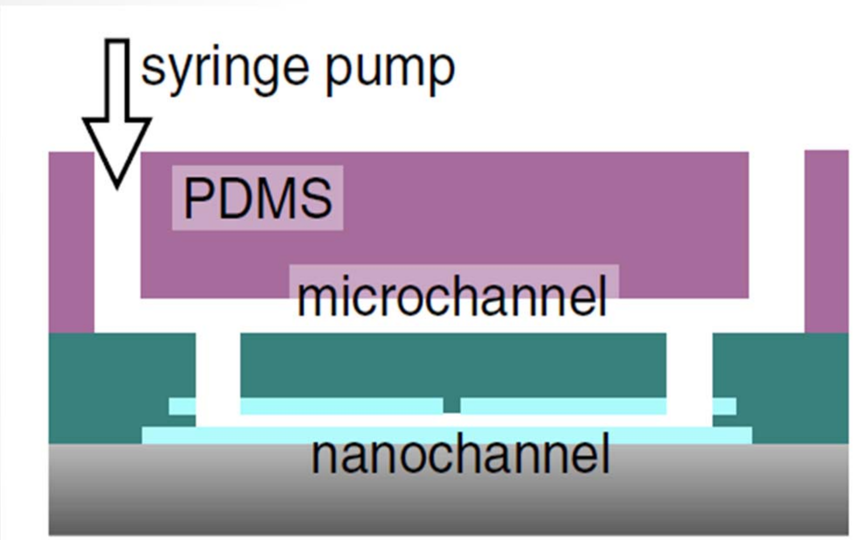
Electrical Cross-Correlation Spectroscopy: Measuring Picoliter-per-Minute Flows in Nanochannels

Klaus Mathwig, Dileep Mampallil, Shuo Kang, and Serge G. Lemay, Phys. Rev. Lett. ***109****, 11 (2012).*



Angela Chen
Li Chen
Patrick Coleman
Karl Decker
University of Illinois

November 30, 2012

Outline

- Context for experiment
- Experiment and analysis
- Moving beyond the experiment

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Prior Work

- Parallel flow control (PFC) system for syringe driven nanofluidics—measured nanochannel flow rate at the value of 30 pL/min.
- Fluorescence correlation spectroscopy—by measuring the rates of decay of spontaneous concentration fluctuation, we can determine chemical kinetic constants and diffusion coefficients.

Why use cross-correlation spectroscopy?

- Estimate ultralow liquid flow rates of electrochemically active molecules.
- Realize multiple detectors in more complex nanochannel networks.
- Avoid using bulky optical equipment (lab on a chip compatibility).

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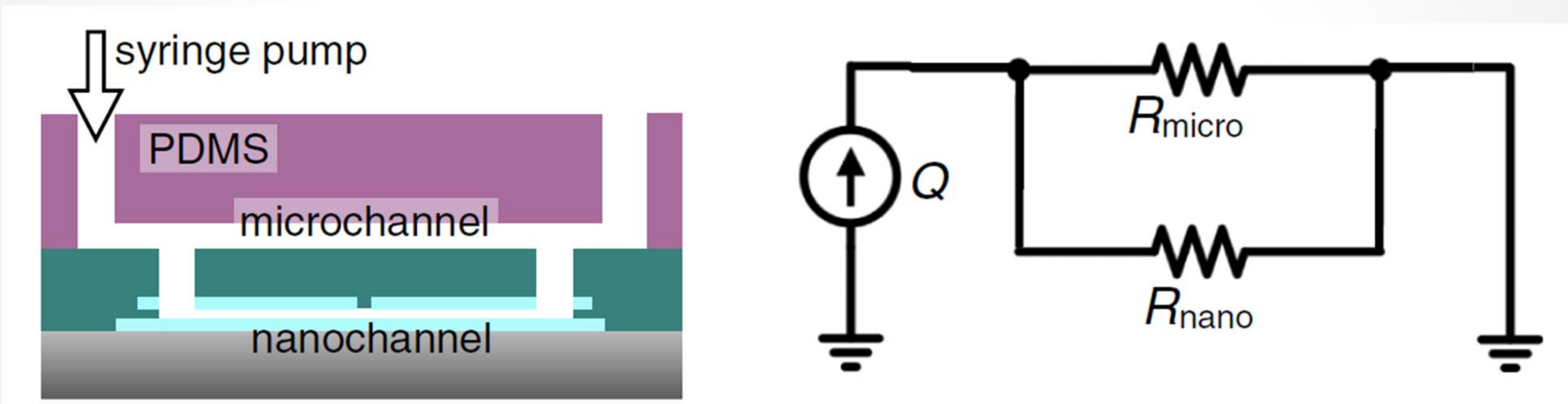
Time-of-flight measurements

- Detect current in nanogap transducers.
- Perform time-of-flight measurement of fluctuations using cross-correlation functions.

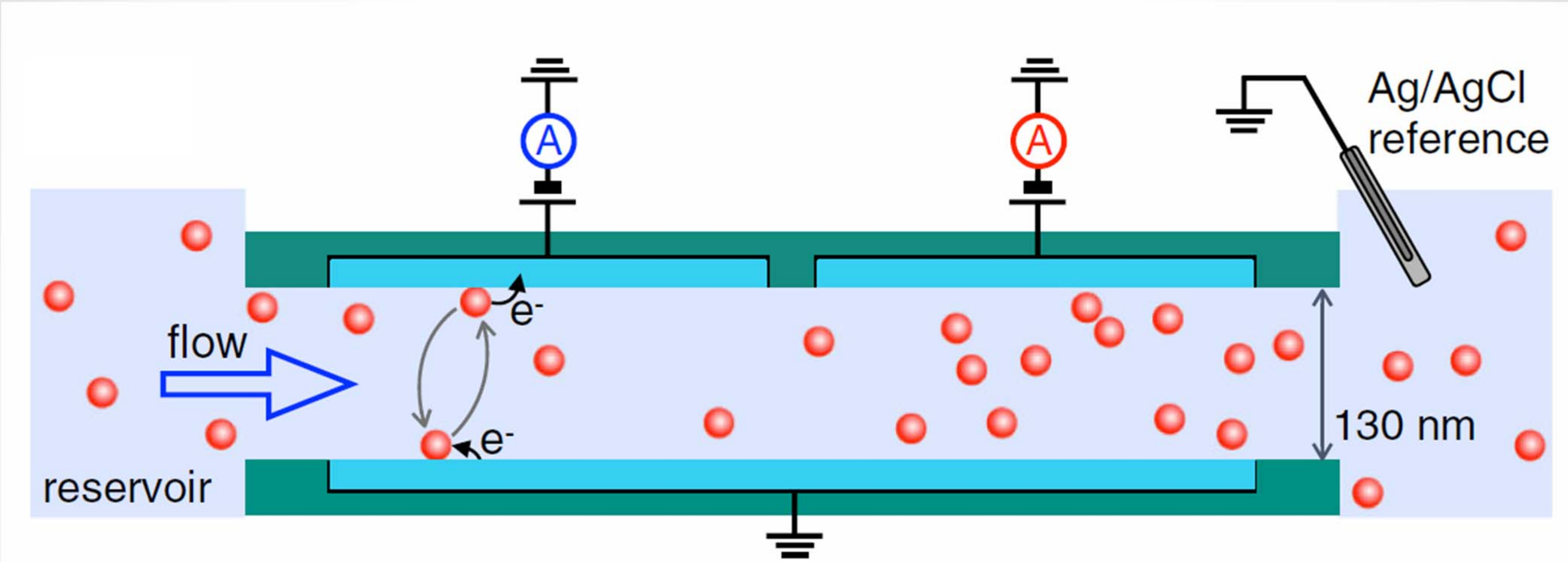
Parallel Flow Device



Schematic of parallel flow. Mathwig et al., 2012

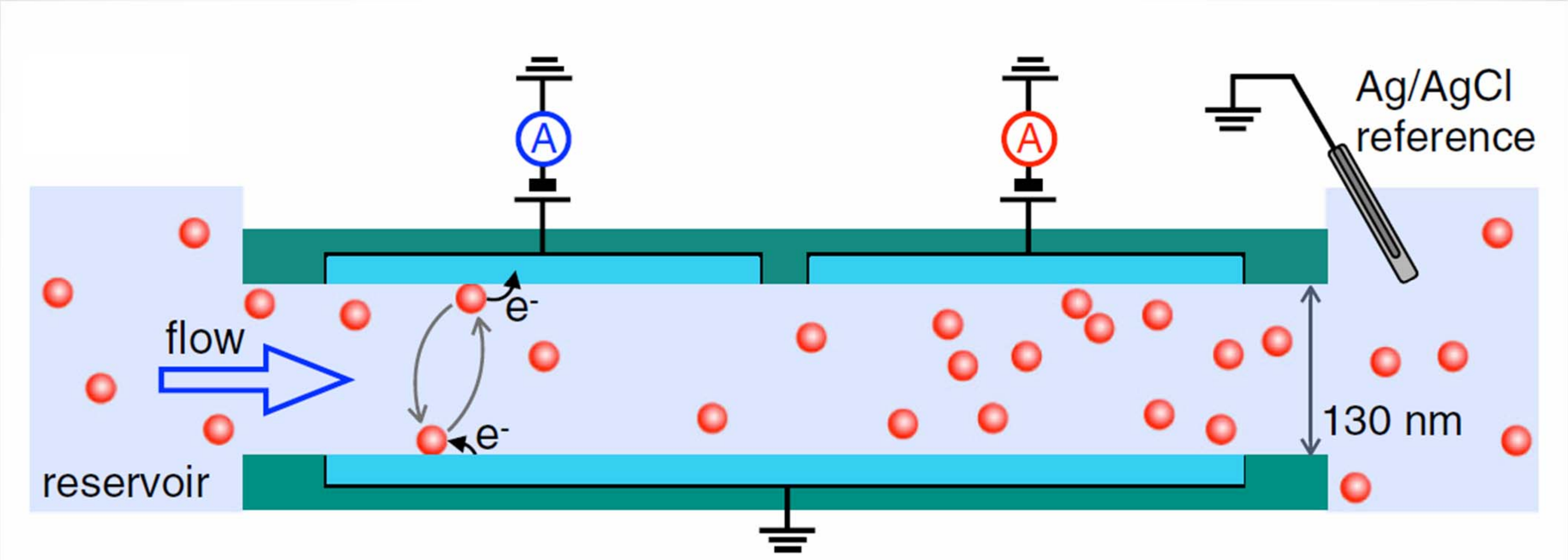
- Slow flow rates: 5 μL/h to 50 μL/h
- Microchannel bonded to nanochannel.

Nanogap transducers measure fluid flow



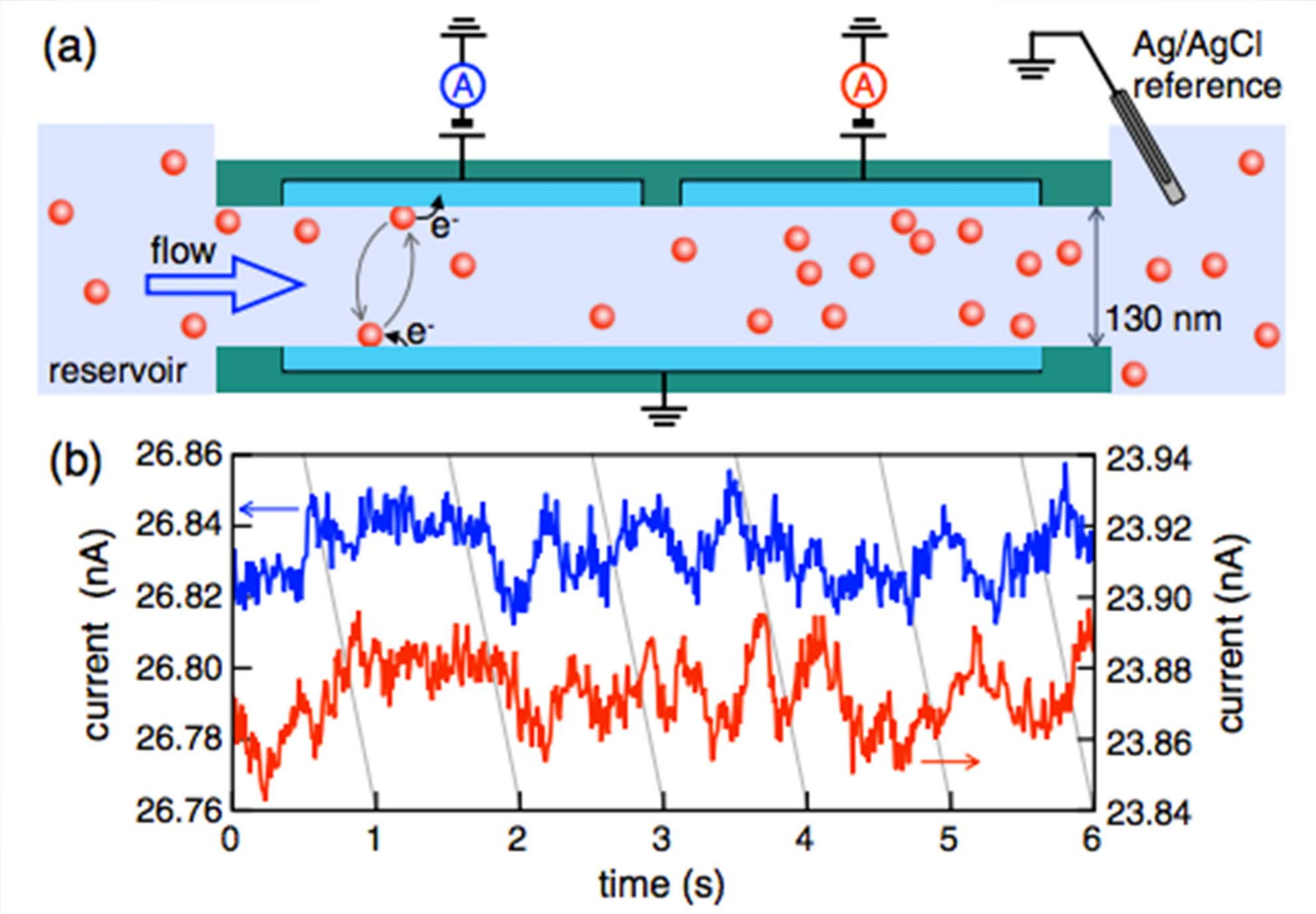
- 130 nm channel between electrodes.
- Repeated oxidation and reduction of molecules.
  - Enhanced current
  - Current proportional to number of molecules

Two detection volumes track fluctuation

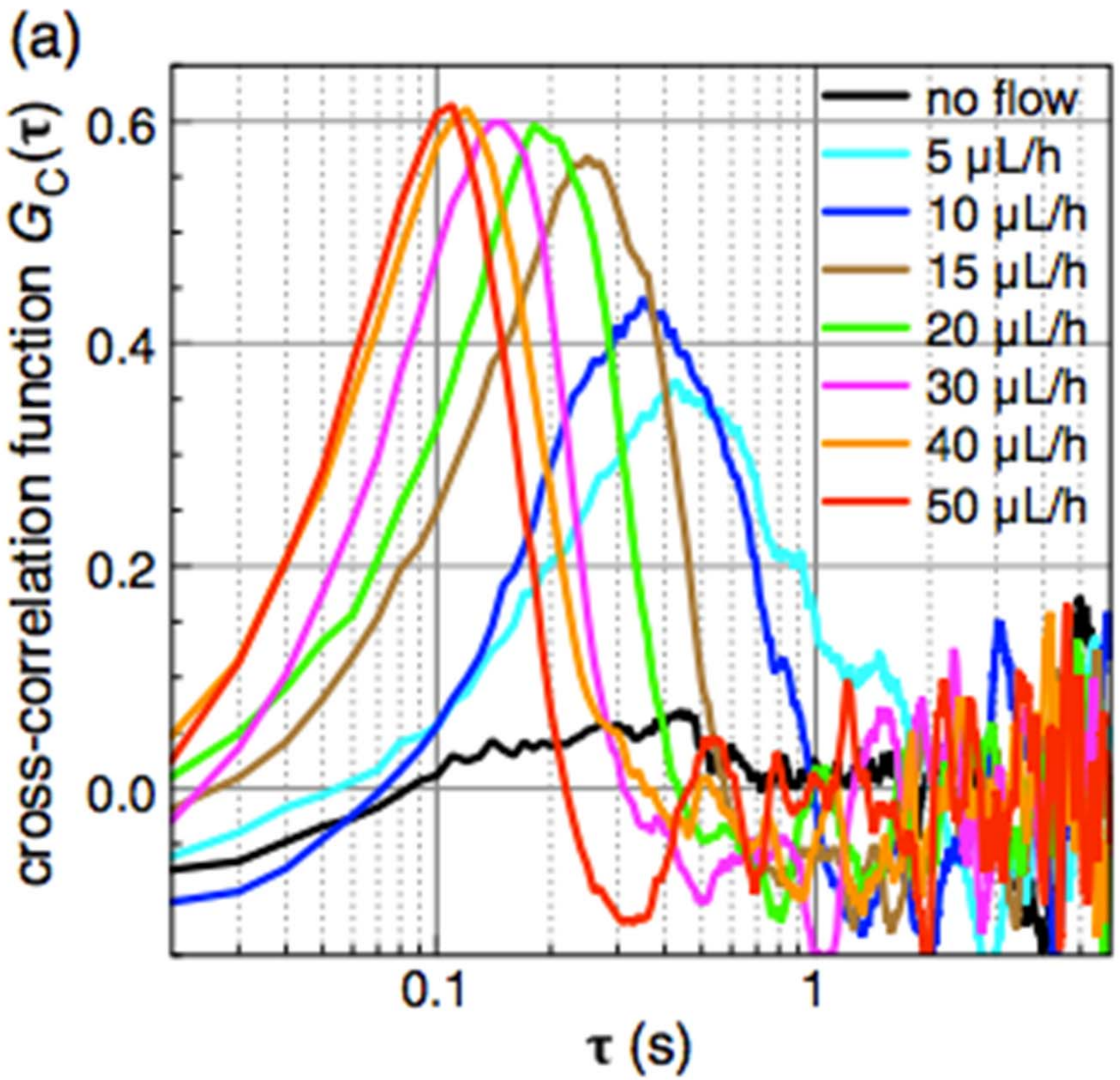


- Two detection electrodes.
- Fluctuation measured by both electrodes as it flows downstream.

Cross-correlated current signals yield flow rates

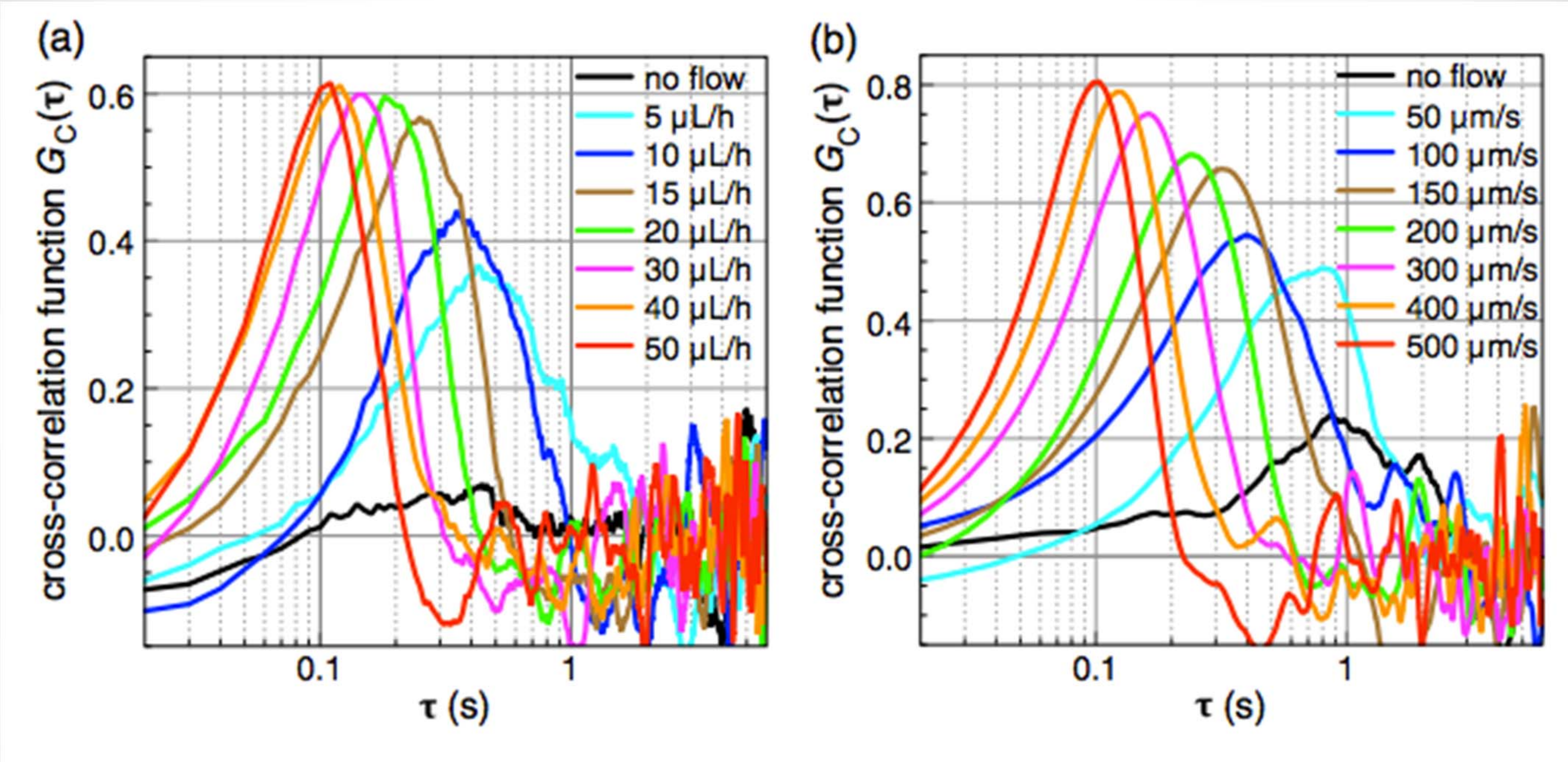


Peaks indicate time of flight (tau)



- Higher flow rates correspond with lower time of flight.
- Noise at tau > 1s is due to finite length of signals.

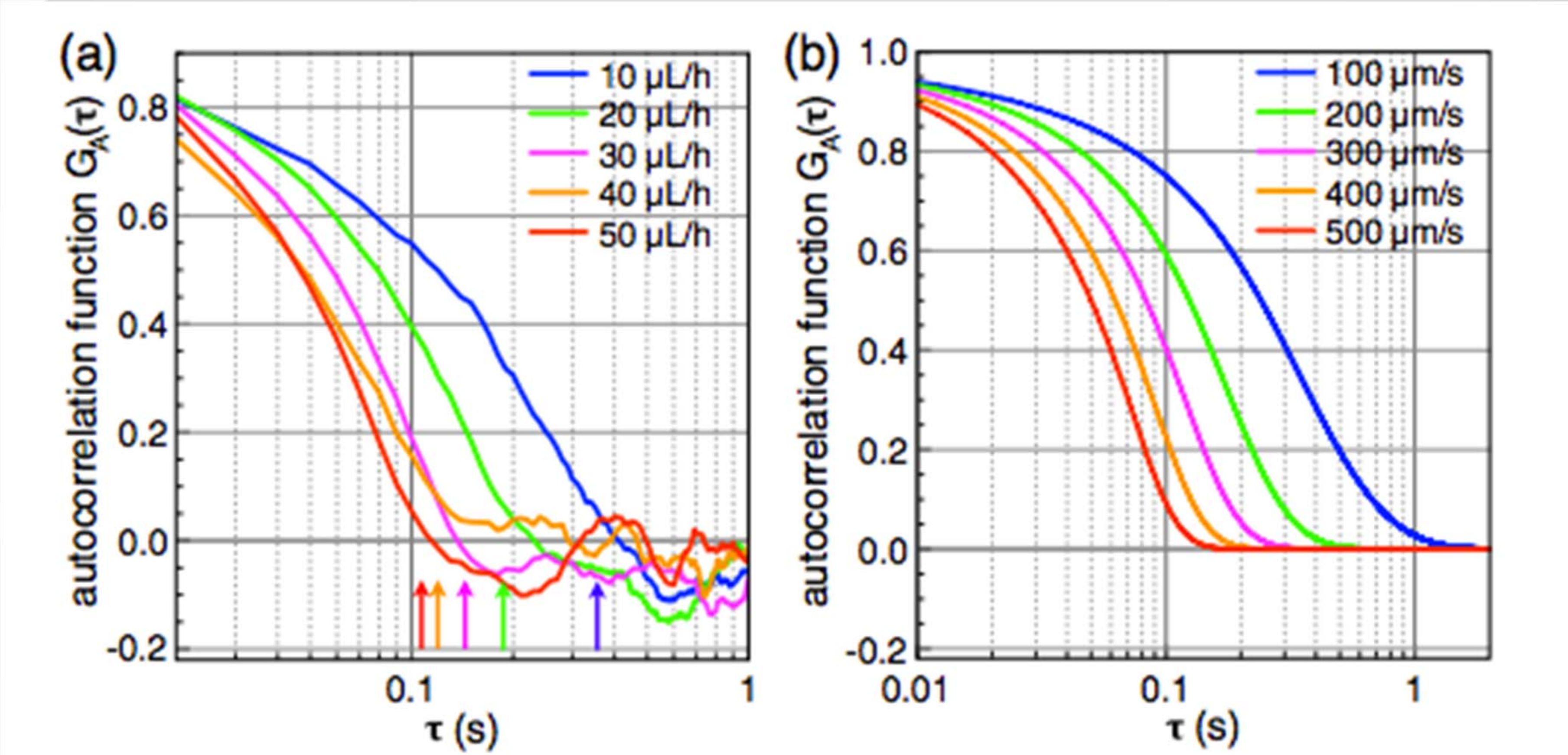
Simulation agrees with experiment



Experiment

Simulation

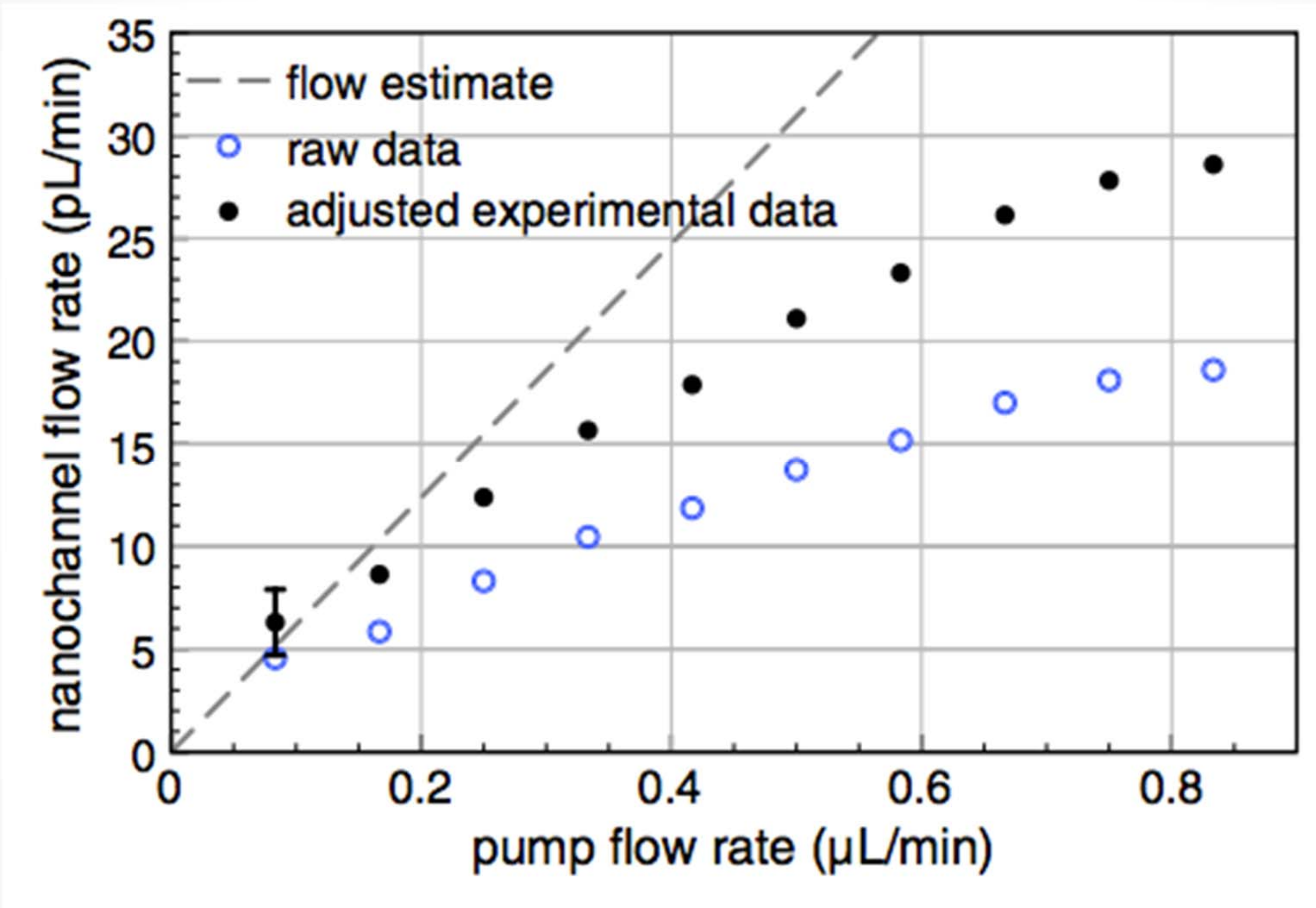
Auto-correlation yields time-of-flight



Experiment

Simulation

Nanochannel flow rate varies linearly with pump flow rate



- Adjusted data accounts for adsorption.
- Remaining disparity blamed on bulging microchannel.

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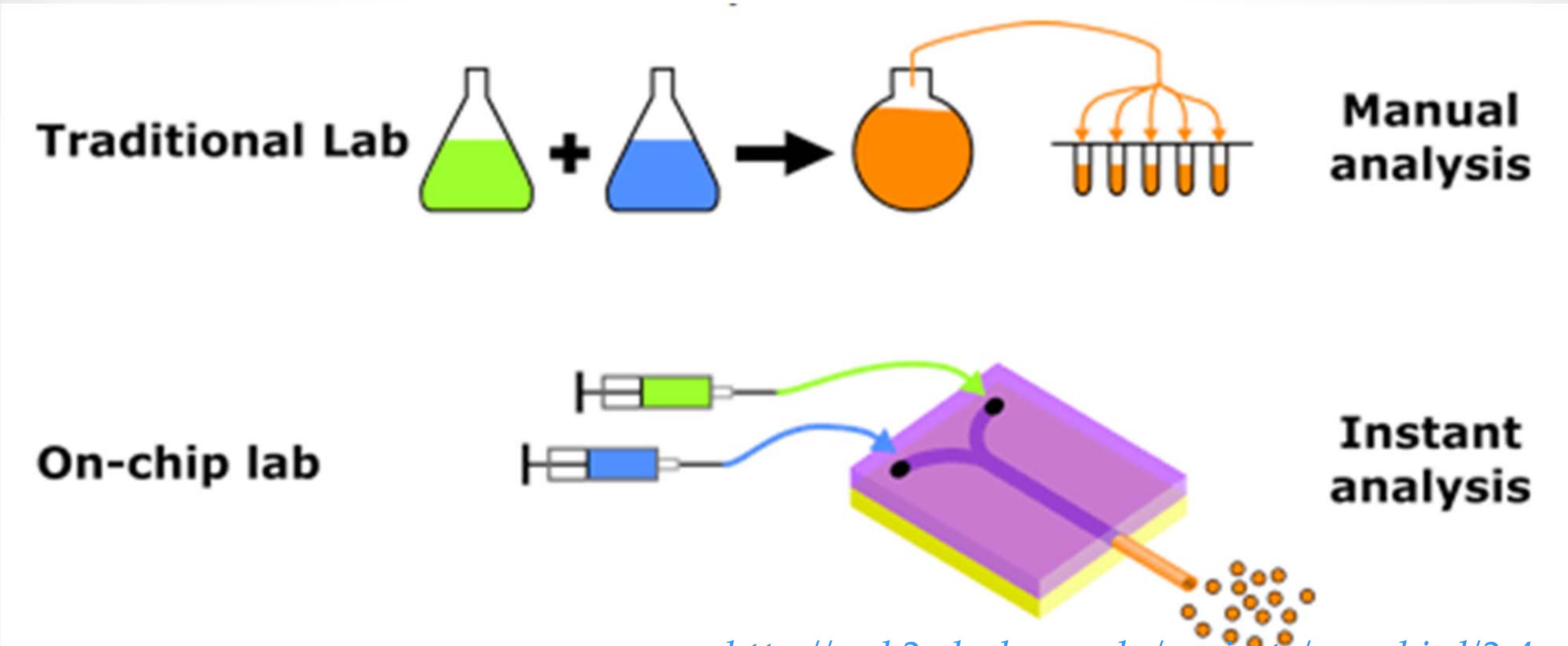
Huge improvements in tiny flow rate detection

- Flow rate measurements of 10 pL/min – slowest rate ever reliably measured
- Limited by signal-to-noise issues
- Possible improvements: “Improved instrumentation or reduced channel height”

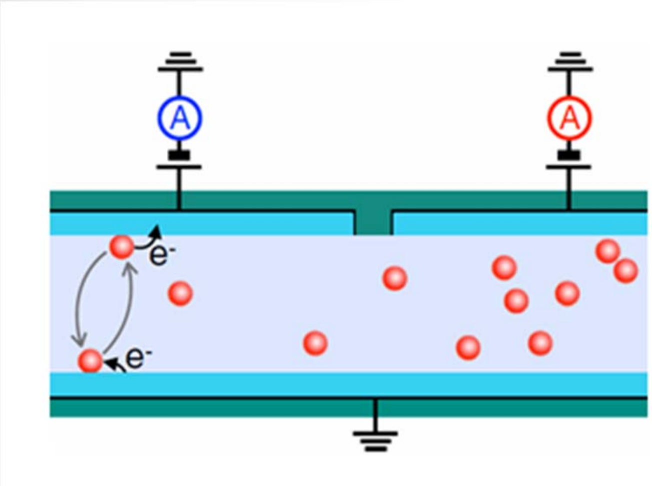
Innovating towards…



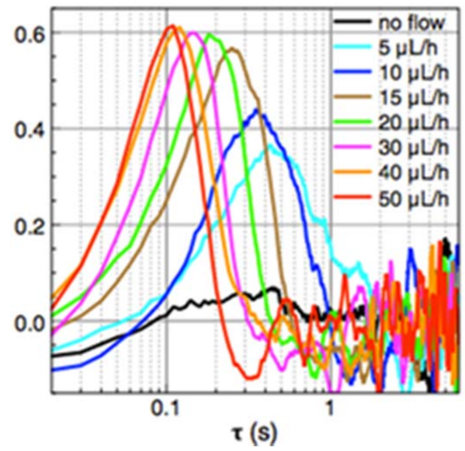
http://web2.clarkson.edu/projects/nanobird/2.4.php

- Compatible with complete "Lab-on-a-chip"
- Ability to identify single-molecules

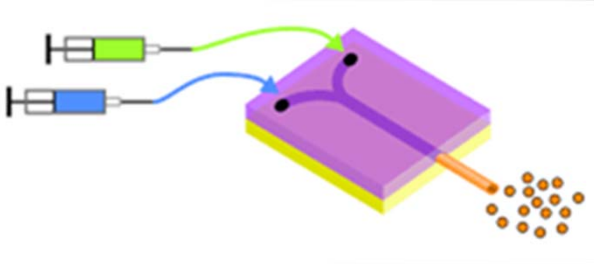
Summary



Nanogap transducers



Small flow rate detection



Lab-on-a-chip applications

- Since the article was published on September 12, 2012, no papers have cited it yet.

Questions?