

A Centrifugal Microfluidic Platform Integrating Immunomagnetic Separation and Isothermal Amplification for Rapid and High-Sensitivity Detection of Foodborne Pathogens

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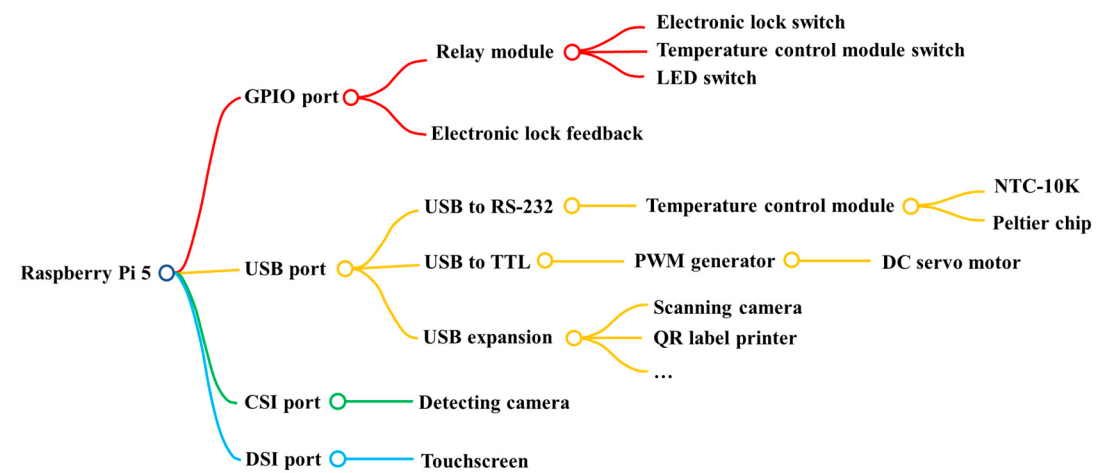


Figure S1. Electrical connection flowchart of the main hardware of the POTC system.

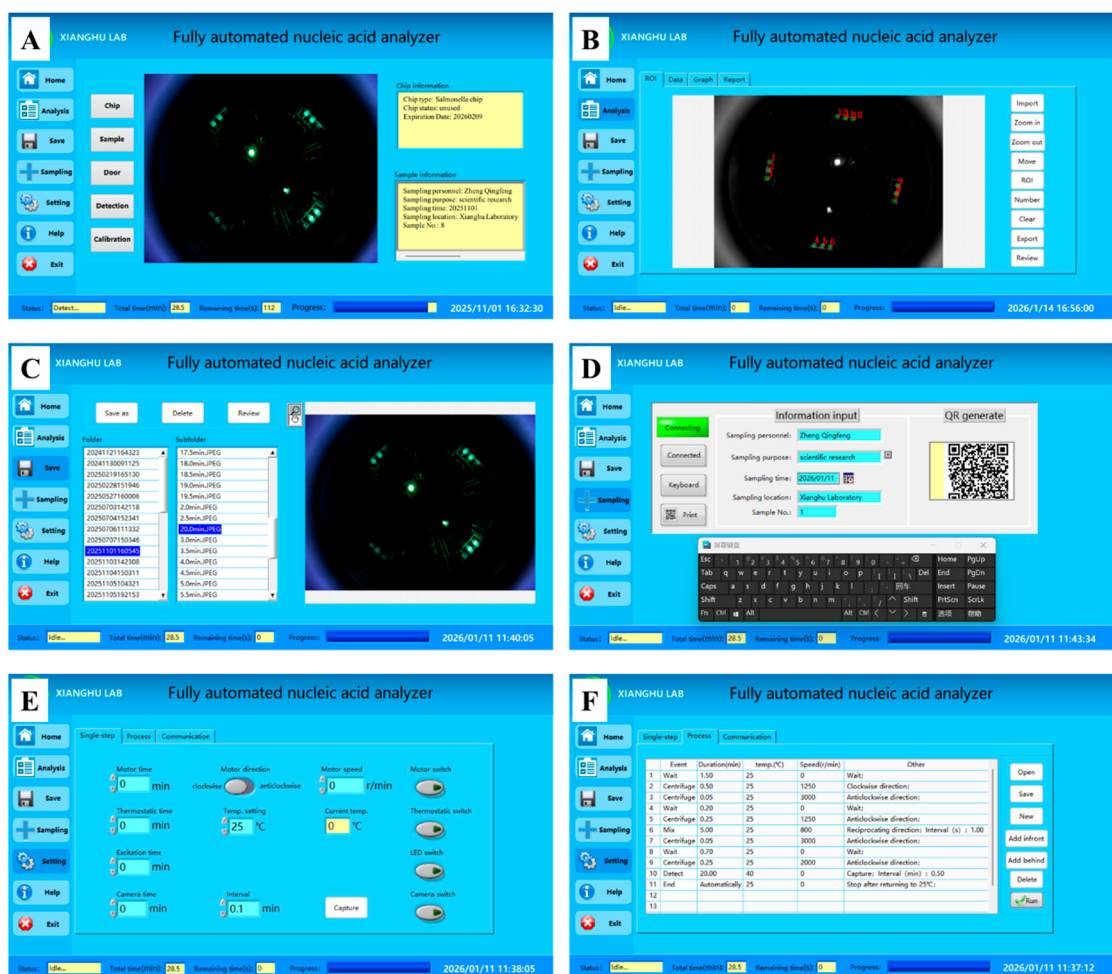


Figure S2. The main supporting human-computer interaction software include: (A) detection information entry and operation; (B) data analysis; (C) data saving and review; (D) QR code printing of sampling information; (E) single-step debugging of the control unit; and (F) editing of the overall detection process.

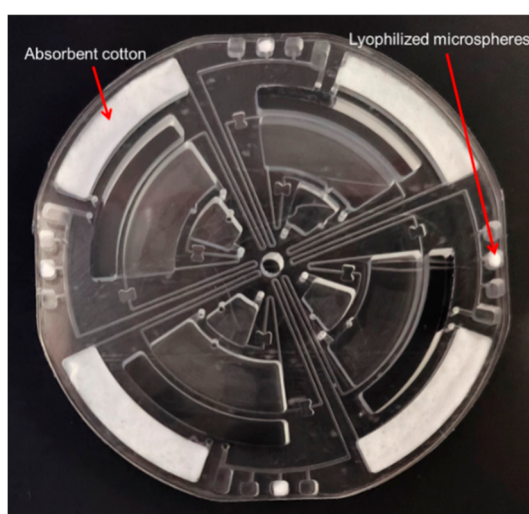


Figure S3. Image of centrifugal microfluidic chip, pre-embedded with absorbent cotton and lyophilized microspheres for MIRA reaction.

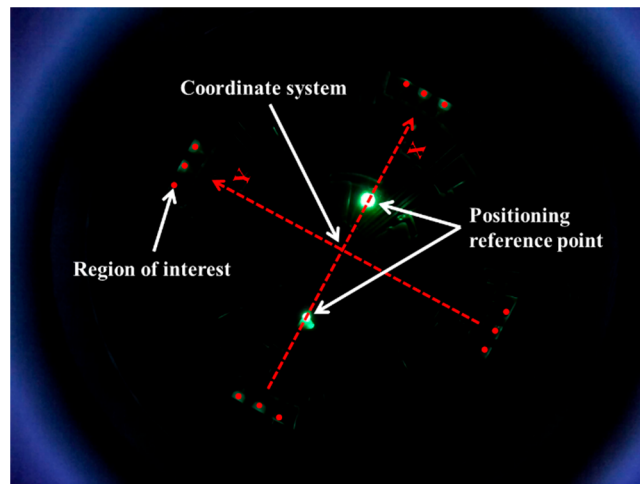


Figure S4. Typical fluorescence image captured by the detecting camera after MIRA reaction.

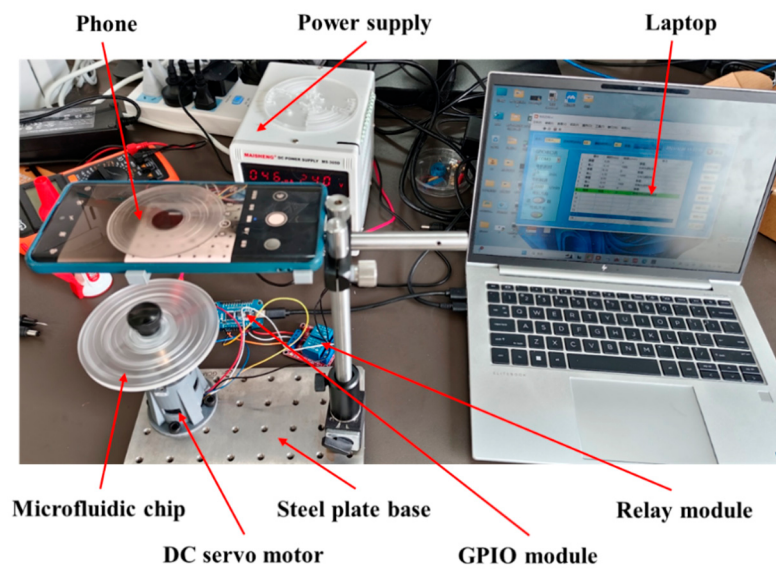


Figure S5. The simple centrifuge control system used for shooting demonstration videos of microfluidic chip workflows.

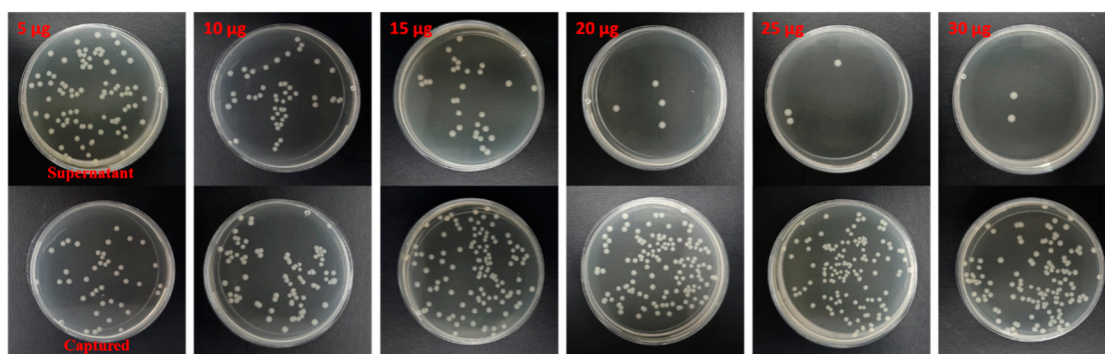


Figure S6. Colony culture agar plate images after capturing *Salmonella* with different amounts of IMNPs: the upper image shows the supernatant of uncaptured bacteria, while the lower image shows the precipitate of captured bacteria ($N = 3$).

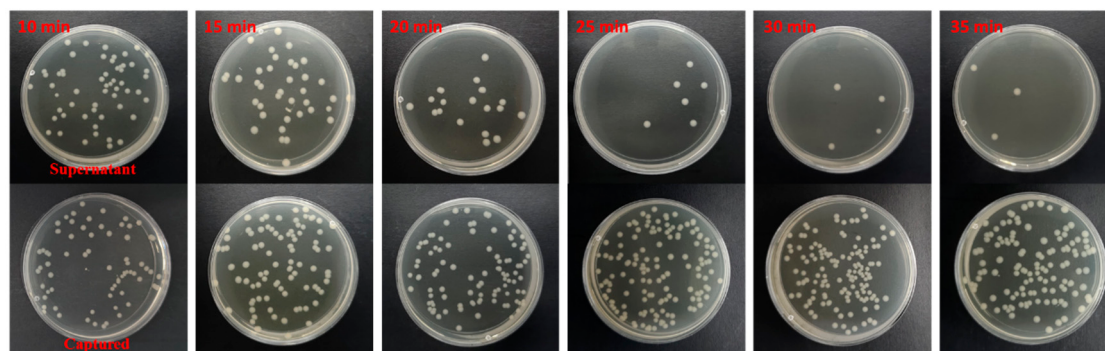


Figure S7. Colony culture agar plate images after capturing *Salmonella* with IMNPs under different reaction durations: the upper image shows the supernatant of uncaptured bacteria, while the lower image shows the precipitate of captured bacteria ($N = 3$).

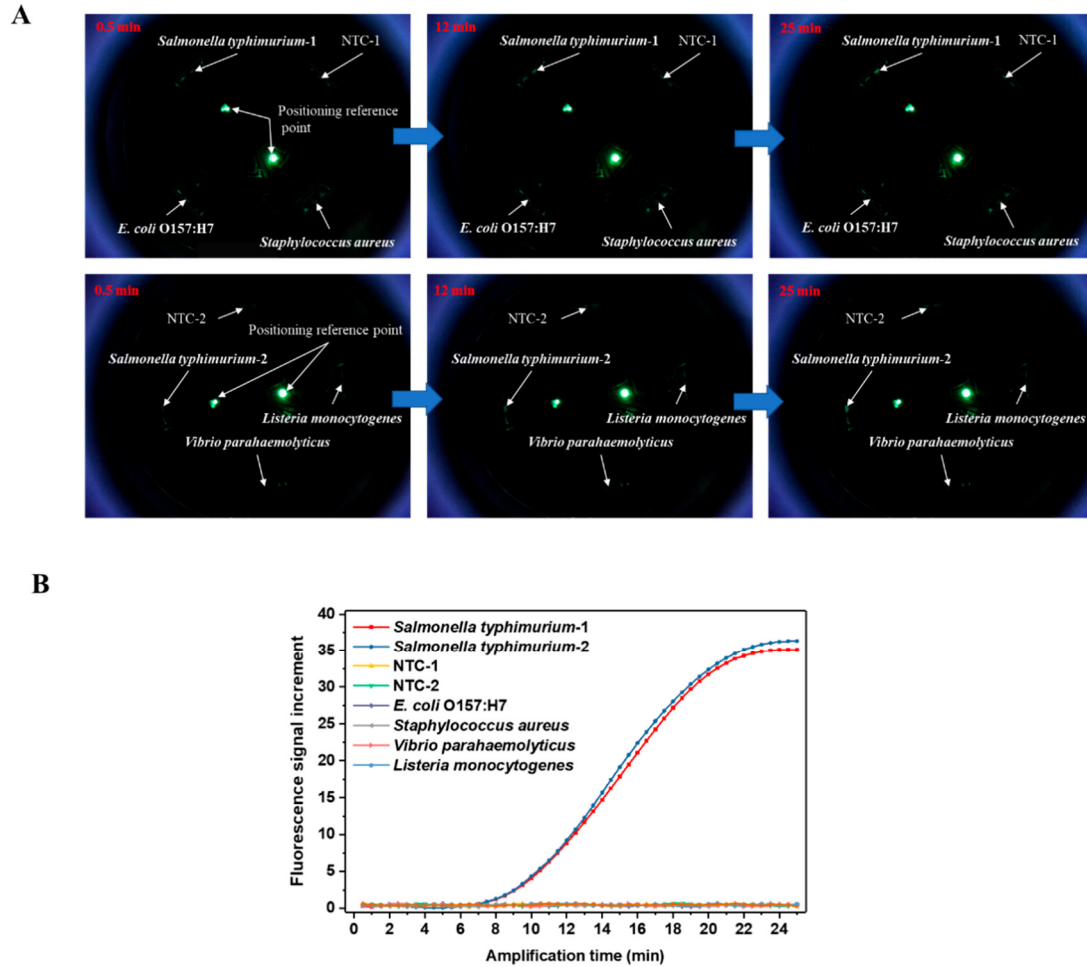


Figure S8. (A) Fluorescence detection images and (B) time-sequence plots of fluorescence detection signals to verify the specificity of the POCT system.

Table S1. Comparison of the proposed platform with standard qPCR and representative isothermal amplification-based assays

Method	Detection time	LOD / sensitivity	Sample preparation	Equipment needs	Assay cost	Ref
IMS-MIRA-FLD	<1 h	10 CFU/mL	IMNPs enrichment, lysis, MIRA amplification, on-chip fluorescence detection	Portable centrifugal POCT system	Low-moderate	This work
FDA BAM culture method	4-5 days	Presence/absence confirmation	Pre-enrichment, selective enrichment, selective plating, biochemical/serological confirmation	Incubator, biosafety cabinet, selective media, biochemical/serological tests	Low reagent cost; high labor/time cost	[1]
qPCR screening after pre-enrichment	Day 2 after 24 h pre-enrichment	positive results still require culture confirmation	Pre-enrichment and DNA extraction/template preparation	qPCR instrument and molecular laboratory workflow	High equipment and moderate-high reagent cost	[1]
LAMP-TtAgo centrifugal chip	17 min	1 CFU/mL	Fast nucleic acid extraction and one-pot LAMP-TtAgo reaction	Centrifugal microfluidic chip and fluorescence reader	Moderate-high	[2]
High-throughput centrifugal LAMP chip	60 min	10^{-2} CFU/mL	On-chip lysis, magnetic-bead extraction, LAMP	Portable centrifugal device with heating, magnetic mixing, fluorescence detection	Moderate-high	[3]

Method	Detection time	LOD / sensitivity	Sample preparation	Equipment needs	Assay cost	Ref
RPA microfluidic system	30 min	10 ⁻² copies/uL	Purified DNA or RPA reagent loading	Microfluidic chip, heater, smartphone fluorescence module	Moderate	[4]
MIRA-LFD	<20 min	115 CFU/mL	Cellulose filter paper DNA extraction, MIRA, lateral-flow dipstick	Simple heater at 39 °C and visual strip readout	Low-moderate	[5]
IMS-LAMP-NALFS	90 min	10 ⁻² CFU/mL	IMS enrichment, PMAxx treatment, LAMP, lateral-flow strip	Magnetic separator, constant-temperature heater, strip readout	Moderate	[6]

Table S2. Comparison of representative microfluidic platforms integrating on-chip DNA amplification for pathogenic bacteria detection

Target	Integrated components	Fabrication complexity	Detection principle	Assay time	Sensitivity	Ref
<i>S. Typhimurium</i>	IMNPs enrichment, lysis, MIRA amplification, fluorescence detection	Low-moderate; PSA/structural disc and portable centrifugal analyzer	IMNPs -MIRA fluorescence	<1 h	10 CFU/mL in spiked milk	This work
<i>S. aureus</i>	Fast nucleic acid extraction, LAMP, TtAgo cleavage, fluorescence readout	Moderate-high; centrifugal multi-channel chip with preloaded LAMP/TtAgo reagents	LAMP-TtAgo fluorescence	17 min	1 CFU/mL	[2]
<i>E. coli</i>	Lysis, magnetic-bead extraction, LAMP, fluorescence detection	High; multilayer centrifugal disc with valves, magnetic mixing, heating, and fluorescence detection	LAMP fluorescence	60 min	10 ⁻² CFU/mL	[3]
<i>S. Typhimurium</i>	Mixing chamber, RPA chamber, versatile valve, smartphone fluorescence	Moderate; PDMS/glass chip, 3D-printed valve, and magnetic mixer	RPA fluorescence	30 min	10 ⁻² copies/uL	[4]
<i>S. Typhimurium</i>	DNA extraction, RPA, micro-capillary electrophoresis	High; PMMA/PSA chip, heater, and micro-capillary electrophoresis module	RPA + electrophoretic readout	75 min	10 ⁻³ CFU/mL	[7]
<i>Salmonella and E. coli</i>	Bacterial lysis, nucleic acid capture, elution, distribution, LAMP	High; active/passive valves, pneumatic module, and silicon-membrane extraction	LAMP fluorescence	40 min	25 <i>Salmonella</i> cells; 40 <i>E. coli</i> cells	[8]
<i>S. Typhimurium</i> , <i>E. coli</i> O157:H7, <i>L. monocytogenes</i>	Magnetic DNA extraction, RAA, pneumatic check valves, rotating valve, LED fluorescence	Moderate; PDMS chip, 3D-printed valve, and finger-driven operation	RAA fluorescence	45 min	15, 48, and 38 CFU/mL, respectively	[9]
<i>A. hydrophila</i>	DNA extraction, MIRA reaction chamber, vibration mixing, ceramic heating, air-pump transfer	Moderate-high; active fluid handling and heating modules	MIRA fluorescence	40 min	10 CFU/mL	[10]
<i>S. Enteritidis</i> , <i>E. coli</i> O157:H7, <i>S. aureus</i>	Silica-membrane DNA extraction, LAMP, magnet-regulating valves	High; 3D-printed disc, magnetic valves, and silicone sealing pads	LAMP fluorescence	40 min	10 CFU/mL in spiked chicken supernatant	[11]

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