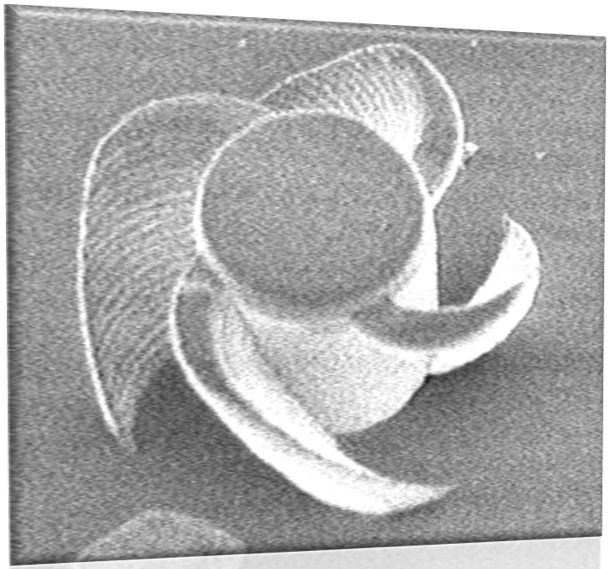
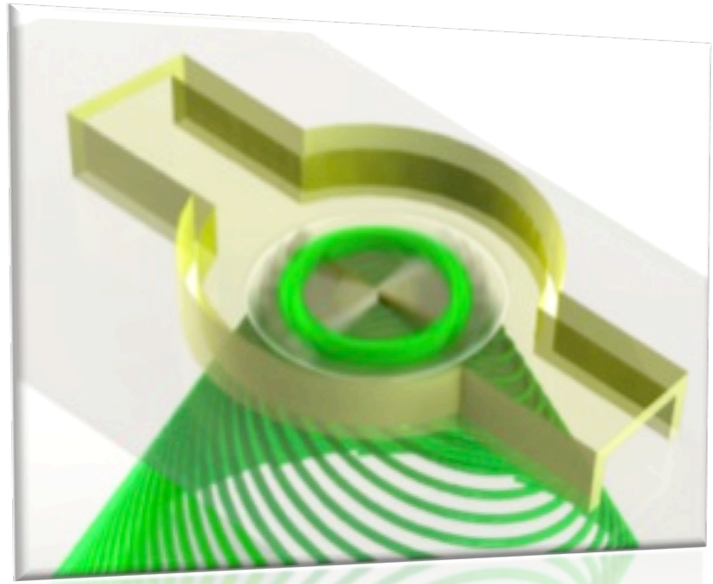
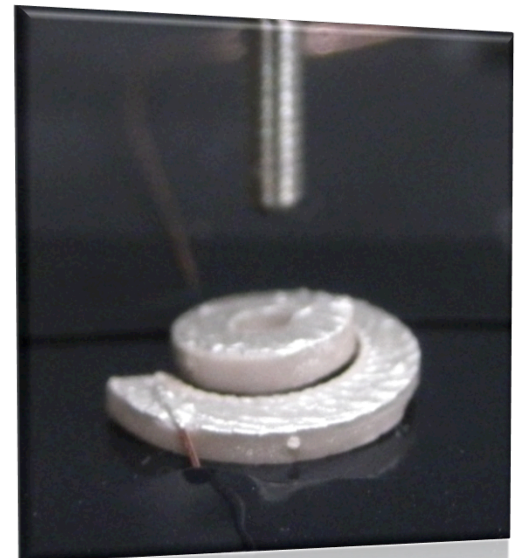
COMSOLを用いたマイクロ・ナノマシンの設計・開発





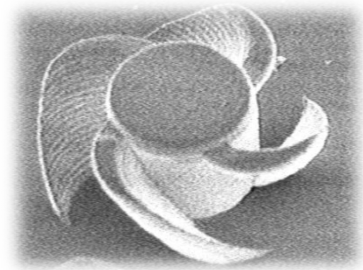


横浜国立大学大学院　工学研究院
丸尾 昭二

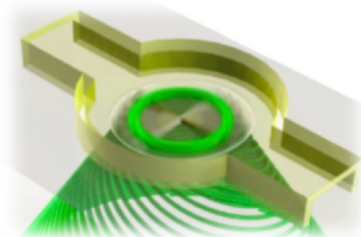
COMSOLカンファレンス東京　2013.12.6

Outline

1. Introduction (3D printing & microstereolithography)



2. Laser-driven micromachines produced by two-photon microfabrication

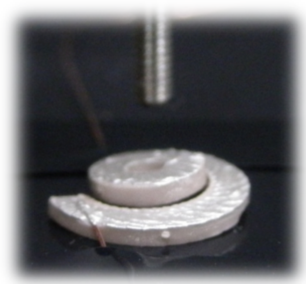


3. Nanowire manipulation for nanofluidic application

4. Three-dimensional molding based on microstereolithography

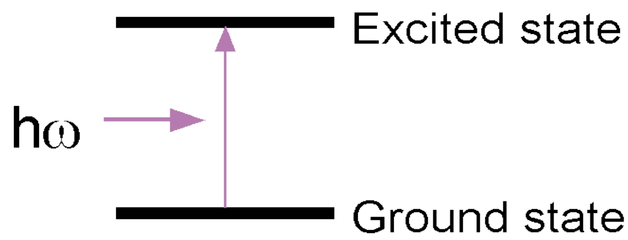
5. Vibration energy harvester using a spiral piezoelectric element

6. Conclusions



Two-photon microfabrication

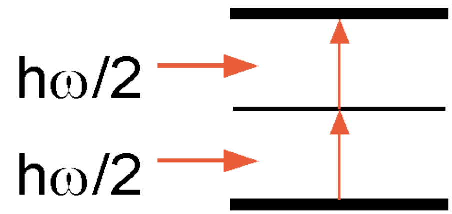
Single-photon absorption



λ: 350 nm

CW laser beam

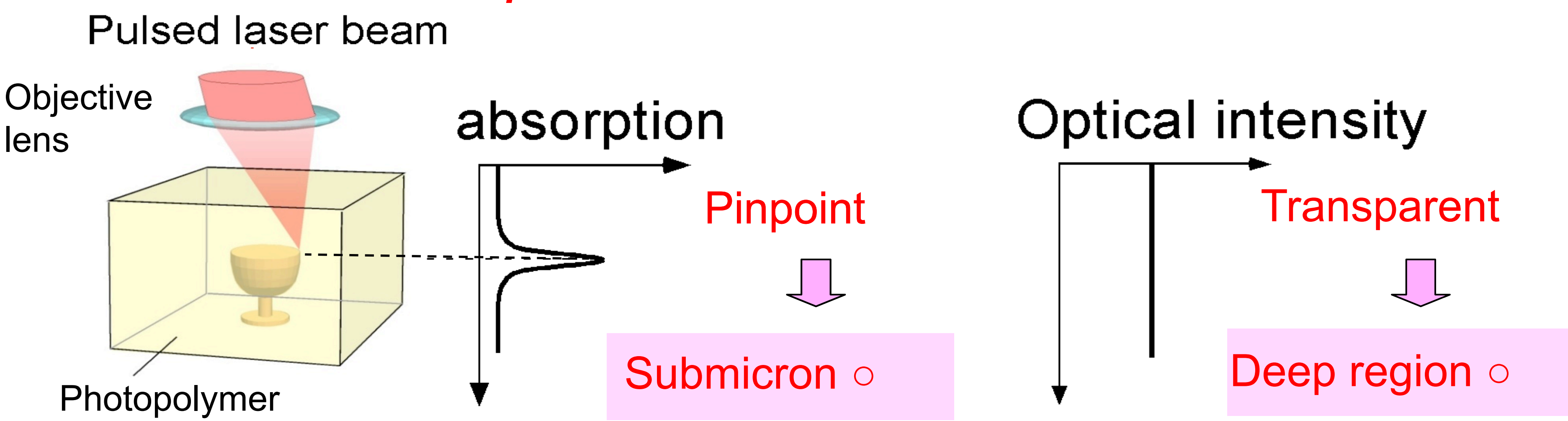
Two-photon absorption



λ: 700 nm

Pulsed laser beam

Two-photon microfabrication

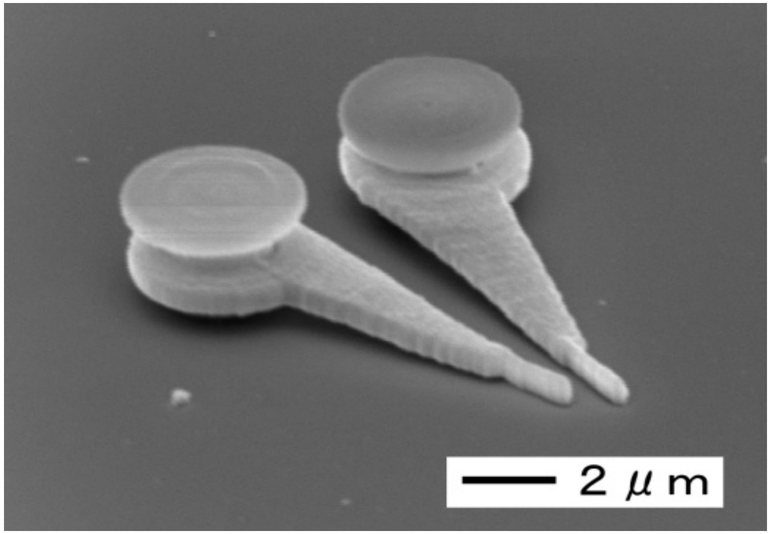


Absorption ∝ (Light intensity)^2

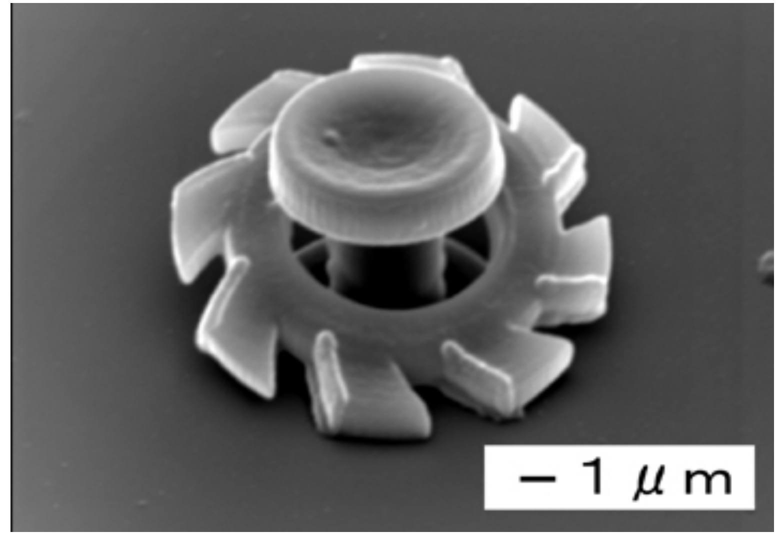
S. Maruo, O. Nakamura, S. Kawata, Opt.Lett. **22**, 132 (1997)

Times Cited: 984

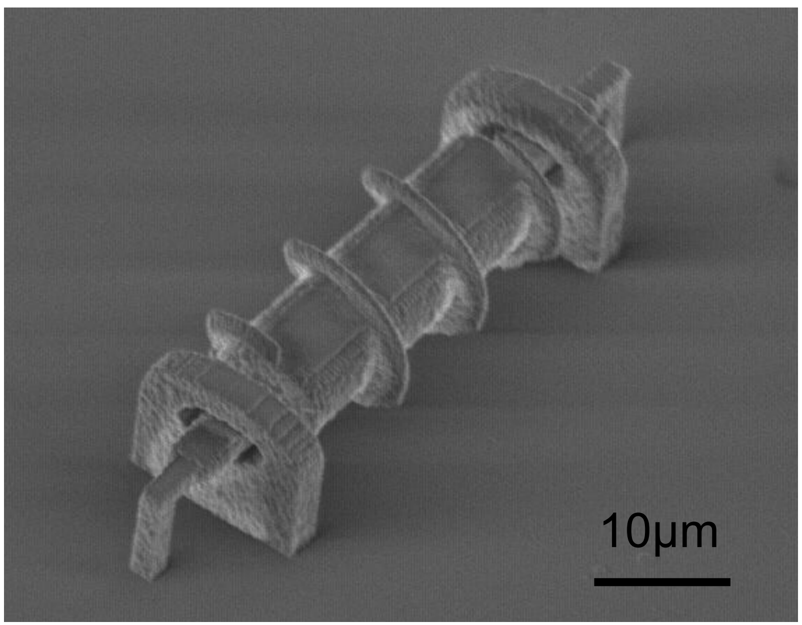
3D movable micromachines

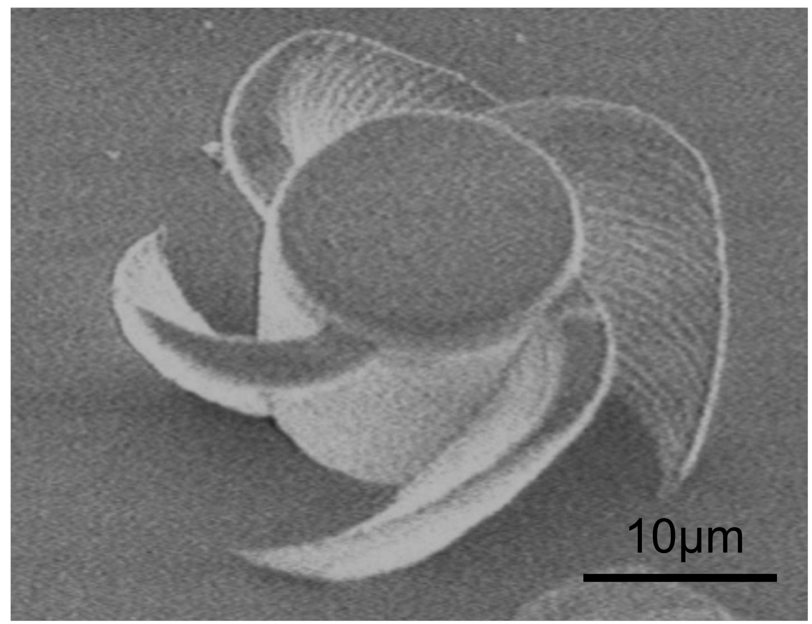


Appl. Phys. Lett. **82**, 133 (2003).



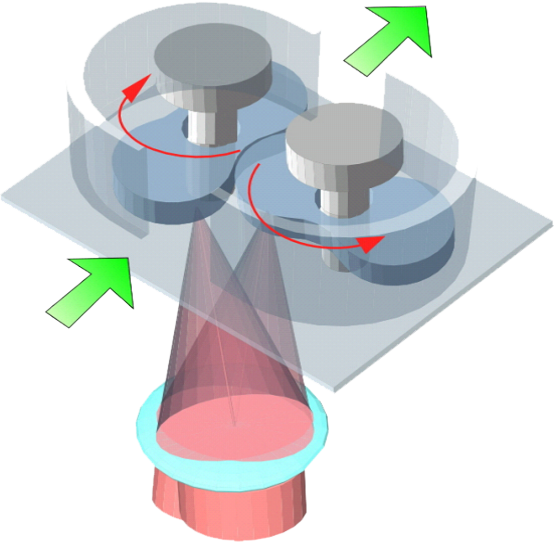
J MEMS **12**, 533 (2003).

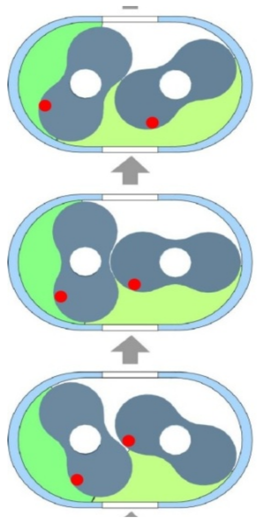


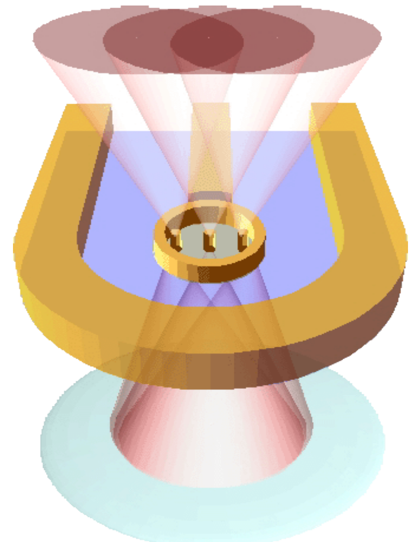


Optically driven micropumps

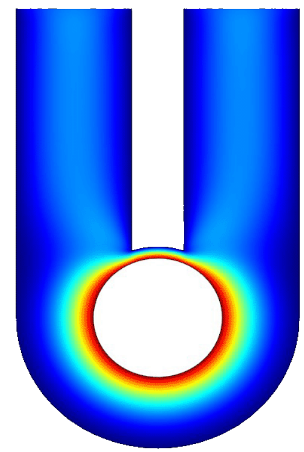
Lobed type

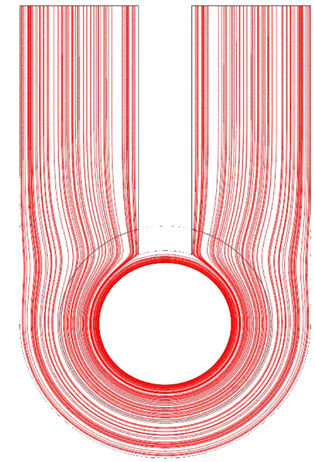




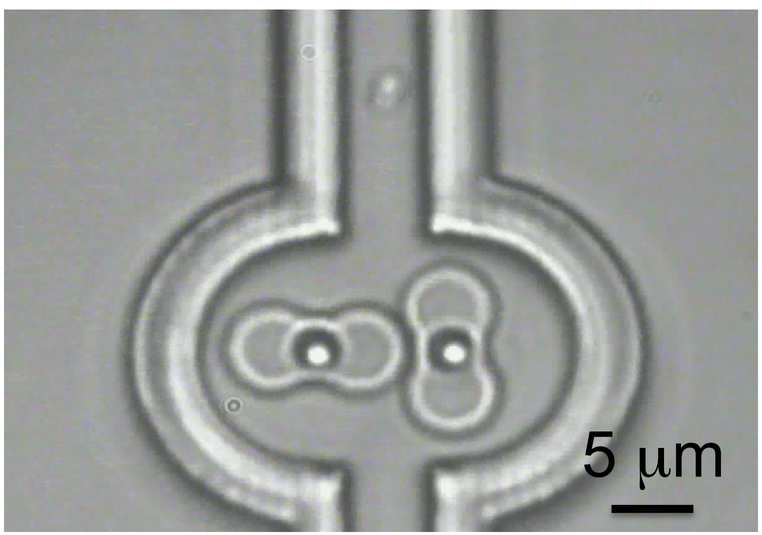


Viscous type

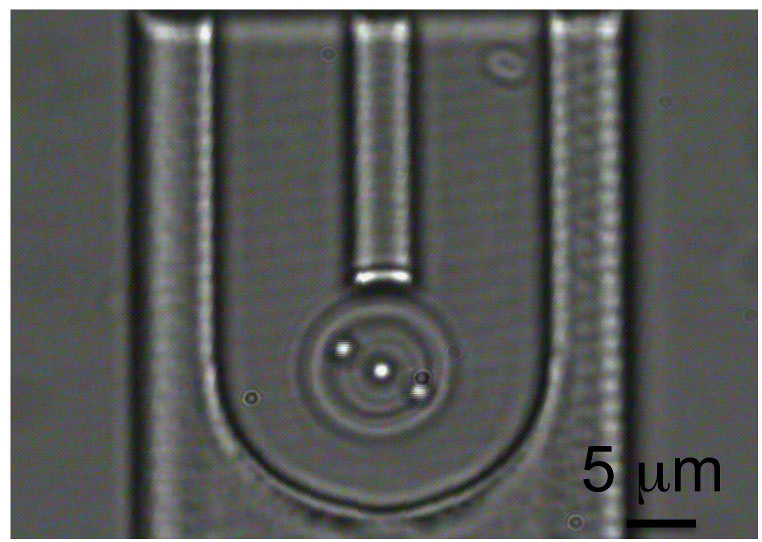




Time-shared laser scanning



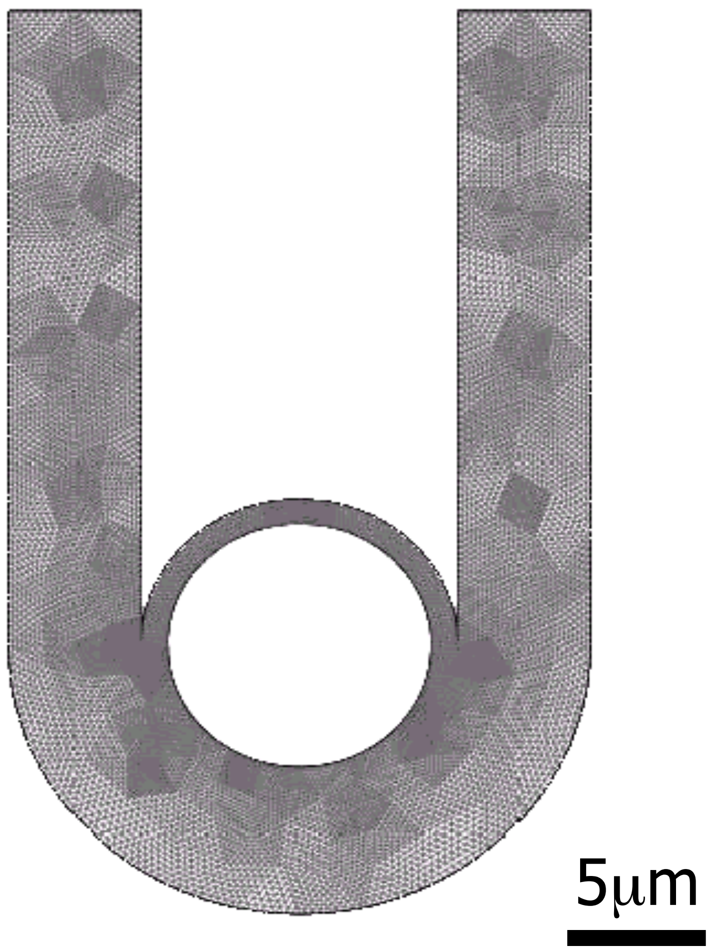
APL **89**, 144101 (2006).



APL**91**, 084101 (2007).

Microflow analysis using FEM

Model



COMSOL ver.3.2

- Same size of the prototype of the micropump
- 15000 mesh

Parameters

- Fluid: Glycol ether ester

  Density:960[kg/m^3]

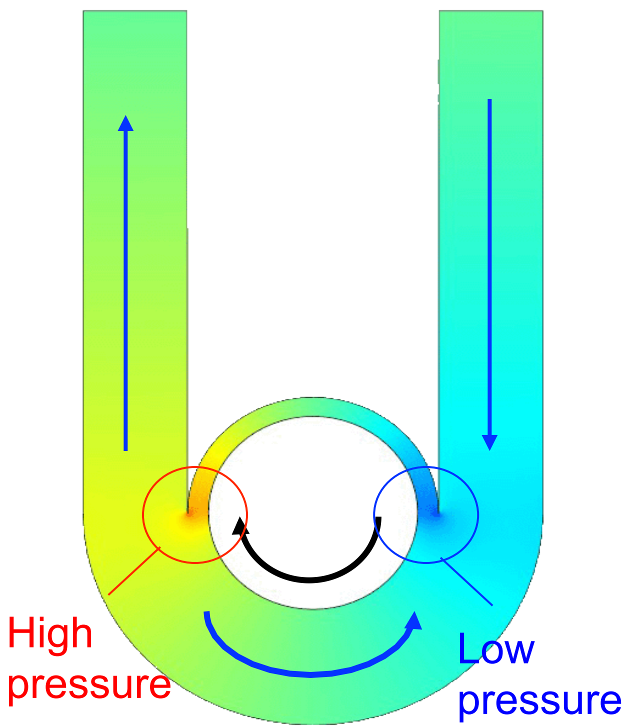
  Viscousity:1.92×10^{-3}[Pa・s]

Boundary conditions

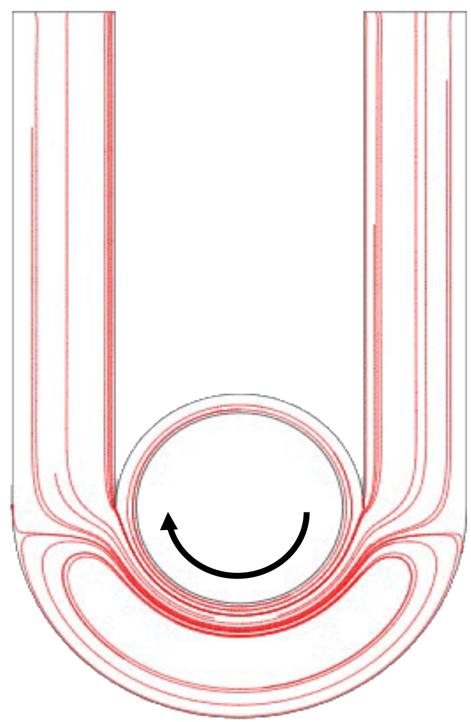
- No-load at inlet and outlet
- No slip at the surface of rotor & channel
- Flow velocity is applied at the surface of the rotor

Microflow analysis of the first prototype of the viscous micropump

Pressure field



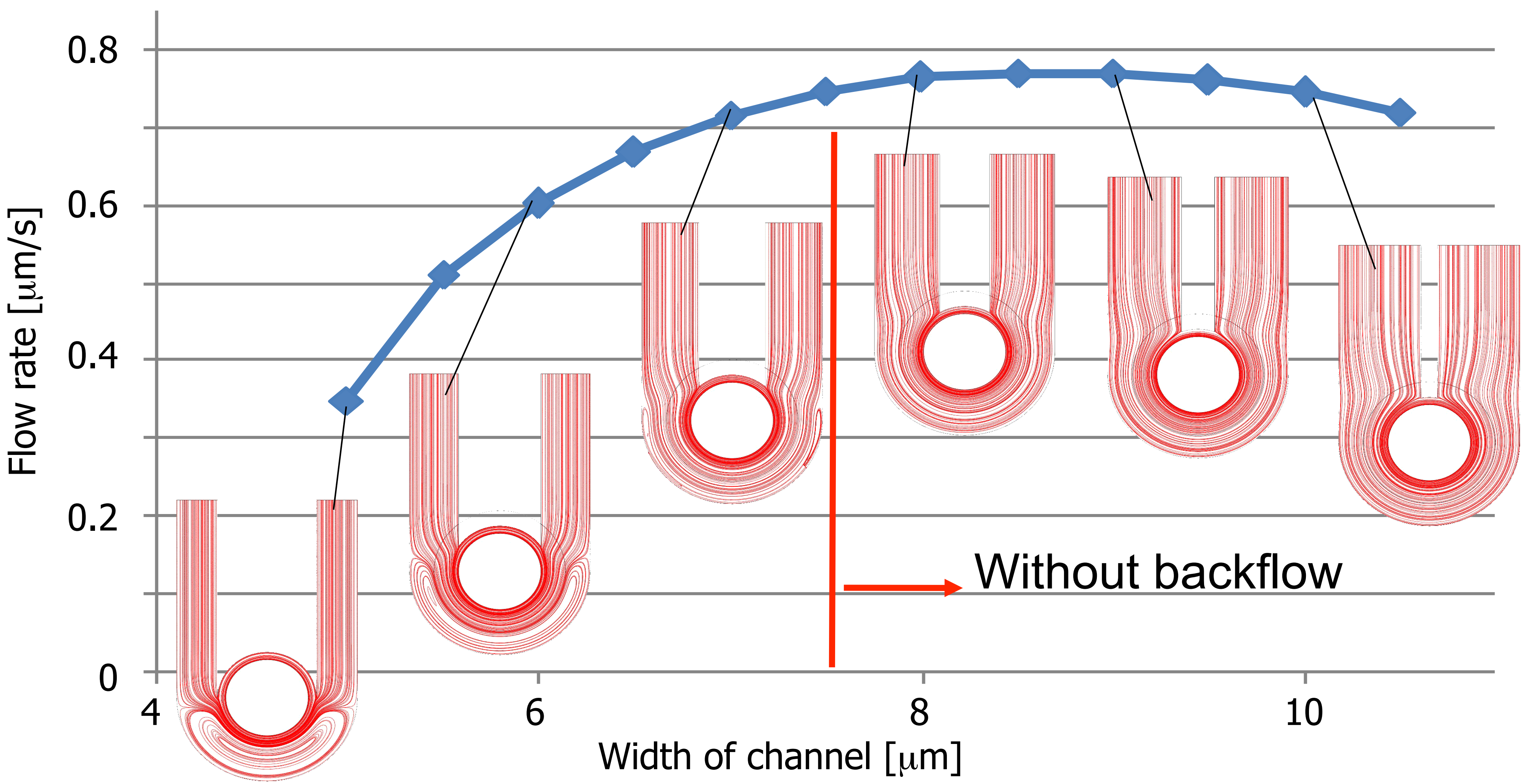
Stream line



Rotation of a disk generates pressure gradient.

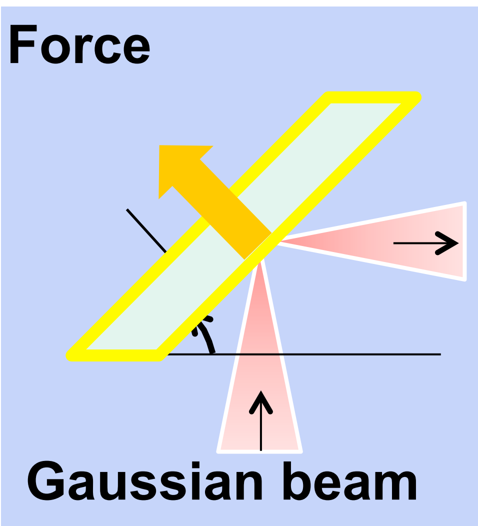
Backpressure causes backflow around the rotor.

Channel width dependence

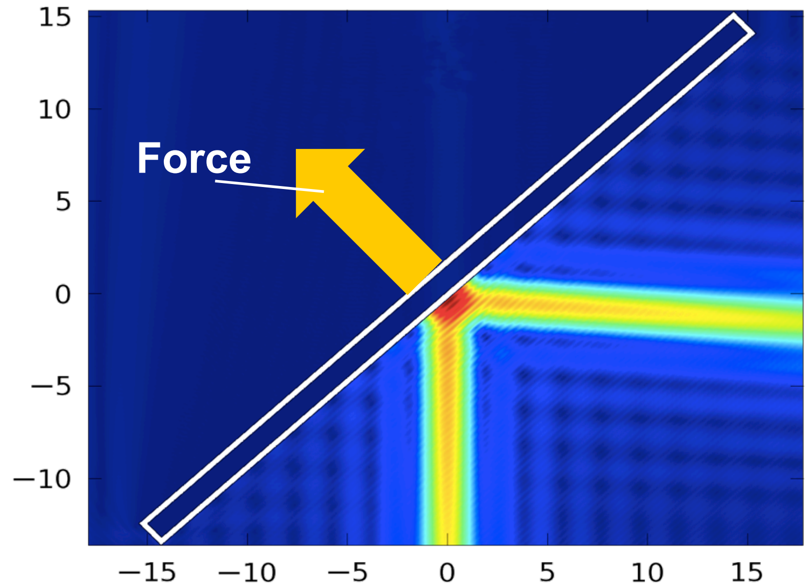


Analysis of optical force exerted on a tilted blade

Cross section of a blade



2-D electric field around a tilted blade

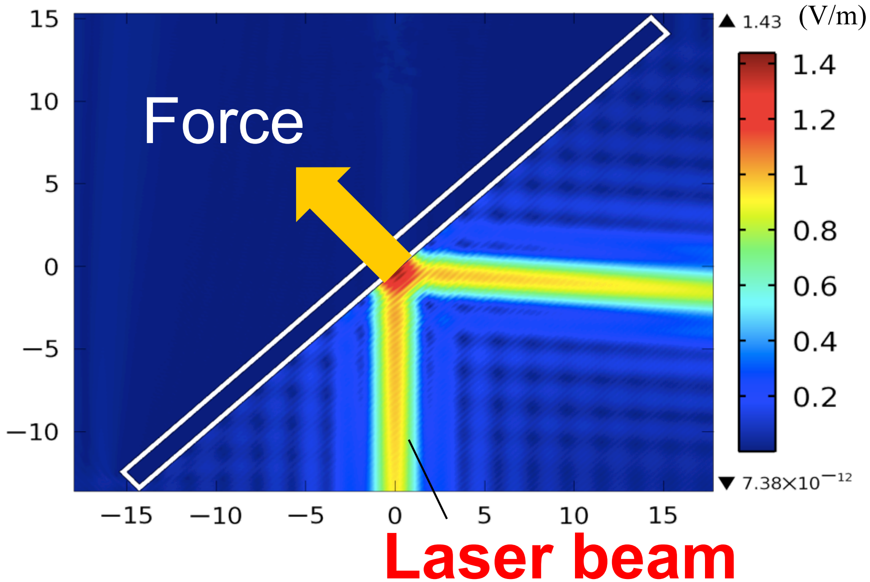


Analysis condition

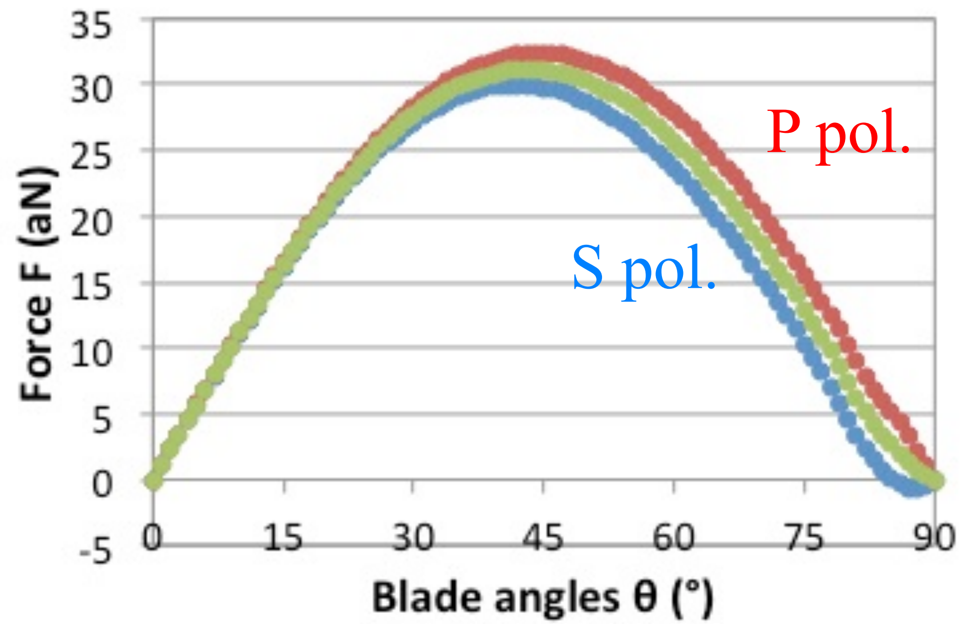
- λ: 633 nm
- NA: 0.4
- Refractive index :
  Cu n: 0.249 κ:3.41
- Surrounding liquid:
  Glycol Ether ester
- Finite element analysis:
  COMSOL Multiphysics
- The tilted angle : 43°

Blade angle dependence of lateral optical force

Optical intensity distribution

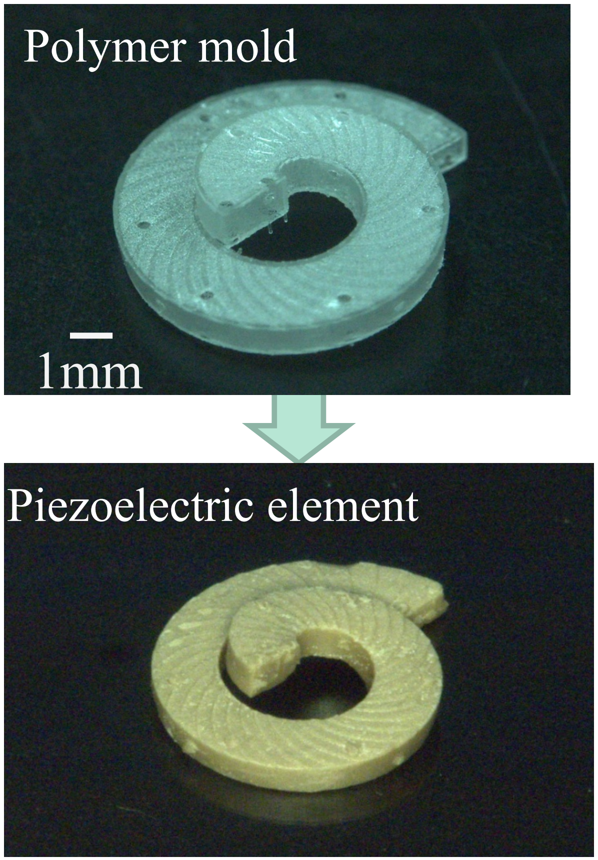


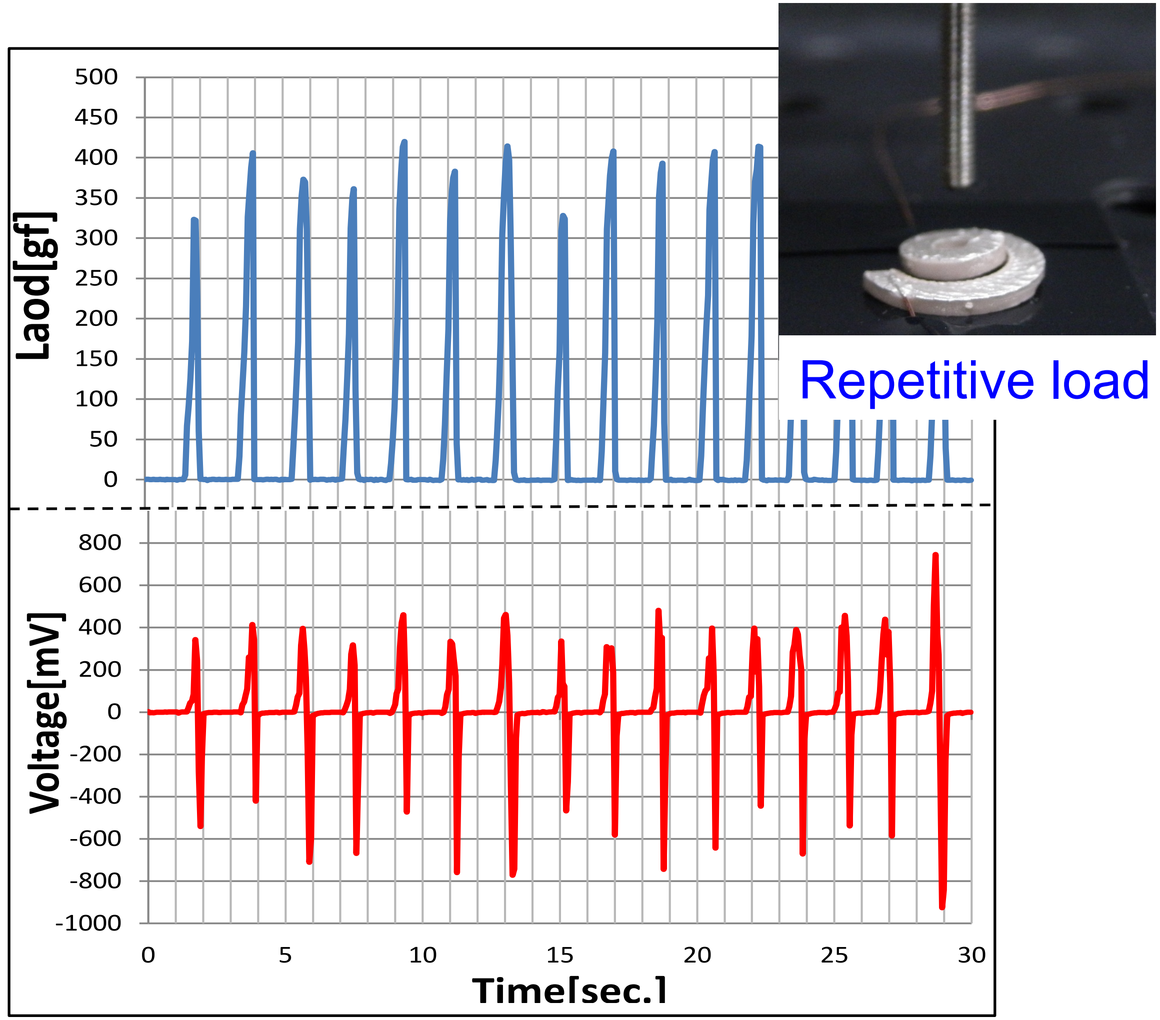
Blade angle dependence



Maximum lateral force was obtained at a 43 degrees angle.

Spiral piezoelectric element produced by 3D ceramic molding





Sensors and Actuators A **200**, 31–36 (2013).

Conclusions

Development of optically driven microfluidic devices

• Laser scanning, asymmetric rotors, optical vortex

Optical manipulation of a single silver nanowire

• Rotation, translation, alignment of nanowires

Development of a piezoelectric energy harvester

•Stress analysis, Surface potential analysis, device design

Multiphysics analysis using COMSOL

Two-photon microfabrication & 3D molding techniques are promising technologies to produce functional 3D micro/nano devices