according to the present disclosure, three-dimensional sample manipulation is possible, including rotation in addition to linear transport. In the context of RF detection and imaging discussed in greater detail below, the vertical microcoil may allow large-signal RF perturbations for imaging, while the planar microcoil provides a DC field to manipulate the samples, thereby enhancing the capability of a hybrid system incorporating both vertical and planar microcoils.

**[0123]** Having discussed various aspects of the structure and fabrication of an exemplary microcoil according to the present disclosure based on conventional semiconductor fabrication processes, the interaction between neighboring microcoils in an array with respect to the generation of magnetic fields for sample manipulation is now considered in greater detail. As discussed above, the principle of operation of the microcoil array **200**B shown in FIGS. **6**(*a*) and (*b*) is to create and move one or more magnetic field peaks by modulating currents in the respective microcoils **212** of the array so as to move and/or trap magnetic samples. The magnitude of the magnetic field generated by a given microcoil of the array is based on the magnitude of the current flowing through the microcoil, and each microcoil in the array is capable of generating a local magnetic field peak above the microcoil. In this sense, the array **200**B may be thought of generally in terms of "magnetic pixels," wherein an N×N array of microcoils is capable of producing at least N×N magnetic peaks, or "pixels," each capable of attracting and trapping a sample. **FIG. 10** conceptually illustrates two neighboring microcoils **212-1** and **212-2** of the array **200**B, in which an essentially equal current **230** flows through the microcoils to generate two essentially equal magnetic field peaks **232-1** and **232-2** above the coils. In **FIG. 10**, the distance between the two magnetic field peaks generally corresponds to the pitch **216** of the array **200**B, as indicated in FIGS. **6**(*a*) and **10**.

**[0124]** In one embodiment, not only may the magnitude of the current flowing through each microcoil be modulated to facilitate sample manipulation, but also the direction of the current flowing through a given coil may be altered, so as to facilitate a smoother transition of a sample from pixel to pixel, or effectively increase the spatial resolution for sample manipulation (i.e., effectively decrease the pitch **216** of the array). FIGS. **11**(*a*)-(*e*) show five exemplary scenarios for the neighboring microcoils **212-1** and **212-2** of **FIG. 10**, with varying current magnitudes and directions in the respective coils and the resulting magnetic fields generated. **FIG. 12** is a graph illustrating the current magnitude and direction in each of the coils for each of the five exemplary scenarios illustrated in FIGS. **1** I(*a*)-(*e*). On the horizontal axis of **FIG. 12**, the steps **1-5** correspond respectively to the five scenarios illustrated in FIGS. **11**(*a*)-(*e*). The upper plot shown on the graph of **FIG. 12** indicates the current **230-1** flowing through the "left" microcoil **212-1** in each scenario, and the lower plot indicates the current **230-2** flowing through the "right" microcoil **212-2** in each scenario.

**[0125]** In particular, in **FIG. 11**(*a*), as indicated in step **1** of the graph of **FIG. 12**, the left microcoil **212-1** has no current flowing through it, while the right microcoil **212-2** has −20 mA of current flowing through it. As a result, a magnetic field peak **232-2** is generated above the right microcoil **212-2**. In one exemplary implementation based on the microcoil structure discussed above in connection with **FIGS. 7-9**, the magnitude of the magnetic field peak **232-2** thus generated may be on the order of approximately 30 Gauss. In **FIG. 11**(*b*), as indicated in step **2** of **FIG. 12**, the current **230-1** in the left microcoil is increased to approximately 12-13 mA, while the current **230-2** in the right microcoil is decreased to approximately −19 mA. As shown in **FIG. 11**(*b*), the magnetic field starts to broaden somewhat above the two microcoils, as there is now some field contribution from both the left and right microcoils.

**[0126]** In **FIG. 11**(*c*), as indicated in step **3** of **FIG. 12**, the left and right microcoils have equal magnitude currents flowing through them (approximately 17-18 mA), but in opposite directions; as a result, a broad magnetic field peak is generated, roughly centered over the midpoint between the centers of the respective coils. In **FIG. 11**(*d*), the current **230-1** is further increased in the left microcoil **212-1** and the current **230-2** is further decreased in the right microcoil **212-2**, and in **FIG. 11**(*e*) the current **230-1** ultimately is increased to 20 mA while the current **230-2** ultimately is reduced to zero; as a result, a single magnetic field peak **232-1** is maintained over the left microcoil **212-1**. It should be appreciated that the respective fields generated in FIGS. **11**(*a*) and **11**(*e*) have the same magnitude, but opposite field directions. Accordingly, by gradually varying currents of different directions through the coils, a magnetic field peak may be continuously moved between two adjacent coils, thus effectively enhancing the resolution of the array to facilitate precise positioning as well as smooth translation of samples across the array **200**B.

**[0127]** As discussed above in connection with **FIGS. 1 and 2**, in one embodiment various field control components **400** for controlling and distributing current (and/or voltage) to the microcoils of the array **200**B may be integrated together with the array in an IC chip **102**. In one exemplary implementation, these field control components include one or more current sources (and/or voltage sources), as well as various switching or multiplexing components to facilitate digital (and computer programmable) control of the fields generated by the array **200**B.

**[0128]** **FIG. 13** is a diagram showing the microcoil array **200**B and various field control components associated with the array **200**B, according to one embodiment of the present disclosure. In the example of **FIG. 13**, the array **200**B includes eight rows and eight columns of "microcoil cells"**250**, wherein each microcoil cell includes a microcoil **212**, as well as switches and logic circuits, as discussed further below in connection with **FIGS. 14 and 15**. For purposes of distributing current (and/or voltage) to the microcoil cells **250**, the array **200**B of this embodiment is divided into four quadrants **200**B-**1**, **200**B-**2**, **200**B-**3** and **200**B-**4**, each quadrant having sixteen microcoil cells **250** (i.e., four rows and four columns per quadrant). It should be appreciated, however, that microcoil arrays and associated control components according to the present disclosure are not limited in this respect, and that the particular configuration shown in **FIG. 13** is provided primarily for purposes of illustration.

**[0129]** As shown in **FIG. 13**, the various field control components associated with the array **200**B in this embodiment include a row decoder **460-1** that provides row enable signals **R0-R7** to respective rows of the array **200**B, and a column decoder **460-2** that provides column enable signals **C0-C7** to respective columns of the array. The row decoder