Nanofluidic Structures for Electrokinetic-Based Hydraulic Pumps on Microchips

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Outline

- Project Objectives
- Microchip Overview
- Electroosmotic Induced Hydraulic Pumping
- Preliminary Results
  - pumping
  - concentrating
  - separation

Objectives

- Develop low and high pressure pumps on microfluidic devices that can be used for:
  - sampling subsurface contaminants
  - concentrating contaminants by solid phase extraction
  - analyzing contaminants by chromatographic separation
- Utilize existing laboratory knowledge to extent possible
- Design devices that can be mass produced

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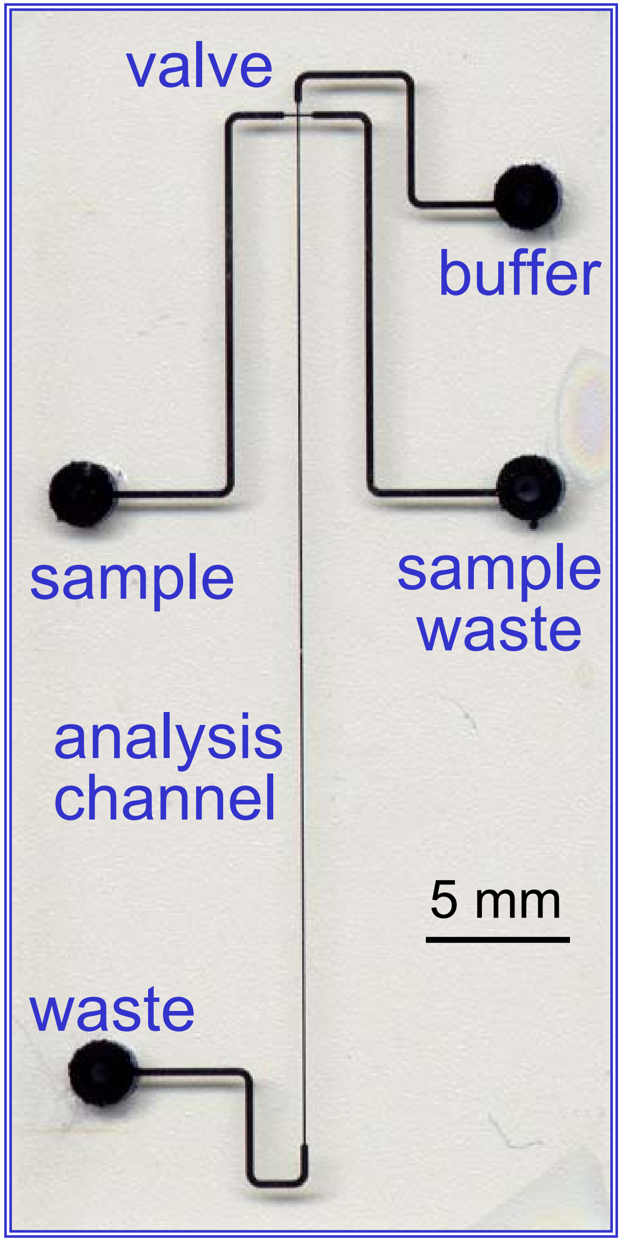
Microfluidic Devices

- Materials
  - quartz/glass
  - plastic
- Dimensions
  - 0.05 -100 μm channels
  - 1-25 cm^2 substrates
- Volumes
  - 1fL-1nL injections
  - 1-100 μL reservoirs
- Fluid transport
  - electrokinetic
  - pressure or vacuum



Microfluidic Functional Elements

I/O	pipette inkjet electrospray
separations	electrophoretic chromatographic sieving
filters	physical polymeric
cytometry	immunoassay counting sorting
reactions	stopped flow continuous flow thermal cycling
detection	fluorescence absorbance refractive scattering electrochemical mass spectrometry
concentration	extraction membrane
transport	electrokinetic pressure

Miniaturization of Chemical Instrumentation

Advantages

- Compact
- High speed analysis
- Integration
- Reliability
- Operational simplicity
- Parallel architectures
- Low cost

Electroosmotic Hydraulic Pumping on Microchips

Concept

Electroosmotically generate fluid flow in a portion of the channel and use that momentum to generate a pressure in the field free portion of the channel

Implementation

- heterogenous charged surfaces
- in-channel electrical connections
- nanofluidic structures

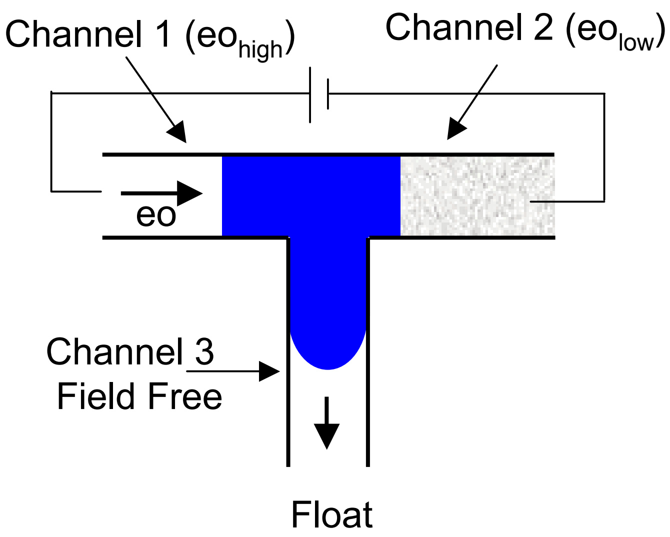
Advantages

- easy to implement
- control via applied voltage
- flow rate independent of analyte mobility
- pulsation free flow

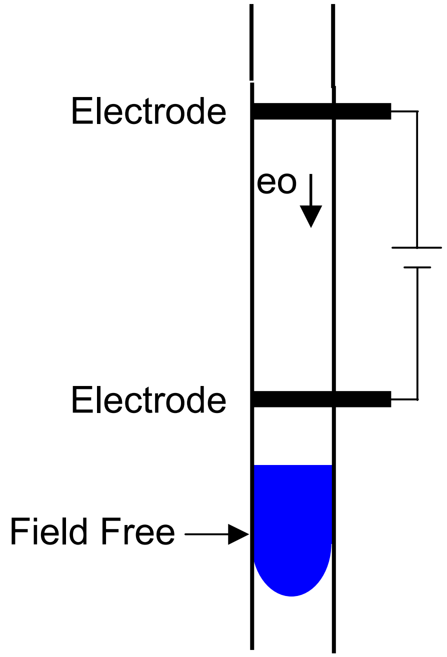
Electroosmotic Induced Hydraulic Pumping

schemes

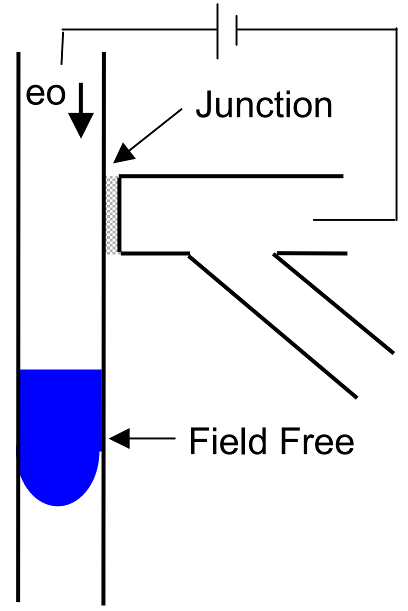
Heterogeneous Channel Surfaces



In-channel Electrical Connections



Nanofluidic Structures

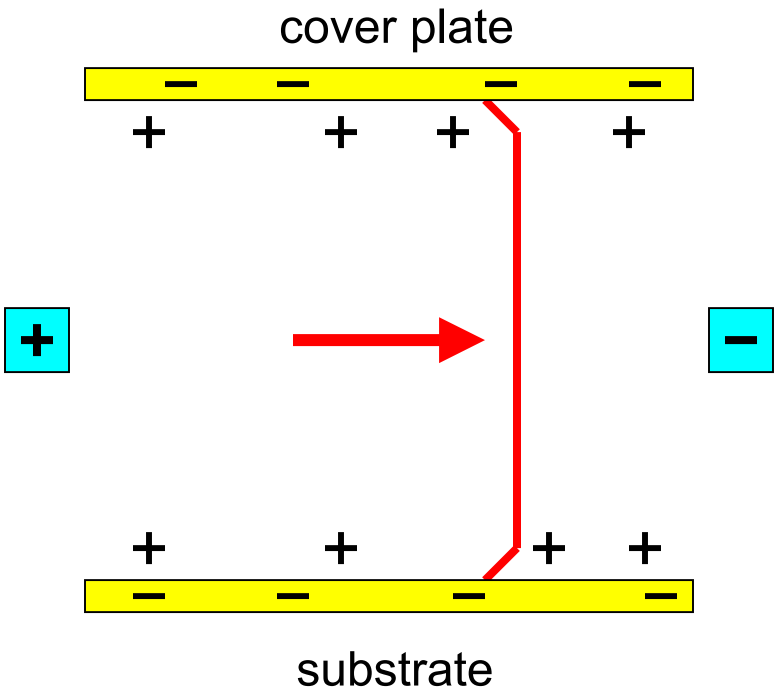


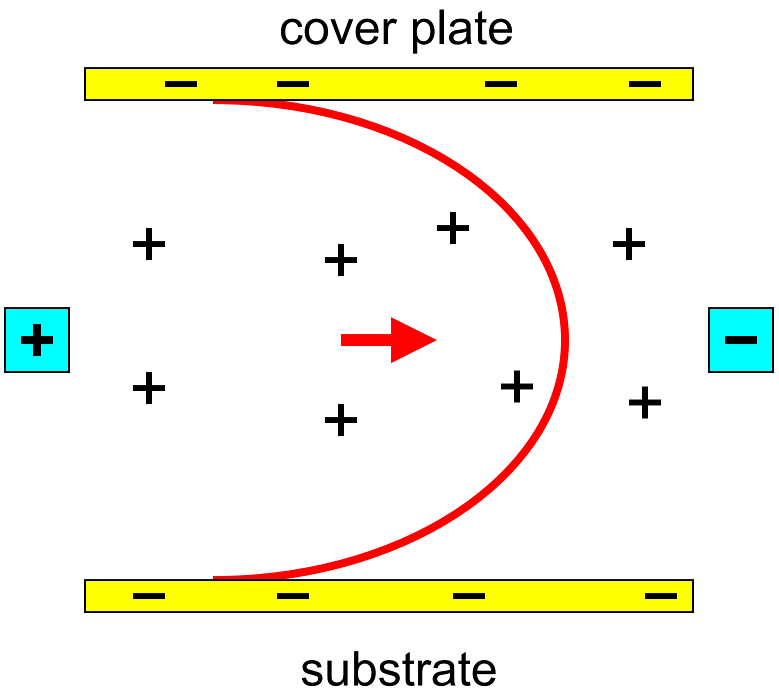
Electrokinetic Flow in Channels

Microchannel vs Nanochannel Flow

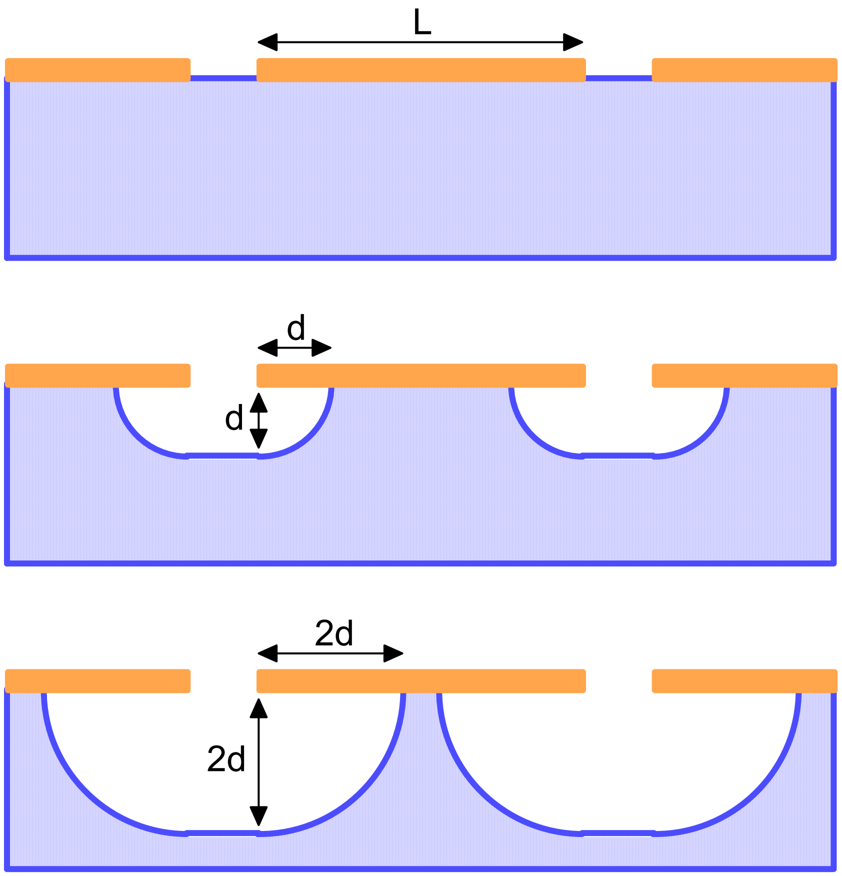
microchannel
(1 μm deep)

nanochannel
(100 nm deep)





Isotropic Etching



patterned substrate

etch time = t
etch depth = d

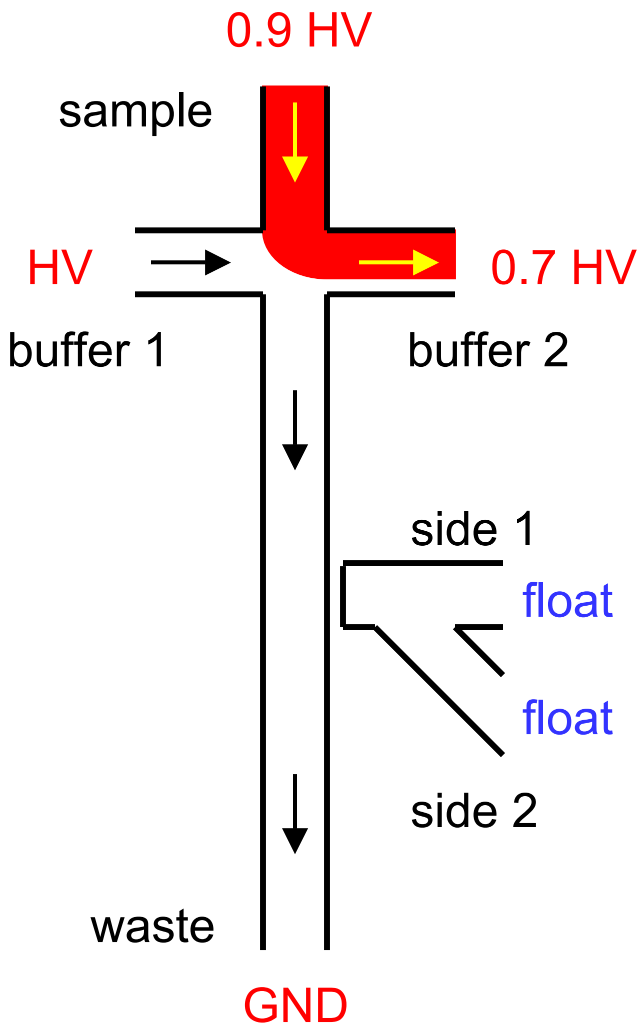
etch time = 2 t
etch depth = 2d

bridge width = channel spacing - 2 (etch time) (etch rate)

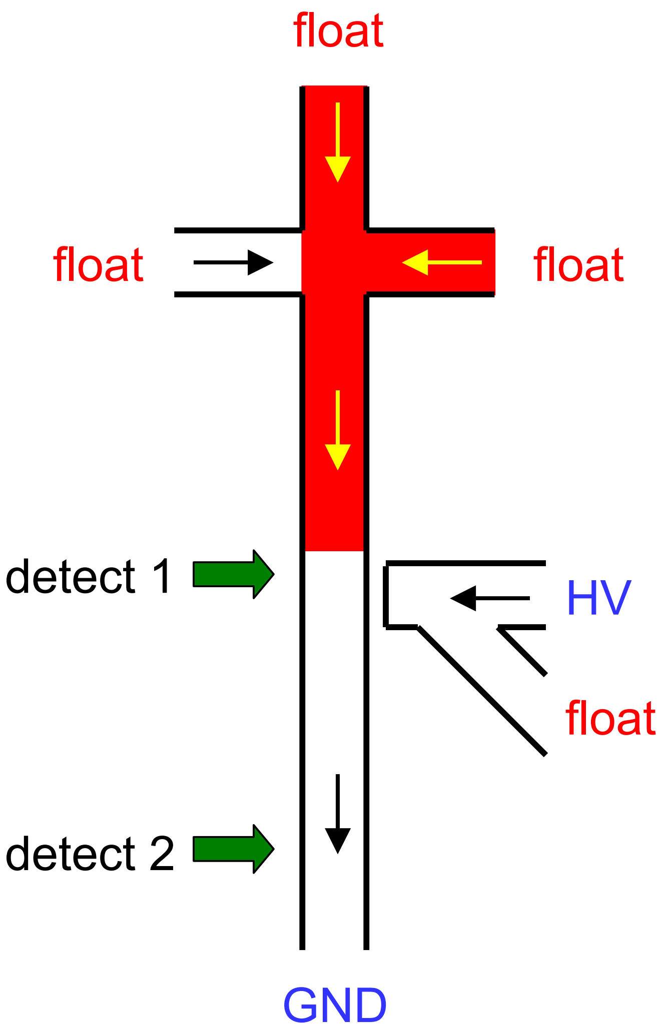
Electroosmotically Induced Pumping

Measure pumping rates

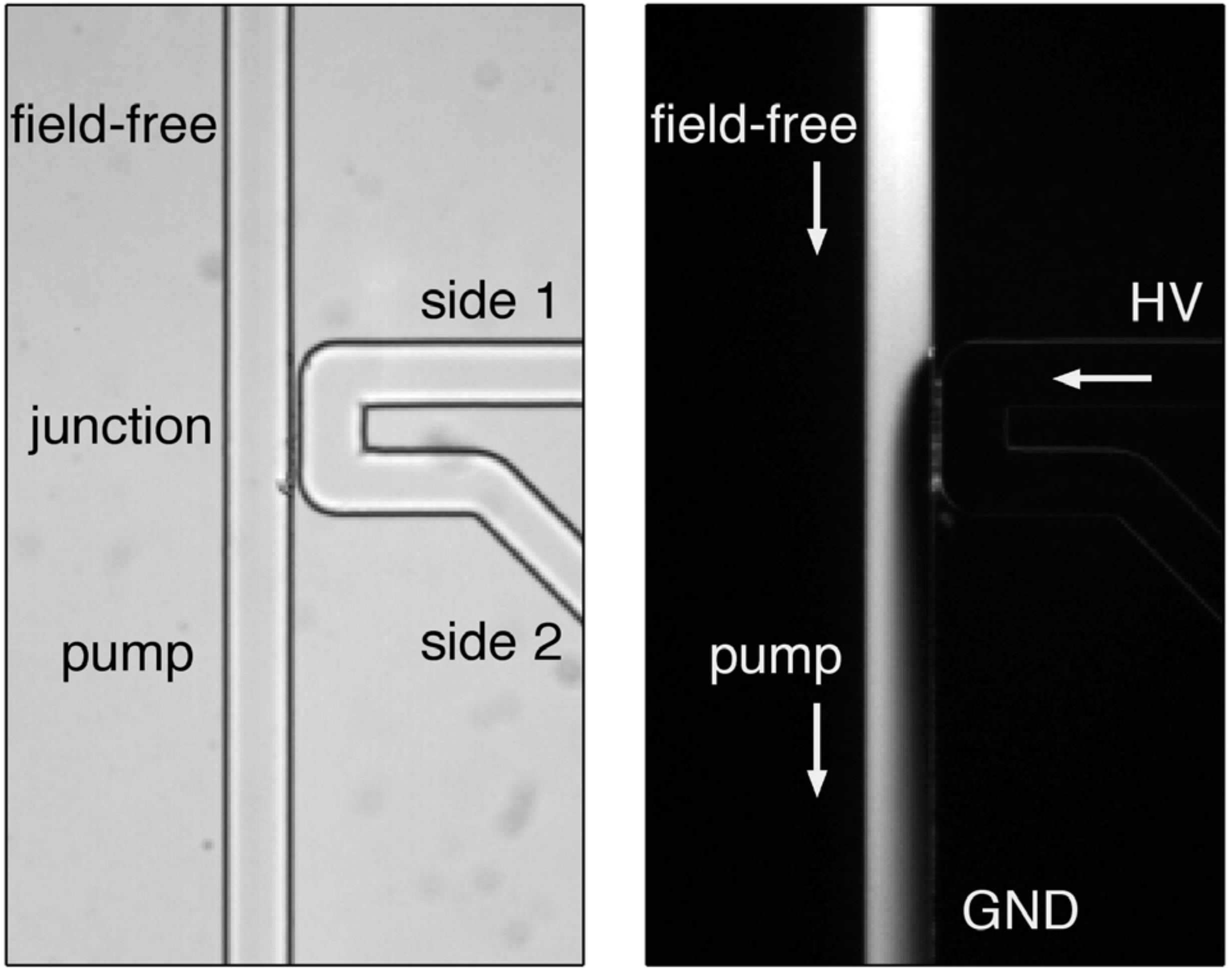
load mode



pump mode



Flow at Junction



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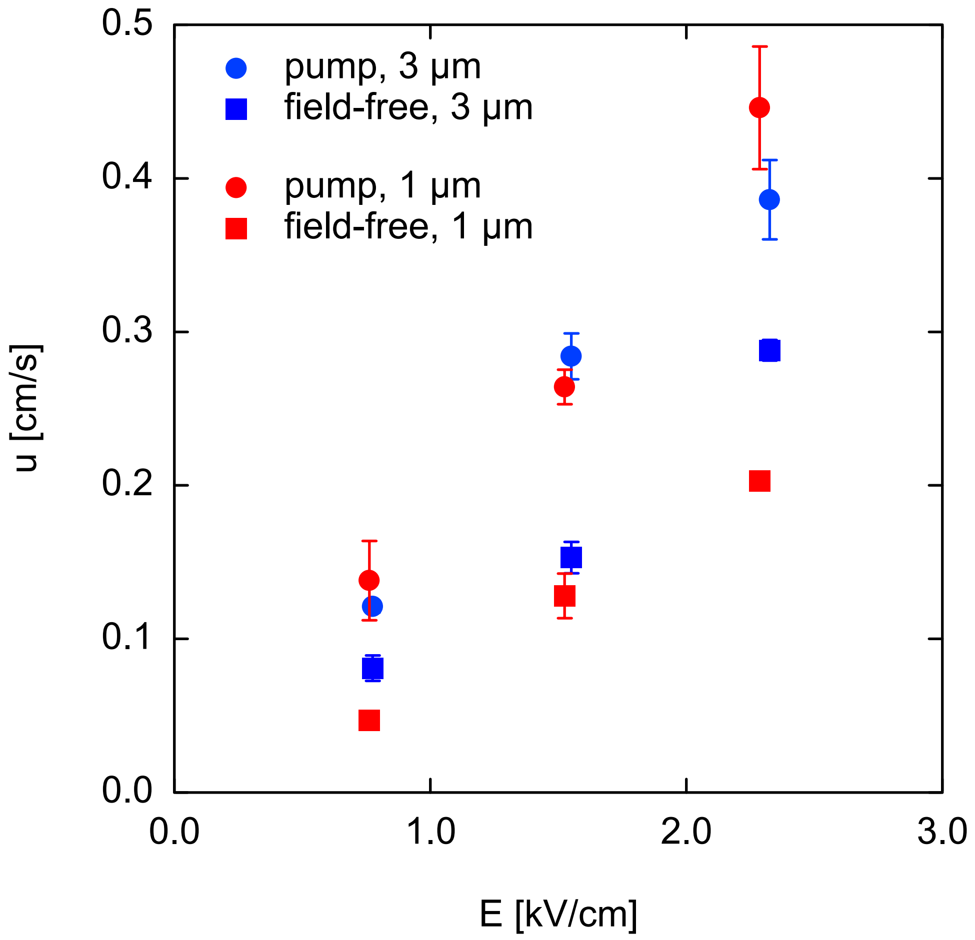
Pumping Rates for 1 and 3 μm Junctions



Pumping efficiency:

1 μm junction

$u_{ff} / u_p = 0.43$

3 μm junction

$u_{ff} / u_p = 0.63$

sample: rhodamine B

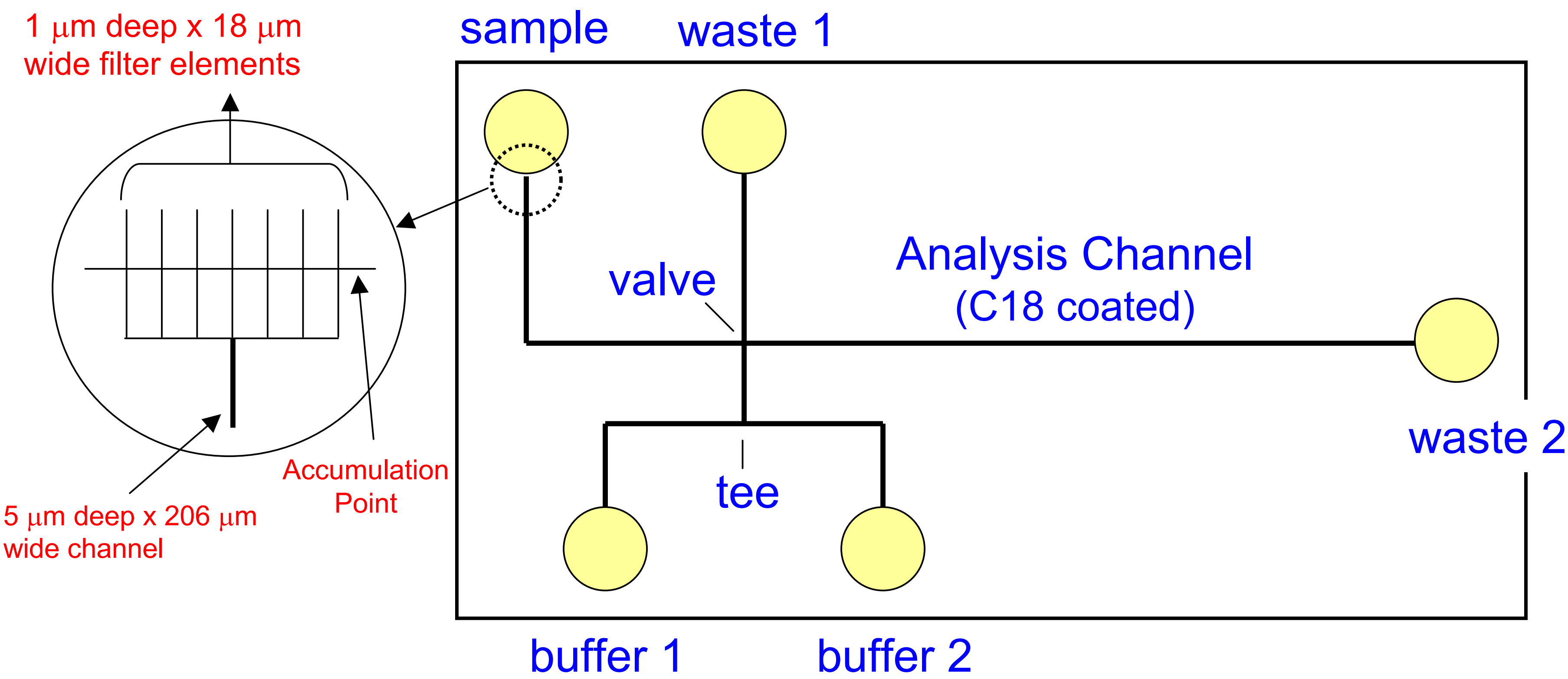
buffer: sodium tetraborate

p = pump channel

ff = field-free channel

Microchip Functional Element Integration

Filtering, Solid Phase Extraction and Separation



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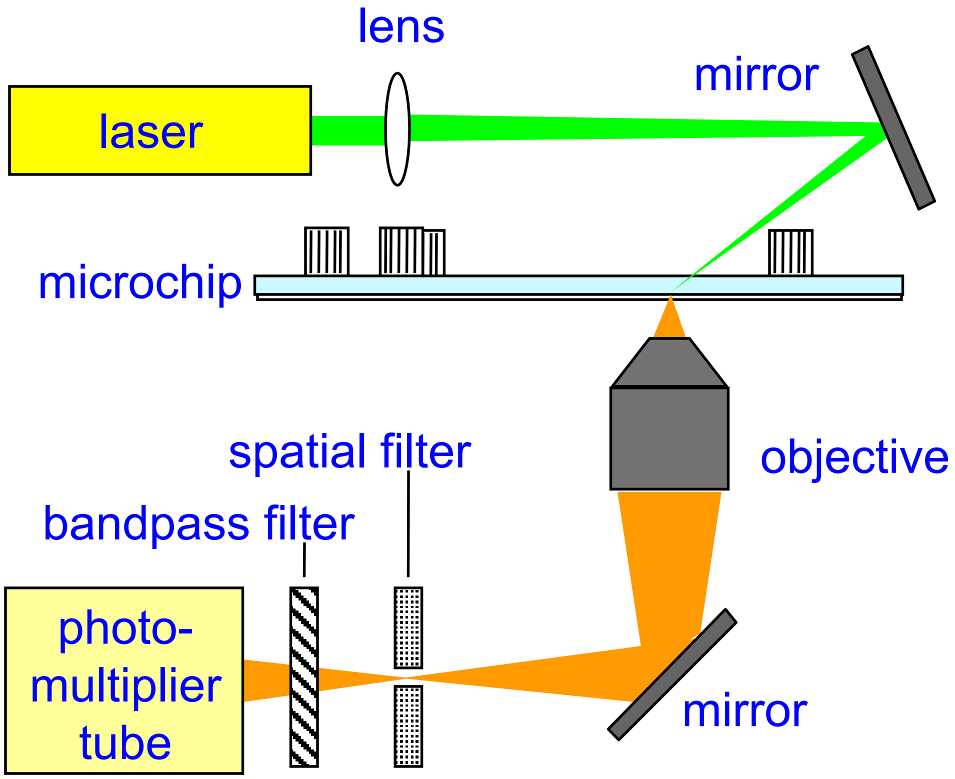
Laser-Induced Fluorescence Detection



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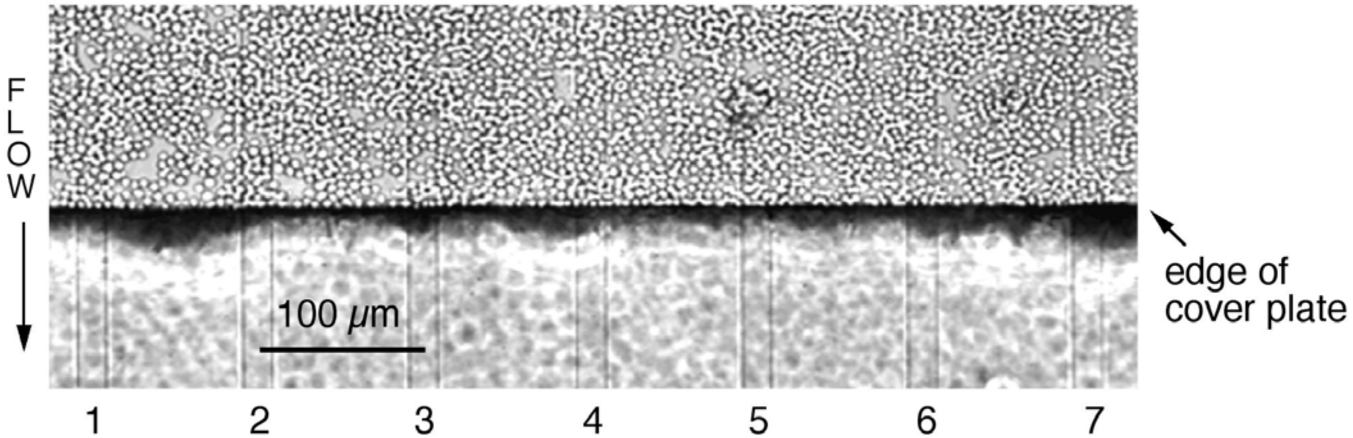
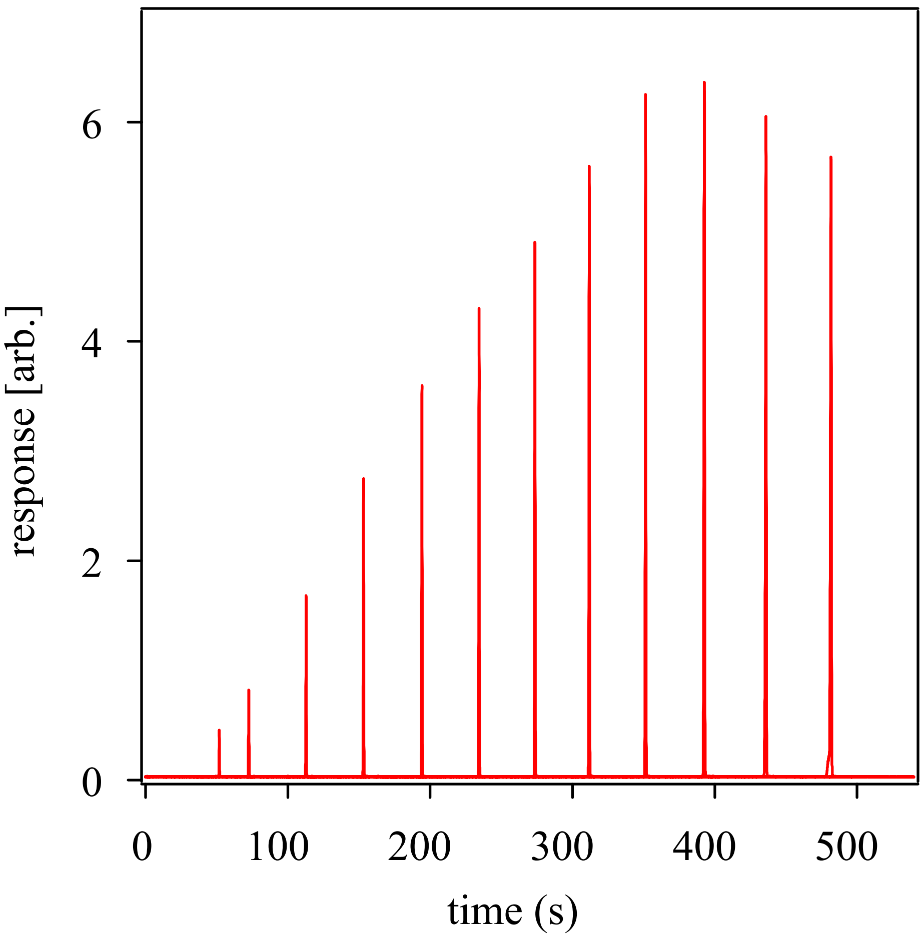
Sample Filtration

5 μm silica particles



Solid Phase Extraction

pyrene



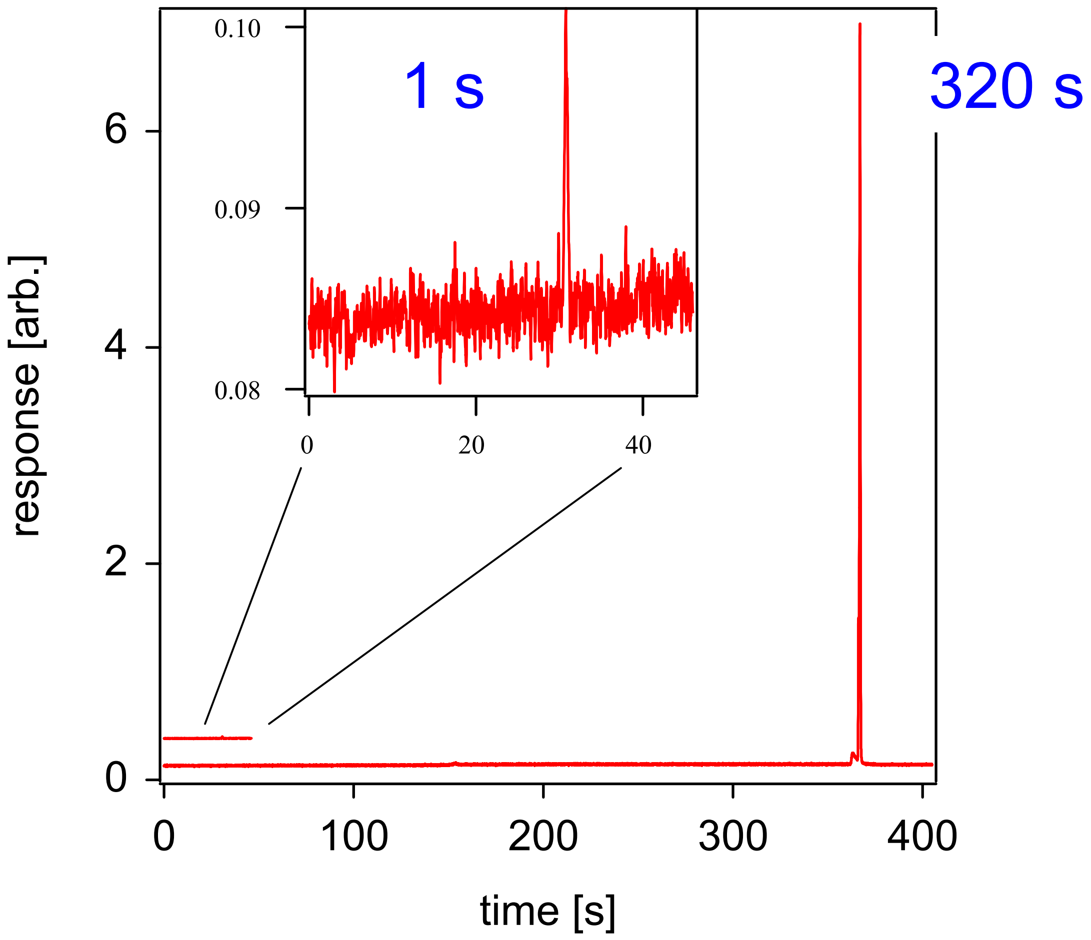
acetonitrile

load = 20%

elute = 56%

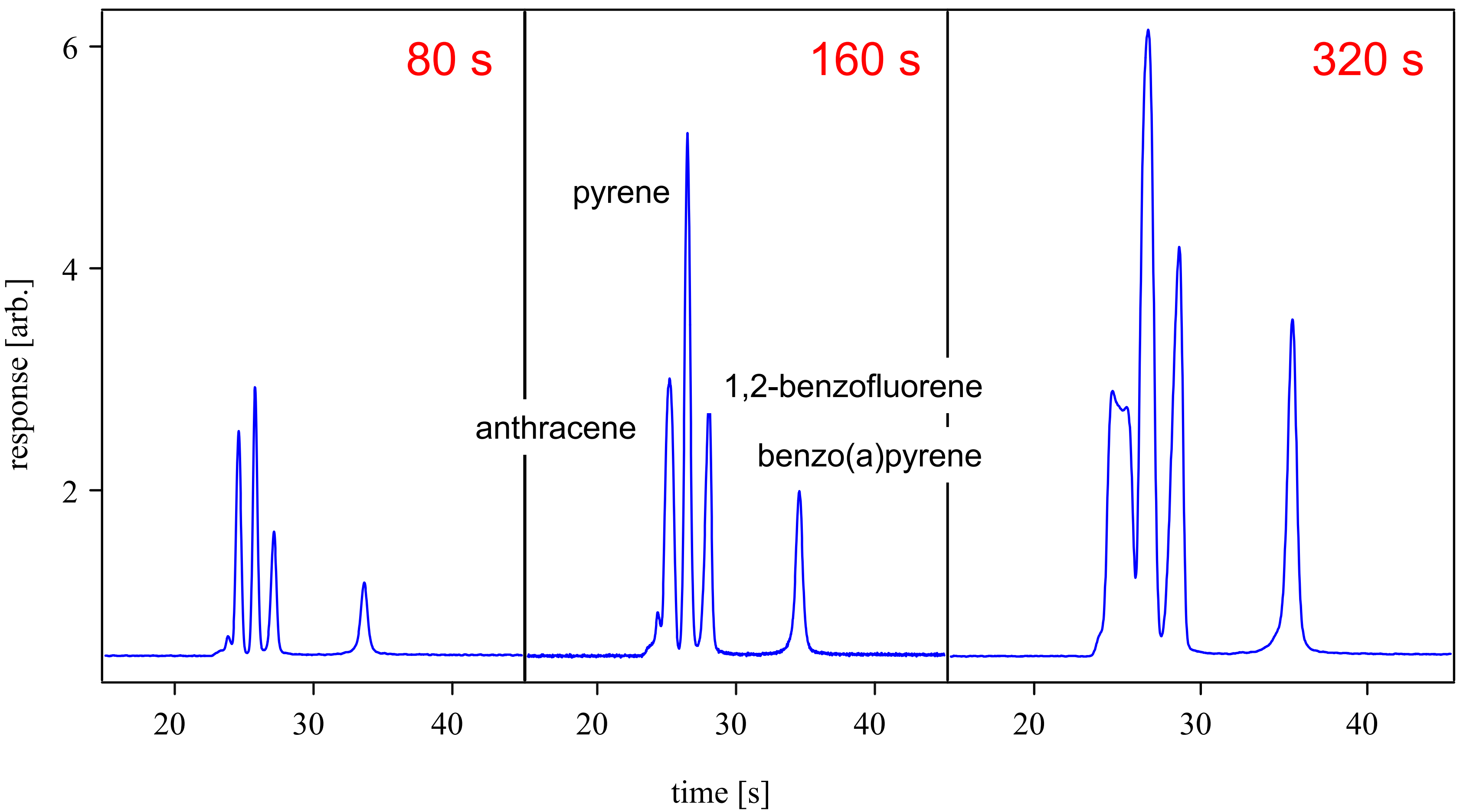
Solid Phase Extraction

pyrene

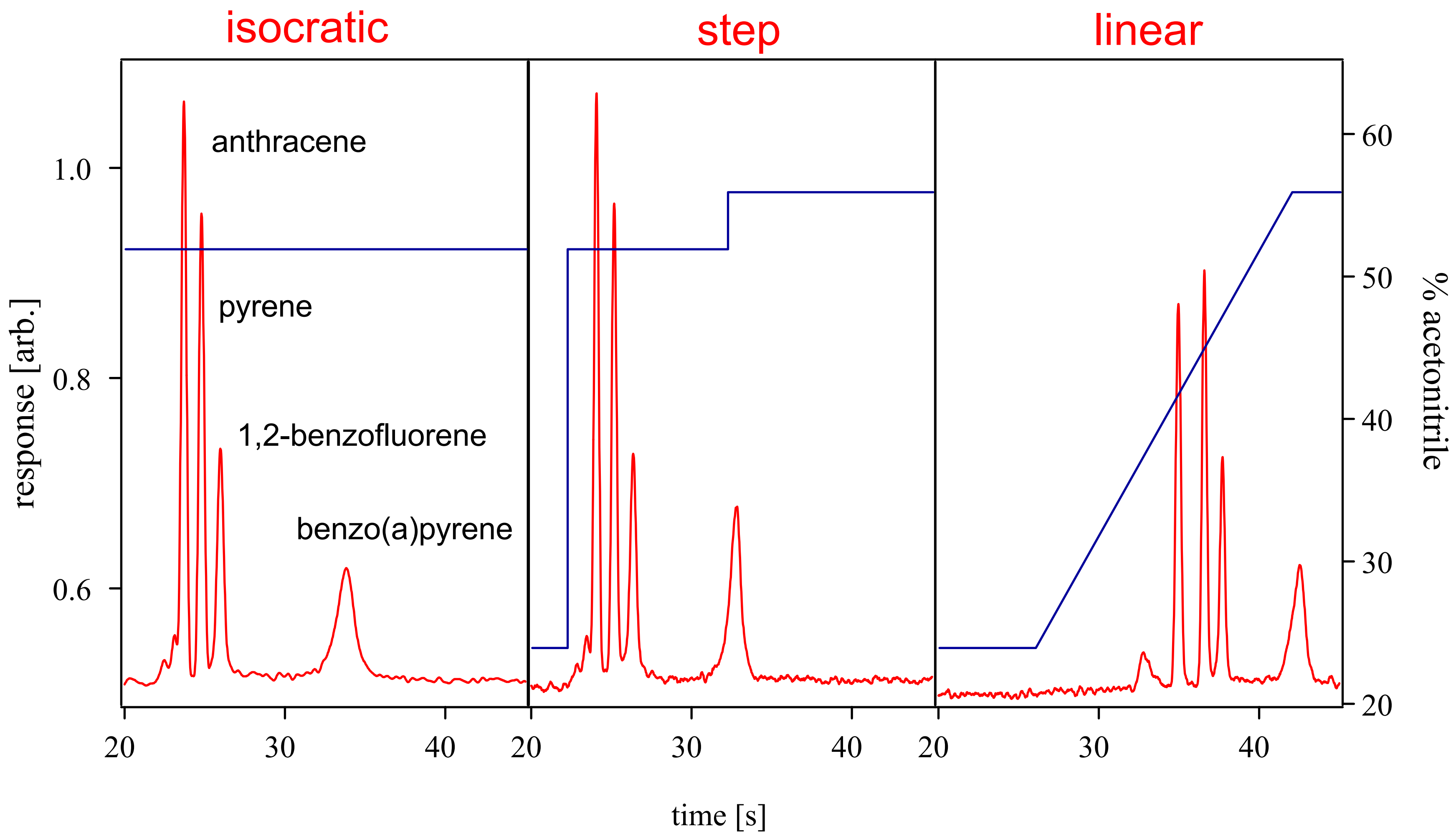


400-fold enhancement

Concentration and Separation



Solvent Programming



Future Research

- Design and fabricate improved nanochannel membranes
- Evaluate electroosmotic transport in nanochannels
- Investigate surface chemistries that promote and inhibit electroosmotic flow
- Integrate the optimum pumping segment and junction into a single unit
- Assess pumping efficiency as a function of solvent and sample composition
- Test pumping strategy for sample introduction and liquid chromatography

Personnel

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