

Analyte Capture from Liquid Samples: Size Matters

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Introduction: Arrays of vertical pillars functionalized with antibodies have been used for analyte capture from liquid samples. Micro Purification Chips, have shown promising results 10% capture efficiency, when applied as upstream filtration devices for direct cancer marker detection from whole blood.

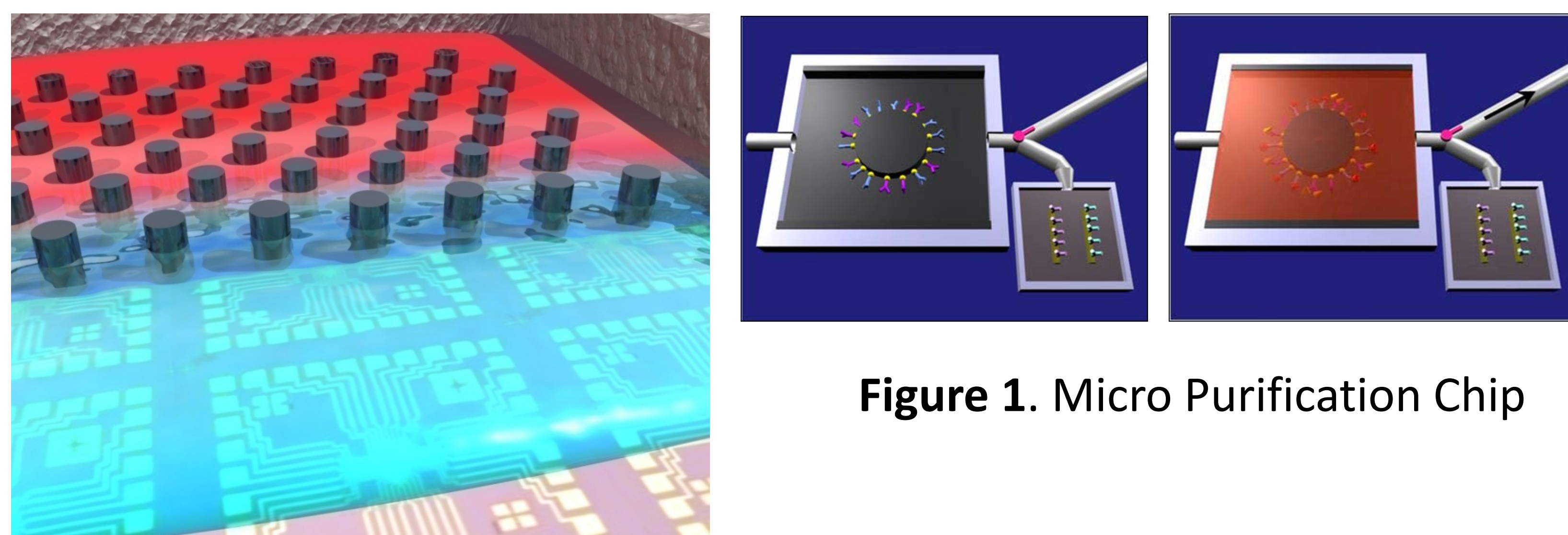


Figure 1. Micro Purification Chip

Computational Methods: The model is a combination of mass balance, analyte binding represented as reaction on the pillar surface, convection and diffusion and Navier-Stokes equation to account for pressure driven flow inside of the microchannel.

The boundary conditions are concentration c_0 at the microchannel inlet, initial flow velocity. At the outlet the boundary condition is atmospheric pressure and convective flux. All constants for the model were matched for Prostate Specific Antigen (PSA) binding from a physiological solution. The model solves the distribution of analyte molecules in microfluidic channel in steady state.

Mass balance

$$\frac{\partial c_s}{\partial t} + \nabla \cdot (-D_s \nabla c_s) = k_{ads} c (\theta_0 - c_s) - k_{des} c_s$$

Convection & diff

$$\frac{\partial c}{\partial t} + \nabla \cdot (-D \nabla c + c \mathbf{u}) = 0$$

Navier-Stokes

$$\rho \frac{\partial \mathbf{u}}{\partial t} - \nabla \cdot \eta (\nabla \mathbf{u} + (\nabla \mathbf{u})^T) + \rho \mathbf{u} \cdot \nabla \mathbf{u} + \nabla p = 0$$

Reaction at pillar

Bc @ t=0

$$c + \theta \rightleftharpoons c_s$$

$$c = c_0 \quad c_s = 0$$

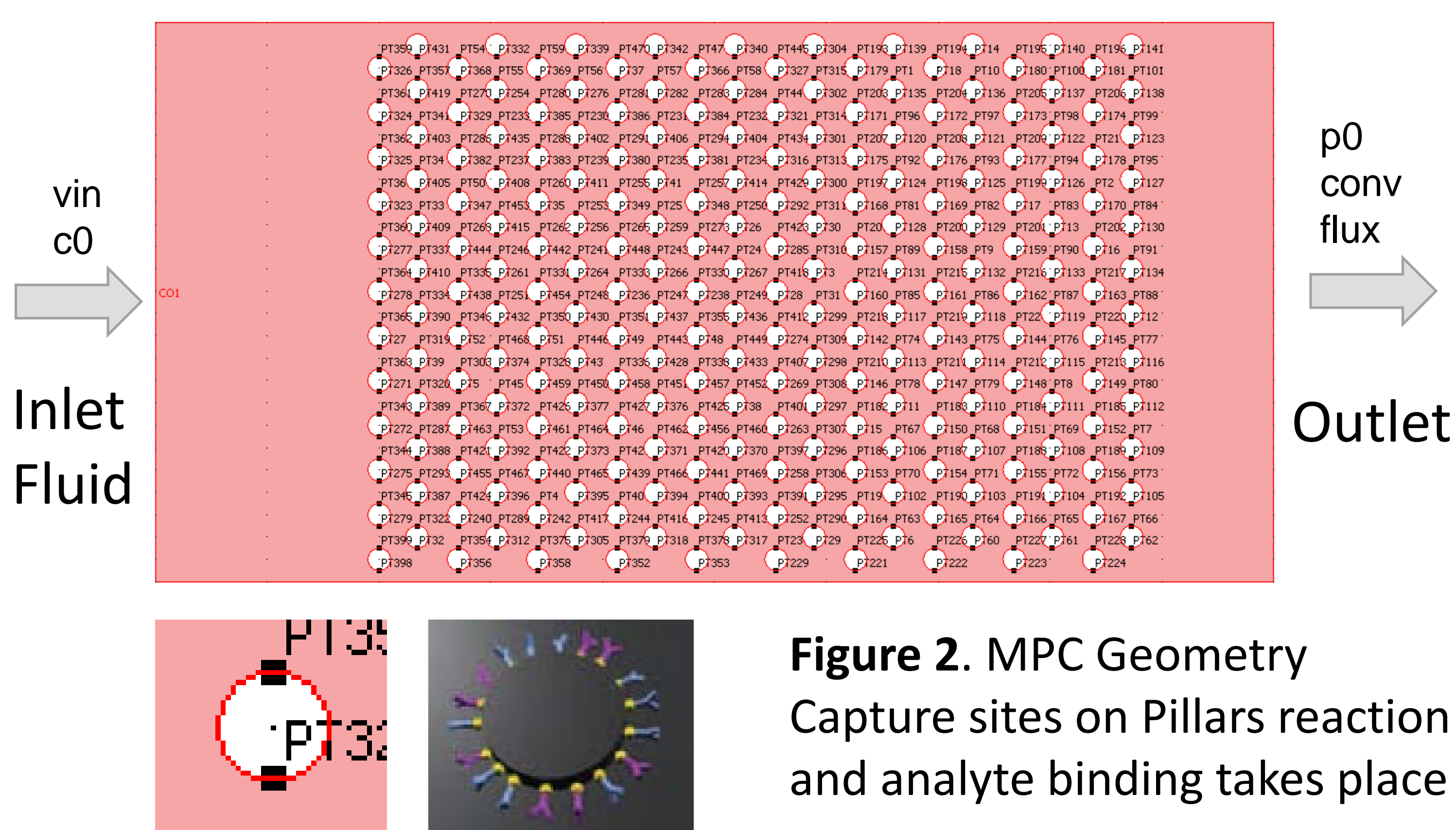


Figure 2. MPC Geometry
Capture sites on Pillars reaction and analyte binding takes place

Results: Analyte capture on three different pillar sizes: 2um, 4um and 10um (Fig.3). In the same microchannel geometry with varied only the pillar size, capture efficiency, defined as the number of analyte molecules remaining in solution after the sample passes the array divided by the initial number of analyte molecules, varies by 10 orders of magnitude. Fig. 4 shows capture efficiency dependence on initial concentration and saturation conditions.

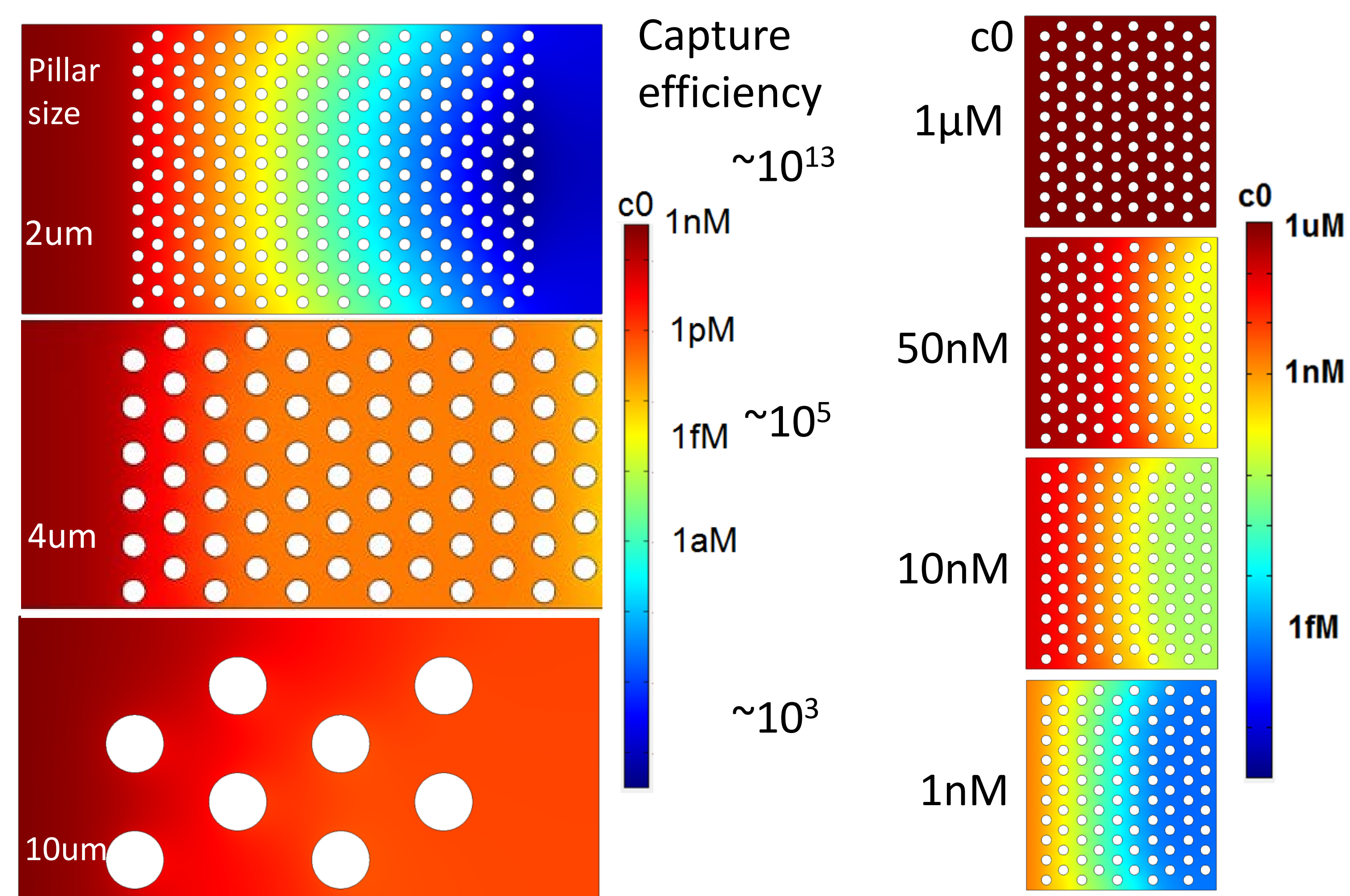


Figure 3. MPC capture
 $c_0=1\text{nM}$ size dependence

Figure 4. MPC capture
2um pillars, c_0 dependence

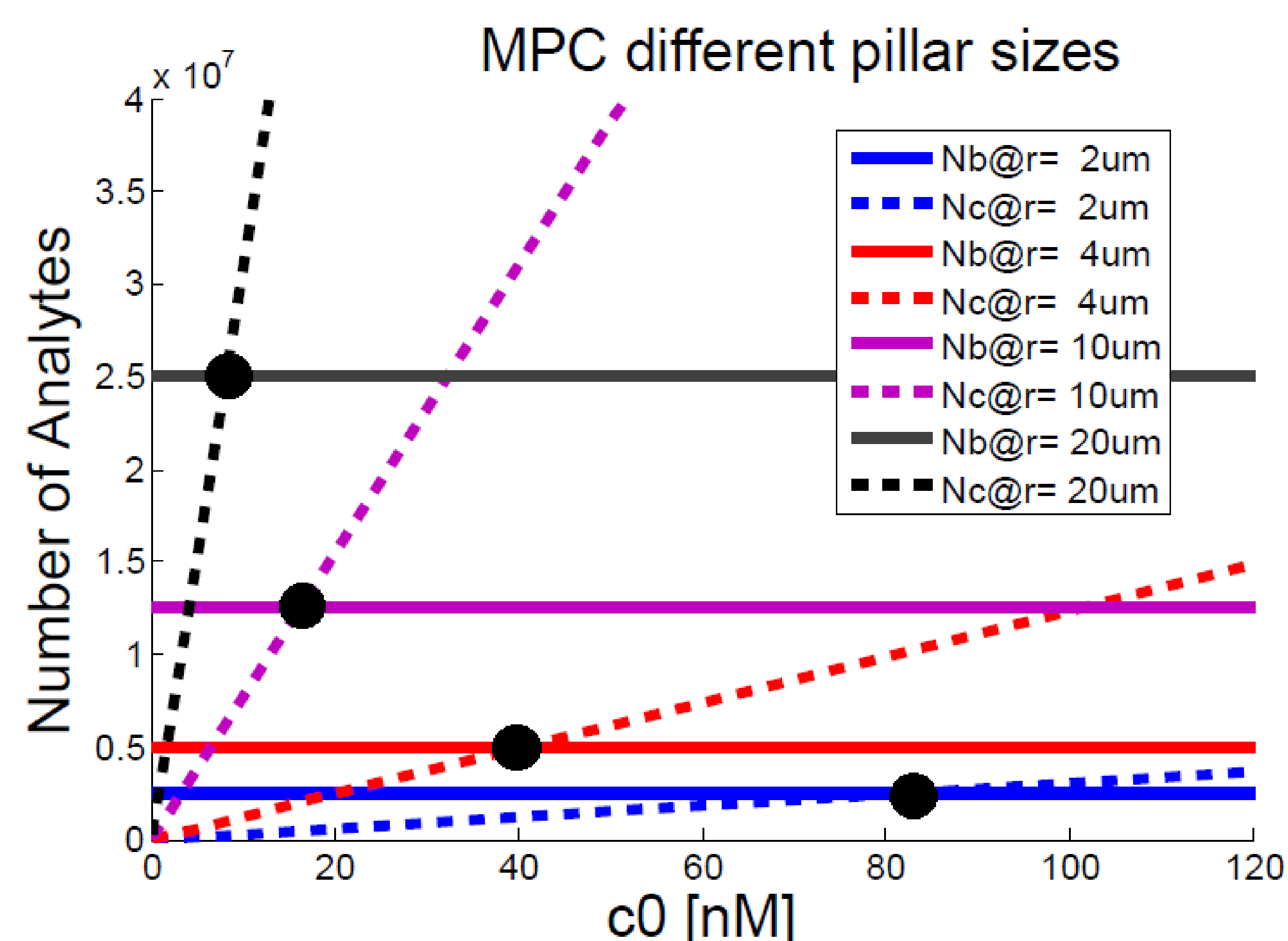


Figure 5. Analyte in fluid for different pillar sizes

Conclusions: Here we report that depending on the choice of pillar size and density the analyte capture efficiency can vary from 10% to more than 99.999%. The choice of Micro-Purification Chip geometry for sample processing has a significant influence on the accuracy of analyte concentration measurements

References:

Stern et. al, 2010, Henderson et. al, 2006
Toner et. al, 2007, Hwang et. al, 2011

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