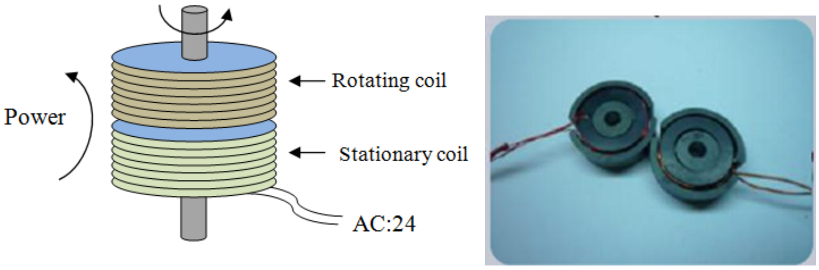
Electronic Supplementary Information

Section A: split-core transformer for power delivery

In this part, we present a simple yet effective LOAD platform with electrical power delivered to the disc through a split-core transformer, as shown in Figure.S 1(a) and a photo of this device is shown in Figure.S 1(b). There is a very tiny gap between both coils. Two halves connected to the rotating platform and the stationary base respectively so that magnetic flux can be coupled to the rotating disc while it is moving. In our system, the stationary base connects to a 24V AC power supply and the maximum power available from the transformer is estimated to be 8 W. Further power rating may be achieved by using a larger core.



(a) (b)

Figure.S 1 Split-core transformer design with two halves

Section B: Principle of speed actuated bidirectional control

In order to achieve the bidirectional flow control on LOAD system by tuning the speed of spinning, a simple yet effective mechanical structure is proposed to change the relative position of chip on the rotating disc and make the channel becomes bidirectional channel. Generally, one could construct the speed actuated switching mechanism by tuning the balance between two forces, as shown in Figure.S 2, and one related with speed and the other does not. From the figure, the speed related centrifugal force is a parabolic function, while the spring force and magnet force is rotation insensitive. So in low speed state, the chip is in state1, while in high speed, the chip switches to state2. We can see from the video in Electronic Supplementary Information that it only takes about 3 seconds for the droplet to move from one heater to the other.

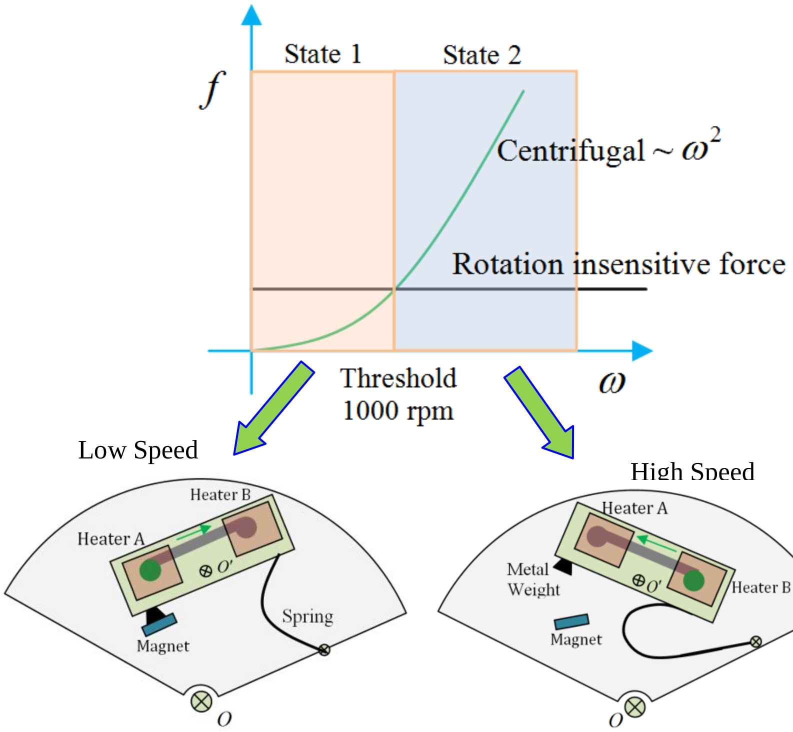


Figure.S 2, The balance between centrifugal force and rotation insensitive force

Section C: signal detection and processing for spinning disc

It is very important to detect the optical fluorescence signal when the disc is in high speed spinning. It enables a lot of applications for LOAD system, especially real time case. As shown in Figure.S 3, a A-to-D sampling card (NI PCI 6289) is used to capture the PMT output through channel 1. At the same time, we also capture a reference trace from the trigger output of the motor controller through channel 2.

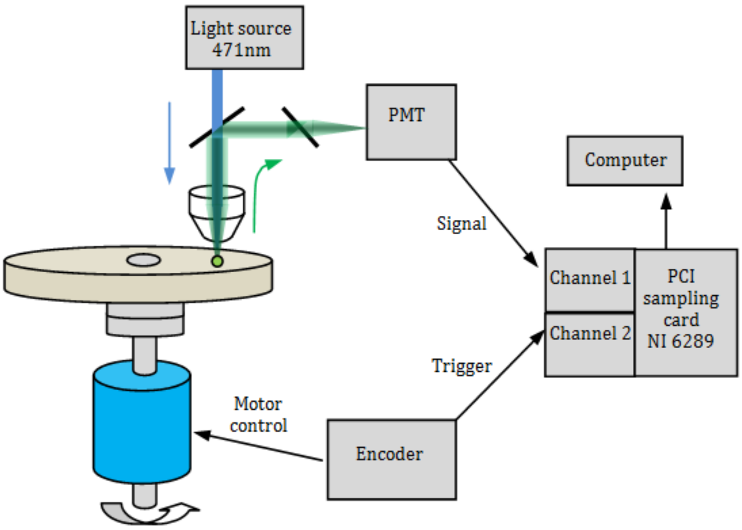


Figure.S 3, Real time signal detection system for spinning disc

In the signal processing, a digital lock-in detection technique has been employed. From Figure.S 4, in the signal output, those two major peaks are due to fluorescence from the sample. In the meantime, the trace of sample 2 is from channel 2 of the motor trigger signal. Due to the fixed phase difference between both channels, we can numerically shift the trigger to obtain a time-synchronized reference trace that will enable superposition of signal traces captured in subsequent sweeps. In this way, we can enhance the fluorescence signal from the noise background, analogous to common lock-in detection.

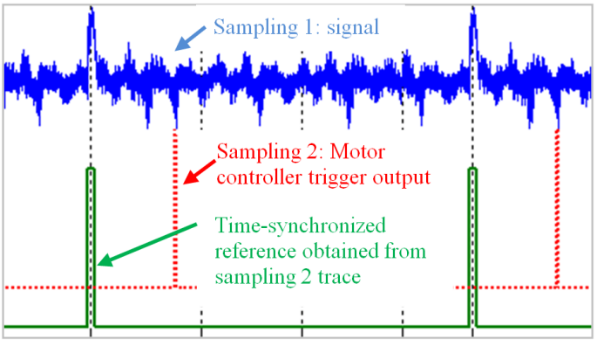
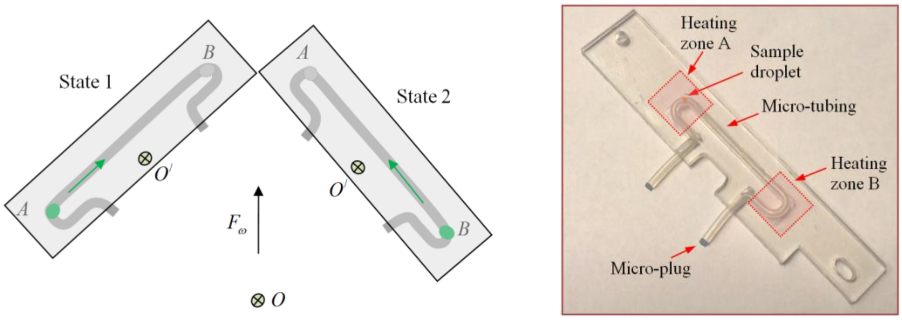


Figure.S 4, Demonstration of digital lock-in detection

Section D: Bidirectional Microchannel

In order to demonstrate the functionality of our platform, we use a simplest way for fast experimental demonstration of lab-in-a-droplet RT-PCR, by forming the micro-channel with PTFE (Teflon) micro-tubing. The smallest Teflon tubing we can obtain is with 300μm diameter, which is small enough for claiming of micro-channel. In order to maintain the shape of the channels after bending, we have to apply some local heating and annealing using a soldering iron. For RT-PCR, the micro-tubing bends to a shape as shown in Figure.S 5(a), while the heating chamber is presented as the U-shaped corner at each end. A photo of the chip in our experiment is shown as Figure.S 5 (b). The micro-tubing is filled with mineral oil and sealed with two micro-plugs. In first state, for example with lower rotating speed, the droplet will start from A side and stop at the U shape corner of heating zone B side. While in the second state with higher speed, its destination is at heater A side. We can see from the video that it only takes about 3 seconds for the droplet to move from one heater to the other. Furthermore, given that the droplet has a small volume (3μL) and the oil environment has a much higher thermal mass, the temperature slew rate should be very high. The droplet may reach its desired temperature within several seconds. The

PETF tubing has a light transmission capacity of about 50%.



(a) (b)

Figure.S 5 (a) Two states of the micro-tubing channel with opposite flow direction, (b) a photo of the micro-tubing device