Electronic Supplementary Material (ESI) for Lab on a Chip

Centrifugo-dynamic inward pumping of liquids on a centrifugal microfluidic platform – Electronic supplementary information

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Content

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Fig. 1 shows the network model for the centrifugo-dynamic inward pumping. Tab. 1 describes the functions of the model elements. All elements communicate with each other via ports. Two (or more) connected ports collapse to one node, so that all ports at one node have the same value. All fluidic elements (no. 3, 4, 6, 7, 9, 10, 11, 13) have six ports:

- *Two hydraulic ports (black)* transfer the pressure and flow rate information to adjacent elements.
- *Two digital input ports (blue)* receive the phase information (wet / dry) from adjacent elements.
- *Two digital output ports (blue)* send the phase information (wet / dry) to adjacent elements.
- *One analog input port (green)* receives the stimulus from the signal generator which is interpreted as the rotational frequency.

The unconnected digital ports (in elements no. 3, 7 and 13) are set to "dry" by default, as these elements are connected to ground.

The flow rate *q* through each element is computed numerically from the total pressure *Δp* across each element. For the elements with radial orientation (no. 3, 6, 7, 10) it holds

$$\Delta p(q) = p_{centrifugal} + p_{viscous}(q) + p_{inertial}(q) + p_{capillary}\,.$$

For the elements with circumferential orientation (no. 4, 9, 11) is holds

$$\Delta p(q) = p_{Euler} + p_{viscous}(q) + p_{inertial}(q) + p_{capillary}\,.$$

The liquid volume in each element (and the resulting fill level) is computed from integration of the flow rate of liquid through the element:

$$V_{liquid}(t) = \int_0^t q(t')\ dt'$$

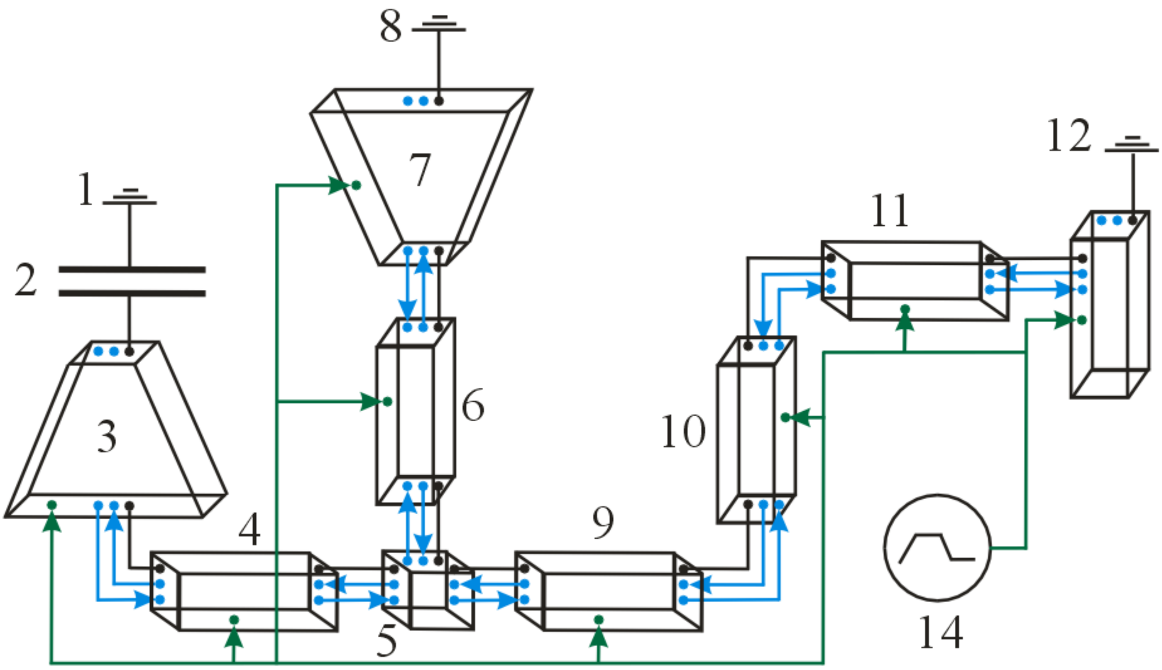

Fig. 1: *Network model for centrifugo-dynamic inward pumping of liquids in a centrifugal microfluidic disk.*

***Tab. 1:** List of the network elements and their functions.*

No.	Name	Function
1	Ground	Models the ambient, defines the reference pressure: 1013 hPa
2	Ideal gas	Fluidic capacitance: Models the enclosed air bubble as an ideal gas
3	Compression chamber	Models the compression chamber as a fluidic element with radial orientation
4	Connection channel, left	Models the channel connecting the compression chamber to the inlet channel as a fluidic element with circumferential orientation
5	T-connector	Collapses all connected ports to nodes
6	Inlet channel	Models the inlet channel as a fluidic element with radial orientation
7	Inlet chamber	Models the inlet chamber as a fluidic element with radial orientation
8	Ground	Models the air vent in inlet chamber, defines reference pressure: 1013 hPa
9	Connection channel, right	Models the channel connecting the inlet channel to the outlet channel as a fluidic element with circumferential orientation
10	Outlet channel	Models the outlet channel as a fluidic element with radial orientation
11	Connection channel, top	Models the upper, bended part of the outlet channel as a fluidic element with circumferential orientation
12	Ground	Models the air vent in collection chamber, defines reference pressure: 1013 hPa
13	Collection chamber	Models the collection chamber as a fluidic element that takes up the incoming liquid.
14	Signal generator	Models the rotational frequency: It provides the stimulus for the fluidic elements as a piecewise linear function.

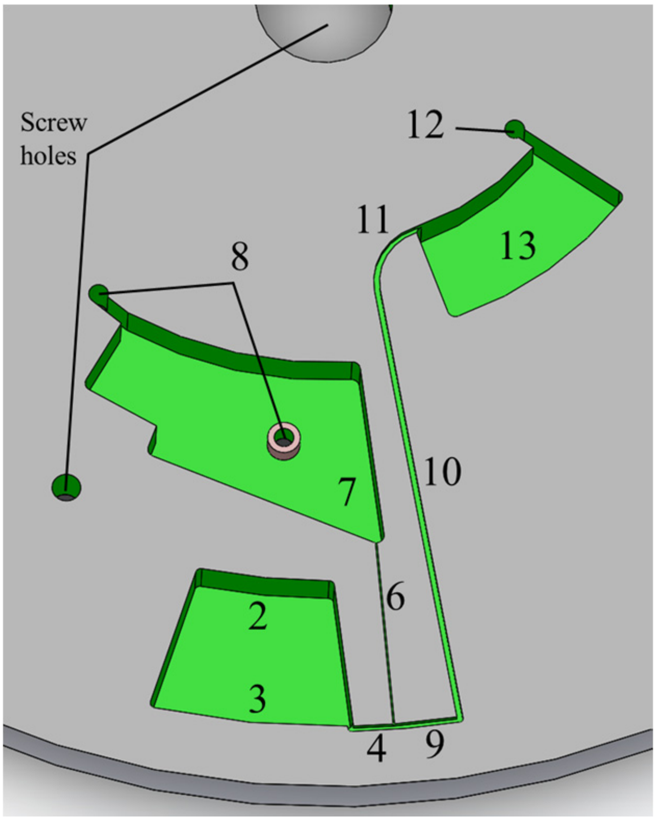

***Fig. 2:** SolidWorks drawing of the inward pumping module in the microfluidic disk. The numbers refer to the elements in the network simulation.*

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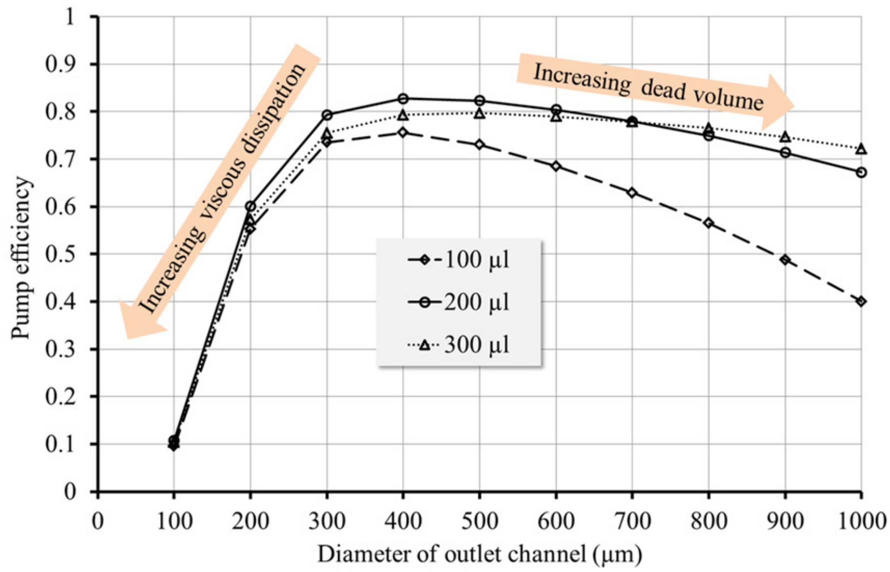

Fig. 3: *Result of the network simulation for optimization of the outlet channel diameter to achieve the maximum pump efficiency for water (varying sample volumes) at 30 Hz s^{-1}. Parameters used: Diameter of the inlet channel: 120 µm, rotational frequencies: 75 Hz (compression) and 6 Hz (collection), deceleration: 30 Hz s^{-1}, initial volume of gas bubble: 549 µl.*

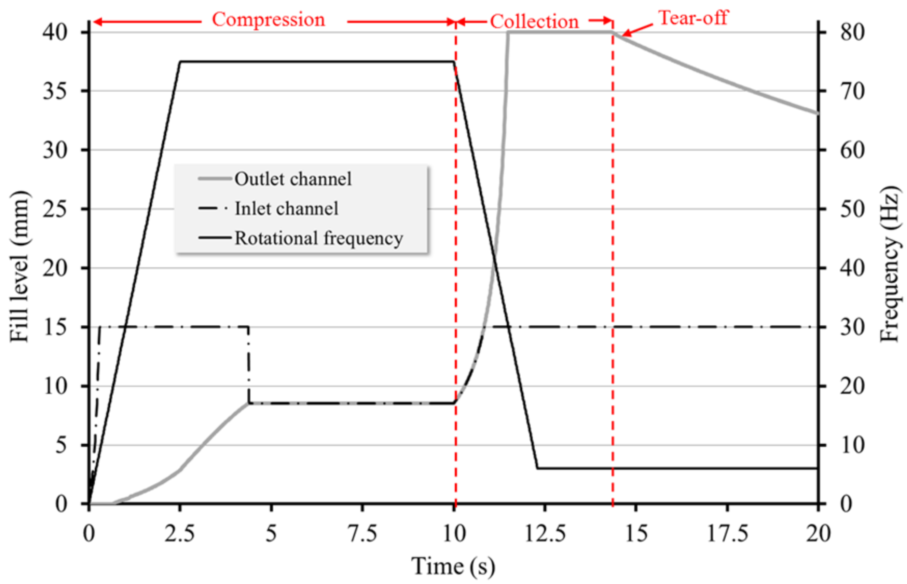

Fig. 4: *Simulated fill levels in the microfluidic channels during centrifugo-dynamic inward pumping of 200 µl of water. The plot shows that the compression phase can be reduced from 10 s to 5 s when the fill levels have already reached equilibrium. The channels are full when their fill levels reach 15 mm (inlet channel) and 40 mm (outlet channel), respectively. The "tear-off" point marks the time when the liquid flow in the outlet channel reverses, such that the liquid stream tears off and terminates the pumping process.*

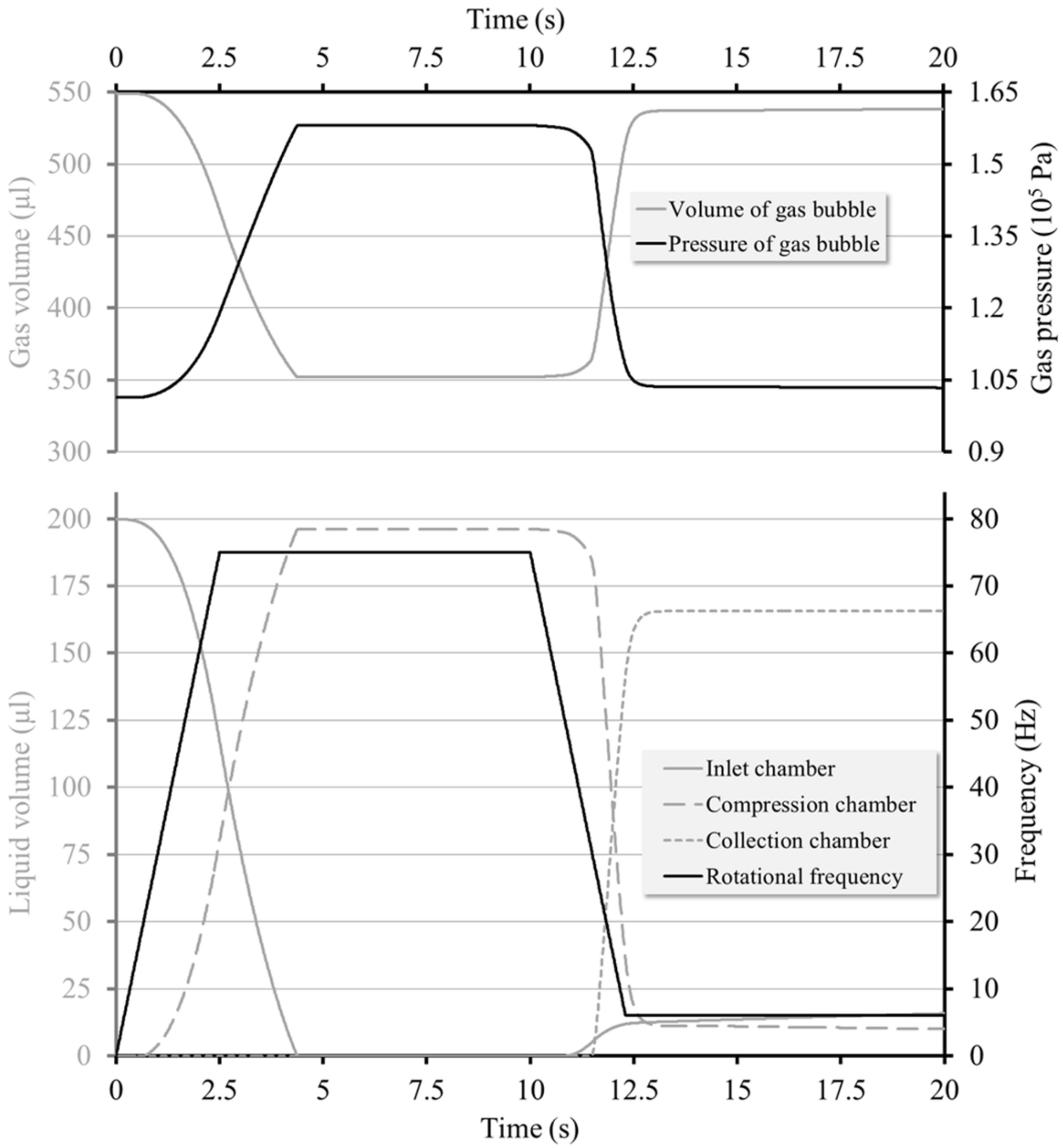

Fig. 5: *Simulated volume and pressure of the gas bubble (top) and simulated liquid volumes in the fluidic chambers (bottom) during centrifugo-dynamic inward pumping of 200 µl of water.*

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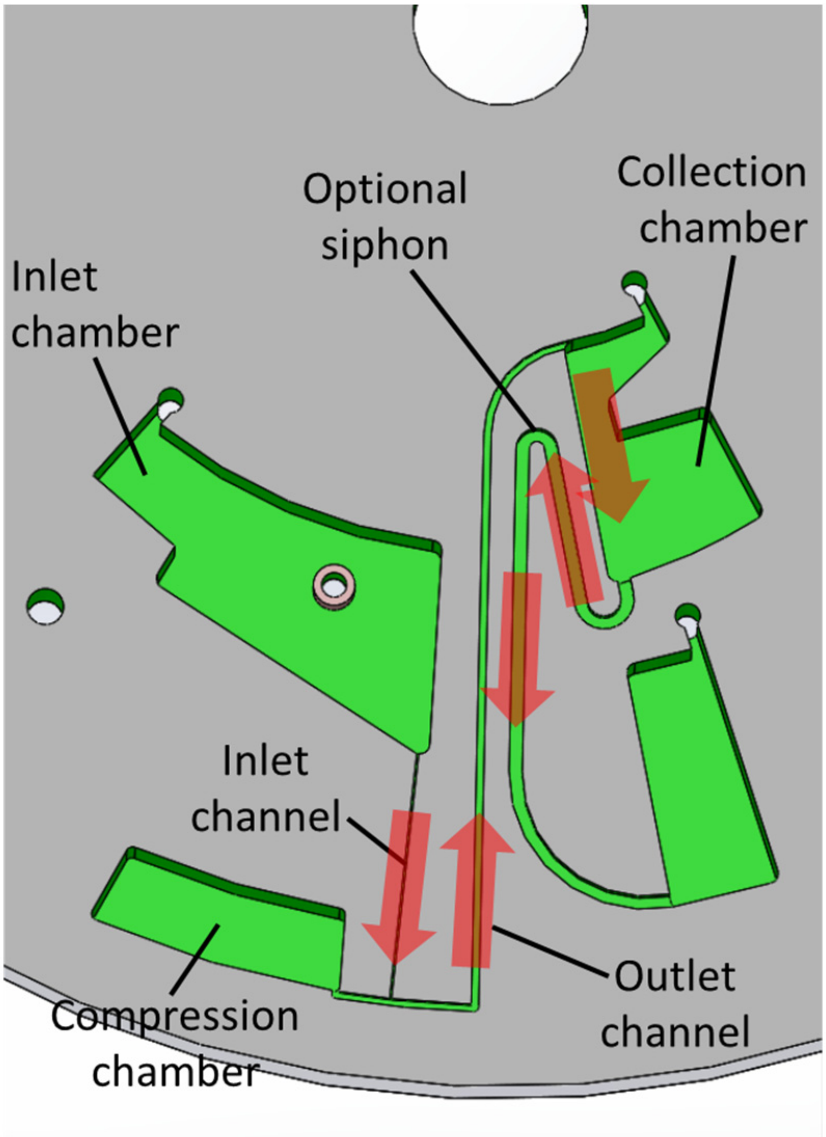

***Fig. 6:** SolidWorks drawing of the inward pumping module in the microfluidic disk used for the experiment with three pump cycles. It includes a small compression chamber and the optional siphon that is triggered during the third pump cycle. Arrows indicate the flow direction.*