

ICRA 2002 Workshop

Manipulation Technologies of Micro-objects for BioMEMS

Nagoya University
Dept. of Micro System Engineering

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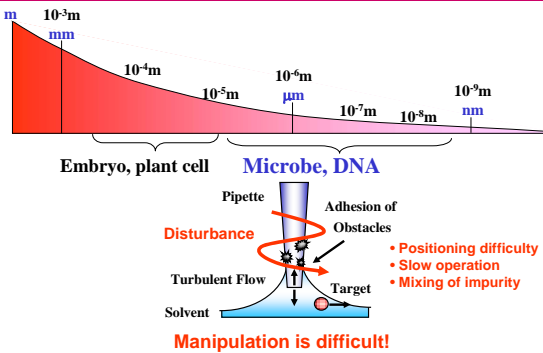
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Outline

1. Background of Manipulation Technologies
2. Classification of Manipulation for BioMEMS
3. Manipulation by Electrostatic Force
4. Manipulation by Laser Scanning
5. Manipulation by Laser Trap and Flow Control
6. Manipulation by Laser Trapped Micro Tools
7. Conclusions

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Manipulation of Micro Scale Objects



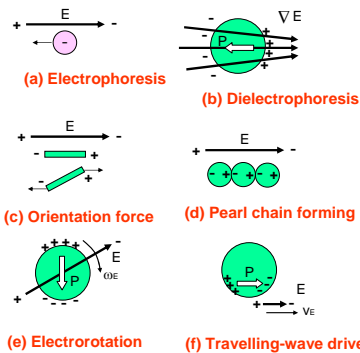
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Non-contact Manipulation Methods of Micro-object

Method	Force Action
1. Laser manipulator	Point
2. Ultrasonic	Multiple points
3. Pump	Line
4. Electrophoresis	Line
5. Dielectrophoresis	Space

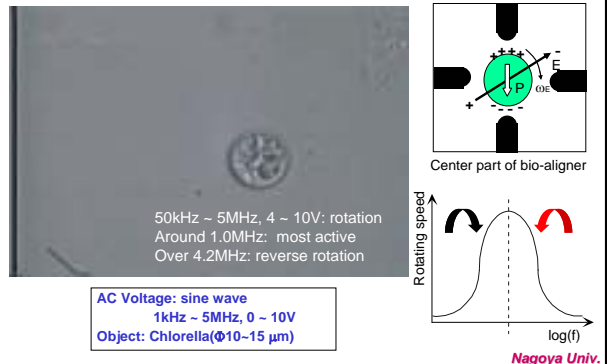
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Motion Control of a Fine Particle by Electrostatic Force



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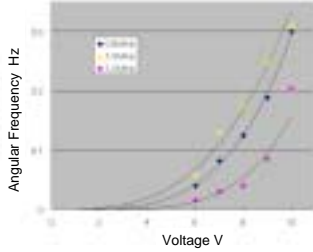
Experiment of Horizontal Rotation



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Measurement of Horizontal Rotation

- Object: Chlorella ($\Phi 10\text{--}15\ \mu\text{m}$)
- Most active around 1.0 MHz
- Proportional to E^2



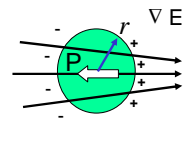
Generated torque:

$$\tau = 12\pi\epsilon_0\epsilon_s r^3 E^2 \frac{(\epsilon_s\sigma_p - \epsilon_p\sigma_s)(\omega / \omega_c)}{(\epsilon_p + 2\epsilon_s)(\sigma_p + 2\sigma_s)(1 + (\omega / \omega_c)^2)}$$

$$\omega_c = \frac{\sigma_p + 2\sigma_s}{\epsilon_0(\epsilon_p + 2\epsilon_s)}$$

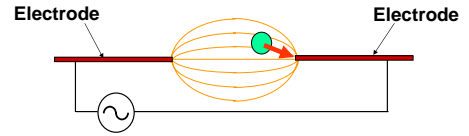
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Dielectrophoresis (DEP)



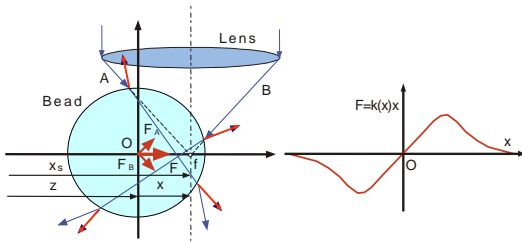
$$F_{DEP} = 2\pi r^3 \epsilon_s \text{Re}[K(\omega)] \nabla(E^2)$$

$$K(\omega) = \frac{\kappa_p - \kappa_s}{\kappa_p + 2\kappa_s} \begin{cases} \kappa_p = \epsilon_p - j\frac{\sigma_p}{\omega} \\ \kappa_s = \epsilon_s - j\frac{\sigma_s}{\omega} \end{cases}$$



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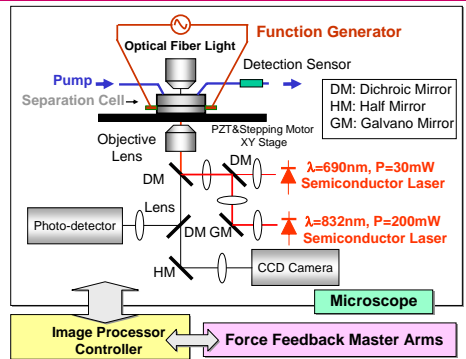
Laser Trap Model in Ray Optics Regime



Coordinate system Optical trapping force image

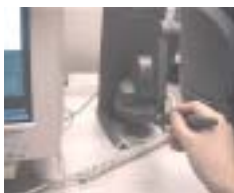
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Laser Manipulator High Speed Separation System

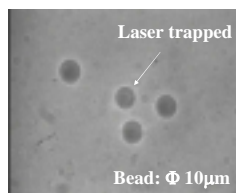


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Bilateral Laser Telemanipulation



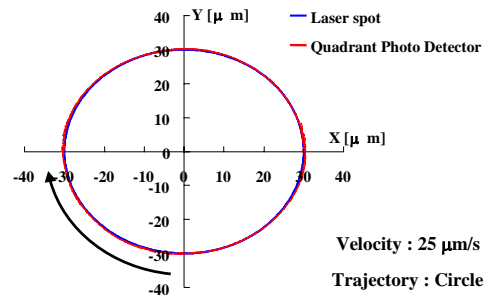
(a) Master manipulator (3DOF, Force feedback)



(b) Laser Manipulation
Bead: $\Phi 10\ \mu\text{m}$

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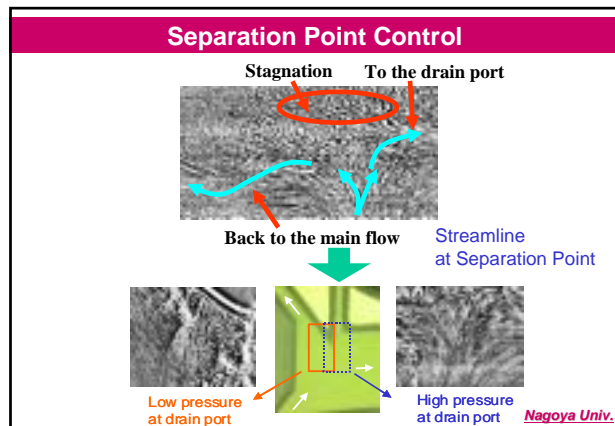
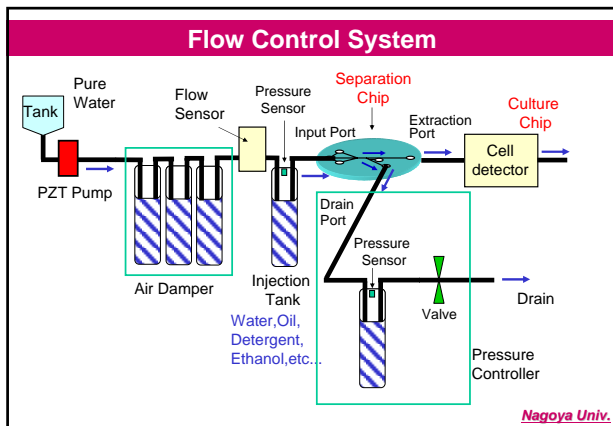
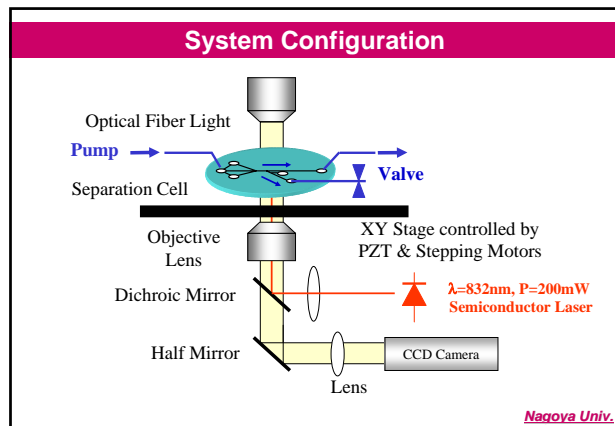
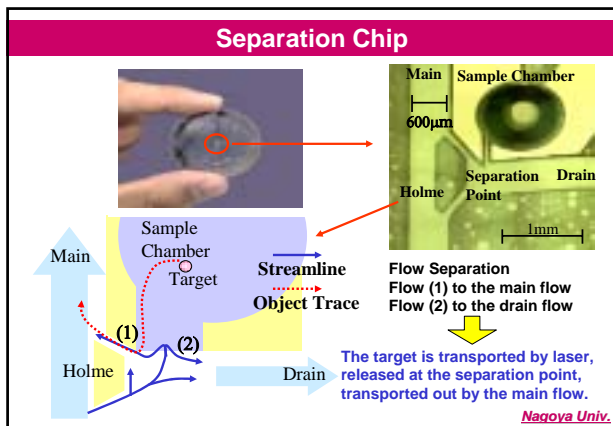
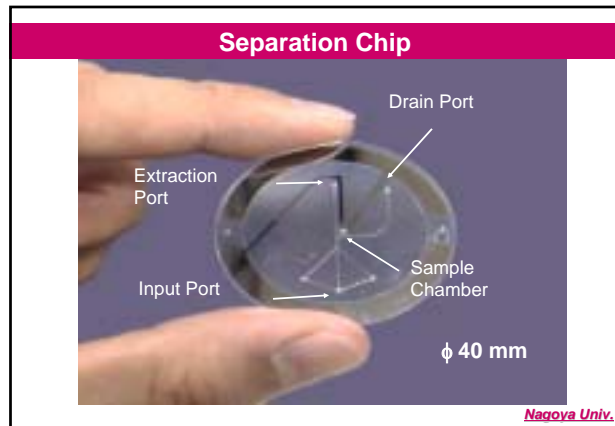
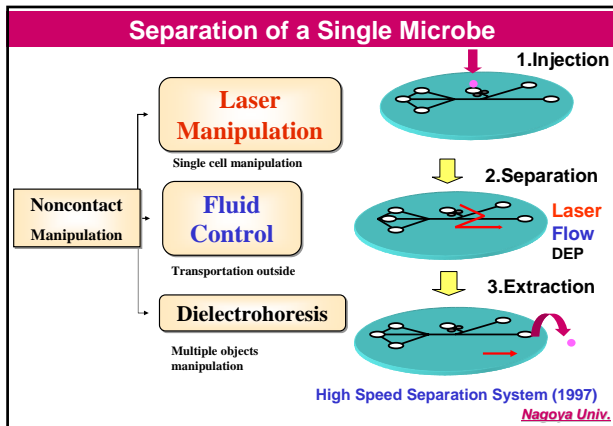
Automatic Transportation with Quadrant Photo Detector



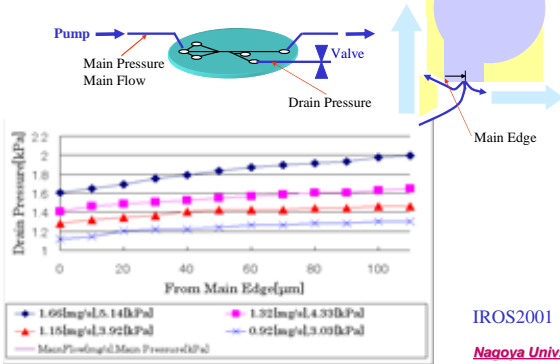
Velocity : $25\ \mu\text{m/s}$

Trajectory : Circle

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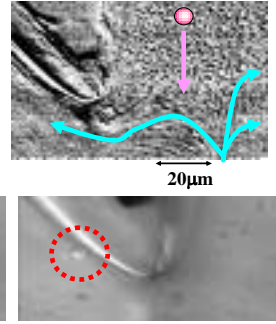


Separation Point Control

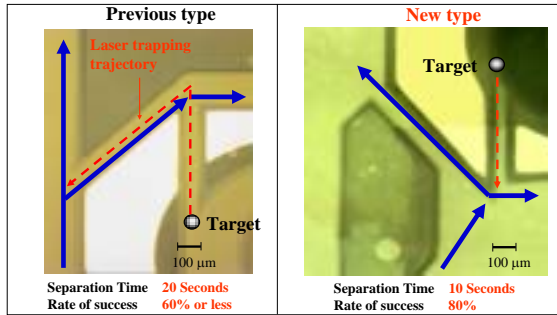


Separation Experiment

1. Separation point was adjusted.
2. Target was transported near the stagnation point.
3. Target was transported to the main flow.



Comparison

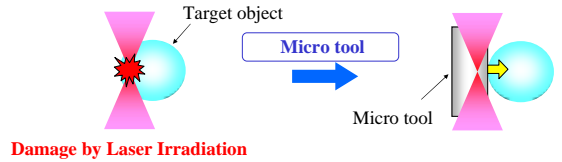


Points of Improvement

1. Transportation distance is reduced 1/2.
2. No need to transport against the flow.

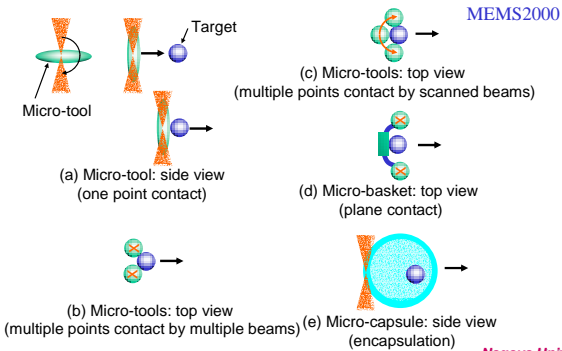
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Problem of Laser Manipulation



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Indirect Laser Manipulation with Micro Tools



Design of Micro Tools

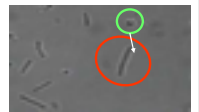
1. Microbe: Dead Bacillus
2. Artificial micro object

Figure?

Function?

How to inject?

- Low Cost
- No disturbance
- Easy



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Self-alignment of Micro Tools by the Liquid Bridge Force

X 2500



Before Desiccation



After Desiccation

Micro tools ($\Phi 10 \mu\text{m}$) are aligned autonomously. *Nagoya Univ.*

Conclusions

1. Non-contact manipulation is classified briefly and some examples are introduced.
2. Non-contact manipulation is suitable for tasks inside the chip.
3. Integration of different methods can improve performance.
4. Sensing method is important for automation.
5. System integration is necessary.
6. Coordination of the system should be done based on purpose.

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