Internet of Lab (IoL)

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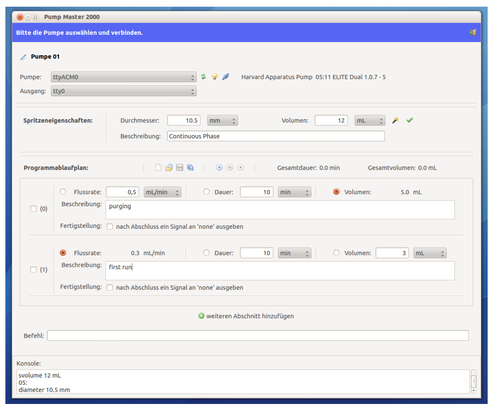
Introduction

Until today, lots of microfluidic reaction systems have to be performed manually and contain several enclosed devices, which are physically connectable but not centrally controllable. The so called Internet of Lab (IoL) gives the opportunity to steer all parts electronically within a mesh, managed by a common PC, a so-called main controller. Such a controller acts as smart as an auto-pilot for chemical reactions. With the gained data from the different sensors all over the system, e.g. flow-meter, pressure sensor, droplet detector and of course analytic devices like in-line Raman or in-line IR, the smart controller is able to drive all necessary actuators (pumps, electrochemical cell, phase separator, sample collector, analytic devices, etc.). The controller intelligence can be used for screening of reaction parameter and to optimize the reaction on-the-fly and without human interaction. Especially for droplet-based systems the integration into the Internet of Lab will simplify optimizing chemical reactions.

Supply chain

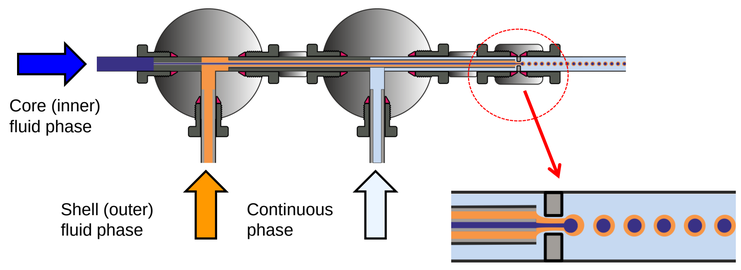
- Pump programming to control
  - HPLC pumps
  - Syringe pumps
- All flow parameters dynamically calculated from different sensors all over the system like
  - Flow controllers
  - Pressure sensors
  - Thermometers
- User-defined pump sequences e.g. for purging



Pump control software written in python and QT, integrating pumps from various manufactors by using an open plugin API

Flow preparation

- Reactand mixing
- Droplet generation
- Segment generation
- Emulsion generation
- Droplet counting
- Droplet manipulation

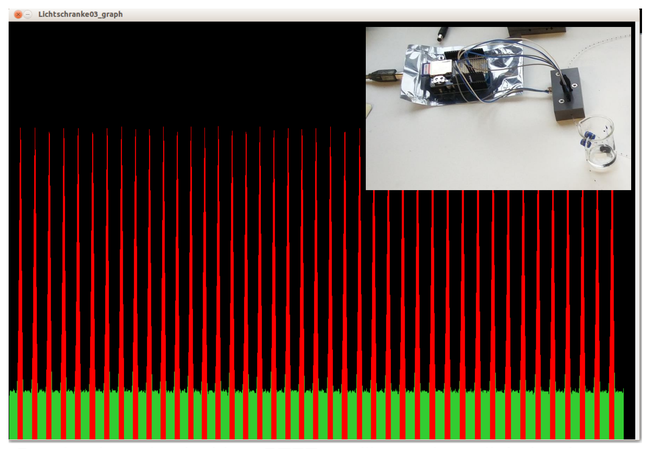


Double emulsion droplet generation as already shown in [1]

- Coaxial flow with optional flow focusing by an orifice
- Core (inner) and shell (outer) phases are monodisperse
- Volume ration between care and shell is exactly adjustable
- Every droplet acts as an enclosed reactor

Reactor

- Inline-measurment of all reaction-parameters (e.g. temperature, pressure, flowrate)
- Use of light barriers for droplet-detection with an Arduino UNO[3,4]
- Determination of droplet position, e.g. for electrochemical, photochemical or other reactions where knowledge about the exact droplet position is important
- Voltage and current control for electrochemical reactions managed by the Internet-of-Lab (IoL) controller



Droplet detection inside a PTFE-capillary using a light barrier managed by a microcontroller connected to the Internet-of-Lab-(IoL)-system

- The **Smart Main Controller** can be locally managed or remotely managed through an interactive web-interface.
- Comparable to the modern smart home, several different devices can be connected together
- Extensible system, growing with Your requirements

IoL
Internet of Lab

Smart Main Controller

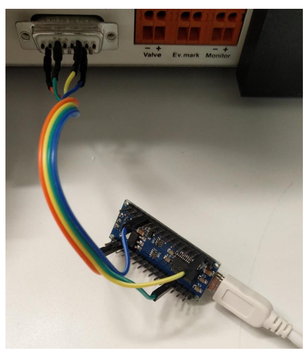
Analytics (to be done)

inline, offline analysis, HPLC, GC, Raman

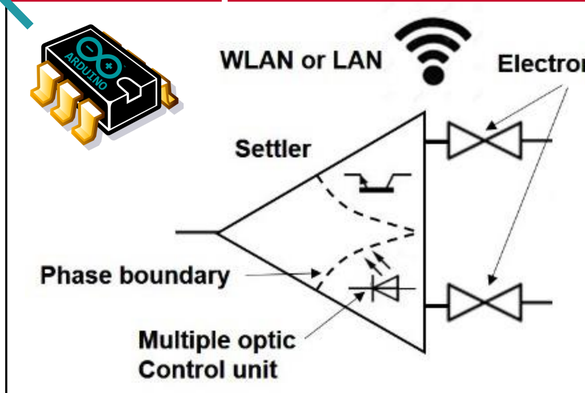
- data acquisition
- evaluation

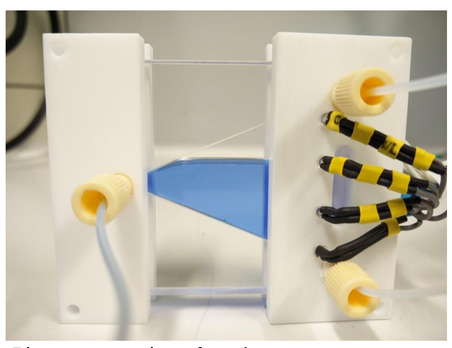
Sample collection

- Sample collection with a modified conventional fraction collector controlled by an Arduino Nano[3,4]
- Turning an existing device into an Internet of Lab device
- Fluid splitting using turnouts
- Preparation
- Easy waste management



Phase separator





Phase separation of a toluene – water (stained with blue ink) system in the triangular glass frame with 4 UV-light barriers

- Glass frame triangular phase separator[2]
- Four UV-light barriers measuring the light-transmission
- Two electronically steered valves on each output
- Light barriers and valves controlled by an Arduino UNO[3,4] for calculating interphase position and valve steering

Summary

- A fully **autonomous reaction parameter screening system**
- All sensors and actuators meshed through the **Internet of Lab (IoL)** and centrally controlled
- Novel process making use of meshed **microcontroller technology** for sensing and actuating
- Not restricted to reaction parameter screening, also **continuous and smart reaction controlling** possible
- **Variable setup** of all components which is **easily expandable** at **low costs**

References

[1] Misuk, V., Mai, A., Zhao, Y., Heinrich, J. Rauber, D., Giannopoulos, K., Löwe, H., J. Flow Chemistry, 2015, 5(2), 101-109

[2] Manufactured by Little Things Factory GmbH, Germany, http://www.ltf-gmbh.de

[3] Mellis, D., Banzi, M., Cuartielles, D., Igoe, T., Proc. CHI., Vol. 2007

[4] Arduino Microcontroller, 2016, http://www.arduino.cc