Supplementary Material (ESI)

Passive pressure control in fully closed PCR modules by microfluidic vapor-diffusion barrier

SUPPLEMENTARY INFORMATION

Content

1) Designs of LabDisk 1a and LabDisk 1b

LabDisk 1a incorporates six structures that only differ in the dimension of the VDB channel that connects the PCR chamber with the compression chamber (Figure S1). The geometry of the compression chamber is designed to reduce the effects of buckling of the sealing that would lead to additional volume and thus distortion of pressure generation.
LabDisk 1b (Figure S2) incorporates three segments, each with three structures for processing of 21.0 µL, 10.5 µL and 5.0 µL of liquid volume. Therefore, the VDB and the volumes of the pneumatic chamber have been scaled down according to structure 1 of LabDisk 1a, keeping the same ratio between the PCR chamber and the pneumatic chamber and between the PCR chamber and the cross-section of the VDB.

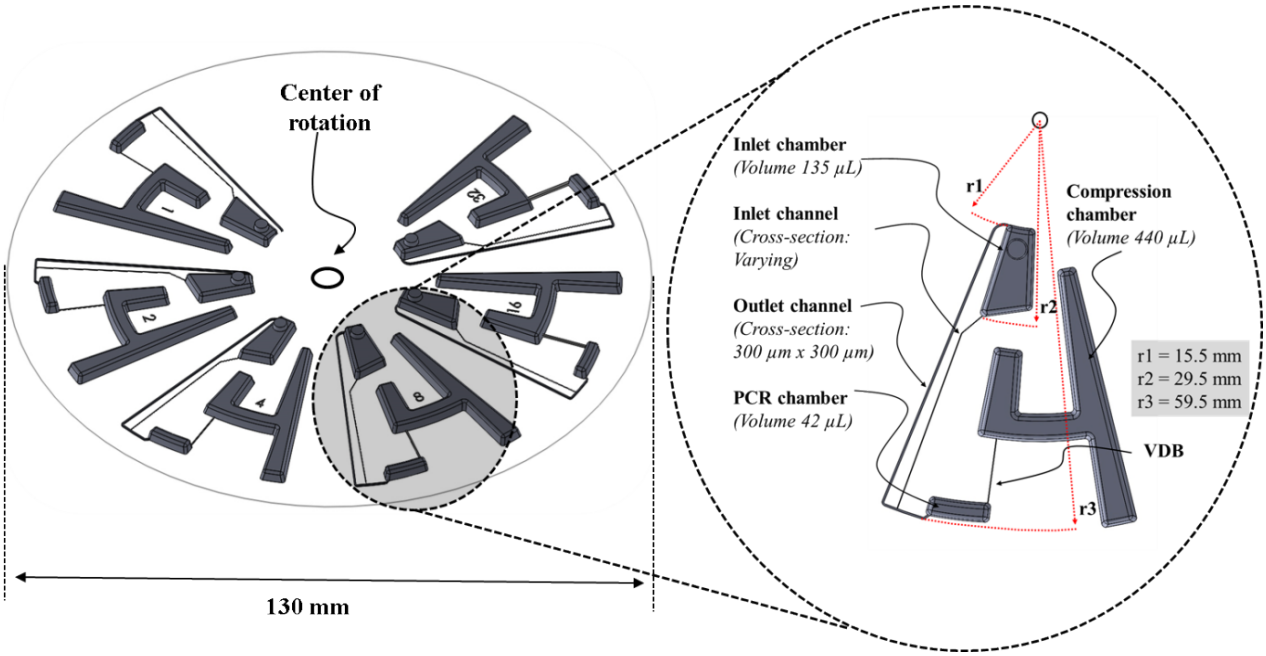

Figure S1 – Design of LabDisk 1a. The LabDisk with a diameter of 130 mm incorporates six structures that only differ in the dimension of the VDB. One structure (dashed circle) is exemplary highlighted.

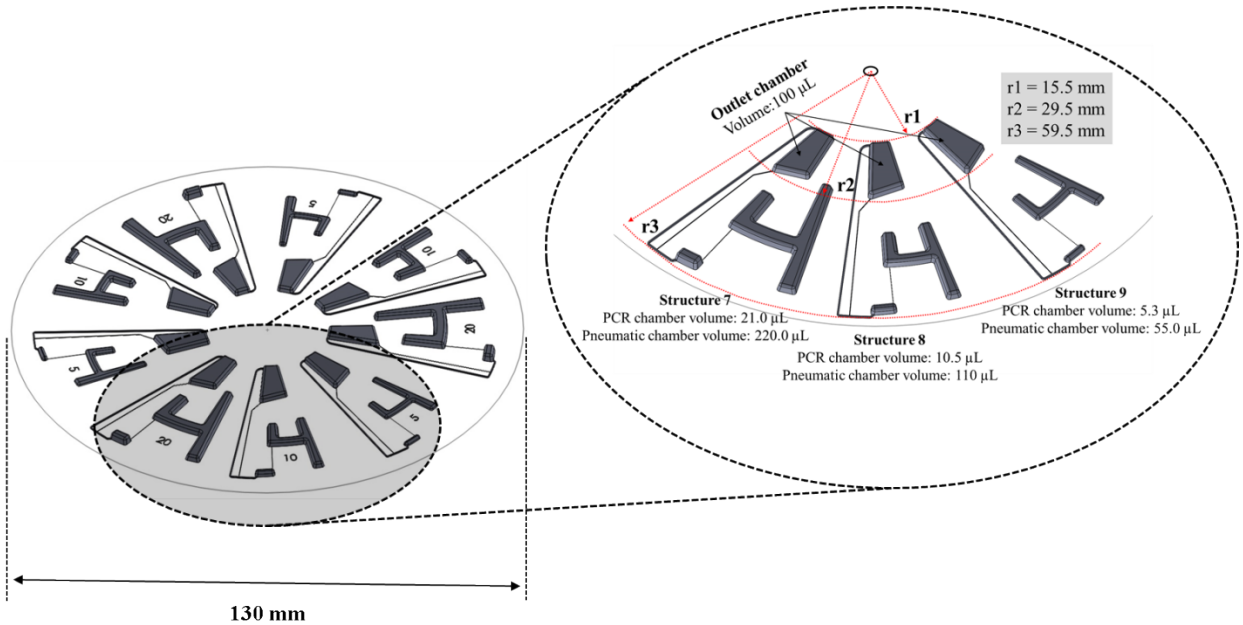

Figure S2 – Design of LabDisk 1b. The LabDisk with a diameter of 130 mm incorporates three identical segments, each incorporating three structures (structure 7,8 and 9) with varying dimensions of the VDB, pneumatic chamber and PCR chamber, respectively.

2) Design of LabDisk 2

LabDisk 2 incorporates two structures. The structures only differ in the geomtery of the PCR chamber and compression chamber respectively, as depicted in Figure S3.

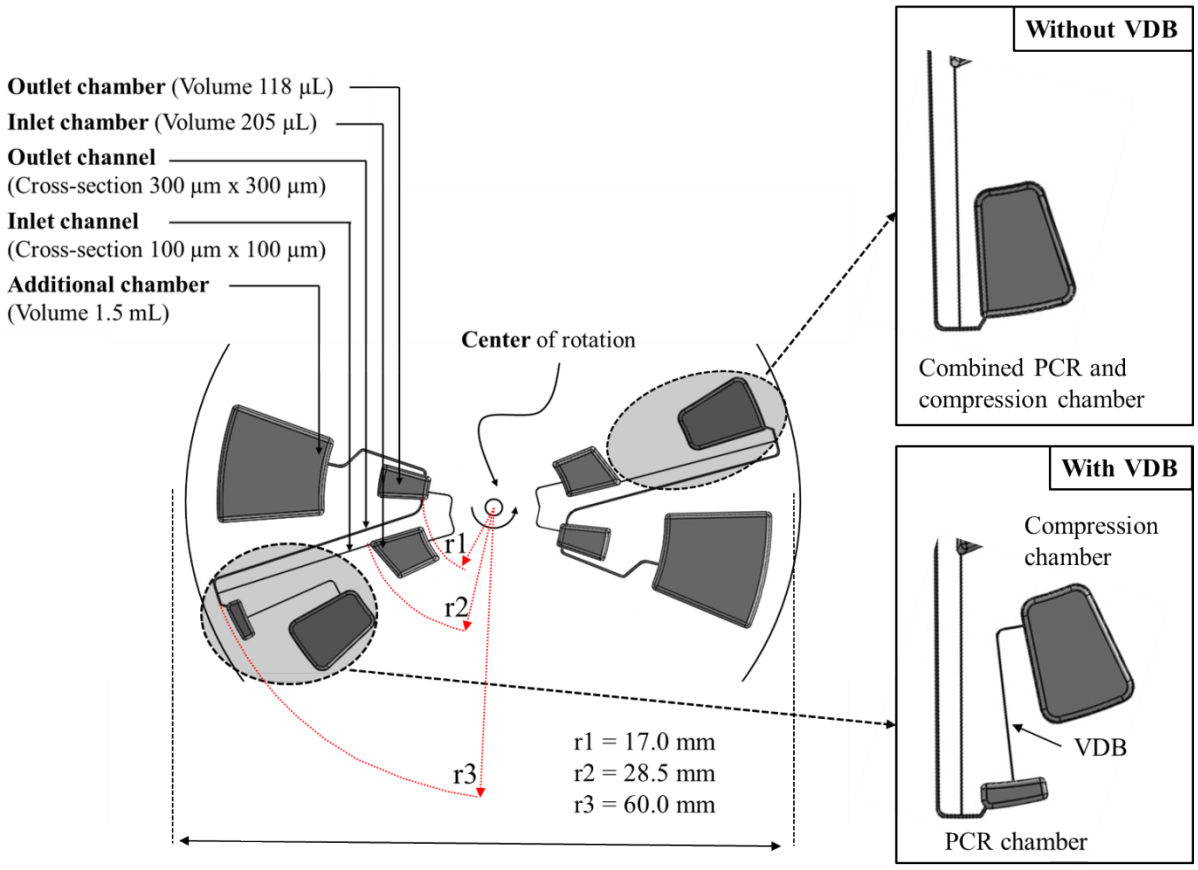

Figure S3 – Design of LabDisk 2. The LabDisk 2 with a diameter of 130 mm incorporates two structures. One uses a combined PCR and compression chamber (overall volume of 265 µL), the other separates the PCR chamber (volume of 42 µL) from the compression chamber (volume of 223 µL) by a VDB channel of 100 µm x 100 µm diameter and a length of 15.1 mm. For both structures, the outlet channel is connected to an additional chamber of 1.5 mL volume that assures a relatively lower gas compression in the outlet chamber during inward pumping of liquid, if the design is applied in a fully closed manner with closed venting holes.

3) Principle of inward pumping with LabDisk 2

The inward pumping after PCR thermocycling, schematically depicted in Figure S3 is accomplished in three major phases:

a) Compression: By centrifugation at 40 Hz, the sample liquid is pumped by centrifugal forces from the inlet chamber through an inlet channel into the radially outer PCR chamber. The air in the PCR chamber is evacuated and encapsuled in the compression chamber by the centrifugal pressure of the sample liquid in the inlet and outlet channels. This converts the centrifugal potential energy of the sample liquid into the potential energy of the compressed air in the compression chamber. Subsequently, when the fill levels in the inlet channel, the compression chamber and the outlet channel reach equilibrium, the centrifugal pressure balances the overpressure of the compressed air in the compression chamber.

b) Thermocycling: For PCR amplification, thermocycling is initiated leading to an increasing pressure in the compression chamber and PCR chamber. The increase in pressure is influenced by the partial pressures of air and vapor. The VDB channel reduces the overall vapor pressure in the system and thus the overpressure.

c) Inward Pumping: Inward pumping is conducted after PCR thermocycling. At a constant temperature of 75°C, fast deceleration (10 Hz/s) of LabDisk 2 to 2 Hz rapidly decreases the centrifugal pressure of the liquid exerted on the compressed air volume. The relative overpressure of the air leads to immediate expansion of the air volume, and the sample liquid is displaced mainly through the outlet channel having a low hydraulic resistance (channel with large cross section). In parallel, a minor fraction of the sample liquid is displaced through the inlet channel having a higher hydraulic resistance (channel with small cross-section). The high viscous dissipation in the inlet channel decreases the backflow of sample liquid into the inlet chamber. Therefore the main fraction of the sample liquid is transferred to the outlet chamber. A minor fraction is lost to the inlet chamber. Note, the initial overpressure before inward pumping can be adjusted with the temperature at which the pumping is conducted.

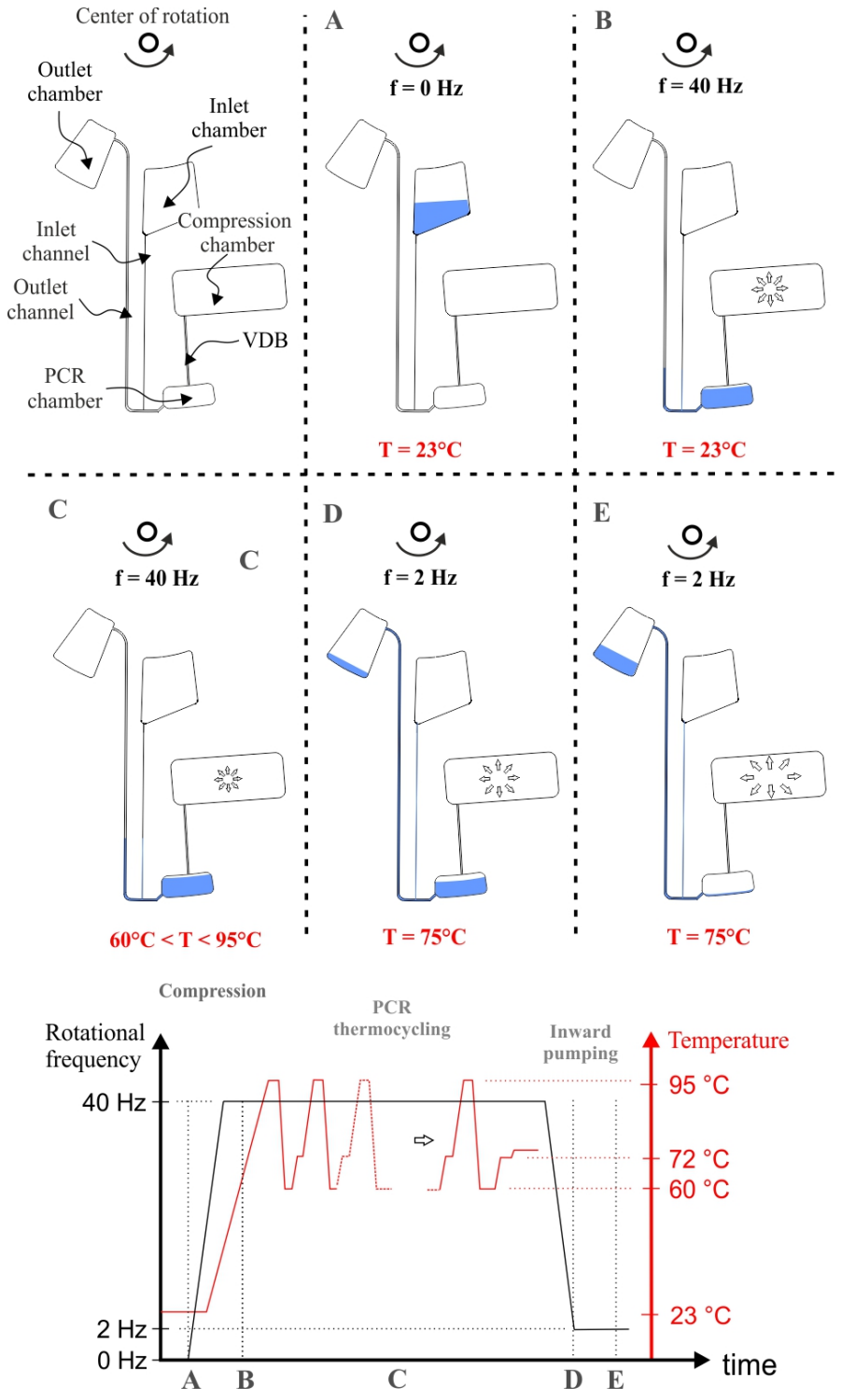

Figure S4 – Inward pumping principle. A: The sample liquid is pipetted into the inlet chamber. B: At high rotational speed at 40 Hz, the liquid is pumped into the PCR chamber by centrifugal force and air is therein displaced and evacuated through the VDB, leading to compression of air in the compression chamber. The air overpressure in the compression chamber is balanced by centrifugal pressure in the inlet and outlet channels respectively. C: Heating during thermocycling between 60°C and 95°C leads to an increase of overpressure in the compression chamber. D) Fast deceleration of the LabDisk to 2 Hz at constant temperature of 75°C rapidly reduces centrifugal pressure, so that the compressed air volume quickly expands and displaces the liquid mainly through the outlet channel. E: The liquid stream in the outlet channel tears off, thereby terminating the pumping process.

4) PCR primers

For PCR amplification of the *PAL* gene in the genome of *Escherichia coli* a forward primer 5'-GGC AAT TGC GGC ATG TTC TTC C-3' and a reverse primer 5'-TGT TGC ATT TGC AGA CGA GCC T-3' were used.