New strategies towards the next generation of bio-detector

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A new concept for in-the-field military bio-detection

Digital microfluidics (DMF) systems associated with personal samplers [1] have the potential to bring the traditional lab bench assay to the field to allow quick response to biological aerosol threats (pathogenic bacteria, viruses and toxins). This new concept [2] for high concentration rate sampling integrates a lightweight personal electrostatic precipitator (ESP), used to collect aerosol particulates onto a removable hydrophobic surface, with an electrowetting-on-dielectric (EWOD) droplet actuator system, used to transfer the collected sample into a microlitre-size water droplet [3], thus delivering a highly concentrated sample for analysis and detection. With the droplet volume, V = 2 µl and sample flow rate, Q = 5 l min^{-1}, a theoretical maximum concentration rate (R_c) of 2.5 × 10^6 per minute of sampling can be expected.

Collection → **Concentration** → **Detection**

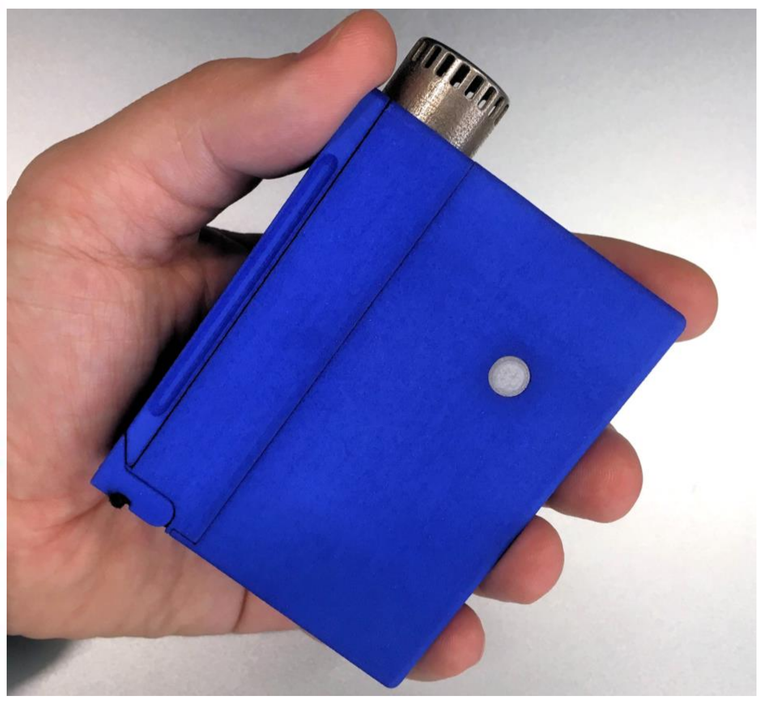

Fig. 1 – Hand held electrostatic precipitator

ESP aerosol collection unit

- Wearable unit (Fig. 1) for electrostatic precipitation of aerosol.
- Particles are charged through the corona discharge and collected on the field forming plate electrode of the ESP.
- 1 µm to 20 µm particles collected.
- Powered by two AA batteries (more than 8 hours running time).

Collection efficiency

- Collection of 1 µm and 3.1 µm fluorescent beads (Fig. 2) measured in 8 m^3 aerosol chamber.
- Collection efficiency (η_{ESP}) for beads of 37 % for 1 µm and 47 % for 3.1 µm.
- Bacterial spore to be evaluated (previous results [2]: η_{ESP} = 4.3 %).

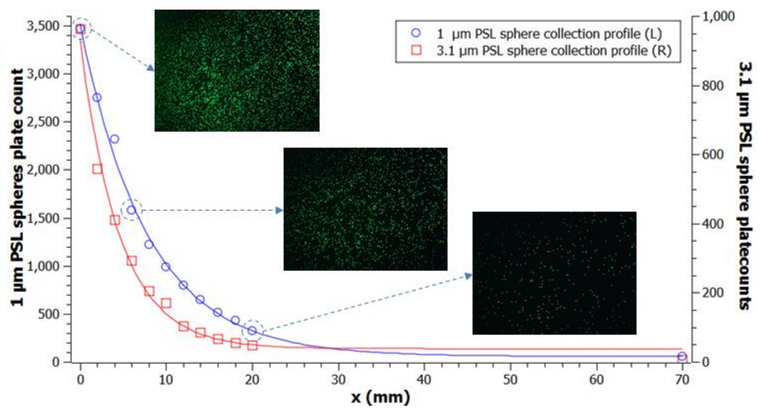

Fig. 2 – Fluorescent beads collection profile

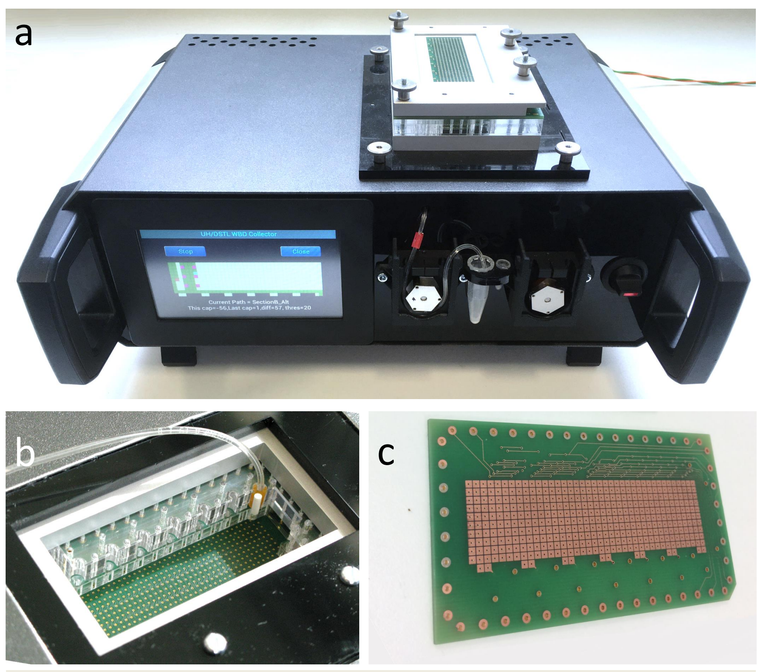

Fig. 3 – EWOD droplet concentrator. a) full unit. b) fluid delivery system c) planar PCB actuation surface

In-droplet concentration

- The collection plate from the ESP is used as the ground electrode in the EWOD droplet concentrator unit (Fig. 3 a).
- 2 µl droplet automatically delivered (Fig. 3 b) onto the actuation plate (printed circuit board) comprising 48 electrical channels to address 400 pads (Fig. 3 c).
- The droplet is actuated across the surface of the ESP collection plate to collect/concentrate precipitated material.

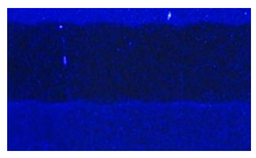

Fig. 4 – droplet collection trail

- Droplet sensing and routing algorithm to ensure maximum surface coverage to maximise sample for assay.

Concentration rate

- At 5 l min^{-1} $R_{c\,max}$ = 2.5 · 10^6 min^{-1} (Fig. 5)

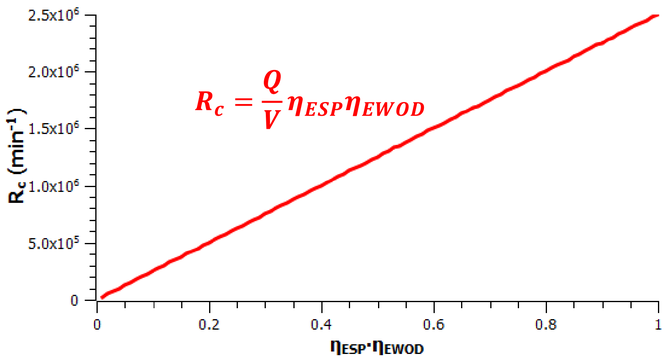

Fig. 5 – Concentration rate R_c as a function of the overall collection efficiency. η_{EWOD} is the EWOD transfer efficiency

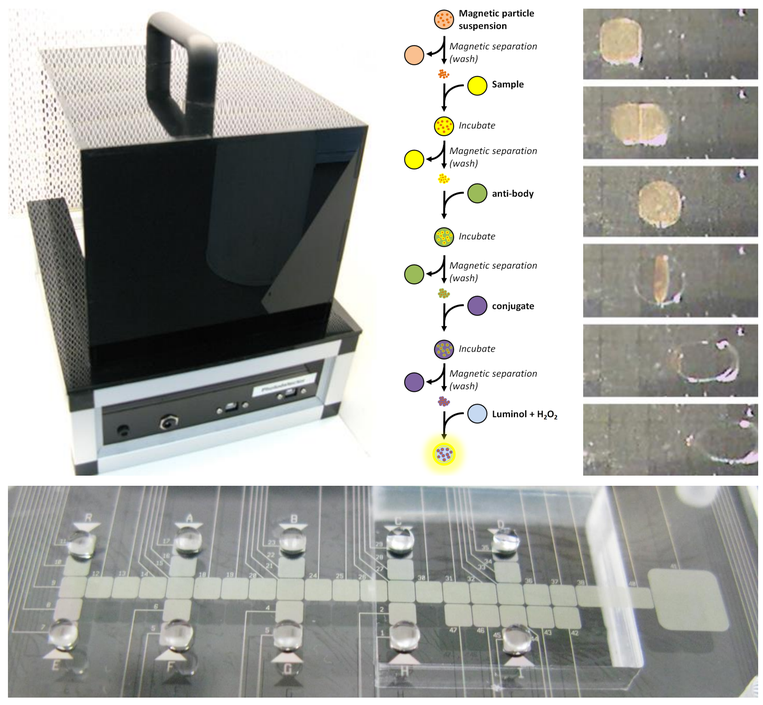

Fig. 6 – DMF bioassay proof of principle

In-droplet detection

- Uses the sample droplet of previous step, which contains the precipitated aerosol, with preferably no (or minimal) dilution.
  - ➔ DMF assay (Fig. 6).
  - ➔ Or lateral flow immuno-assay (dilution required).
- Transportable detection system for quick in-the-field analysis.
- To be discussed in talk 290039, session W1: Lab-on-Chip II.

Next steps

- **Assessment of the efficiencies of the second generation ESP & EWOD prototypes.**
- **Automatic droplet transfer to the detection system.**
- **Third generation: integrated ESP-EWOD miniaturised bio-assay system.**
- **Fourth generation: personal, worn bio-detector.**

REFERENCES

1. J. Vincent, *Aerosol sampling*, Wiley, Chichester, UK (2007)
2. T. Foat, W. Sellors, M. Walker, P. Rachwal, J. Jones, D. Despeyroux, L. Coudron, I. Munro, D. McCluskey, C. Tan, M. Tracey, *J Aerosol Sci,* **95** 43 (2016)
3. M. Jonsson-Niedziolka, F. Lapierre, Y. Coffinier, S. J. Parry, F. Zoueshtiagh, T. Foat, V. Thomy and R. Boukherroub, *Lab on a Chip*, **11** 490 (2011)