Chicome: An open-source microtube autosampler add-on module to flow cytometers

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SUMMARY

Time-resolved microbial flow cytometry requires frequent sample acquisition, but manual tube loading is labor-intensive and commercial autosamplers are often prohibitively expensive. We present **Chicome**, an open-source rotary autosampler add-on for conventional benchtop flow cytometers. Chicome positions seven standard microcentrifuge tubes using a 3D-printed carousel driven by a precision stepper motor, with integrated Peltier temperature control and a graphical interface for programmable sampling schedules. Across three experimental assays, Chicome achieved repeatable tube indexing and enabled unattended 14-hour time-course acquisition. CAD files, electronics schematics, and software are openly released under CERN-OHL-S v2 and GPLv3 licenses. Costing under US$100, Chicome provides an accessible and adaptable platform for high-resolution single-cell kinetics.

KEYWORDS

open science hardware; laboratory automation; flow cytometry; microbial dynamics; low-cost instrumentation

1 INTRODUCTION

Time-resolved flow cytometry enables the study of gene-expression dynamics, microbial growth, cell morphology, and viability at single-cell resolution. However, experiments spanning several hours or overnight require frequent and consistently timed sample acquisition. Manual tube loading is labor-intensive, susceptible to missed or delayed measurements, and can introduce variability in sampling intervals.

Commercial autosamplers can automate sample loading, but they are often costly, designed for proprietary plate-based workflows, and difficult to adapt to custom experimental setups. These limitations restrict automated time-course cytometry, particularly in resource-constrained laboratories and in experiments requiring repeated sampling from microcentrifuge tubes.

Chicome is an open-source, sub-US$100 add-on module for conventional benchtop flow cytometers. Using digitally fabricated components and off-the-shelf electronics, it automates periodic sampling from standard microcentrifuge tubes. The design is released under the CERN Open Hardware Licence, enabling users to inspect, reproduce, repair, and modify the system. By providing openly documented hardware and software, Chicome supports more

accessible and adaptable time-resolved single-cell analysis, in accordance with Global Open Science Hardware principles (OSHWA, 2016; CERN, 2020).

2 METHODS

Chicome integrates sample positioning, temperature control, and cytometer-acquisition triggering through three modular subsystems: a mechanical carousel, an environmental-control module, and a software-control interface (Figure 1).

Structural components were designed parametrically in OpenSCAD and fabricated by fused-deposition modeling (FDM) using polylactic acid (PLA; 0.15 mm layer height, 15% infill). The device holds seven standard 1.5 mL microcentrifuge tubes in a radial carousel, which sequentially positions each tube beneath the cytometer's fixed intake needle. Carousel rotation is driven by a NEMA 11 stepper motor controlled by an A4988 driver operating at 1/16 microstepping.

Temperature regulation is provided by a 40×40 mm TEC1-12706 Peltier element monitored with a DS18B20 digital temperature sensor and supported by forced-air cooling. A $3~\mu$m particulate filter is incorporated into the airflow path. An addressable WS2812B RGB LED strip provides visual feedback on the system's operating state.

A Raspberry Pi runs a Python control daemon that receives Open Sound Control (OSC) commands through local UDP and manages motor actuation, temperature monitoring, and device status. High-level control is provided through a browser-based Plotly Dash interface hosted on the acquisition computer. The interface supports carousel-position calibration, homing and cleaning routines, closed-loop temperature control, and user-defined acquisition schedules, specified by a sampling-cycle interval (M minutes) and an inter-tube dwell time (N seconds).

As the cytometer acquisition software does not provide an open external API, an AutoHotkey script automates keyboard and mouse inputs to initiate data acquisition and save output files in coordination with carousel indexing. This approach enables integration with existing commercial cytometers without modifying their internal hardware or software.

All design files, source code, and documentation are available in a public GitHub repository. Mechanical components and CAD assemblies are released in SCAD and STL formats under the CERN Open Hardware Licence v2—Strongly Reciprocal (CERN-OHL-S v2). The control software and automation scripts are released under the GNU General Public License v3 (GPLv3). The bill of materials and step-by-step assembly documentation are maintained with GitBuilding and released under CC-BY 4.0.

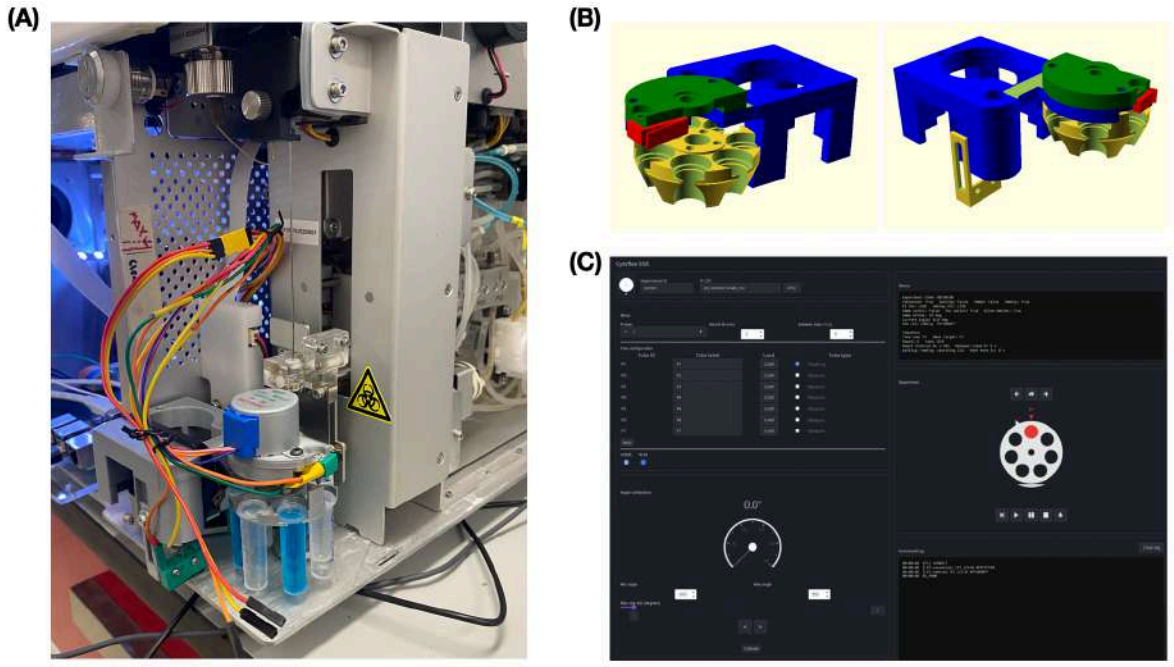

Figure 1. Overview of the Chicome add-on module: **(A)** benchtop implementation mounted on a flow cytometer, **(B)** 3D rendering of the rotary carousel and motor assembly, and **(C)** graphical user interface for calibration, temperature monitoring, and scheduling.

3 RESULTS AND DISCUSSION

To demonstrate automated, long-term kinetic tracking without operator oversight or sample cross-contamination, Chicome was validated across three distinct *Escherichia coli* dynamic culture experiments sampled every 30 minutes (Figure 2).

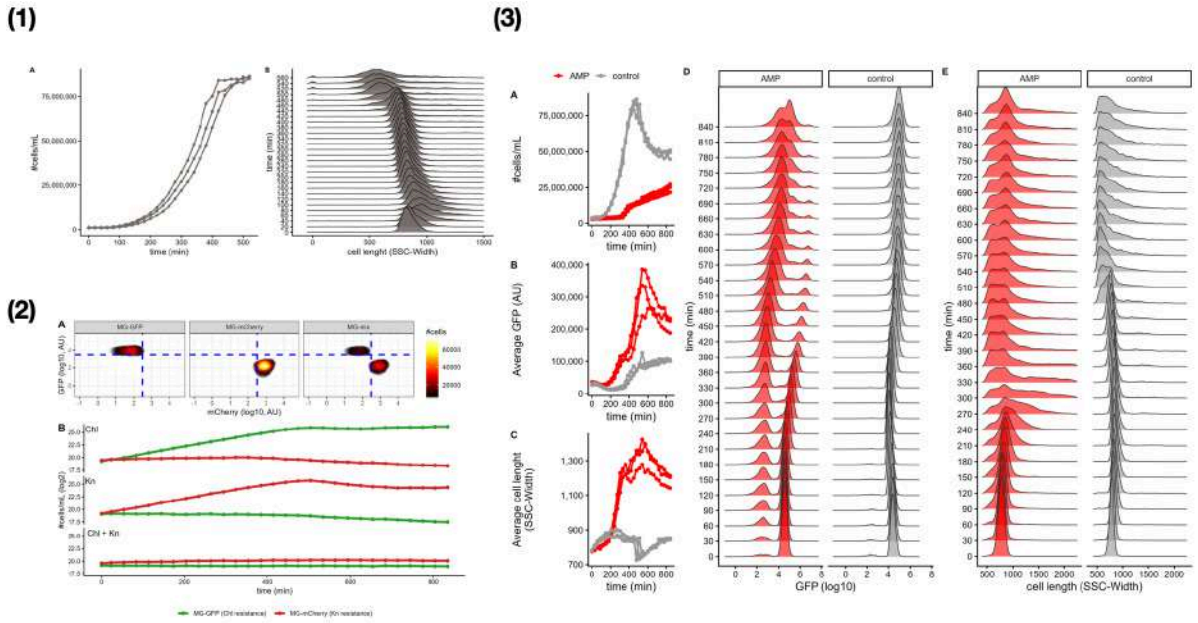

Figure 2. Biological validation assays sampled every 30 min using Chicome. **(1) Growth and morphology:** (A) Cell counts and (B) cell length distributions over time. **(2) Co-culture discrimination:** (A) Gating thresholds for MG-GFP and MG-mCherry monocultures versus co-culture; (B) population kinetics under chloramphenicol, kanamycin, and both (7 μg/mL). **(3) Antibiotic response in MGpBGT1 ($n = 3$):** (A) Growth curves, (B) mean GFP intensity (plasmid copy number proxy), (C) mean cell length, (D) temporal GFP distributions, and (E) cell length distributions under control (gray) and 15 μg/mL ampicillin (red).

4 CONCLUSIONS

Chicome demonstrates that open-source hardware can make automated, time-resolved flow cytometry more accessible. Using digital fabrication, off-the-shelf electronics, and openly available software, the platform provides a low-cost retrofit for repeated sampling from microcentrifuge tubes on conventional benchtop cytometers.

Its modular architecture supports adaptation, repair, and integration with locally developed workflows. By releasing the design under open hardware and software licenses, Chicome enables researchers to reproduce, modify, and extend the system rather than depending on costly, closed commercial alternatives. The platform can therefore broaden access to high-resolution single-cell kinetic measurements in resource-constrained laboratories, teaching environments, and open-science communities.

5 REFERENCES

CERN. 2020. CERN Open Hardware Licence Version 2 - Strongly Reciprocal. Geneva: CERN.

OSHWA. 2016. Open Source Hardware (OSHW) Statement of Principles 1.0. Open Source Hardware Association.