Manufacturing Design and Fabrication for Microfluidic Busses, Valve Arrays, Pumps, and Other Microfluidic Systems Employing Interlaminate-Spanning Structures

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Background of the Invention

Field of the Invention

This patent application generally relates to the area of microfluidic and micro-scale gas-flow systems, and in particular to manufacturing design and fabrication techniques for microfluidic and micro-scale gas-flow systems comprising valve arrays, bus structures, and other microfluidic and micro-scale gas-flow arrangements and configurations.

Introduction

Microfluidic systems, and by extension micro-scale gas-flow systems and subsystems, hold great promise in a wide range of future applications. Many microfluidic systems are passive and contain no pumps or valves. Some microfluidic systems, and by extension micro-scale gas-flow systems and subsystems, comprise at least one valve or pump. A next generation of microfluidic systems and micro-scale gas-flow systems and subsystems is expected to comprise a large number of valves, and in some cases the valves would be arranged in arrays. Important examples include the microfluidic (and micro-scale gas-flow) buss arrangements taught in US 8,032,258, US 8,606,414, and US 8,812,163, as well as software reconfigurable / software defined / software operated microfluidic (and micro-scale gas-flow) systems taught in US 13/314,170 (published as US App 2012/0094366), US 13/761,142 (published as 2013/0217598), US 13/815,757 (published as 2014/027481), and US 13/844,621 (published as US App 2014/0273191).

In one approach to the fabrication of passive conduit-based microfluidic systems, such as that taught in Hu e*t al.* US 6,623,860, a microfluidic system is constructed from a stack of specifically-configured laminate layers, wherein each layer can be machined and/or molded. The stack of specifically-configured laminate layers stacked together in appropriate order and with appropriate alignment and bonding form a microfluidic system comprising a plurality of vias linking passageways in among pairs of layers. Such an arrangement is analogous to multi-layer printed circuit boards commonly used in consumer and industrial electronics.

The present application addresses manufacturing design and fabrication techniques for active conduit-based microfluidic and micro-scale gas-flow systems comprising valves and/or pumps of arbitrary complexity, and in particular comprising complex structures such as valve arrays, bus structures, and intricate or high-replication microfluidic and micro-scale gas-flow arrangements and configurations. Of special value in implementing such complex flow-network topologies in compact volumes is the use of stack of specifically-configured laminate layers linked by electrically-operated, pneumatically operated, or fluidicly-operated interlaminate-spanning flow-valve structures and pumps comprising interlaminate-spanning structures.

Brief Description of the Drawings

The above and other aspects, features, and advantages of the present invention will become more apparent upon consideration of the following description of preferred embodiments, taken in conjunction with the accompanying drawing figures.

Figure 1A depicts an example arrangement wherein an example on/off valve links a T-joint tap on a first channel in a first laminate layer with a T-joint tap on a second channel in a second laminate layer.

Figure 1B depicts an example arrangement wherein an example on/off valve links a T-joint tap on a first channel in a first laminate layer with an L-joint on a second channel in a second laminate layer.

Figure 1C depicts an example arrangement wherein an example on/off valve links an L-joint on a first channel in a first laminate layer with a T-joint tap to a second channel in a second laminate layer.

Figure 1B depicts an example arrangement wherein an example on/off valve links an L-joint on a first channel in a first laminate layer with an L-joint on a second channel in a second laminate layer.

Figure 2A depicts an example arrangement wherein an example valve is formed or comprised by openings and/or structures in at least one of the first laminate layer and second laminate layer described in conjunction with Figure 1A and which can be adapted for use with the configurations of Figures 1B-1D.

Figure 2B depicts an example arrangement wherein an example valve is formed or comprised by openings and/or structures in both the first laminate layer and second laminate layer described in conjunction with F Figure 1A and which can be adapted for use with the configurations of Figures 1B-1D.

Figure 2C depicts an example arrangement wherein an example valve is formed or comprised by openings and/or structures in at least an additional third laminate layer, the additional third laminate layer sandwiched between the first laminate layer and second laminate layer described in conjunction with Figure 1A and which can be adapted for use with the configurations of Figures 1B-1D.

Figure 2D depicts an example arrangement wherein an example valve is formed or comprised by openings and/or structures in at least a plurality of additional laminates layers, the plurality of additional laminates layers sandwiched between the first laminate layer and second laminate layer described in conjunction with Figure 1A and which can be adapted for use with the configurations of Figures 1B-1D.

Figure 3 depicts an example arrangement of a 5-layer microfludic device wherein each layer can be machined and/or molded and when stacked together with appropriate alignment and bonding form a microfluidic and/or micro-scale gas-flow system comprising a plurality of valves. The left half of the figure depicts an angular vantage point of the separated layers from position at the top and side, while the right half of the figure depicts a direct side view of each layer.

Figure 4 depicts an example arrangement wherein the layers depicted in Figure 3 are appropriately aligned and bonded to form a microfluidic and/or micro-scale gas-flow system comprising a plurality of valves.

Figure 5 depicts a more detailed view of the individual laminate layers for the example arrangement depicted in Figure 3.

Figure 6 depicts details of how a deformable elastic membrane layer can be affixed atop one of the laminate layers of the example arrangement of Figure 3; appropriate deformation of the membrane prevents flows from occurring between the fluidic/gas passage channels connecting with the valve structure.

Figure 7 depicts an example 3- layer arrangement, which in turn can be embedded with a larger arrangement comprising more laminate layers (such as the arrangement depicted in Figure 3) wherein at least one valve is formed or comprised by openings and/or structures in at least one side of the center laminate layer and an attached first laminate layer and at least one valve is formed or comprised by openings and/or structures in at least another side of the center laminate layer and an attached second laminate layer.

Figure 8A depicts an example opening-spanning arrangement wherein two layers of piezoelectric material are configured to be influenced by the same electric field so as to expand and/or contract in a predetermined coordinated fashion. In one arrangement, the range of motion of expansion and contraction are amplified. In an opposite arrangement, the interface between the two layers of piezoelectric material

Figure 8B depicts an example swaying-member or rotating-member arrangement wherein one or more layers of piezoelectric material is configured to actuate a lever element for use in locally deforming or positioning a membrane or other flow-controlling mechanical element under the control of electrical potential as part of a valve, pump, or other flow-manipulating or flow-controlling arrangement.

Figure 8C depicts an example opening-spanning arrangement wherein one or more layers of piezoelectric material is configured to actuate a cantilever arrangement for use in locally deforming or positioning a membrane or other flow-controlling mechanical element under the control of electrical potential as part of a valve, pump, or other flow-manipulating or flow-controlling arrangement.

Detailed Description

In the following detailed description, reference is made to the accompanying drawing figures which form a part hereof, and which show by way of illustration specific embodiments of the invention. It is to be understood by those of ordinary skill in this technological field that other embodiments may be utilized, and structural, electrical, as well as procedural changes may be made without departing from the scope of the present invention. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or similar parts.

Xxx

Figure 1A depicts an example arrangement wherein an example on/off valve links a T-joint tap on a first channel in a first laminate layer with a T-joint tap on a second channel in a second laminate layer.

Figure 1B depicts an example arrangement wherein an example on/off valve links a T-joint tap on a first channel in a first laminate layer with an L-joint on a second channel in a second laminate layer.

Figure 1C depicts an example arrangement wherein an example on/off valve links an L-joint on a first channel in a first laminate layer with a T-joint tap to a second channel in a second laminate layer.

Figure 1B depicts an example arrangement wherein an example on/off valve links an L-joint on a first channel in a first laminate layer with an L-joint on a second channel in a second laminate layer.

Xxx

Figure 2A depicts an example arrangement wherein an example valve is formed or comprised by openings and/or structures in at least one of the first laminate layer and second laminate layer described in conjunction with Figure 1A and which can be adapted for use with the configurations of Figures 1B-1D.

Xxx

Figure 2B depicts an example arrangement wherein an example valve is formed or comprised by openings and/or structures in both the first laminate layer and second laminate layer described in conjunction with F Figure 1A and which can be adapted for use with the configurations of Figures 1B-1D.

Xxx

Figure 2C depicts an example arrangement wherein an example valve is formed or comprised by openings and/or structures in at least an additional third laminate layer, the additional third laminate layer sandwiched between the first laminate layer and second laminate layer described in conjunction with Figure 1A and which can be adapted for use with the configurations of Figures 1B-1D.

Xxx

Figure 2D depicts an example arrangement wherein an example valve is formed or comprised by openings and/or structures in at least a plurality of additional laminates layers, the plurality of additional laminates layers sandwiched between the first laminate layer and second laminate layer described in conjunction with Figure 1A and which can be adapted for use with the configurations of Figures 1B-1D.

Xxx

Figure 3 depicts an example arrangement of a 5-layer microfludic device wherein each layer can be machined and/or molded and when stacked together with appropriate alignment and bonding form a microfluidic and/or micro-scale gas-flow system comprising a plurality of valves. The left half of the figure depicts an angular vantage point of the separated layers from position at the top and side, while the right half of the figure depicts a direct side view of each layer.

Xxx

Figure 4 depicts an example arrangement wherein the layers depicted in Figure 3 are appropriately aligned and bonded to form a microfluidic and/or micro-scale gas-flow system comprising a plurality of valves.

Xxx

Figure 5 depicts a more detailed view of the individual laminate layers for the example arrangement depicted in Figure 3.

Xxx

Figure 6 depicts details of how a deformable elastic membrane layer can be affixed atop one of the laminate layers of the example arrangement of Figure 3; appropriate deformation of the membrane prevents flows from occurring between the fluidic/gas passage channels connecting with the valve structure.

Xxx

Figure 7 depicts an example 3- layer arrangement, which in turn can be embedded with a larger arrangement comprising more laminate layers (such as the arrangement depicted in Figure 3) wherein at least one valve is formed or comprised by openings and/or structures in at least one side of the center laminate layer and an attached first laminate layer and at least one valve is formed or comprised by openings and/or structures in at least another side of the center laminate layer and an attached second laminate layer.

Xxx

Figure 8A depicts an example opening-spanning arrangement wherein two layers of piezoelectric material are configured to be influenced by the same electric field so as to expand and/or contract in a predetermined coordinated fashion. In one arrangement, the range of motion of expansion and contraction are amplified. In an opposite arrangement, the interface between the two layers of piezoelectric material

Xxx

Figure 8B depicts an example swaying-member or rotating-member arrangement wherein one or more layers of piezoelectric material is configured to actuate a lever element for use in locally deforming or positioning a membrane or other flow-controlling mechanical element under the control of electrical potential as part of a valve, pump, or other flow-manipulating or flow-controlling arrangement.

Xxx

Figure 8C depicts an example opening-spanning arrangement wherein one or more layers of piezoelectric material is configured to actuate a cantilever arrangement for use in locally deforming or positioning a membrane or other flow-controlling mechanical element under the control of electrical potential as part of a valve, pump, or other flow-manipulating or flow-controlling arrangement.

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Closing

While the invention has been described in detail with reference to disclosed embodiments, various modifications within the scope of the invention will be apparent to those of ordinary skill in this technological field. It is to be appreciated that features described with respect to one embodiment typically may be applied to other embodiments. Therefore, the invention properly is to be construed with reference to the claims.

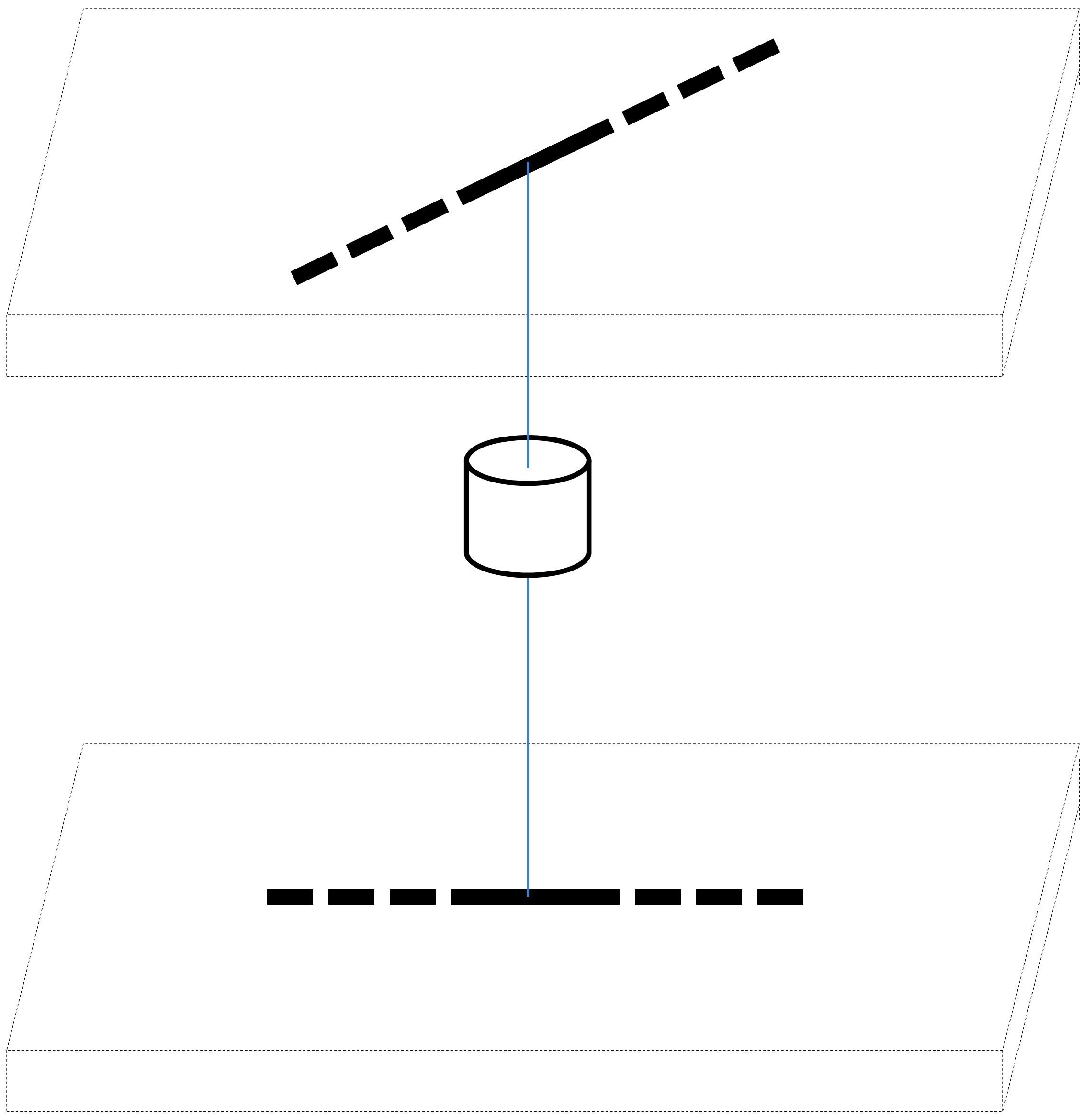

Figure 1A

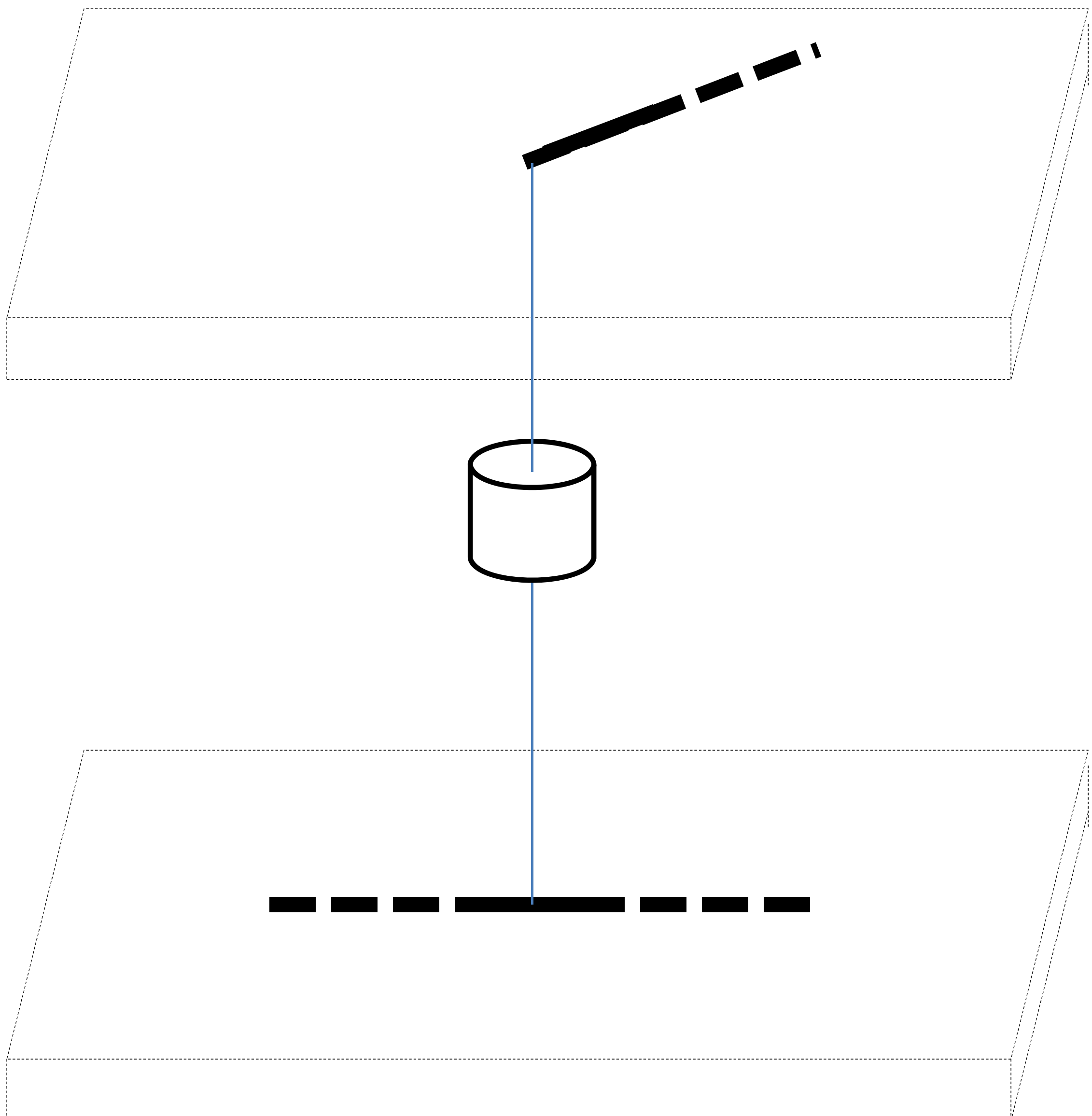

Figure 1B

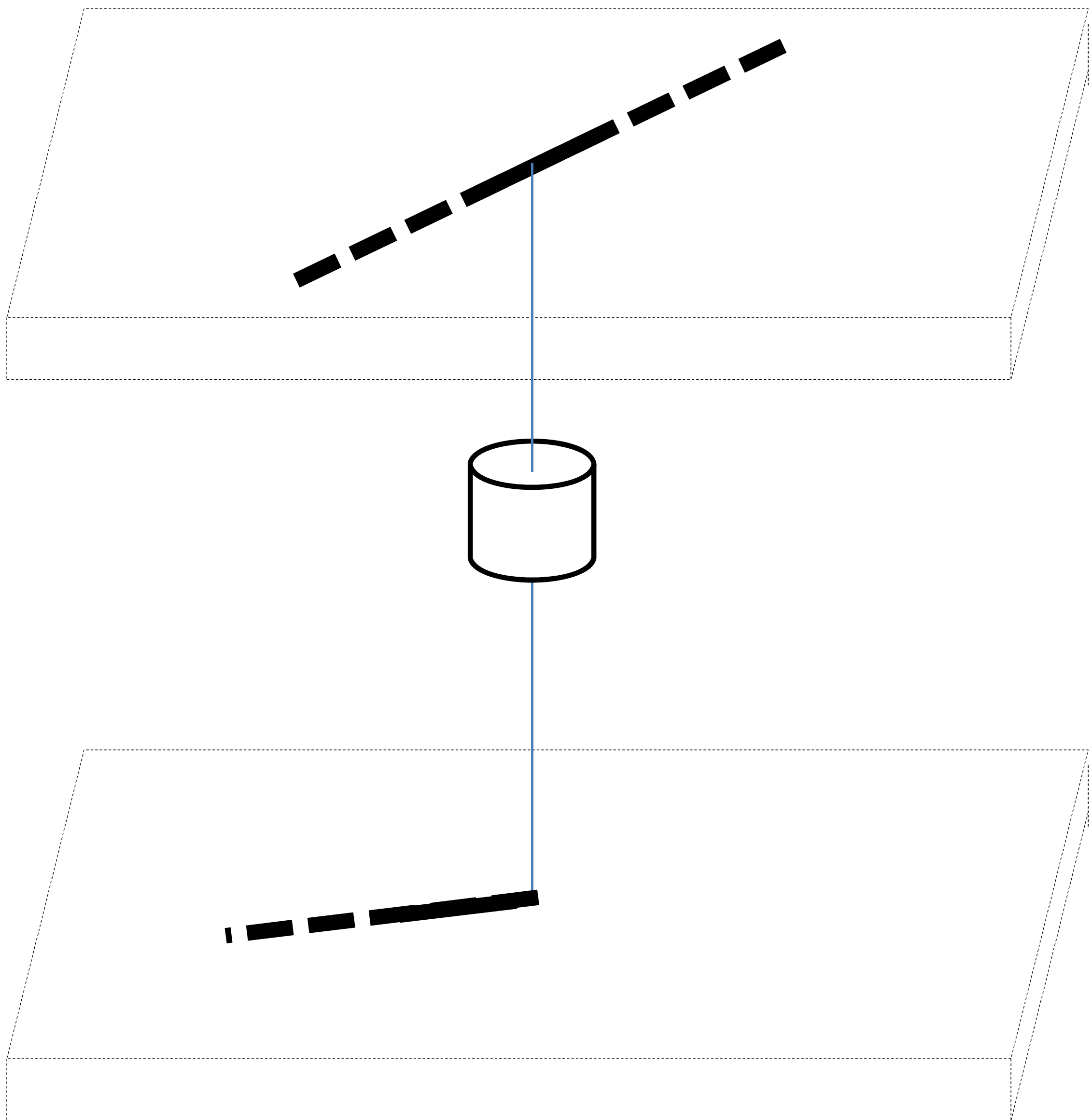

Figure 1C

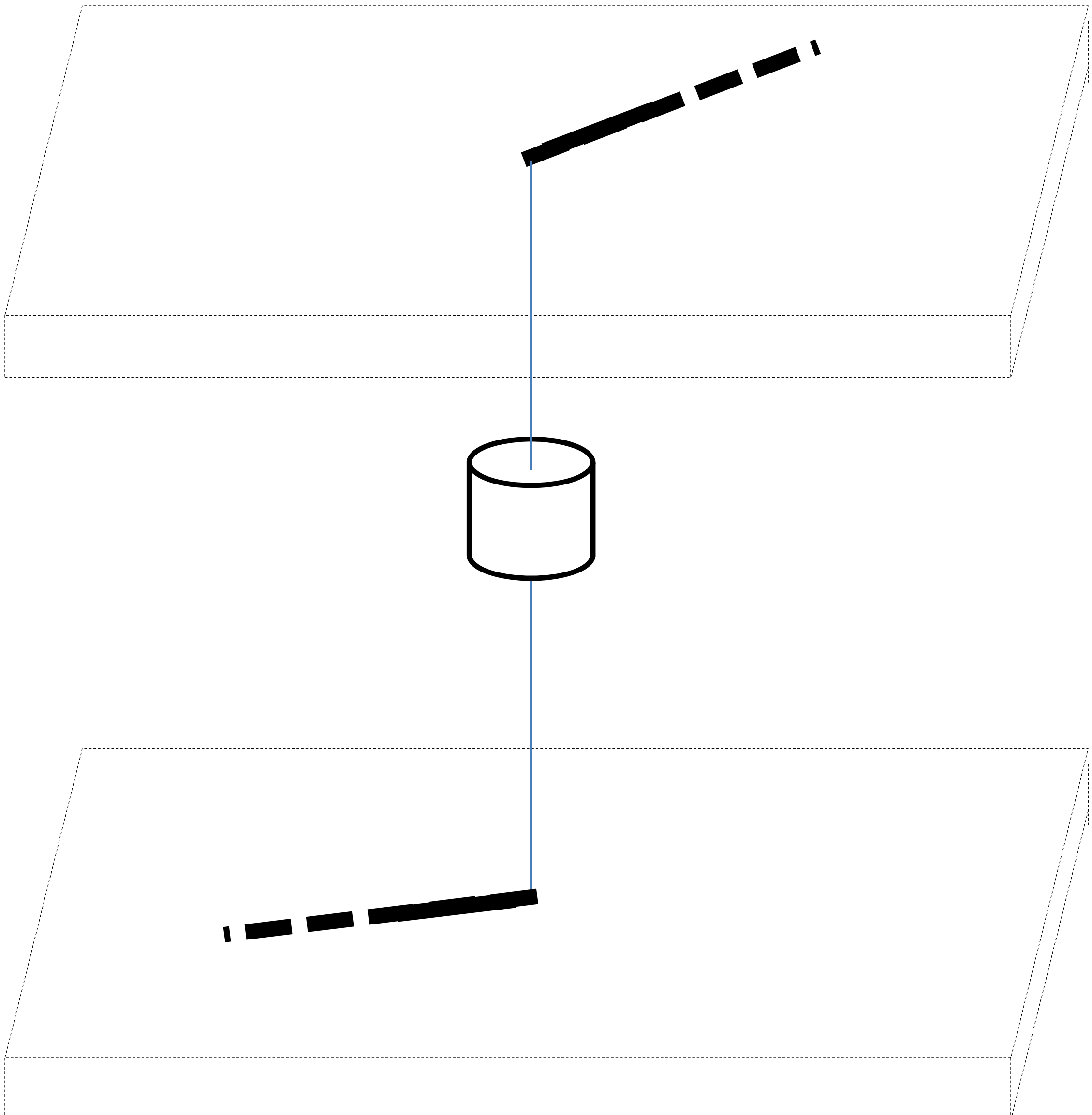

Figure 1D

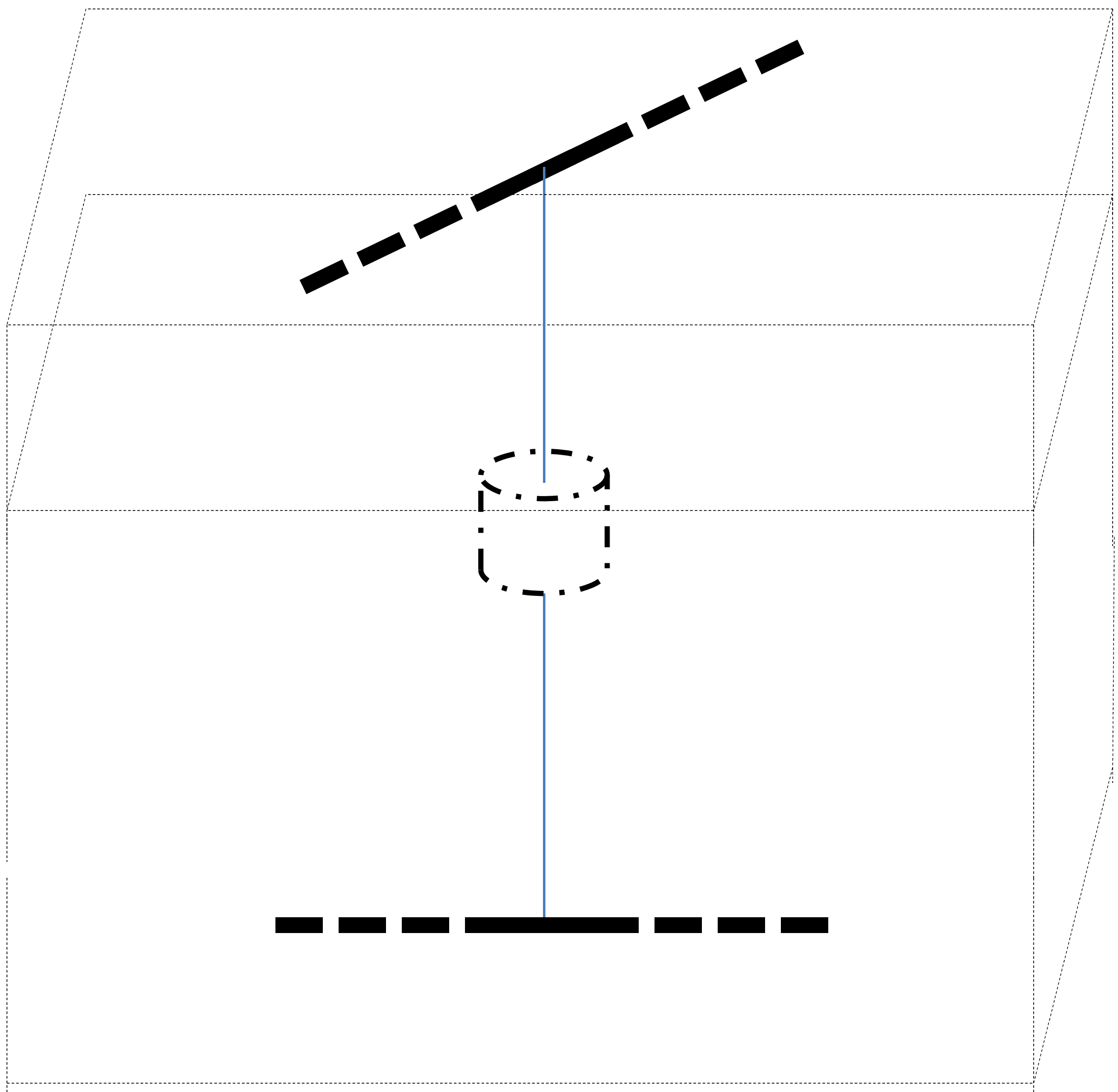

Figure 2A

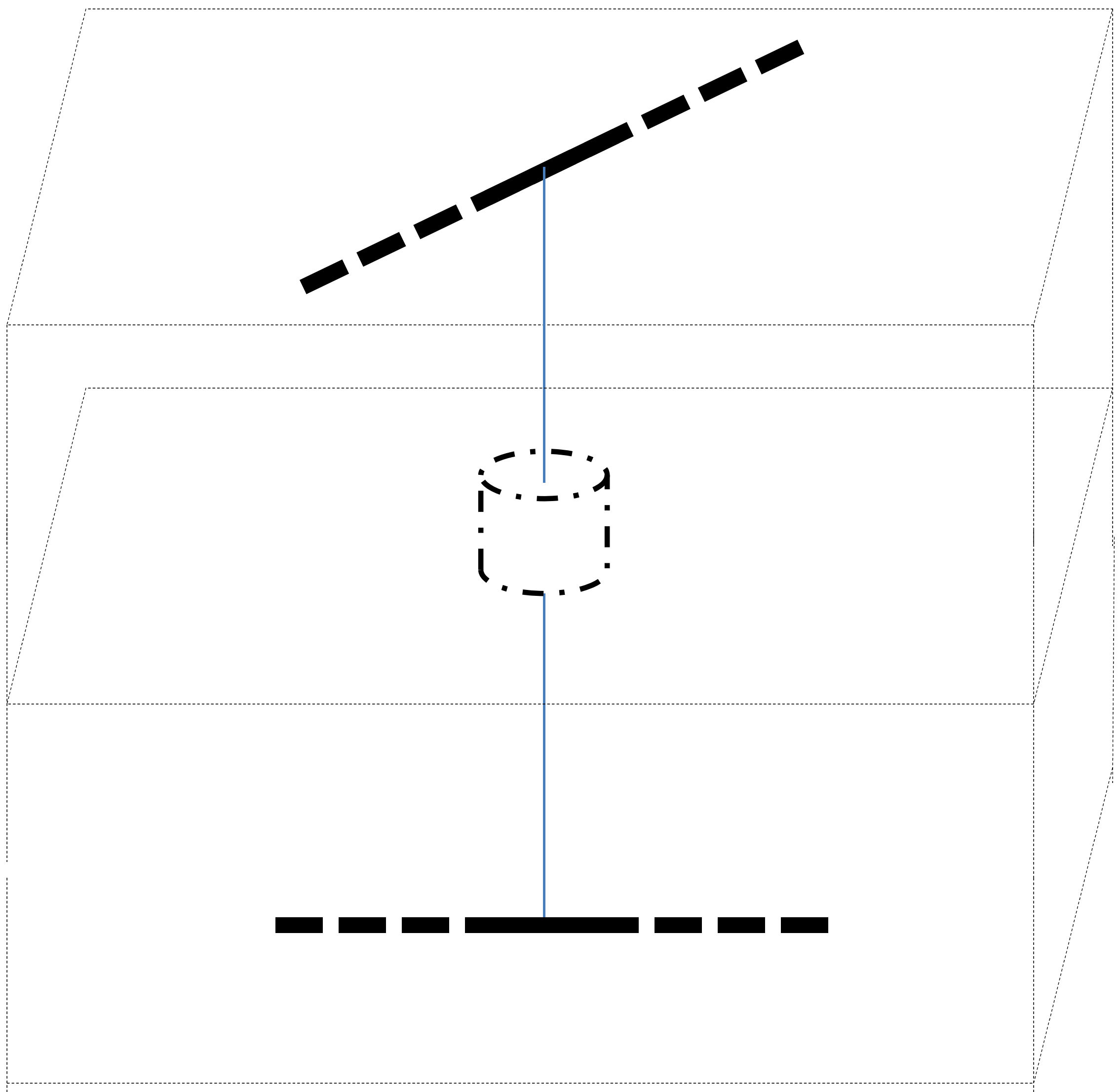

Figure 2B

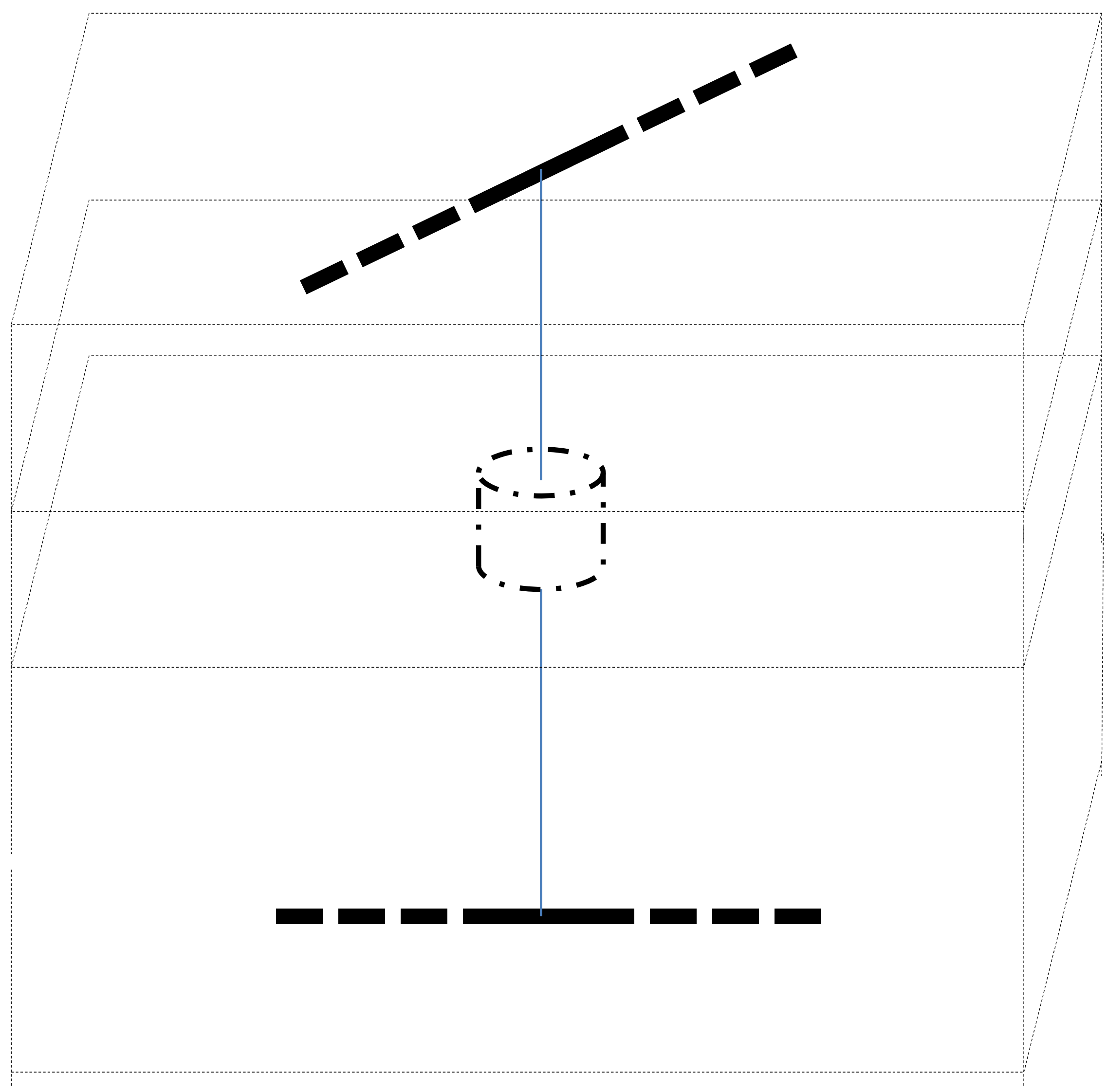

Figure 2C

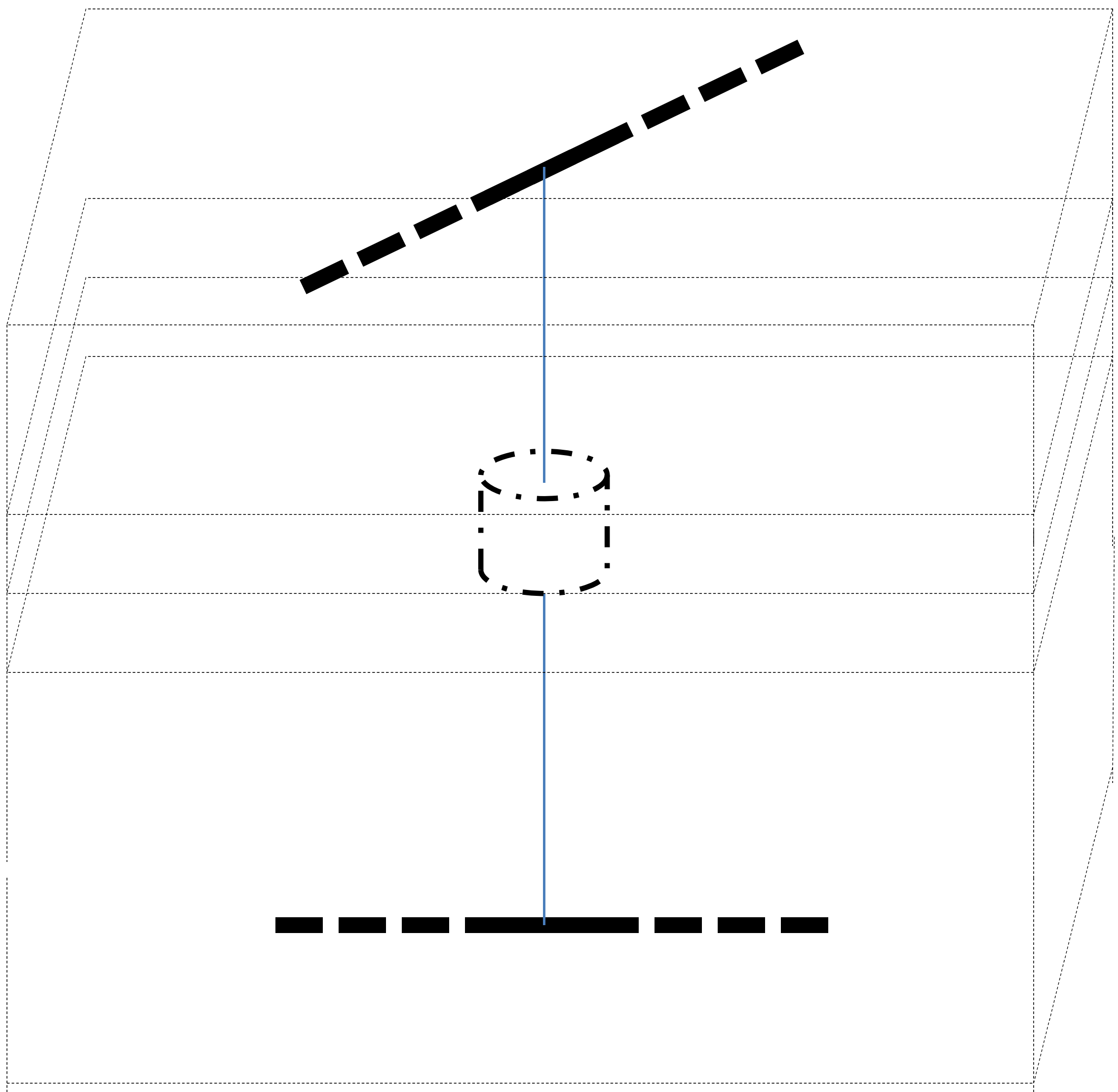

Figure 2D