0024] In some examples, for each of the heatsink cells 130, the respective inlet slot can receive the coolant from the inlet 105 (e.g., through the manifold 120), direct a first portion of the coolant into a first set of microchannels 135 in a first direction (e.g., +x direction), and direct a second portion of the coolant into a second set of microchannels 135 in a second direction opposite to the first direction (e.g., –x direction). In some examples, the inlet slot of the heatsink cells 130 can fluidically couple a first set of the microchannels 135 and a second set of the microchannels at an inner side (e.g., a central portion) of the microchannels 135 (or of a corresponding one of the heatsink cells 130). In some examples, the inlet slot can direct a first portion of the coolant into a first one of the microchannels 135 in which the first portion of the coolant flows in the first direction, and can direct a second portion of the coolant into a second one of the microchannels 135 in which the second portion of the coolant flows in the second direction (e.g., opposite to the first direction). In

some examples, the inlet slot can direct a first portion of the coolant into a first set of microchannels 135 at a first rate, and direct a second portion of the coolant into a second set of microchannels 135 at a second rate. In some examples, the first rate and the second rate are the same or substantially the same (e.g., differ by less than 10 %), thereby providing a uniform flow rate (and thus a uniform cooling) across the microchannels 135. In some examples, the inlet slot can direct a first portion of the coolant into a first one of the microchannels 135 at a rate, and direct the first portion of the coolant into a second one of the microchannels 135 at the same rate (or substantially the same), thereby providing a uniform or substantially uniform flow rate (and thus a uniform or substantially uniform cooling) within the microchannels 135.

[0025] The heatsink cells 130 can direct the coolant that has flown through the microchannels 135 into the manifold 120, and then into the outlet 110. The heatsink cells 130 can include an outlet slot to fluidically couple the manifold 120 and the microchannels 135. The outlet slot can receive the coolant from the microchannels 135 and direct the coolant into the manifold 120. In some examples, the heatsink cells 130 can include a pair of outlet slots for each of the heatsink cells 130. For example, a first outlet slot can fluidically couple a first set of microchannels 135 at a first outer side of the microchannels 135, and a second outlet slot can fluidically couple a second set of microchannels 135 at a second outer side of the microchannels 135. In some examples, the first set of microchannels 135 can receive first coolant (e.g., a first portion of the coolant) from the inlet slot of the heatsink cells 130 and output the first coolant through the first outlet slot, and the second set of microchannels 135 can receive second coolant (e.g., a second portion of the coolant) from the inlet slot of the heatsink cells 130 and output the second coolant through the second outlet slot. In some examples, the inlet slot and the outlet slot of the microchannels 135 (or one of the heatsink cells 130) may be formed such that the coolant flow therebetween can be symmetrical and/or uniform, thereby allowing for symmetric and/or uniform cooling performance. In some examples, a first distance can be defined between the inlet slot and the first outlet slot and a second distance can be defined between the inlet slot and the second outlet slot. The first distance and the second distance may be substantially the same.

[0026] In some examples, when the heatsink cells 130 include a plurality of heatsink cells (e.g., an array of heatsink cells, each array including a set of microchannels 135), the

heatsink cells 130 can include a plurality of outlet slots. For example, each of the outlet slots can be fluidically coupled to a respective one of the heatsink cells 130. In some examples, a pair of outlet slots can be fluidically coupled to a respective one heatsink cell of the heatsink cells 130. The outlet slot can receive a respective portion of the coolant from the respective one heatsink cell and direct the respective portion of the coolant into the outlet 110. For example, the heatsink cells 130 may include a first outlet slot to receive, from a first set of microchannels, a first portion of the coolant, and direct the first portion of the coolant into the outlet 110, and a second outlet slot to receive, from a second set of microchannels, a second portion of the coolant, and direct the second portion of the coolant into the outlet 110. In some examples, the heatsink cells 130 can include a pair of outlet slots disposed opposite to each other with respect to a respective inlet slot. For example, the inlet slot can be located between the respective pair of the outlet slots. In some examples, the inlet slot and the pair of the outlet slots can be arranged in parallel. The pair of outlet slots can receive the respective portion of the coolant from the inlet slot (e.g., through the respective microchannels) and direct the coolant into the outlet 110.

[0027] The manifold 120 can receive the coolant from the heatsink cells 130 and direct the coolant into the outlet 110. In some examples, the manifold 120 can include an outlet fluid connector to receive the coolant from the heatsink cells 130 and direct the coolant into the outlet 110. In some examples, when the heatsink cells 130 includes a plurality of heatsink cells, the outlet fluid connector can include a first outlet pathway fluidically coupled with a first heatsink cell of the heatsink cells 130 and a second outlet pathway fluidically coupled with a second heatsink cell of the heatsink cells 130. In some examples, a first portion of the coolant can be directed from a first set of the heatsink cells 130 to the outlet 110 through the first inlet pathway, and a second portion of the coolant can be directed from a second set of the heatsink cells 130 to the outlet 110 through the second inlet pathway. In some examples, the first portion of the coolant can be directed from the first set of the heatsink cells 130 to the outlet 110 through the first inlet pathway at a first rate, and the second portion of the coolant can be directed from the second set of the heatsink cells 130 to the outlet 110 through the second inlet pathway at a second rate.

[0028] The outlet 110 may be an exit point or opening through which the coolant exits the heatsink system 100. In some examples, the outlet 110 may include a valve or other control mechanisms to regulate the flow of the coolant.

[0029] In some examples, the inlet 105 can include an inlet valve and the outlet 110 can include an outlet valve to control the flow of the coolant between the heatsink system 100 and an external device (e.g., a coolant supply, a coolant circulating device, a coolant control system 1210 shown in FIG. 10, etc.). This can prevent the coolant inside the heatsink system 100 from escaping in the event of a system failure or when the heatsink system 100 is disconnected from the external device (e.g., to replace the heatsink system 100, etc.).

[0030] FIG. 2 is a schematic diagram of an example heatsink system 200 including heatsink cells 230 and a manifold 220. The heatsink system 200 may be substantially similar to or incorporate features of the heatsink system 100. For example, the heatsink system 200 includes an inlet 205, an outlet 210, the manifold 220, and the heatsink cells 230, which may be substantially similar to or incorporate features of the inlet 105, the outlet 110, the manifold 120, and the heatsink cells 130, respectively. It is noted that the heatsink system 200 is merely an example and is not intended to limit the present disclosure.

[0031] Referring to FIG. 2, the heatsink system 200 may be a stack of layered components. In some examples, the manifold 220 may include various layered components to fluidically couple the inlet 205, the outlet 210, and the heatsink cells 230. For example, the various layered components of the manifold 220 can direct the coolant from the inlet 205 into the heatsink cells 230, and can direct the coolant from the heatsink cells 230 into the outlet 210. In some examples, the heatsink cells 230 may include various components to fluidically couple with the manifold 220. For example, a layered component of the heatsink cells 230 may include an inlet slot and an outlet slot discussed above. For example, microchannels (e.g., the microchannels 135) of the heatsink cells 230 may be formed within a layered component. The various components of the manifold 220 and of the heatsink cells 230 are discussed in greater detail below, for example, with respect to FIG. 3 to FIG. 9.

[0032] In some examples, the heatsink cells 230 can be vertically stacked on the manifold 220, and the coolant can be vertically directed from the manifold 220 to the heatsink cells 230 (e.g., an inlet slot). This allows for a low profile in z-axis, which enhances adaptability of the heatsink system 200, particularly in environments where the system dimensions are limited. In some examples, a height of the heatsink system 200 may be less than 25 mm. For example, the height may be 15 mm, 17 mm, 20 mm, 23 mm, etc.

[0033] In some examples, the heatsink cells 230 may be arrayed. Shown in FIG. 2 is a one dimensional array of the heatsink cells 230 arrayed in x-axis (e.g., five cells), and each of the arrayed cells includes a sub-cell arrayed in y-axis (e.g., two sub-cells). The heatsink cells 230 may be arrayed in various manners, for example, varying in a dimension, an arrangement, a number of cells or sub-cells, etc. The heatsink cells 230 can fluidically couple with the manifold 220 in various manners. In some examples, the manifold 220 can fluidically couple with the heatsink cells 230 in parallel, while the sub-cells within each of the cells are fluidically coupled in series. For example, as shown, the fluidic coupling between the manifold 220 and the heatsink cells 230 can include five cells coupled in parallel (arrayed in x axis), each of which can include two sub-cells coupled in series (arrayed in y axis). The manifold 220 can direct a respective portion of the coolant into each of the heatsink cells 230 (e.g., each element of the arrayed heatsink cells 230).

[0034] FIG. 3A is a schematic diagram of example heatsink cells 300. The heatsink cells 300 may be substantially similar to or incorporate features of the heatsink cells 130, etc. The heatsink cells 300 may include a cell 301. FIG. 3B is a schematic diagram of an example of the cell 301 shown in FIG. 3A. It is noted that the heatsink cells 300 and the cell 301 are merely an example and are not intended to limit the present disclosure.

[0035] As shown, the cell 301 includes microchannels 307. The microchannels 307 may be substantially similar to or incorporate features of the microchannels 135. The microchannels 307 may include a first set 305A of the microchannels 307 and a second set 305B of the microchannels 307. In some examples, as shown, the first set 305A may be a first column, and the second set 305B may be a second column.

[0036] In some examples, the cell 301 may be or include an array of sub-cells (e.g., a first sub-cell 302, a second sub-cell 303). For example, the cell 301 may include an array of substrates (e.g., silicon substrates), in which the microchannels 307 are formed, and each of the substrates can be defined as a sub-cell (e.g., a first substrate for the first sub-cell 302, a second substrate for the second sub-cell 303, etc.). For example, the first set 305A of the microchannels 307 and the second set 305B of the microchannels 307 may be formed on an array of silicon substrates.

[0037] The cell 301 can include or be fluidically coupled with various structures to fluidically couple with a manifold (e.g., the manifold 120, the manifold 220, etc.), an inlet

(e.g., the inlet 105, the inlet 205, etc.), and an outlet (e.g., the outlet 110, the outlet 110, etc.). The cell 301 can include an inlet slot 310 to fluidically couple with the inlet (e.g., through the manifold) and outlet slots (e.g., first and second outlet slots 320A, 320B) to fluidically couple with the outlet (e.g., through the manifold). In some examples, the inlet slot 310 can receive the coolant at a cell end 315 of the cell 301, and the outlet slot (e.g., the first and second outlet slots 320A, 320B) can output the coolant at another cell end (e.g., cell ends 325A, 325B) of the cell 301. As shown, in some examples, the cell end 315 may be located opposite to the cell ends 325A, 325B. By receiving the coolant at the cell end 315 and outputting the coolant at the opposite end (e.g., at the cell ends 325A, 325B), the fluid paths of the coolant within the microchannels 307 can be balanced. For example, a fluid path length of the coolant flowing through a first row of the microchannels 307 can be the same (or substantially the same) as a fluid path length of the coolant flowing through a second row (or any row, including the last row) of the microchannels 307. This balance in the fluid path lengths between the microchannels 307 can increase the pressure uniformity across the cell 301 and thus the cooling performance.

[0038] The cell 301 may be formed of the microchannels 307, the inlet slot 310, and the first and second outlet slots 320A, 320B in various manners. As shown, in some examples, the inlet slot 310 and the first and second outlet slots 320A, 320B may be arranged in parallel. In some examples, the microchannels 307 may be arranged along a first axis (e.g., y-axis) parallel to the inlet slot 310. In some examples, the microchannels 307 can be elongated through a second axis (e.g., x-axis) perpendicular to the first axis (e.g., y-axis).

[0039] In some examples, the inlet slot 310 can fluidically couple the first set 305A and the second set 305B at an inner side (e.g., a central portion) of the microchannels 307 (or of the cell 301). For example, as shown, the inlet slot 310 can fluidically couple a right-hand side of the first set 305A and a left-hand side of the second set 305B at a central portion of the microchannels 307. The inlet slot 310 can direct the coolant into the first set 305A and the second set 305B at the inner side of the cell 301. In some examples, the first outlet slot 320A can fluidically couple the first set 305A at a first outer side (e.g., a first peripheral portion, a left-hand side of the first set 305A) of the microchannels 307 (or the cell 301), and the second outlet slot 320B can fluidically couple the second set 305B at a second outer side (e.g., a first peripheral portion, a right-hand side of the second set 305B) of the microchannels 307 (or the cell 301). The first outlet slot 320A can receive the coolant from

the first set 305A at the first outer side of the cell 301, and the second outlet slot 320B can receive the coolant from the second set 305B at the second outer side of the cell 301.

[0040] In some examples, the first set 305A (of the microchannels 307) can receive first coolant (e.g., a first portion of the coolant) from the inlet slot 310 and output the first coolant through the first outlet slot 320A, and the second set 305B (of the microchannels 307) can receive second coolant (e.g., a second portion of the coolant) from the inlet slot 310 and output the second coolant through the second outlet slot 320B. In some examples, the inlet slot 310 and the first and second outlet slots 320A, 320B may be formed such that the coolant flow therebetween can be symmetrical and/or uniform (or substantially uniform), thereby allowing for symmetric and/or uniform cooling performance. For example, a first distance between the inlet slot 310 and the first outlet slot 320A and a second distance between the inlet slot 310 and the second outlet slot 320B may be substantially the same. In some examples, the microchannels 307 may be uniformly (or substantially) distributed within the cell 301. In some examples, the sets (e.g., the first set 305A, the second set 305B, etc.) of the microchannels 307 may be uniformly (or substantially) distributed within the cell 301 or within the heatsink cells 300.

[0041] In some examples, the inlet slot 310 can be disposed between the first set 305A and the second set 305B, as shown in FIG. 3B. The inlet slot 310 can direct the first coolant into the first set 305A through a first end (e.g., the inner side) of the first set 305A and direct the second coolant into the second set 305B through a first end (e.g., the inner side) of the second set 305B. The first outlet slot 320A disposed at a second end (e.g., the outer side) of the first set 305A (e.g., opposite to the first end with respect to the first set 305A) can receive and output the first coolant. The second outlet slot 320B disposed at a second end (e.g., the outer side) of the second set 305B (e.g., opposite to the first end with respect to the second set 305B) can receive and output the second coolant.

[0042] As shown in FIG. 2, in some examples, the coolant can be directed from the manifold 220 to the cell 301 in a first axis (e.g., z-axis as shown in FIG. 2). As shown in FIG. 3B, the coolant can be directed to the microchannels 307 through the inlet slot 310 in a second axis (e.g., y-axis) perpendicular to the first axis. The coolant can flow within the microchannels 307 in a third axis (e.g., x-axis) perpendicular to the first axis and the second axis. For example, as shown, in the first set 305A (of the microchannels 307), the first

coolant can flow in the –x direction, and in the second set 305B (of the microchannels 307), the second coolant can flow in the +x direction.

[0043] In some examples, the microchannels 307 can share a same dimension in various manners. For example, the microchannels 307 can share a same dimension, including one of a width, a depth, or a length. For example, the width of the microchannels 307 may range from 25 μm to 150 μm. For example, the depth of the microchannels 307 may range from 150 μm to 600 μm. For example, the length of the microchannels 307 may range from 3 mm to 9 mm. In some examples, a pitch (in y-axis) of the microchannels 307 may be less than 250 μm. For example, the pitch may be 200 μm, 150 μm, 100 μm, etc.

[0044] In some examples, the first set 305A and the second set 305B (of the microchannels 307) can share a same dimension in various manners. For example, the first set 305A and the second set 305B can share a same dimension, including one of a width, a length, an arrangement, or a shape of the set (or the column). In some examples, a pitch of the first set 305A and the second set 305B may range from 5 mm to 15 mm.

[0045] FIG. 4A is a schematic diagram of a portion of an example heatsink cell 400. The heatsink cell 400 may be substantially similar to or incorporate features of the heatsink cells 130 of the heatsink system 100, etc. FIG. 4B is a cross-sectional view of the example heatsink cell 400 shown in FIG. 4A. It is noted that the heatsink cell 400 is merely an example and is not intended to limit the present disclosure.

[0046] The heatsink cell 400 includes a first set of microchannels 405A, a second set of microchannels 405B, an inlet slot 410, a cell end 415, a first outlet slot 420A, a second outlet slot 420B, and cell ends 425A, 425B. It should be understood that FIG. 4A shows a partial view of the first set of microchannels 405A, the second set of microchannels 405B, the inlet slot 410, the first outlet slot 420A, and the second outlet slot 420B. For example, any of the first set of microchannels 405A, the second set of microchannels 405B, the inlet slot 410, the first outlet slot 420A, and the second outlet slot 420B can be a structure elongated along y-axis.

[0047] In a brief overview, the inlet slot 410 can receive the coolant through the cell end 415 (e.g., from the inlet 105) and direct the coolant into the first set of microchannels 405A and the second set of microchannels 405B. The coolant can be directed, through the first set of microchannels 405A and the second set of microchannels 405B, into the first outlet slot

420A and the second outlet slot 420B, respectively. The first outlet slot 420A and the second outlet slot 420B can output the coolant through the cell ends 425A, 425B, respectively.

[0048] The first set of microchannels 405A and the second set of microchannels 405B can fluidically couple with the inlet slot 410 and fluidically couple with the first outlet slot 420A and the second outlet slot 420B, respectively. As shown in FIG. 4B, an inlet portion 411 of the first set of microchannels 405A and the second set of microchannels 405B can fluidically couple with the inlet slot 410. A first outlet portion 421A of the first set of microchannels 405A can fluidically couple with the first outlet slot 420A, and a second outlet portion 421B of the second set of microchannels 405B can fluidically couple with the second outlet slot 420B. In some examples, the inlet slot 410 can direct the coolant vertically (e.g., z-axis) to the first set of microchannels 405A and the second set of microchannels 405B. The coolant in the first set of microchannels 405A can flow along the x-axis (e.g., +x direction) and can be vertically (e.g., +z direction) directed to the first outlet slot 420A. The coolant in the second set of microchannels 405B can flow along the x-axis (e.g., –x direction) and can be vertically (e.g., –z direction) directed to the first outlet slot 420A. Shown in FIG. 4B is a non-limiting example, and the inlet portion 411, the first outlet portion 421A, and the second outlet portion 421B can be formed with any shape, orientation, or dimension.

[0049] In some examples, as shown, the inlet slot 410 may be located between the first outlet slot 420A and the second outlet slot 420B. In some examples, a pair of outlet slots (e.g., the first outlet slot 420A, the second outlet slot 420B) can be disposed opposite to each other with respect to the inlet slot 410. In some examples, the inlet slot 410, the first outlet slot 420A, and the second outlet slot 420B can be arranged in parallel.

[0050] In some examples, the first set of microchannels 405A and the first outlet slot 420A may be symmetrical to the second set of microchannels 405B and the second outlet slot 420B with respect to the inlet slot 410. This allows for a symmetrical and/or uniform flow of coolant within the first set of microchannels 405A and the second set of microchannels 405B.

[0051] As discussed above, the first set of microchannels 405A, the second set of microchannels 405B, and the slots (e.g., the inlet slot 410, the first outlet slot 420A, and the

second outlet slot 420B) may be formed within a cell (e.g., the cell 301). In some examples, the first set of microchannels 405A, the second set of microchannels 405B, and the slots (e.g., the inlet slot 410, the first outlet slot 420A, and the second outlet slot 420B) may be formed within a layered component (e.g., a substrate, a plate, etc.). In some examples, the first set of microchannels 405A and the second set of microchannels 405B can be formed within a first layer, and the slots (e.g., the inlet slot 410, the first outlet slot 420A, and the second outlet slot 420B) can be formed within a second layer stacked on the first layer.

[0052] As discussed herein, the coolant can be bifurcated into the two sets of microchannels (e.g., 405A, 405B), which can reduce a coolant path length (e.g., 50 %) and thus reduce a pressure drop to drive the coolant through the microchannels. Thus, this allows for increased uniformity, enhanced and reliability for operating the heatsink systems.

[0053] FIG. 5 is a schematic diagram of a portion of an example heatsink cell 500. The heatsink cell 500 may be substantially similar to or incorporate features of the heatsink cells 130, etc. For example, the heatsink cell 500 may be the heatsink cell 400, in which a first inlet slot 510A, a second inlet slot 510B, a first set of microchannels 505A, and a second set of microchannels 505B are alternatively incorporated. It is noted that the heatsink cell 500 is merely an example and is not intended to limit the present disclosure.

[0054] In a brief overview, the first inlet slot 510A can receive first coolant (e.g., a first portion of the coolant) through a cell end 515A (e.g., from the inlet 105) and direct the first coolant into the first set of microchannels 505A. The first coolant flows through the first set of microchannels 505A into the second outlet slot 420B. The second outlet slot 420B can output the first coolant through a cell end 425B. The second inlet slot 510B can receive second coolant (e.g., a second portion of the coolant) through a cell end 515B (e.g., from the inlet 105) and direct the second coolant into the second set of microchannels 505B. The second coolant flows through the second set of microchannels 505B into the first outlet slot 420A. The first outlet slot 420A can output the second coolant through a cell end 425A. In some examples, although depicted separately, the first inlet slot 510A and the second inlet slot 510B may be fluidically coupled. For example, the first inlet slot 510A and the second inlet slot 510B may be pathways of a single inlet slot (e.g., the inlet slot 410). In some examples, the first set of microchannels 505A and the second set of microchannels 505B may be formed within a cell (e.g., the cell 301). In some examples, the first and second inlet

slots 510A, 510B and the first and second outlet slots 420A, 420B may be formed within a layered component.

[0055] As shown in FIG. 5, in some examples, the first inlet slot 510A can be disposed between the second inlet slot 510B and the first outlet slot 420A, and the second inlet slot 510B can be disposed between the first inlet slot 510A and the second outlet slot 420B. In some examples, the first set of microchannels 505A and the second set of microchannels 505B can be arranged alternately along an axis parallel to the first and second inlet slots 510A, 510B. For example, a first subset of the first set of microchannels 505A can be disposed at the first row (in y-axis), a first subset of the second set of microchannels 505B can be disposed at the second row (in y-axis), a second subset of the first set of microchannels 505A can be disposed at the third row (in y-axis), and a second subset of the second set of microchannels 505B can be disposed at the fourth row (in y-axis). Since the first coolant in the first set of microchannels 505A and the second coolant in the second set of microchannels 505B can flow in different directions (e.g., opposite directions), this arrangement can cancel temperature gradient across the microchannels (e.g., between an entrance side and an exit side) and reduce non-uniformity in cooling. Although the "subset" is depicted to be one microchannel in FIG. 5, the subset may be more than one microchannels. For example, any number of the first set of microchannels 505A can be disposed at the first row (in y-axis), any number of the second set of microchannels 505B can be disposed at the second row (in y-axis), any number of the first set of microchannels 505A can be disposed at the third row (in y-axis), and any number of the second set of microchannels 505B can be disposed at the fourth row (in y-axis).

[0056] FIG. 6A is a schematic diagram of an example layered component 600. FIG. 6B is a top view of the layered component 600. In some examples, the manifold 120 may include the layered component 600. For example, the layered component 600 may be a portion of the manifold 120 or may be incorporated into the manifold 120. For example, the layered component 600 may be one of layers within the manifold 220. The layered component 600 may be or include a plate including various features for fluidic coupling. The layered component 600 may include an inlet opening 610, an outlet opening 620, an inlet coupling 630, and an outlet coupling 640. The inlet coupling 630 may include an inlet passage 630P and an inlet coupling hole 630H. The outlet coupling 640 may include an outlet passage 640P and an outlet coupling hole 640H. In some examples, the layered component 600 may

include any number, shape, or arrangement of fluidic pathways (e.g., the inlet passage 630P, the outlet passage 640P, etc.) and/or portions (e.g., the inlet coupling hole 630H, the outlet coupling hole 640H, etc.) to fluidically couple with heatsink cells (e.g., the heatsink cells 130). It is noted that the layered component 600 is merely an example and is not intended to limit the present disclosure.

[0057] In some examples, the inlet opening 610 can receive the coolant from an inlet (e.g., the inlet 105, 205, etc.) and direct the coolant into the inlet coupling 630. The inlet coupling 630 can direct the coolant through the inlet passage 630P into the inlet coupling hole 630H. The inlet coupling hole 630H can direct the coolant into a fluid connector to direct the coolant into heatsink cells (e.g., the heatsink cells 130). In some examples, the coolant that has flown through the heatsink cells (and/or absorbed heat from a heat generating device) can flow through the outlet coupling hole 640H, the outlet passage 640P, and the outlet opening 620 into an outlet (e.g., the outlet 110, 210, etc.).

[0058] FIG. 7A is a schematic diagram of an example layered component 700. FIG. 7B is a top view of the layered component 700. In some examples, the manifold 120 may include the layered component 700. For example, the layered component 700 may be a portion of the manifold 120 or may be incorporated into the manifold 120. For example, the layered component 700 may be one of layers within the manifold 220. For example, the layered component 700 may be or include a plate including various features for fluidic coupling. For example, the layered component 700 may be fluidically coupled to and/or vertically stacked on the layered component 600.

[0059] The layered component 700 can fluidically couple the heatsink cell (e.g., the heatsink cells 130, the heatsink cells 230, etc.) with the inlet (e.g., the inlet 105, the inlet 205, etc.) and the outlet (e.g., the outlet 110, the outlet 210, etc.).

[0060] The layered component 700 may include an inlet fluid connector 705 and an outlet fluid connector 725. The inlet fluid connector 705 may include a first pathway 710A, a second pathway 710B, and third pathway 710C (collectively referred to as inlet pathways 710). The outlet fluid connector 725 may include a first pathway 730A, a second pathway 730B, and third pathway 730C (collectively referred to as outlet pathways 730).

[0061] In some examples, the inlet fluid connector 705 can receive coolant from the inlet (e.g., the inlet 105, the inlet 205, etc.) and direct the coolant into the heatsink cells (e.g., the

heatsink cells 130, the heatsink cells 230, etc.). In some examples, the inlet fluid connector 705 can receive the coolant from the inlet coupling hole 630H in a first direction (e.g., along z-axis of FIG. 2) and direct the coolant into the microchannels of the heatsink cells in a second direction (e.g., along y-axis of FIG. 3) perpendicular to the first direction. In some examples, when the heatsink cells include a plurality of heatsink cells, the first pathway 710A can fluidically couple with a first heatsink cell of the heatsink cells and direct a first portion of the coolant thereto, and the second pathway 710B can fluidically couple with a second heatsink cell of the heatsink cells and direct a second portion of the coolant thereto.

[0062] In some examples, the first portion of the coolant can be directed from the inlet fluid connector 705 to the respective heatsink cell at a first rate (e.g., through the first pathway 710A), and the second portion of the coolant can be directed from the inlet fluid connector 705 to the respective heatsink cell at a second rate (e.g., through the second pathway 710B). In some examples, the second rate can be higher than the first rate. In some examples, an amount of the second portion of the coolant can be larger than an amount of the first portion of the coolant. As shown in FIG. 7A and FIG. 7B, a geometry of the first pathway 710A and a geometry of the second pathway 710B may be different. For example, as shown, a width of the second pathway 710B can be larger than a width of the first pathway 710A. For example, the inlet pathways 710 can be designed to have predetermined widths corresponding to the respective flow rates. For example, as shown, the second pathway 710B may have a larger cross-sectional area to allow for a more rapid transport of the coolant. In some examples, the first coolant can be directed into a first set of microchannels such that the first coolant in the first set of microchannels can flow at a first rate, and the second coolant can be directed into a second set of microchannels such that the second coolant in the second set of microchannels can flow at a second rate. In some examples, the coolant in the microchannels can flow along a third axis (e.g., x-axis of FIG. 3) perpendicular to the first direction (e.g., z direction of FIG. 2) and the second direction (e.g., y-axis of FIG. 3). In some examples, the inlet fluid connector 705 can direct the coolant into the first hole 715A at a first rate and into the middle holes 715B at a second rate. In some examples, the first rate is higher than the second rate. In some examples, the second rate is higher than the first rate.

[0063] This allows for heatsink systems designed for meeting various cooling needs, for example, by providing a cooling rate according to a need for cooling. For example, a heat

generating device that should have more efficient cooling can be located at a middle portion of the heatsink corresponding to the second pathway 710B.

[0064] The inlet fluid connector 705 may include a first hole 715A at an end portion of the first pathway 710A, second, third, fourth holes 715B1, 715B2, 715B3 (collectively referred to as middle holes 715B) at an end portion of the second pathway 710B, and a fifth hole 715C at an end portion of the third pathway 710C. The outlet fluid connector 725 may include a first hole 735A at an end portion of the first pathway 730A, second, third, fourth holes 735B1, 735B2, 735B3 (collectively referred to as middle holes 735B) at an end portion of the second pathway 730B, and a fifth hole 735C at an end portion of the third pathway 730C.

[0065] The layered component 700 may include any number, shape, or arrangement of fluidic pathways (e.g., the inlet pathways 710, the outlet pathways 730, etc.) and/or portions (e.g., the holes 715, the holes 735, etc.) to fluidically couple with the heatsink cells (e.g., the heatsink cells 130). In some examples, as shown, the first pathway 710A, the second pathway 710B, and the third pathway 710C can be fluidically coupled with any number of heatsink cells. For example, as shown, the first pathway 710A can be fluidically coupled with one heatsink cell. For example, as shown, the second pathway 710B can be fluidically coupled with more than one heatsink cells. It is noted that the layered component 700 is merely an example and is not intended to limit the present disclosure.

[0066] In some examples, the inlet fluid connector 705 can receive the coolant and direct the coolant through the inlet pathways 710 into the holes 715. In some examples, the inlet fluid connector 705 can receive the coolant from the inlet coupling hole 630H. In some examples, the inlet fluid connector 705 can direct the coolant through the inlet pathways 710 and the holes 715 into the respective heatsink cells (e.g., the heatsink cells 130). For example, the first, second, third, fourth, fifth holes 715A, 715B1, 715B2, 715B3, 715C can be fluidically coupled to first, second, third, fourth, fifth heatsink cell of the heatsink cells 130, respectively. For example, the first, second, third, fourth, fifth holes 715A, 715B1, 715B2, 715B3, 715C can direct the respective portion of the coolant into the respective inlet slot (e.g., the inlet slot 410) of first, second, third, fourth, fifth heatsink cells of the heatsink cells 130, respectively.

[0067] In some examples, the coolant that has flown through the heatsink cells (and absorbed heat from a heat generating device) can flow through the holes 735 and the outlet pathways 730 into the outlet coupling hole 640H.

[0068] In some examples, the outlet fluid connector 725 can receive the coolant from the heatsink cells and direct the coolant into the outlet (e.g., the outlet 110, the outlet 210, etc.). The first pathway 730A can fluidically couple with the first heatsink cell of the heatsink cells and receive the coolant therefrom, and the second pathway 730B can fluidically couple with the second heatsink cell of the heatsink cells and receive the coolant therefrom. In some examples, the first portion of the coolant can be directed, through the first pathway 730A, from a first set of the heatsink cells into the outlet, and the second portion of the coolant can be directed, through the second pathway 730B, from a second set of the heatsink cells into the outlet.

[0069] FIG. 8A is a schematic diagram of an example layered component 800. FIG. 8B is a top view of the layered component 800. In some examples, the manifold 120 may include the layered component 800. For example, the layered component 800 may be a portion of the manifold 120 or may be incorporated into the manifold 120. For example, the layered component 800 may be one of layers within the manifold 220. For example, the layered component 800 may be or include a plate including various features for fluidic coupling. For example, the layered component 800 may be fluidically coupled to and/or vertically stacked on the layered component 600 and/or the layered component 700.

[0070] The layered component 800 may include various features to couple a manifold (e.g., the manifold 120) and heatsink cells (e.g., the heatsink cells 130). The layered component 800 may include inlet connecting portions 815, an inlet slot connecting portion 817, outlet slot connecting portions 820, and outlet connecting portions 835. In some examples, the layered component 800 may include any number, shape, or arrangement of fluidic pathways (e.g., the inlet slot connecting portion 817, the outlet slot connecting portions 820, etc.) and/or portions (e.g., the inlet connecting portions 815, the outlet connecting portions 835, etc.) to fluidically couple with heatsink cells (e.g., the heatsink cells 130) and/or a manifold (e.g., the manifold 120). It is noted that the layered component 800 is merely an example and is not intended to limit the present disclosure.

[0071] In some examples, the inlet connecting portions 815 (e.g., 815A, 815B1, 815B2, 815B3, 815C, etc.) can receive the coolant. For example, the first inlet connecting portion 815A can receive a first portion of the coolant from the layered component 700 through the first hole 715A. Then, the inlet connecting portions 815 can direct the respective portion of the coolant into the respective inlet slots (e.g., the inlet slot 310). For example, the first inlet connecting portion 815A can direct the first portion of the coolant into an inlet slot (e.g., the inlet slot 310) of a cell (e.g., the cell 301) of heatsink cells (e.g., the heatsink cells 300).

[0072] The inlet slot connecting portion 817 and the outlet slot connecting portions 820 can be coupled with the inlet slot (e.g., the inlet slot 310) and the outlet slots (e.g., the first and second outlet slots 320A, 320B), respectively. In some examples, the inlet connecting portions 815 can direct the respective portion of the coolant, through the inlet slot connecting portion 817 (e.g., within the inlet slot) and the outlet slot connecting portions 820 (e.g., within the outlet slots), into the outlet connecting portions 835.

[0073] In some examples, the coolant that has flown through the heatsink cells (and absorbed heat from a heat generating device) can flow, through the outlet slot connecting portions 820, into the outlet connecting portions 835. The layered component 800 can output the coolant through the outlet connecting portions 835 (e.g., the first outlet connecting portion 835A for the outlet slot connecting portions 820). The outlet connecting portions 835 can direct the coolant into an outlet (e.g., the outlet 110). In some examples, the outlet connecting portions 835 can direct a respective portion of coolant into a respective fluidic coupling portion of other layered components (e.g., the layered component 700). For example, the outlet connecting portions 835 can direct the coolant into the outlet fluid connector 725 of the layered component 700. For example, the first outlet connecting portion 835A can direct the first portion of coolant output into the first hole 735A.

[0074] FIG. 9A is a schematic diagram (top view) of an example layered component 900. FIG. 9B is a schematic diagram (bottom view) of the layered component 900. The layered component 900 may be or incorporate heatsink cells 901. The heatsink cells 901 may be or incorporate features of the heatsink cells 130. For example, the layered component 900 may be or include a plate including various features for fluidic coupling. For example, the layered component 900 may be fluidically coupled to and/or vertically stacked on the layered component 600, the layered component 700, and/or the layered component 800.

[0075] As shown, the heatsink cells 901 may include cells 901A, 901B, 901C, 901D, and 901E, each of which may be or incorporate features of the cell 301. For example, each of the heatsink cells 901 may include microchannels 905, which can thermally couple with a heat generating device to remove heat therefrom. In some examples, the layered component 900 may include inlet slot portions 917 (e.g., 917A, 917B) and outlet slot portions 920 (e.g., 920A, 920B). The inlet slot portions 917 may be or fluidically couple with an inlet slot (e.g., the inlet slot 310) of the microchannels 905. For example, each of the inlet slot portions 917 may be or fluidically couple with a pathway of the inlet slot 310. For example, the inlet slot portions 917 may be or fluidically couple with the inlet portions of the microchannels (e.g., the inlet portion 411). The outlet slot portions 920 may be or fluidically couple with outlet slots (e.g., the first and second outlet slots 320A, 320B) of the microchannels 905. For example, the outlet slot portions 920A, 920B may be or fluidically couple with a pathway of the first and second outlet slots 320A, 320B, respectively. For example, the outlet slot portions 920A, 920B may be or fluidically couple with the first and second outlet portions 421A, 421B, respectively. In some examples, the layered component 900 may include any number, shape, or arrangement of cells (e.g., the heatsink cells 901), microchannels (e.g., the microchannels 905), fluidic pathways (e.g., the inlet slot portions 917, the outlet slot portions 920, etc.). It is noted that the layered component 900 is merely an example and is not intended to limit the present disclosure.

[0076] In some examples, the heatsink cells 901 may include any number of substrates, in which the microchannels 905 are formed. Shown is a non-limiting example of a 5×2 array of cells, in which five cells are formed in x-axis and two substrates are arrayed for each cell in y-axis. The heatsink cells 901 may include any $m \times n$ arrays of cells, in which m cells are formed in x-axis and n substrates are arrayed for each cell in y-axis. In some examples, more than one substrate may be arrayed for each cell in x-axis.

[0077] In some examples, any of the layered components 600, 700, 800, 900 may be fluidically coupled with each other through various components. For example, such components may include, but not limited to, a gasket, an adhesive layer, an interposer layer, etc. In some examples, one of the layered components 600, 700, 800, 900 may be omitted. For example, the layered component 800 or 900 may be omitted, and a layered component including the heatsink cells (e.g., the heatsink cells 130) can incorporate features of the omitted component.

[0078] FIG. 10 is a block diagram of an example system 1000 for operating the heatsink system 100. The system 1000 may include the heatsink system 100 shown in FIG. 1 and additionally include a heat generating device 1205, a coolant control system 1210, and a controller 1250. In a brief overview, the controller 1250 can control the heatsink system 100 and the coolant control system 1210 to remove heat from the heat generating device 1205.

[0079] The heat generating device 1205 may be or include any heat generating device, including but not limited to, high performance devices (e.g., high-powered silicon devices, GPU, CPU, processors for AI data centers, etc.) and device modules for various applications (e.g., a printhead, chips therein, etc.). The heatsink system 100 can thermally couple with the heat generating device 1205. In some examples, the heatsink system 100 can thermally couple with the heat generating device 1205 through a thermal interface material (TIM). In some examples, the heat generating device 1205 may be one continuous device or a set of chips in a multichip module. In some examples, the heat generating device 1205 may have various sizes or include more than one device. That is, the heatsink system 100 can accommodate a single device or multiple devices having a wide range of sizes. For example, the heatsink system 100 can accommodate the heat generating device(s) 1205 by incorporating more heatsink cells (e.g., the heatsink cells 130) along x-axis (e.g., of FIG. 2). For example, the heatsink system 100 can accommodate the heat generating device(s) 1205 by incorporating more microchannels (e.g., the microchannels 307) along y-axis (e.g., of FIG. 3B). That is, the heatsink system 100 can thermally couple with the heat generating device(s) 1205 in a flexible manner, thereby accommodating the heat generating device(s) 1205 with a wide range of dimensions, shape, etc., while maintaining the cooling uniformity and coolant drive pressure.

[0080] The coolant control system 1210 may be or include a coolant circulating system. In some examples, the coolant control system 1210 may be a closed-loop or recirculating system. The coolant control system 1210 may include various components, including but not limited to, a heat exchange mechanism, a pump to circulate coolant, a flowmeter, a thermometer, etc. The coolant control system 1210 can provide coolant to the heatsink system 100. For example, the coolant control system 1210 can direct the coolant (e.g., at a lower temperature) through the inlet 105 into the heatsink system 100. The coolant control system 1210 can receive the coolant from the heatsink system 100. For example, the coolant control system 1210 can receive the coolant (e.g., at a higher temperature) through the

outlet 110 from the heatsink system 100. The coolant control system 1210 can transfer heat from the received coolant to a separate cooling medium or dissipate the heat into the environment, thereby lowering the temperature of the coolant.

[0081] The controller 1250 may be a processor coupled with the coolant control system 1210, the heatsink system 100, and/or the heat generating device 1205. The controller 1250 may be or include a general purpose processor device, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A control processor can synthesize a model for an FPGA. For example, the control processor can synthesize a model for logical programmable gates to implement a tensor array and/or a pixel array. The control channel can synthesize a model to connect the tensor array and/or pixel array on an FPGA, a reconfigurable chip and/or die, and/or the like. A general purpose processor device can be a microprocessor, but in the alternative, the processor device can be a controller, microcontroller, or state machine, combinations of the same, or the like. A processor device can include electrical circuitry to process computer-executable instructions. In another example, a processor device includes an FPGA or other programmable device that performs logic operations without processing computer-executable instructions. A processor device can also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, a microprocessor in conjunction with a DSP core, or any other such configuration. Although described herein with respect to digital technology, a processor device may also include analog components. A computing environment can include any type of computer system, including, but not limited to, a computer system based on a microprocessor, a mainframe computer, a digital signal processor, a portable computing device, a device controller, or a computational engine within an appliance, to name a few.

[0082] In one aspect of the present disclosure, a system is disclosed. The system includes an inlet, an outlet, a plurality of heatsink cells, including a first heatsink cell and a second heatsink cell, and a manifold structure to fluidically couple the plurality of heatsink cells with the inlet and the outlet. The manifold structure includes an inlet fluid connector to receive coolant from the inlet and direct the coolant into the plurality of heatsink cells, the inlet fluid connector including a first inlet pathway fluidically coupled with the first

heatsink cell and a second inlet pathway fluidically coupled with the second heatsink cell, and an outlet fluid connector to receive the coolant from the plurality of heatsink cells and direct the coolant into the outlet, the outlet fluid connector including a first outlet pathway fluidically coupled with the first heatsink cell and a second outlet pathway fluidically coupled with the second heatsink cell.

[0083] In yet another aspect of the present disclosure, a heatsink system for circulating coolant in a plurality of heatsink cells is disclosed. The heatsink system includes an inlet, an outlet, and a manifold layer to fluidically couple the plurality of heatsink cells with the inlet and the outlet. The manifold layer includes a first inlet pathway, through which a first portion of the coolant is directed from the inlet into a first set of the plurality of heatsink cells, and a second inlet pathway, through which a second portion of the coolant is directed from the inlet into a second set of the plurality of heatsink cells.

[0084] In yet another aspect of the present disclosure, a heatsink system is disclosed. The heatsink system includes a plurality of microchannels, including a first set of microchannels within a first cell and a second set of microchannels within a second cell, a first layer including an inlet and an outlet, a manifold layer to fluidically couple the plurality of microchannels and the first layer in a first direction, wherein the manifold layer is to receive coolant from the inlet, direct first coolant into the first set of microchannels in a second direction, and direct second coolant into the second set of microchannels in the second direction.

[0085] In yet another aspect of the present disclosure, a heatsink cell is disclosed. The heatsink cell includes a first set of microchannels, a second set of microchannels, an inlet slot to fluidically couple the first set of microchannels and the second set of microchannels at an inner side of the heatsink cell, a first outlet slot to fluidically couple the first set of microchannels at a first outer side of the heatsink cell, and a second outlet slot to fluidically couple the second set of microchannels at a second outer side of the heatsink cell. The first set of microchannels is to receive first coolant from the inlet slot of the heatsink cell and output the first coolant through the first outlet slot, and the second set of microchannels is to receive second coolant from the inlet slot of the heatsink cell and output the second coolant through the second outlet slot.

[0086] In yet another aspect of the present disclosure, a heatsink structure is disclosed. The heatsink structure a first set of microchannels, a second set of microchannels, an inlet slot to direct first coolant into the first set of microchannels in which the first coolant flows in a first direction and direct second coolant into the second set of microchannels in which the second coolant flows in a second direction opposite to the first direction, a first outlet slot to receive the first coolant from the first set of microchannels, and a second outlet slot to receive the second coolant from the second set of microchannels. The inlet slot, the first outlet slot, and the second outlet slot are arranged in parallel.

[0087] In yet another aspect of the present disclosure, a heatsink cell is disclosed. The heatsink cell includes a first column including a first plurality of microchannels, a second column including a second plurality of microchannels, an inlet slot disposed between the first column and the second column, the inlet slot to direct first coolant into the first plurality of microchannels through a first end of the first column and direct second coolant into the second plurality of microchannels through a first end of the second column, a first outlet slot to receive the first coolant from the first plurality of microchannels, the first outlet slot disposed at a second end of the first column, the second end opposite to the first end with respect to the first column, and a second outlet slot to receive the second coolant from the second plurality of microchannels, the second outlet slot disposed at a second end of the second column, the second end opposite to the first end with respect to the second column.

[0088] It should be understood that examples described herein should be considered in a descriptive sense and not for purposes of limitation. Descriptions of features or aspects within each example should be considered as available for other similar features or aspects in other examples. While examples have been described with reference to the figures, it should be understood that various changes in form and details may be made therein without departing from the spirit and scope as defined by the following claims.

[0089] The preceding description has been presented to illustrate and describe examples of the principles described. This description is not intended to be exhaustive or to limit these principles to any precise form disclosed. Many modifications and variations are possible in light of the description. Therefore, the foregoing examples provided in the figures and described herein should not be construed as limiting of the scope of the disclosure, which is defined in the Claims.

[0090] The disclosure has been described above with reference to the various examples. However, it is to be understood by those of ordinary skill in the art that various modifications may be made in form and detail without departing from the scope of the disclosure as defined by the appended claims and their equivalents.

[0091] Conditional language used herein, such as, among others, "can," "could," "might," "may," "e.g.," and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain examples include, while other examples do not include, certain features, elements, etc. Thus, such conditional language is not generally intended to imply that an example includes logic for deciding, with or without other input or prompting, whether these features, elements, etc. are included or are to be performed in any particular example. The terms "comprising," "including," "having," and the like are synonymous and are used inclusively, in an open-ended fashion, and do not exclude additional elements, features, acts, operations, and so forth. Also, the term "or" is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term "or" means one, some, or all of the elements in the list.

[0092] While the above detailed description has shown, described, and pointed out novel features as applied to various examples, it can be understood that various omissions, substitutions, and changes in the form and details of the devices illustrated can be made without departing from the spirit of the disclosure. As can be recognized, certain examples described herein can be embodied within a form that does not provide all of the features and benefits set forth herein, as some features can be used or practiced separately from others.

[0093] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. It is to be understood that such depicted architectures are merely examples, and that in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components.

[0094] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0095] It should be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "includes" should be interpreted as "includes but is not limited to," etc.). It should be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent should be explicitly recited in the claim, and in the absence of such recitation no such intent is present. Furthermore, in those instances where a convention analogous to "one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances, where a convention analogous to " one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It should be understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" should be understood to include the possibilities of "A" or "B" or "A and B." Furthermore, unless otherwise noted, the use of the words “approximate,” “about,” “around,” “substantially,” etc., mean plus or minus ten percent.

WHAT IS CLAIMED IS:

1. A heatsink cell comprising:

a first set of microchannels;

a second set of microchannels;

an inlet slot to fluidically couple the first set of microchannels and the second set of microchannels at an inner side of the heatsink cell;

a first outlet slot to fluidically couple the first set of microchannels at a first outer side of the heatsink cell; and

a second outlet slot to fluidically couple the second set of microchannels at a second outer side of the heatsink cell;

wherein the first set of microchannels is to receive first coolant from the inlet slot of the heatsink cell and output the first coolant through the first outlet slot, and the second set of microchannels is to receive second coolant from the inlet slot of the heatsink cell and output the second coolant through the second outlet slot.

2. The heatsink cell of claim 1, wherein the first set of microchannels and the second set of microchannels share a same dimension, the dimension including one of width, length, or depth.

3. The heatsink cell of claim 1, wherein a first one of the first set of microchannels and a second one of the first set of microchannels share a same dimension, the dimension including one of width, length, or depth.

4. The heatsink cell of claim 1,

wherein a first distance is between the inlet slot and the first outlet slot and a second distance is between the inlet slot and the second outlet slot; and

wherein the first distance and the second distance are substantially the same.

5. The heatsink cell of claim 1, wherein the inlet slot of the heatsink cell is to receive coolant at a first cell end of the heatsink cell, and the first outlet slot and the second outlet

slot are to output the coolant at a second cell end of the heatsink cell opposite to the first end.

6. A heatsink structure comprising:

a first set of microchannels;

a second set of microchannels;

an inlet slot to direct first coolant into the first set of microchannels in which the first coolant flows in a first direction and direct second coolant into the second set of microchannels in which the second coolant flows in a second direction opposite to the first direction;

a first outlet slot to receive the first coolant from the first set of microchannels; and

a second outlet slot to receive the second coolant from the second set of microchannels;

wherein the inlet slot, the first outlet slot, and the second outlet slot are arranged in parallel.

7. The heatsink structure of claim 6,

wherein the first coolant flows in the first set of microchannels at a first rate, and the second coolant flows in the second set of microchannels at a second rate; and

wherein the first rate and the second rate are substantially same.

8. The heatsink structure of claim 6, wherein one of the first set of microchannels or one of the second set of microchannels ranges from the first outlet slot to the second outlet slot.

9. The heatsink structure of claim 8, wherein the first set of microchannels and the second set of microchannels are arranged alternately along an axis parallel to the inlet slot.

10. The heatsink structure of claim 8,

wherein the inlet slot includes a first inlet slot to direct the first coolant into the first set of microchannels and a second inlet slot to direct the second coolant into the second set of microchannels; and

wherein the first inlet slot is disposed between the second inlet slot and the second outlet slot, and the second inlet slot is disposed between the first inlet slot and the first outlet slot.

11. A heatsink cell comprising:

a first column comprising a first plurality of microchannels;

a second column comprising a second plurality of microchannels;

an inlet slot disposed between the first column and the second column, the inlet slot to direct first coolant into the first plurality of microchannels through a first end of the first column and direct second coolant into the second plurality of microchannels through a first end of the second column;

a first outlet slot to receive the first coolant from the first plurality of microchannels, the first outlet slot disposed at a second end of the first column, the second end opposite to the first end with respect to the first column; and

a second outlet slot to receive the second coolant from the second plurality of microchannels, the second outlet slot disposed at a second end of the second column, the second end opposite to the first end with respect to the second column.

12. The heatsink cell of claim 11, wherein the first column and the second column share a same dimension, the dimension including one of a width, a length, an arrangement, or a shape.

13. The heatsink cell of claim 11, wherein the first column and the second column have a pitch ranging from 5 mm to 15 mm.

14. The heatsink cell of claim 11, wherein the first plurality of microchannels and the second plurality of microchannels share a same dimension, the dimension including one of:

a width ranging from 25 μm to 150 μm;

a depth ranging from 200 μm to 550 μm; and

a length ranging from 3 mm to 9 mm.

15. The heatsink cell of claim 11, wherein the first column and the second column are formed on an array of silicon substrates.

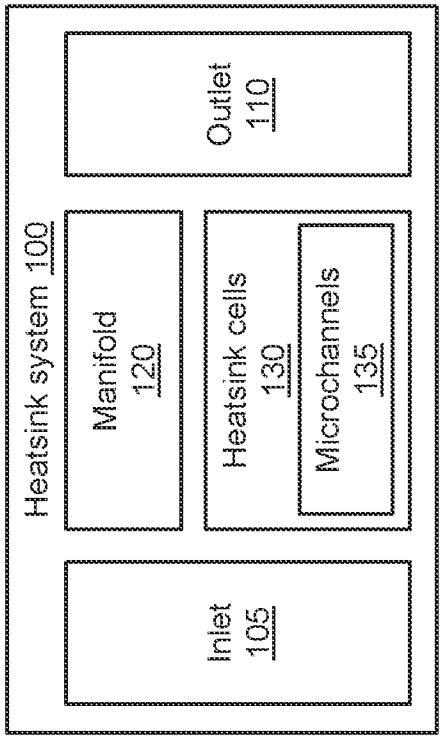

Heatsink system 100
Inlet 105
Manifold 120
Heatsink cells 130
Microchannels 135
Outlet 110

FIG. 1

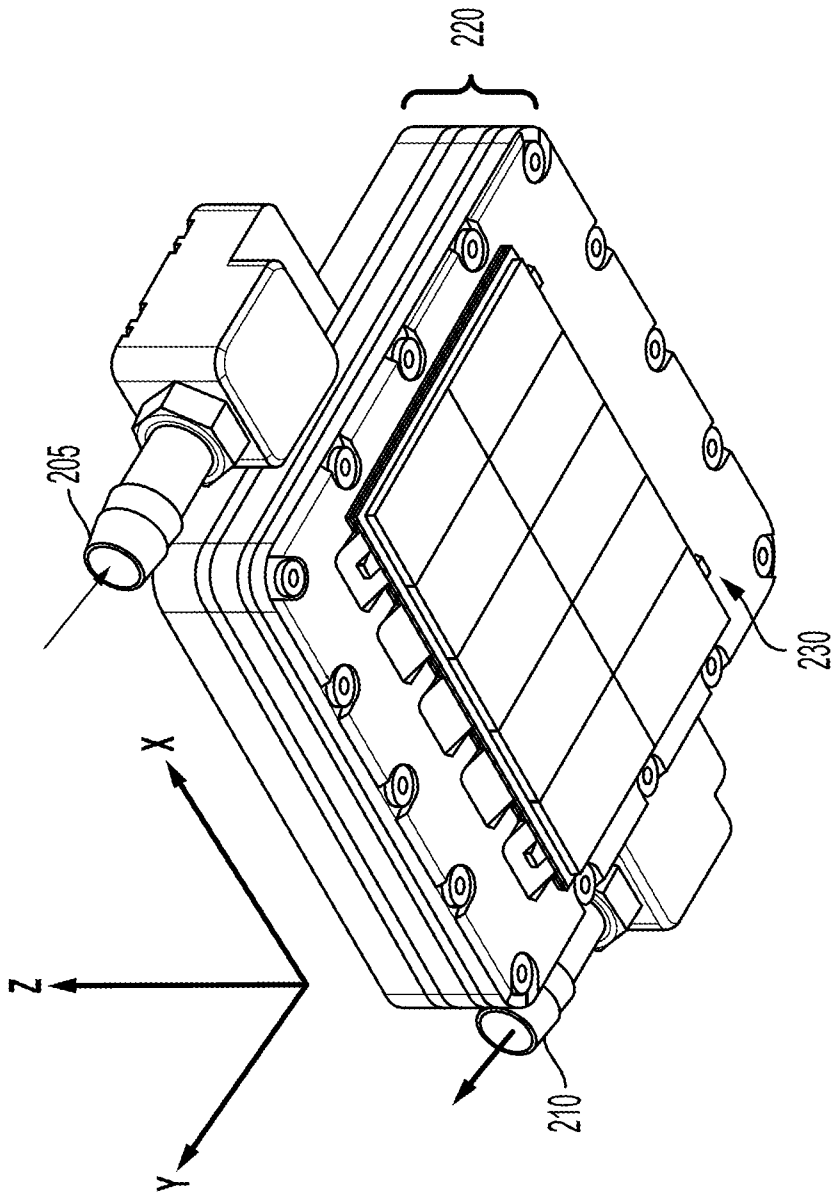


FIG. 2

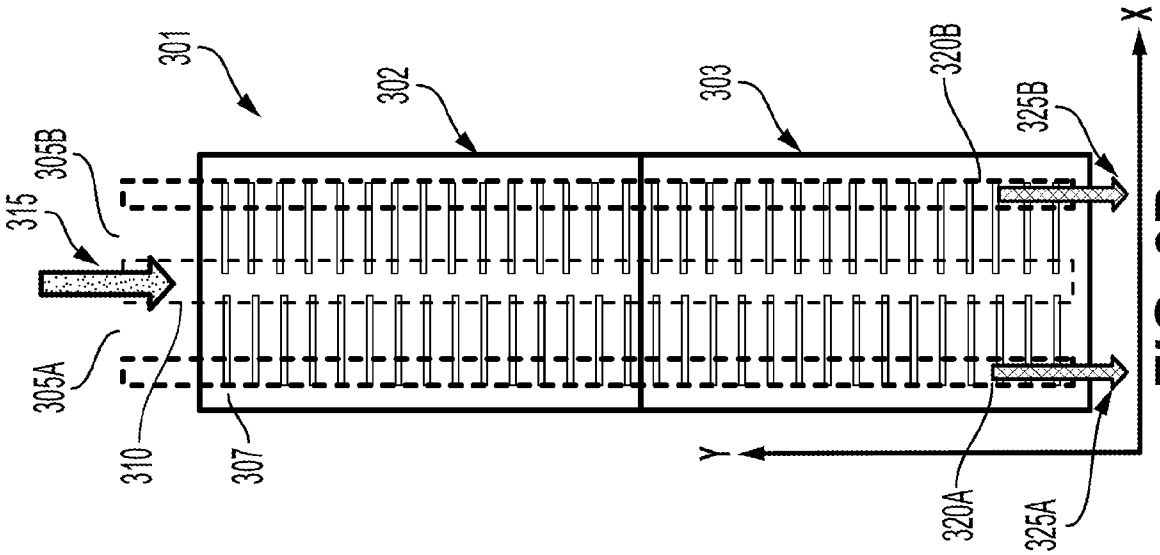

301
302
303
320B
325B
X
305B
315
305A
310
307
Y
320A
325A

FIG. 3B

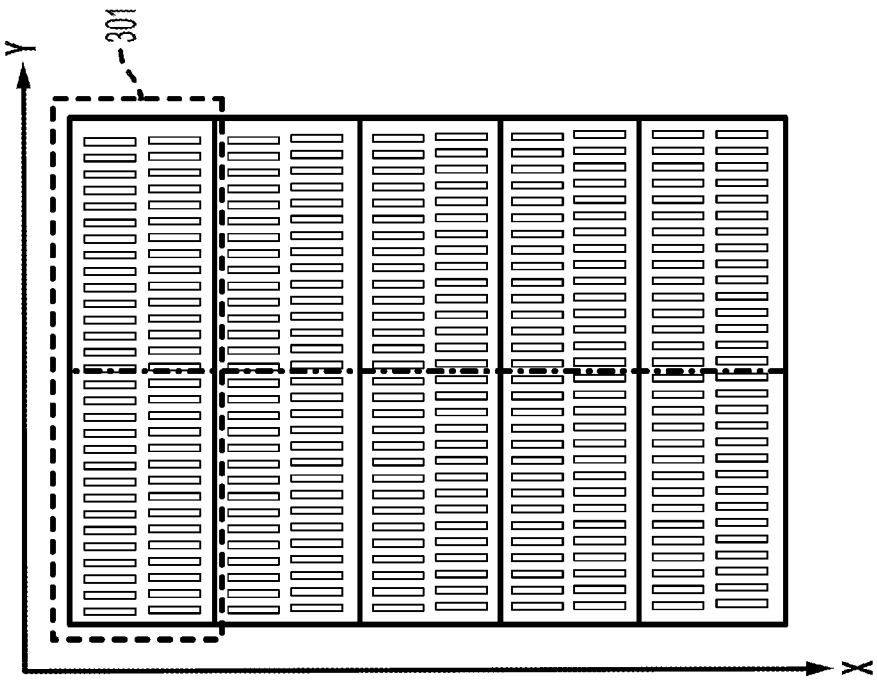

Y
301
X
300

FIG. 3A

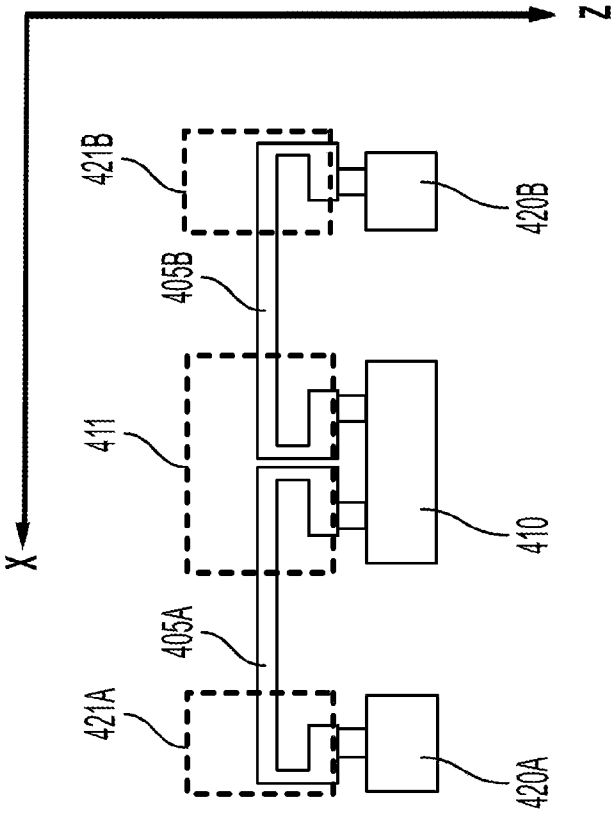

Z
X
421B
420B
405B
411
410
405A
421A
420A
401

FIG. 4B

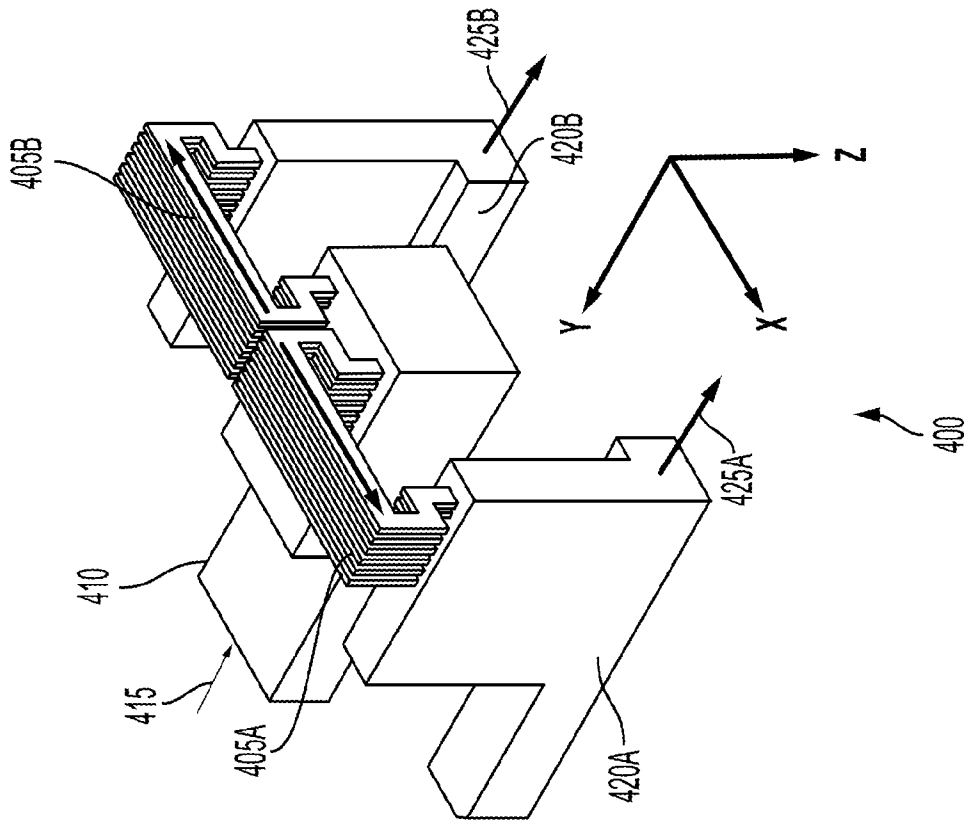

425B
420B
405B
Z
Y
X
425A
410
415
405A
420A
400

FIG. 4A

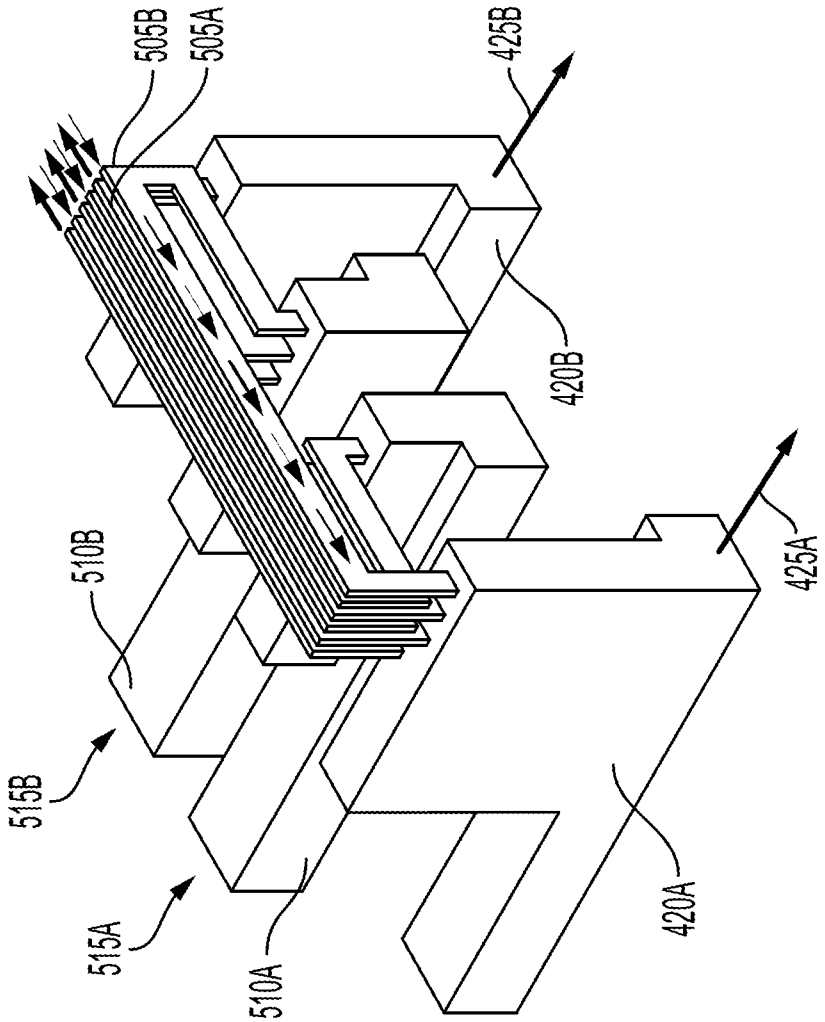


FIG. 5

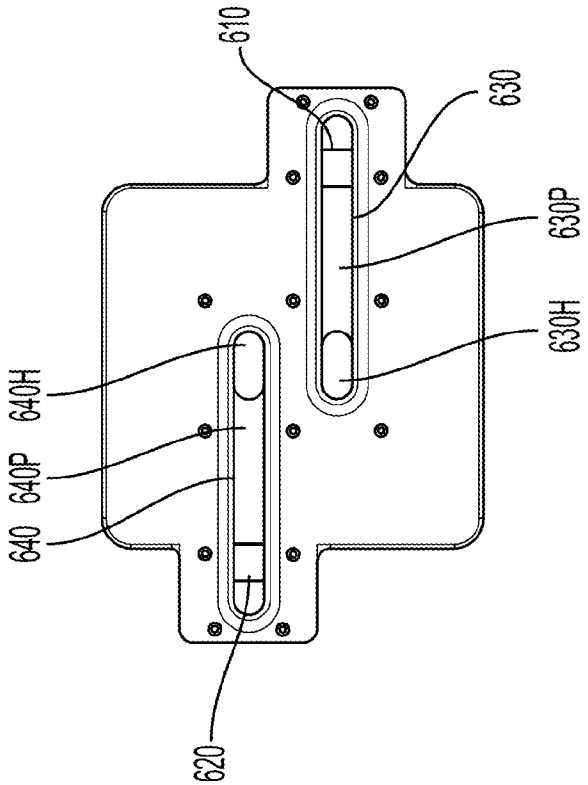


FIG. 6B

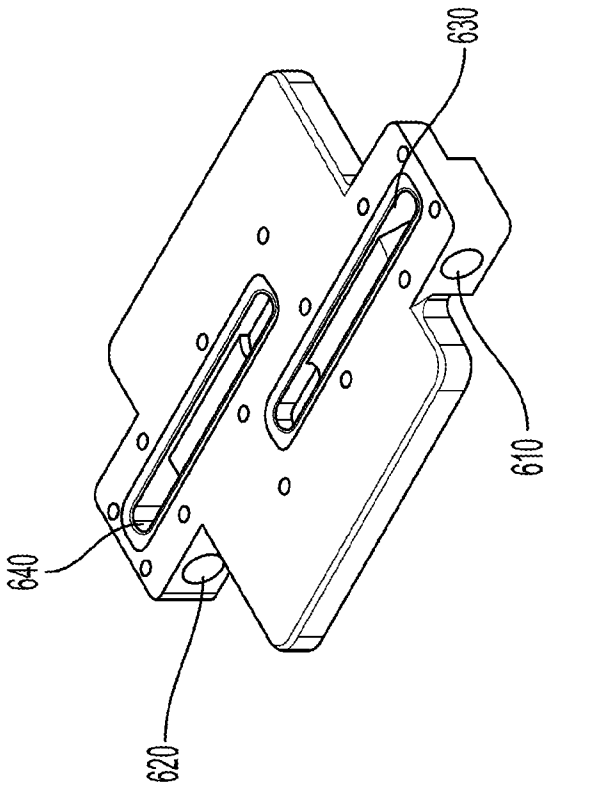


FIG. 6A

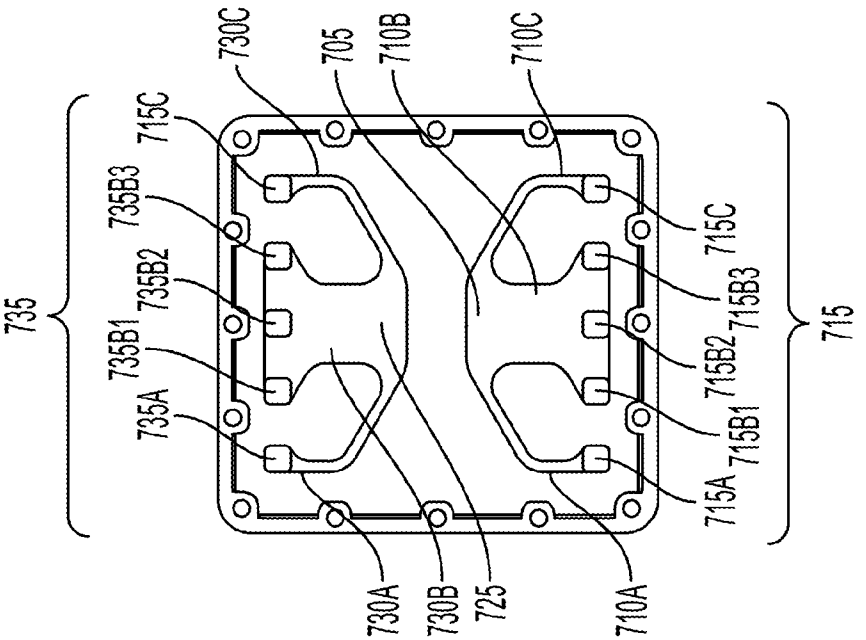

735
730C
705
710B
710C
715C
735B3
735B2
735B1
735A
715B3
715B2
715B1
715A
715
730A
730B
725
710A
700

FIG. 7B

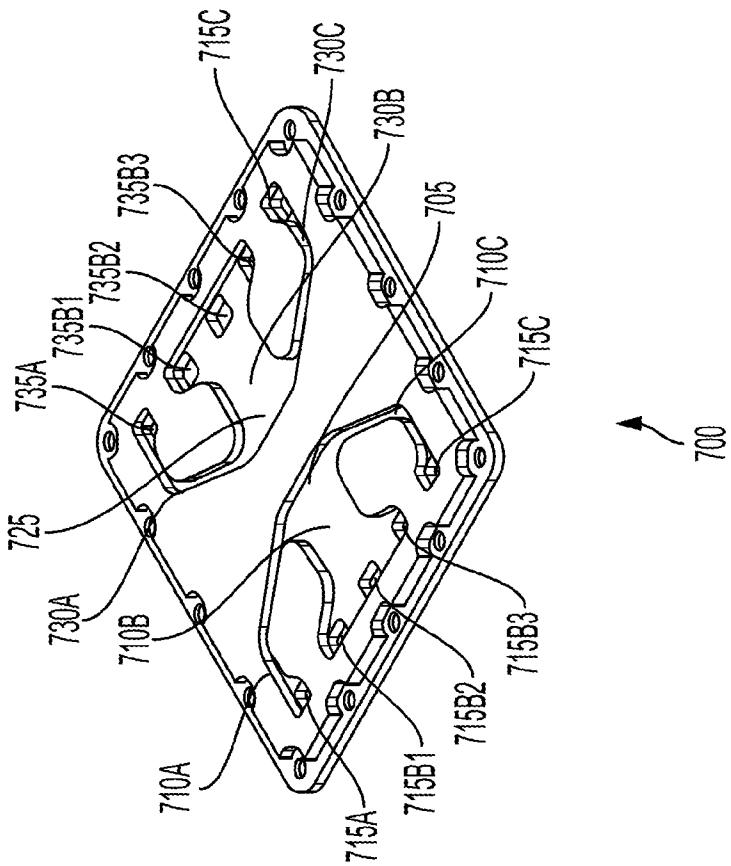

715C
730C
730B
735B3
705
735B2
710C
735B1
735A
715C
725
730A
710B
715B3
715B2
710A
715B1
715A
700

FIG. 7A

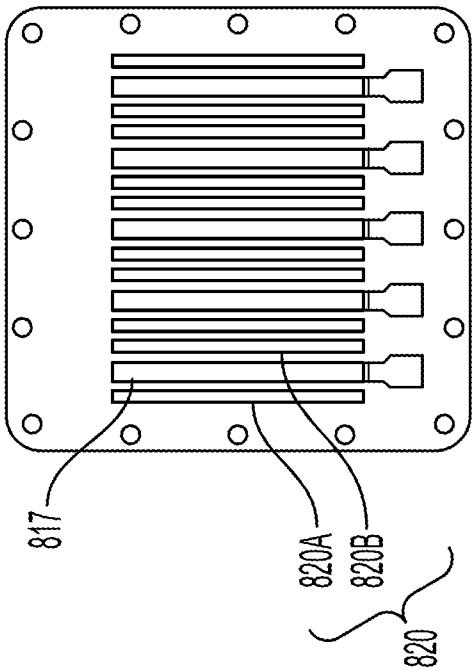

800
817
820A
820B
820

FIG. 8B

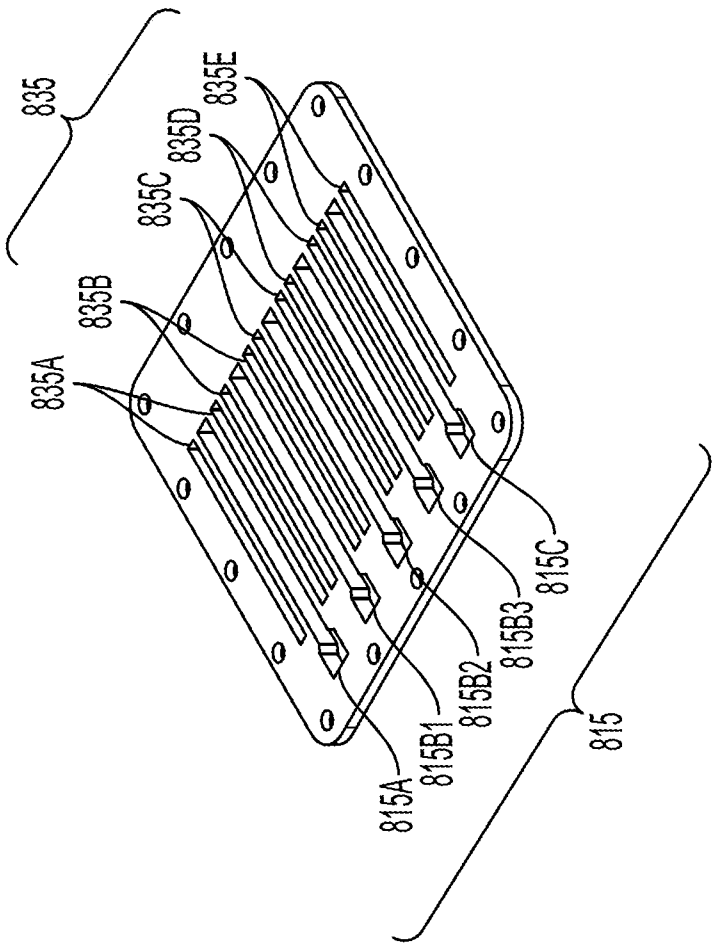

800
835
835E
835D
835C
835B
835A
815C
815B3
815B2
815B1
815A
815

FIG. 8A

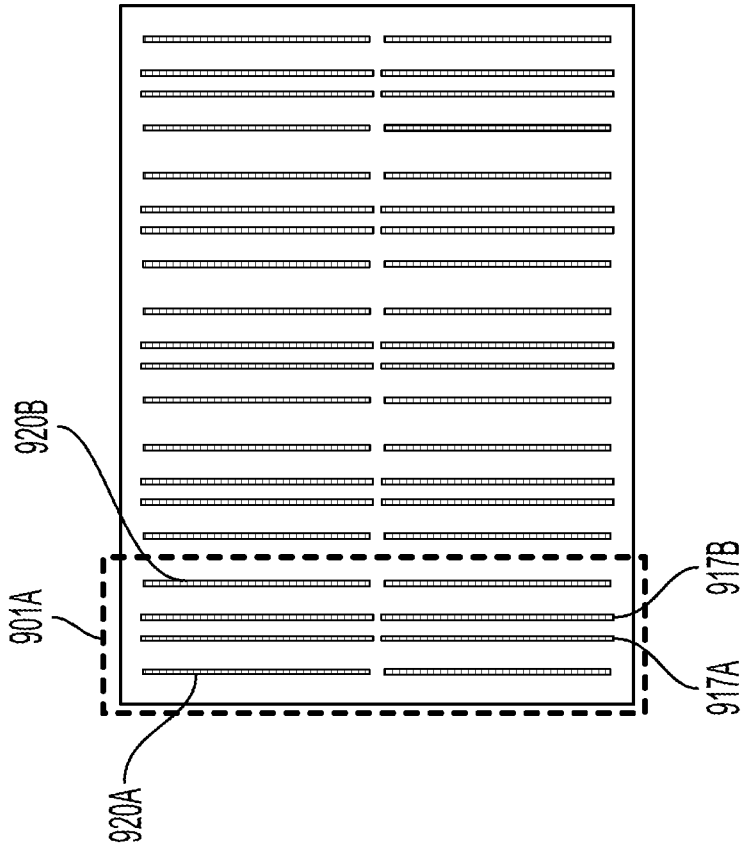

920B
901A
917B
917A
920A
900

FIG. 9B

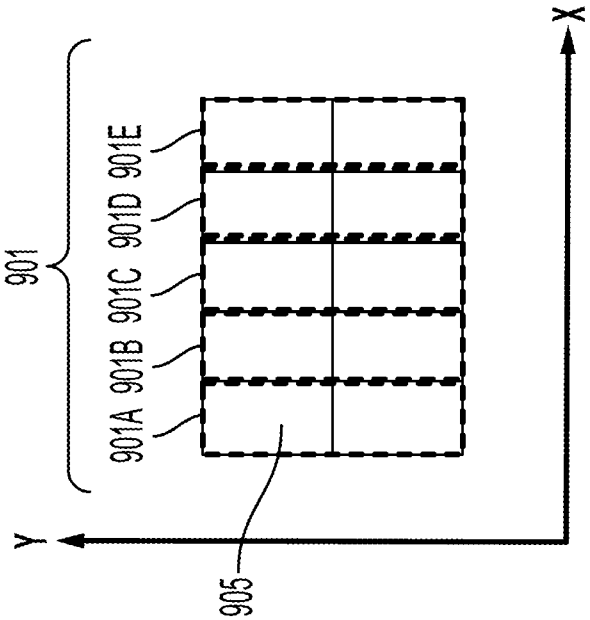

X
Y
901
901A
901B
901C
901D
901E
905
900

FIG. 9A

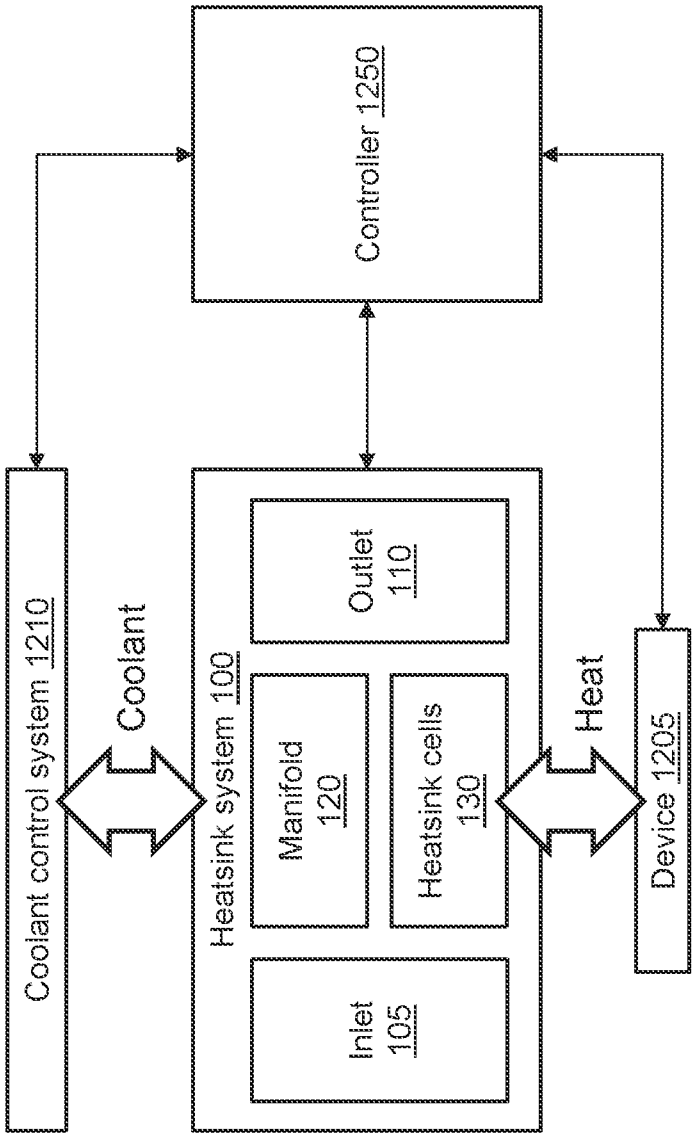

Controller 1250
Coolant control system 1210
Coolant
Heatsink system 100
Outlet 110
Manifold 120
Heatsink cells 130
Inlet 105
Heat
Device 1205
1000

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/010567

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01L23/473 F28F3/14 H05K7/20
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L F28F H05K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/276014 A1 (PRASHER RAVI S [US] ET AL) 15 December 2005 (2005-12-15)	1-5
A	figures 1, 5 paragraph [0012] - paragraph [0030]	6-15

[ ] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 July 2024	02/08/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hofer-Weissenfels, C

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2024/010567

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005276014 A1	15-12-2005	NONE	