Report on Visit to Ruhr University Bochum by International Training Program

From October 1st to November 29th 2010

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Hori・SekineLab.
Nagoya University

Ruhr University Bochum

Bochum

Coal mine city until
19 century

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Auto mobile industry
Financial industry

Ruhr University Bochum(RUB)

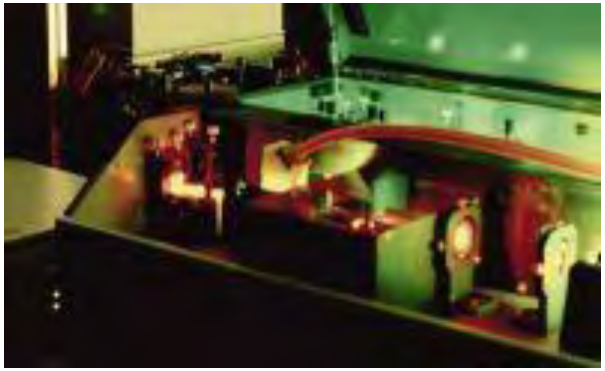
State university
20 departments
34000 students
5000 staff members

Research group of Prof. Czarnetzki

Physics department
Center for Plasma Science and Technology (CPST)

Basic research of plasma
- Optical diagnostics
  - Optical emission spectroscopy
  - Laser induced fluorescence
  - Absorption spectroscopy
  - Thomson scattering

Prof. Czarnetzki

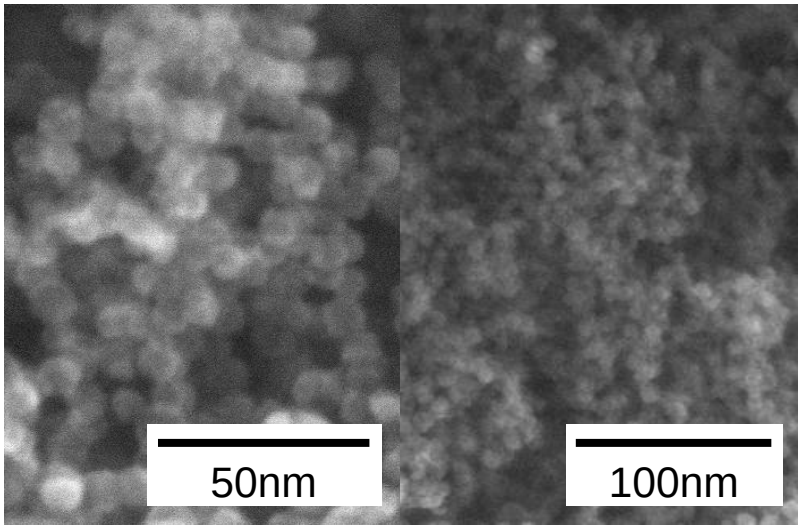


Research theme at RUB

Nano particle composite films

- Light emitting devices
- Sensors
- Solar cells

The properities depend on the size of nano particles and their contained amount.



SEM image of silicon nano particles

Plasma enhanced chemical vapor deposition is one of the fabrication method.

Controlling particles in plasma is required.

My research theme at RUB

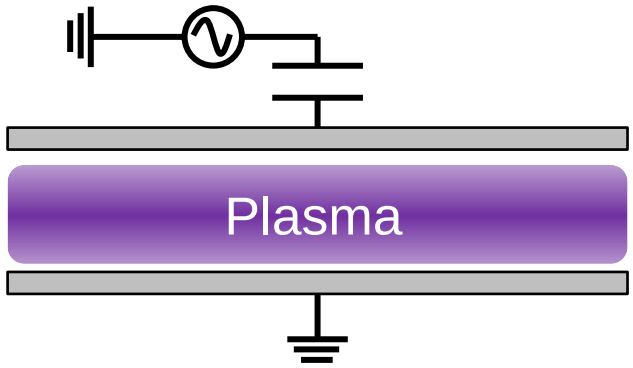
Controlling transport of nano particles using Electrical asymmetry effect (EAE)

Electrical asymmetry effect

Brian G Heil *et al.* J. Phys. D: Appl. Phys. 41(2008) 165202

Applied voltage:

$$\tilde{\phi} = \frac{1}{2}\phi_0\left[cos\left(2\pi ft + \theta\right) + cos\left(4\pi ft\right)\right]$$



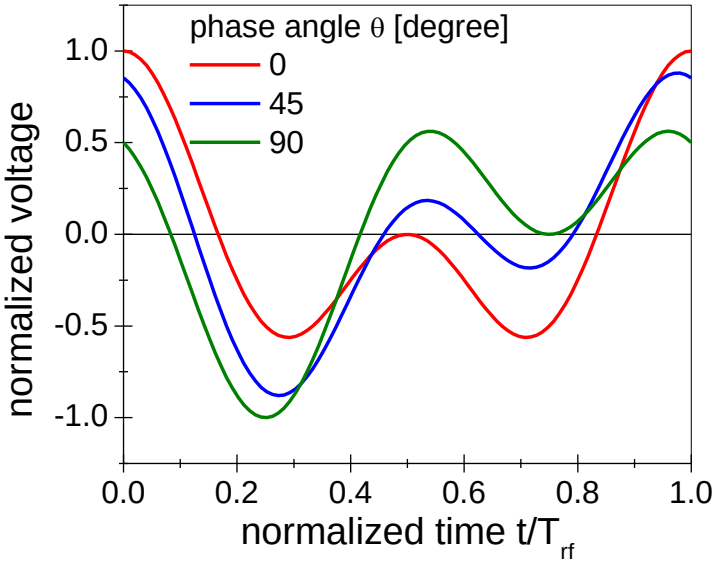
DC self bias:

$$\eta = -\frac{\tilde{\phi}_{m1} + \varepsilon\tilde{\phi}_{m2}}{1+\varepsilon}$$

Maximum voltage: $\tilde{\phi}_{m1}$

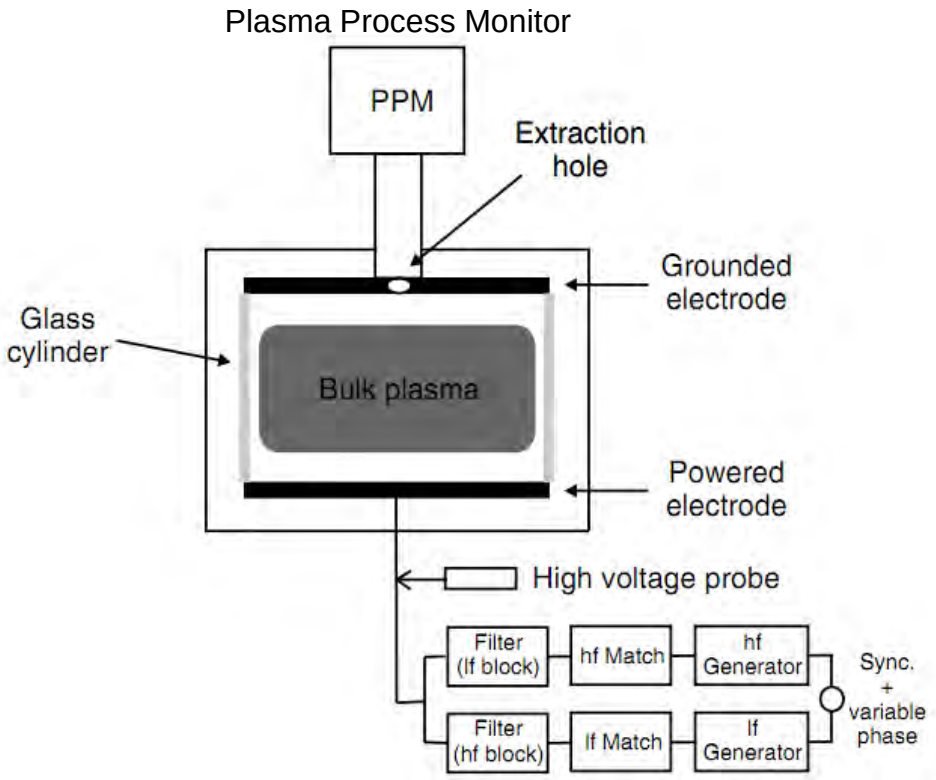
Minimum voltage: $\tilde{\phi}_{m2}$

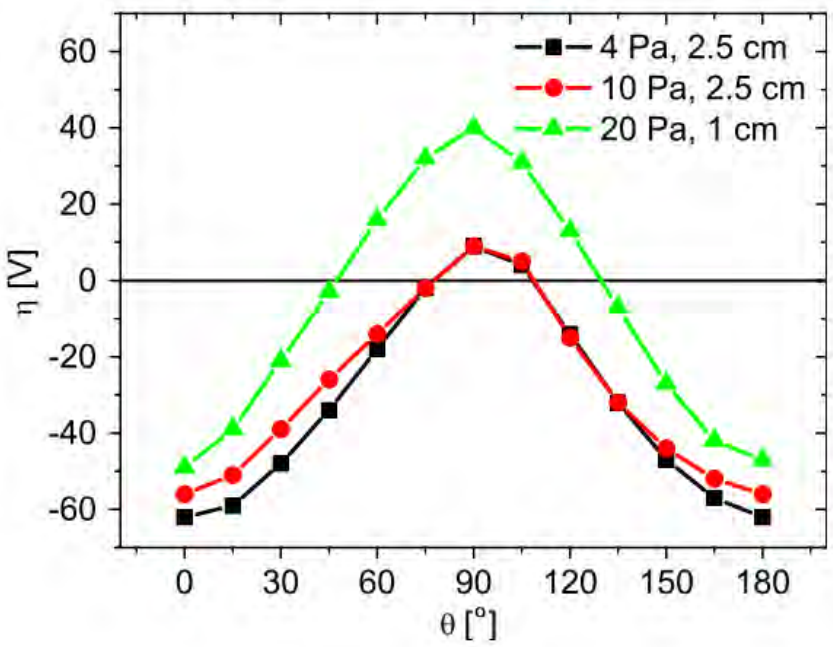
Symmetry parameter: ε



Experimental result of EAE

J. Schulze, E. Schungel and U. Czarnetzki J. Phys. D: Appl. Phys. 42 (2009) 092005





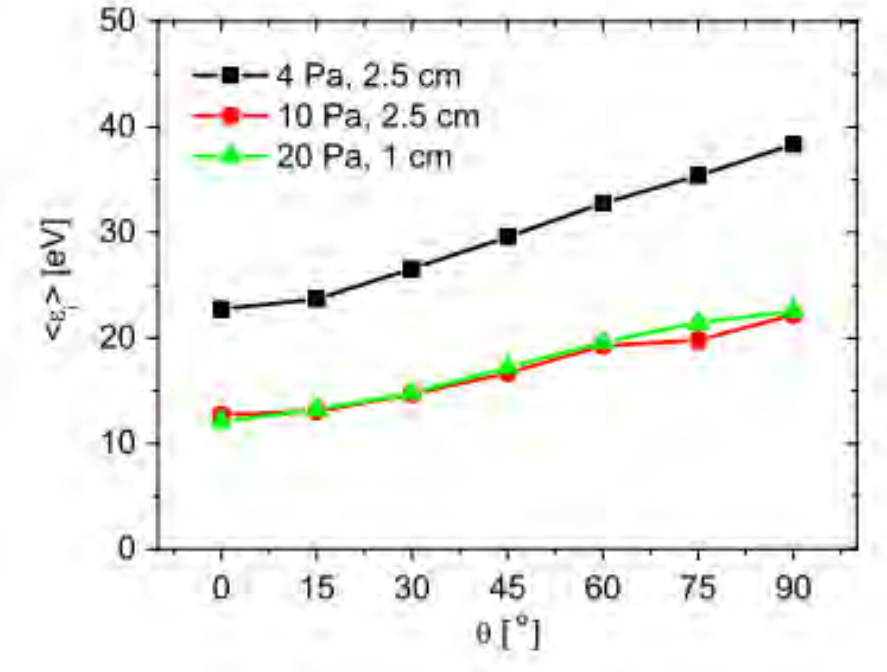
DC self bias as a function of θ

lf(13.56 MHz): 76 V
Pressure: 4-20 Pa

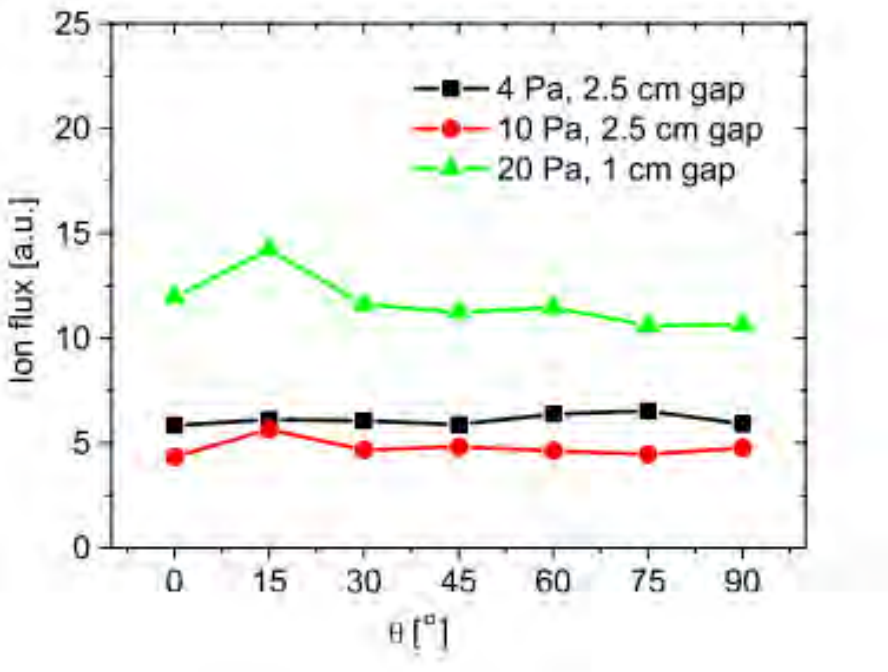
hf(27.12 MHz): 76 V
Electrode gap: 1-2.5 cm

Experimental result of EAE

J. Schulze, E. Schungel and U. Czarnetzki J. Phys. D: Appl. Phys. 42 (2009) 092005



Mean energy of ions hitting the grounded electrode



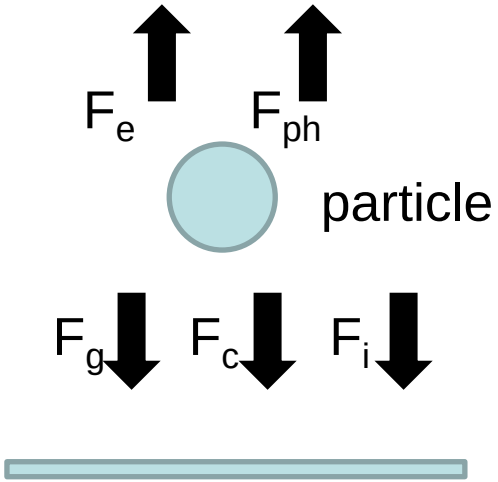
Ion fluxes at the grounded electrode as a function of θ

Ion energy and flux can be separately controlled.

Controlling transport of particles

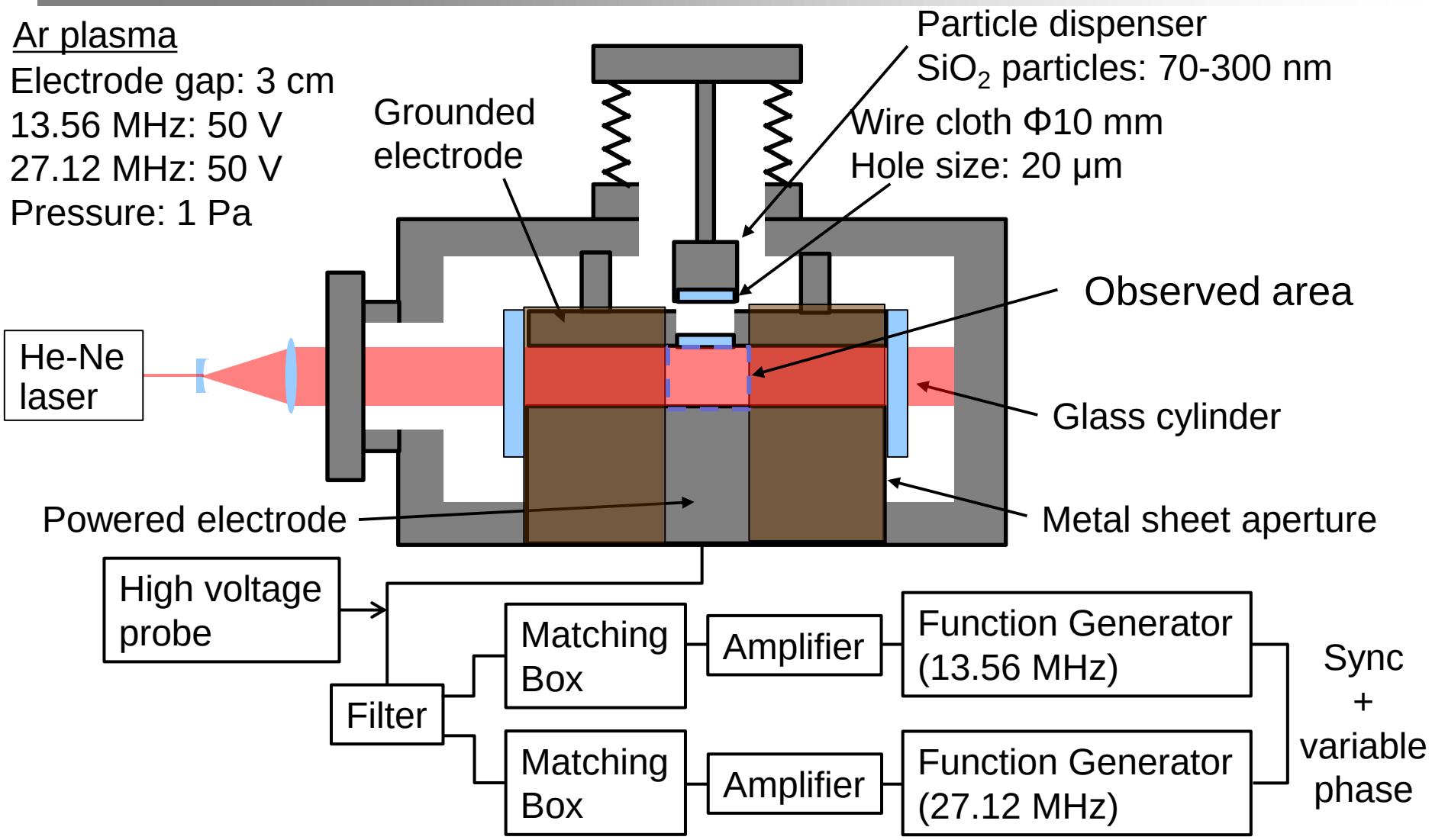
Forces exerted on particles

- Ion drag force
- Electrostatic force
- Coulomb repulsive force
- Thermophoretic force
- Gas viscous force
- Gravity



EAE can affect → Controlling transport of particles using EAE

Experimental setup

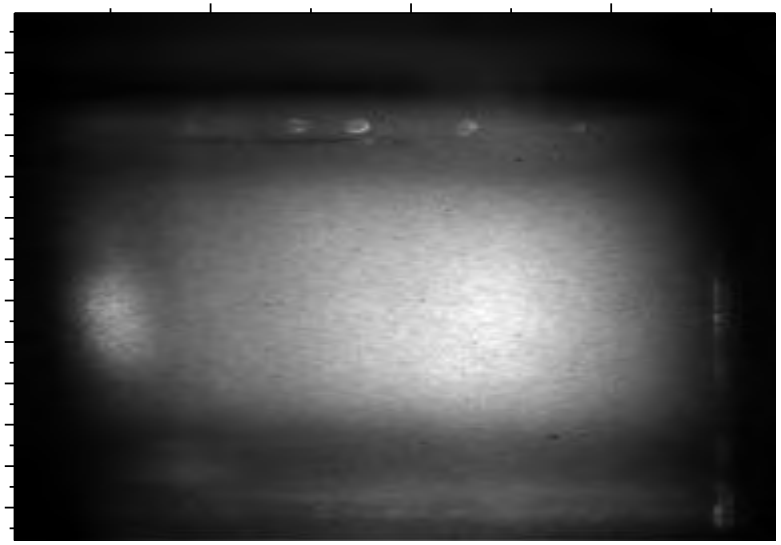


Laser light scattering system

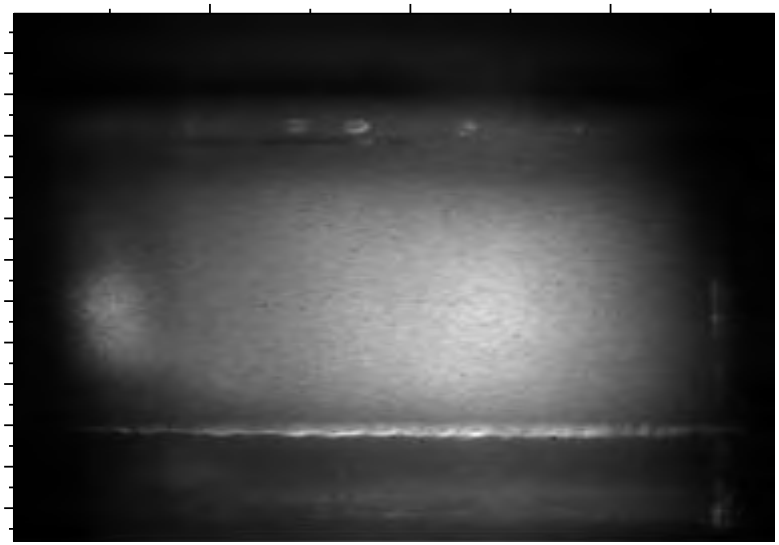
Sheet beam of He-Ne laser: 632 nm, 15 mW, 3 cm in height, 1 mm in width

ICCD camera

Observation of particles in Ar Plasma



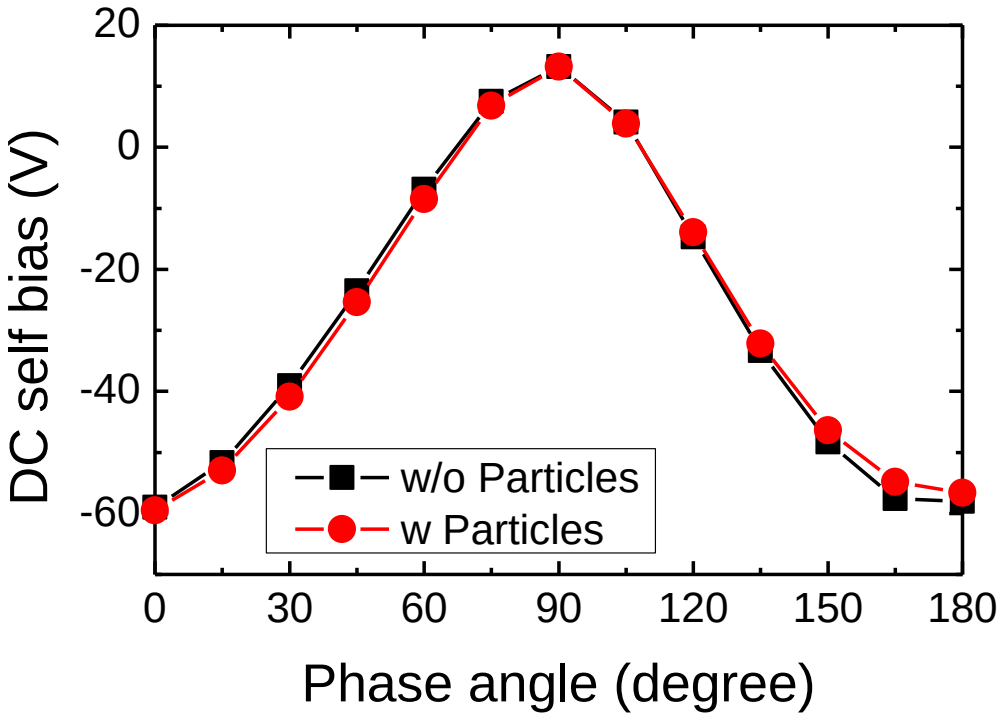
Plasma without particles
with reflections of laser light



Plasma with particles
illuminated by a laser

Particles could be observed.
However, they were bigger particles(several μm) than induced particles(70-300 nm).
Particles aggregated.

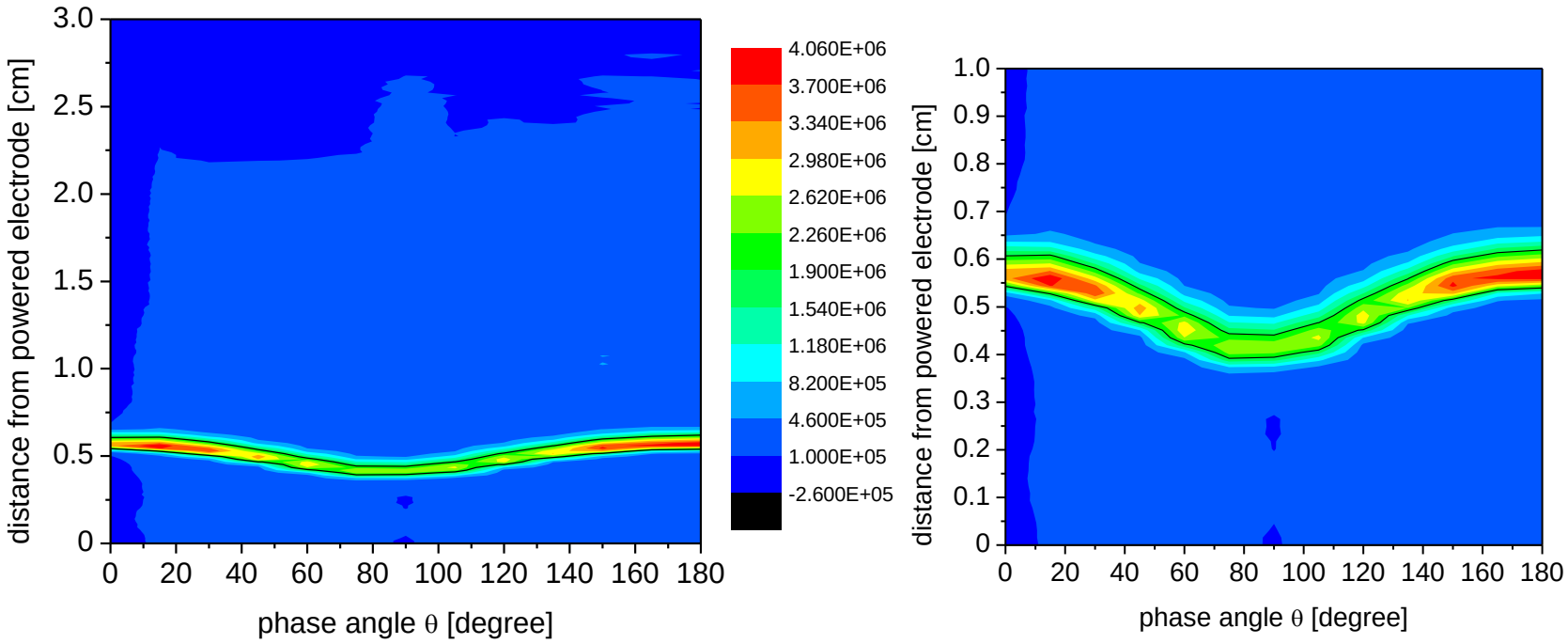
Checking DC self bias with particles



DC self bias as a function of θ

DC self bias could be controlled with particles.

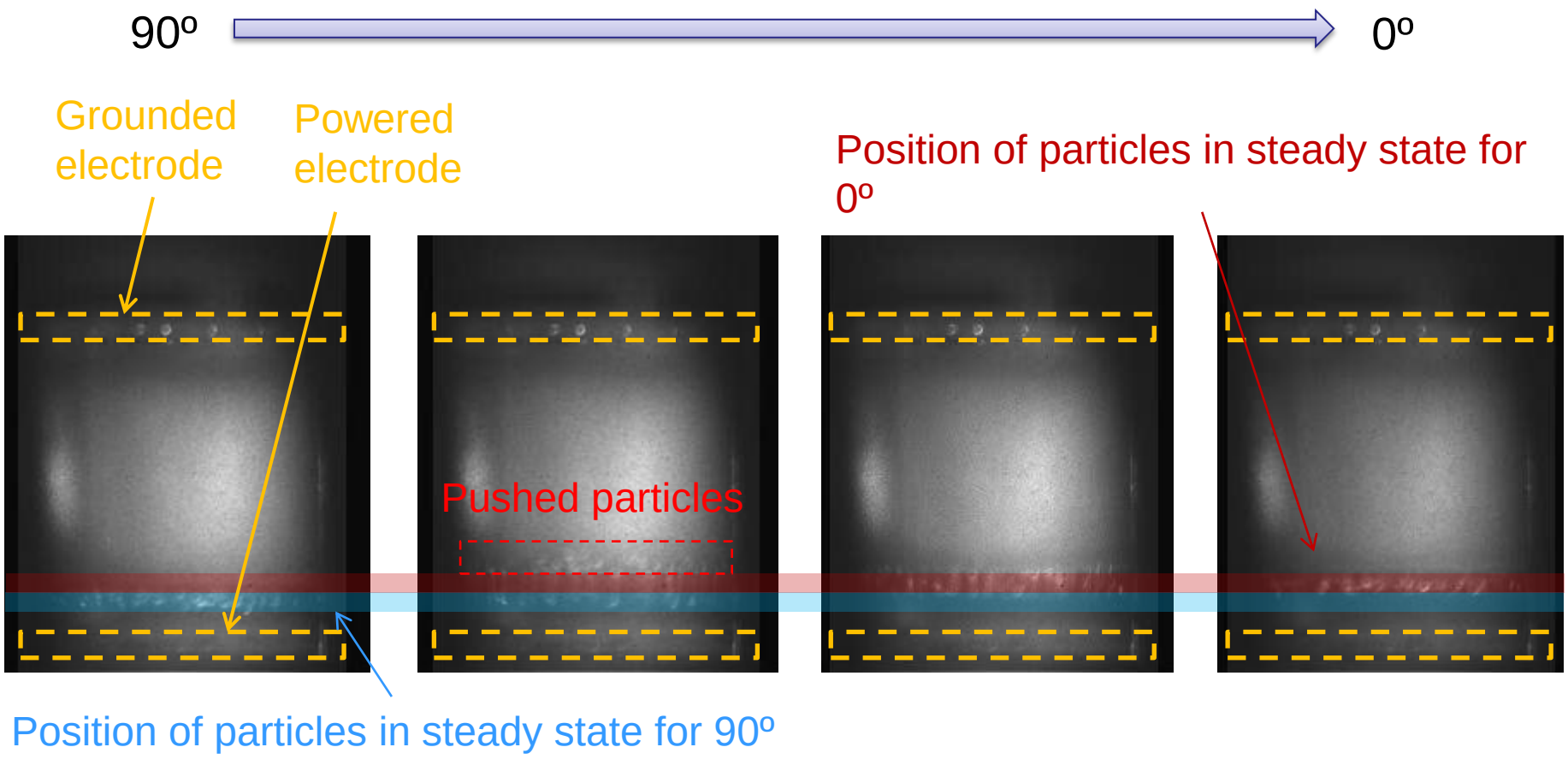
Position of particles in steady state



shift > 1.5 mm

Position of particles can be changed using EAE.

Phase angle switching



Two-dimensional images of laser light scattered intensity as the phase angle changed from 90º to 0º

Particles were pushed toward the upper grounded electrode.
However, it was only several mm.

Summary of experimental result

- Particles could be observed, however they were only bigger paritcles than induced particles.
- EAE could be used in plasma with particles.
- Position of Particles can be changed using EAE.
- Particles were pushed by phase switching, however it was only several mm.

In the future

- Improving the way of inducing particles to avoid particle aggregating.
- Making a system to synchronize ICCD camera and function generators.

Fabrication of nano particles using reactive plasma and controlling transport of them using EAE will be achieved.

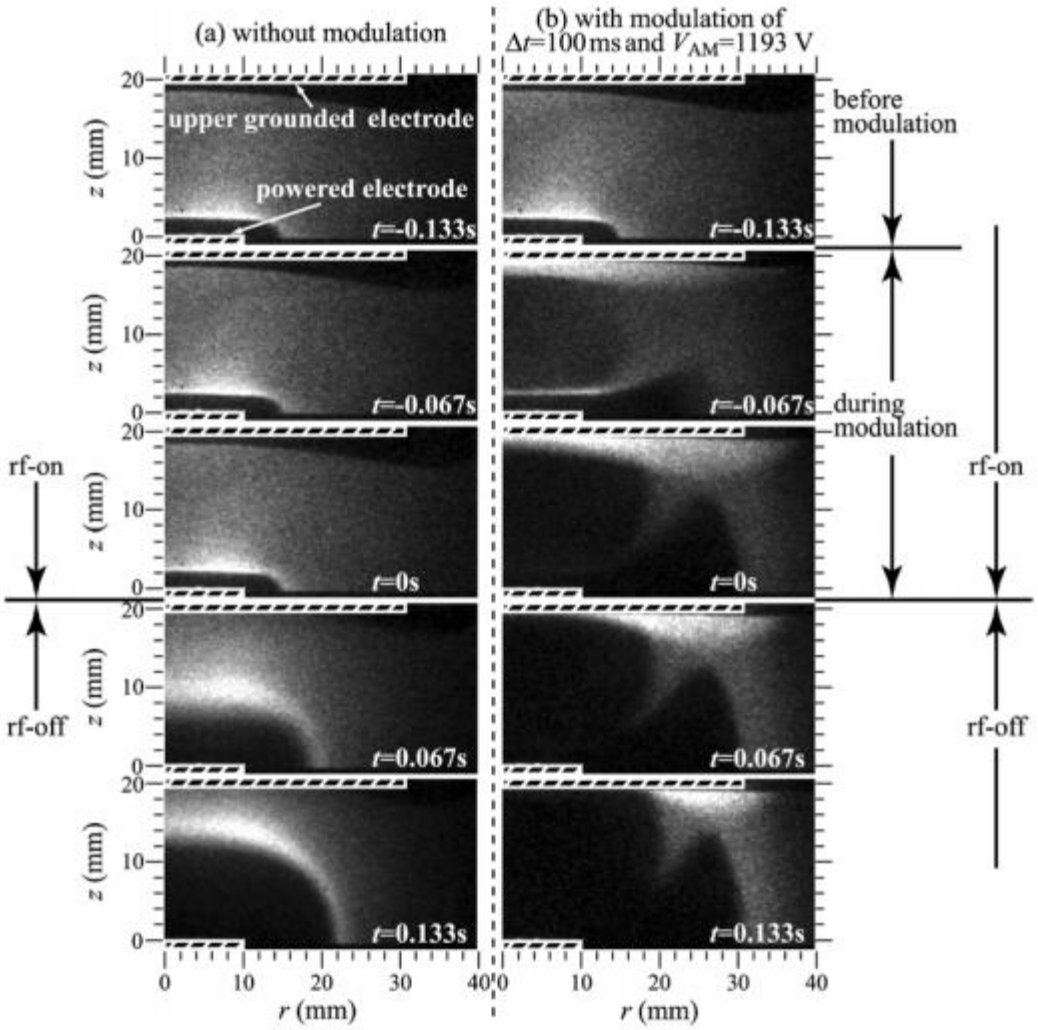
Summary

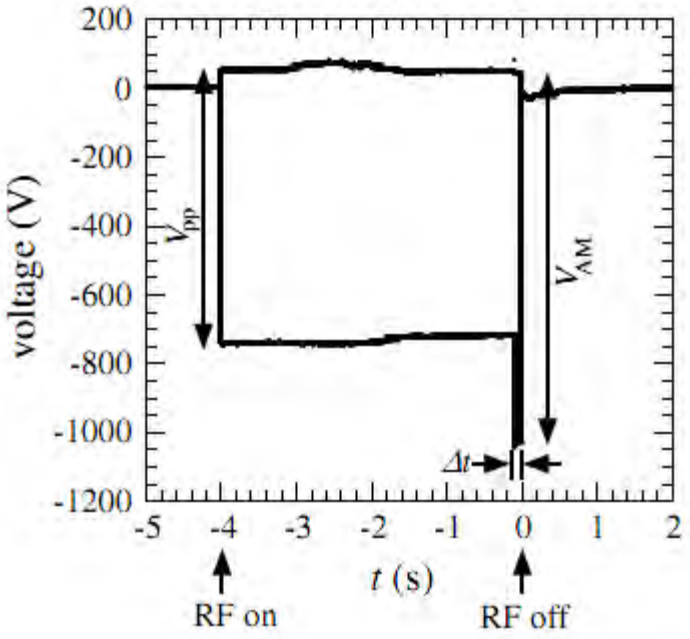
Through ITP

- I learned the Life style and culture of Germany.
- I improved speaking English.
- I learned experimental techniques.
- Presentation and Discussing in a meeting areprecious experience.
- I realized that I can live and study in foreign country.

I would like to appreciate Prof. Czarnetzki and members of his group, Prof. Hori, Prof. Toyoda, and all of person who assisted this program.

Thank you for your attention!


(a) without modulation
(b) with modulation of
Δt=100 ms and V_AM=1193 V
upper grounded electrode
powered electrode
t=-0.133s
t=-0.067s
t=0s
t=0.067s
t=0.133s
z (mm)
r (mm)
before modulation
during modulation
rf-on
rf-off


voltage (V)
t (s)
V_pp
V_AM
Δt
RF on
RF off