Diagnostics for large area RF plasma reacto s

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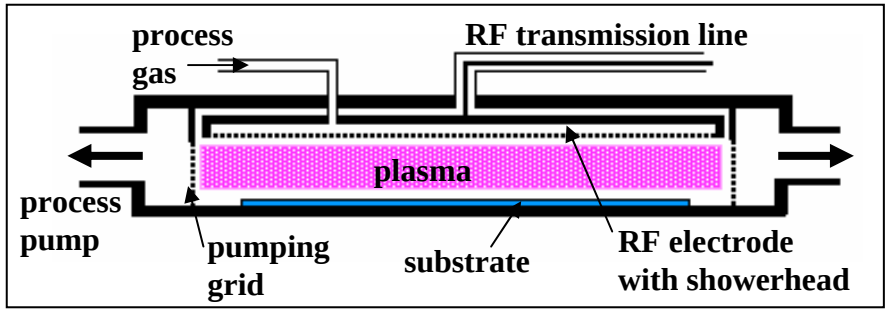
Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

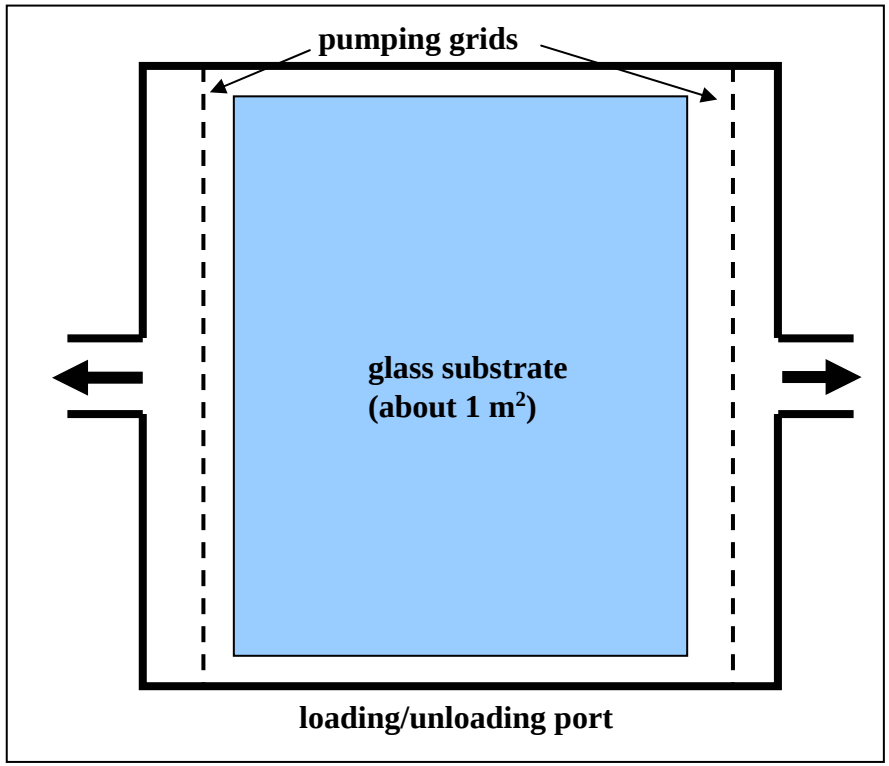
Center for Research in Plasma Physics (CRPP)

start by acknowledging:

Christoph Hollenstein, Laurent Sansonnens, & co.

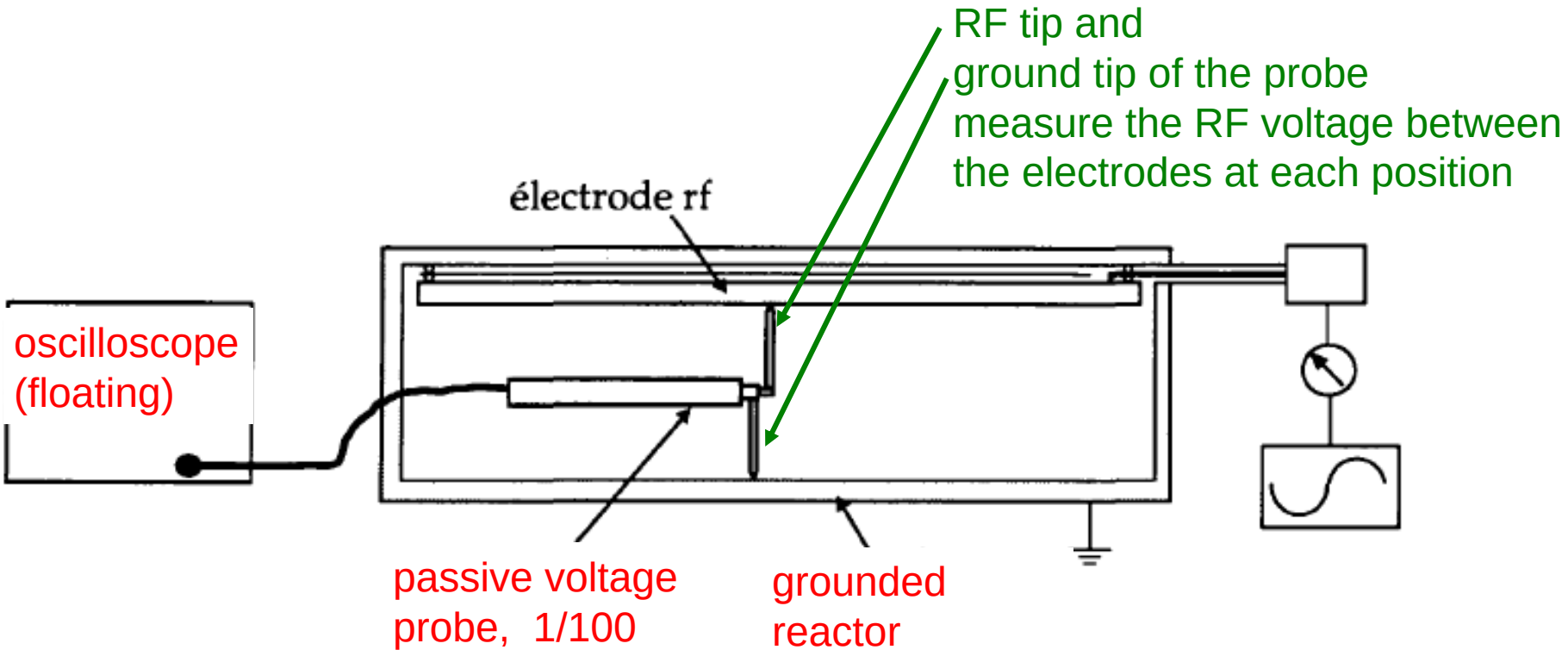
Schematic drawing of a rectangular parallel plate RF capacitive plasma reactor:





RF inter-electrode voltage in vacuum

Plasma Sources Sci. Technol. 6 (1997) 170–178.



RF inter-electrode voltage in vacuum

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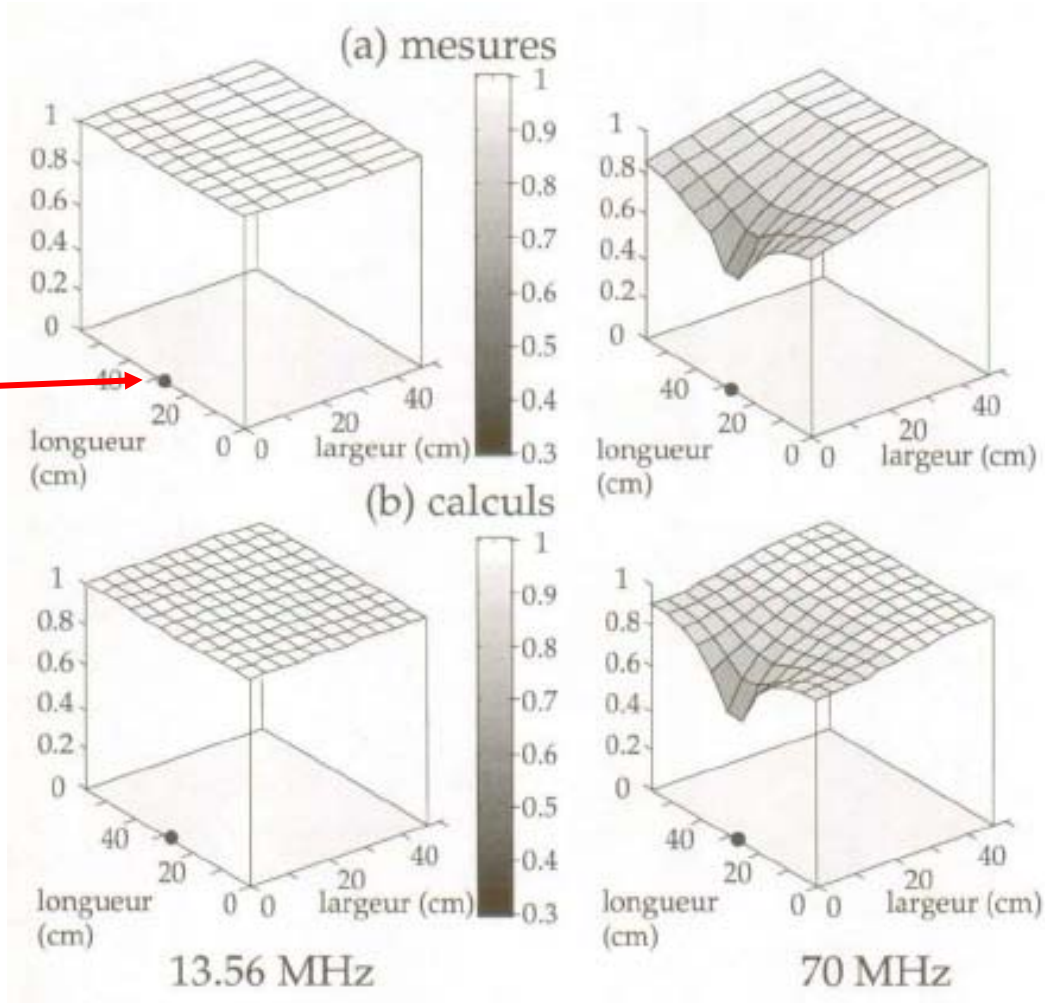
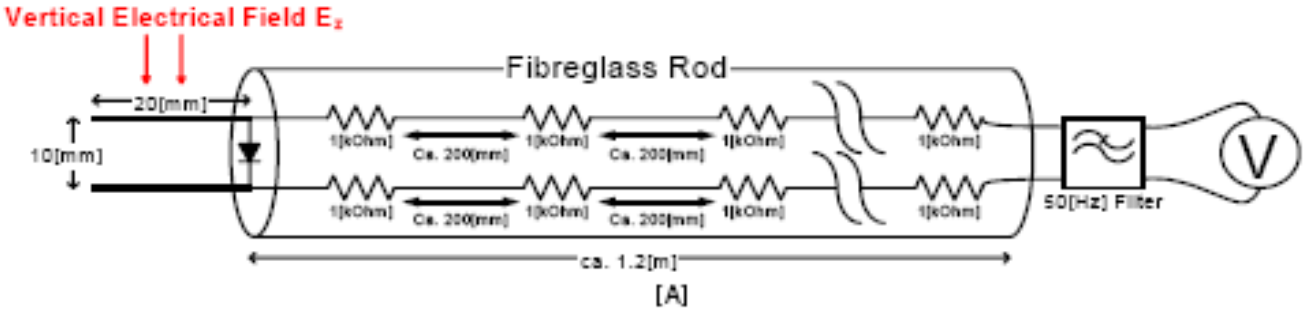
RF power
side connection

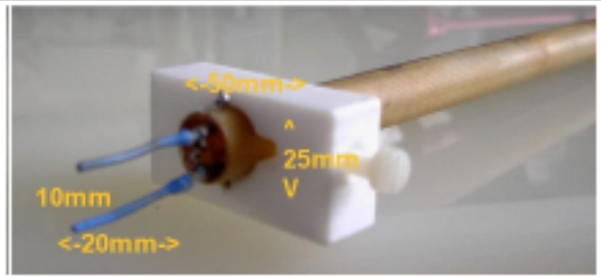


RF inter-electrode electric field in vacuum using a diode probe

J. Appl. Phys. **95** 4559 (2004)



[A]



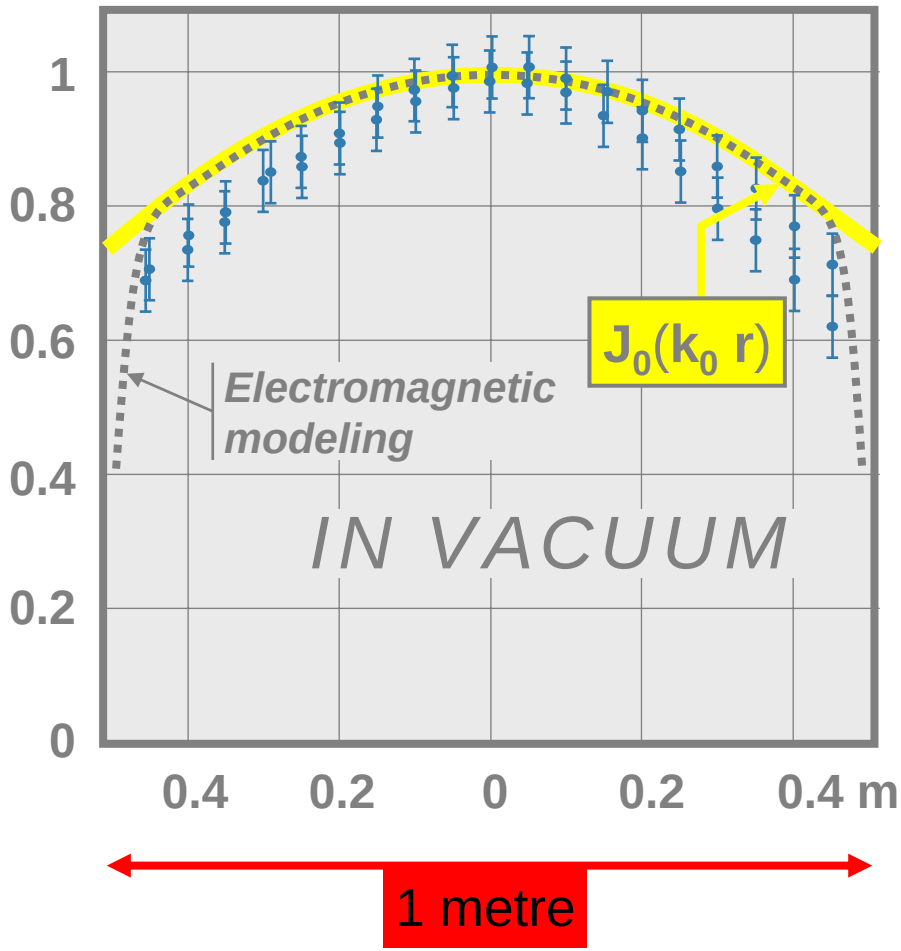
[B]

probe inserted through holes in a side wall

RF inter-electrode electric field in vacuum using a diode probe

J. Appl. Phys. **95** 4559 (2004)

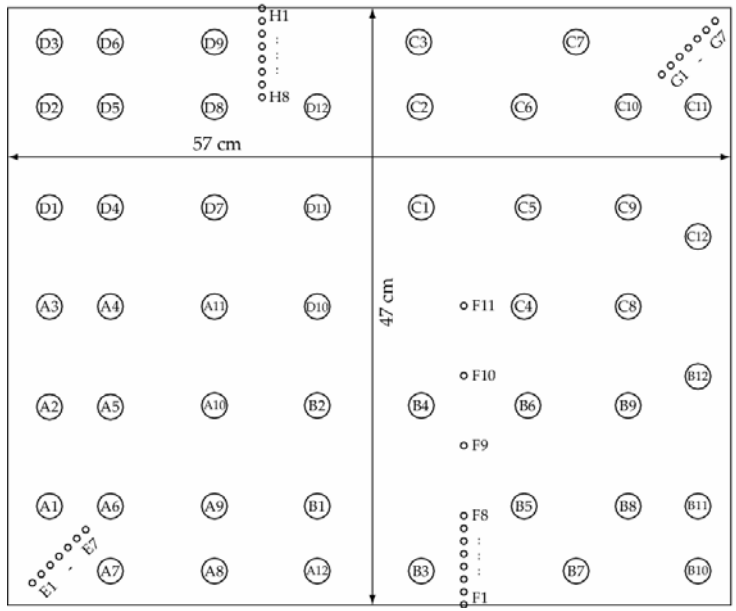
E-field relative profile at 100 MHz
(bench test with scanning probe)



surface electrostatic probes: (i) ion saturated current

JOURNAL OF APPLIED PHYSICS **97**, 123308 (2005)

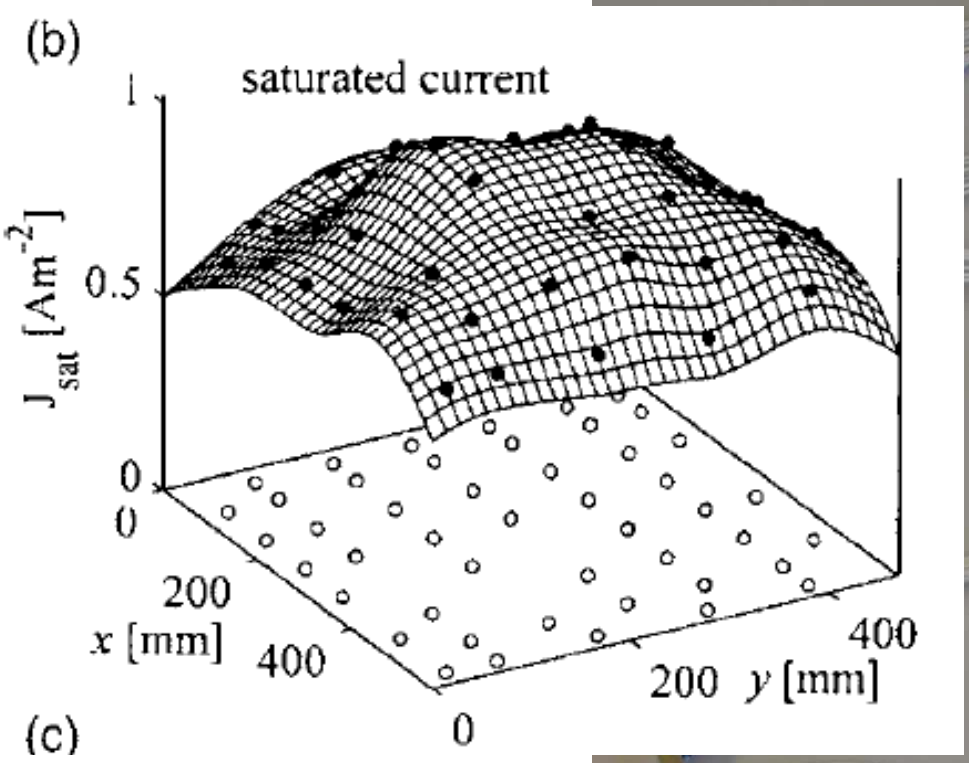
81 surface probes for DC voltage and current measurements

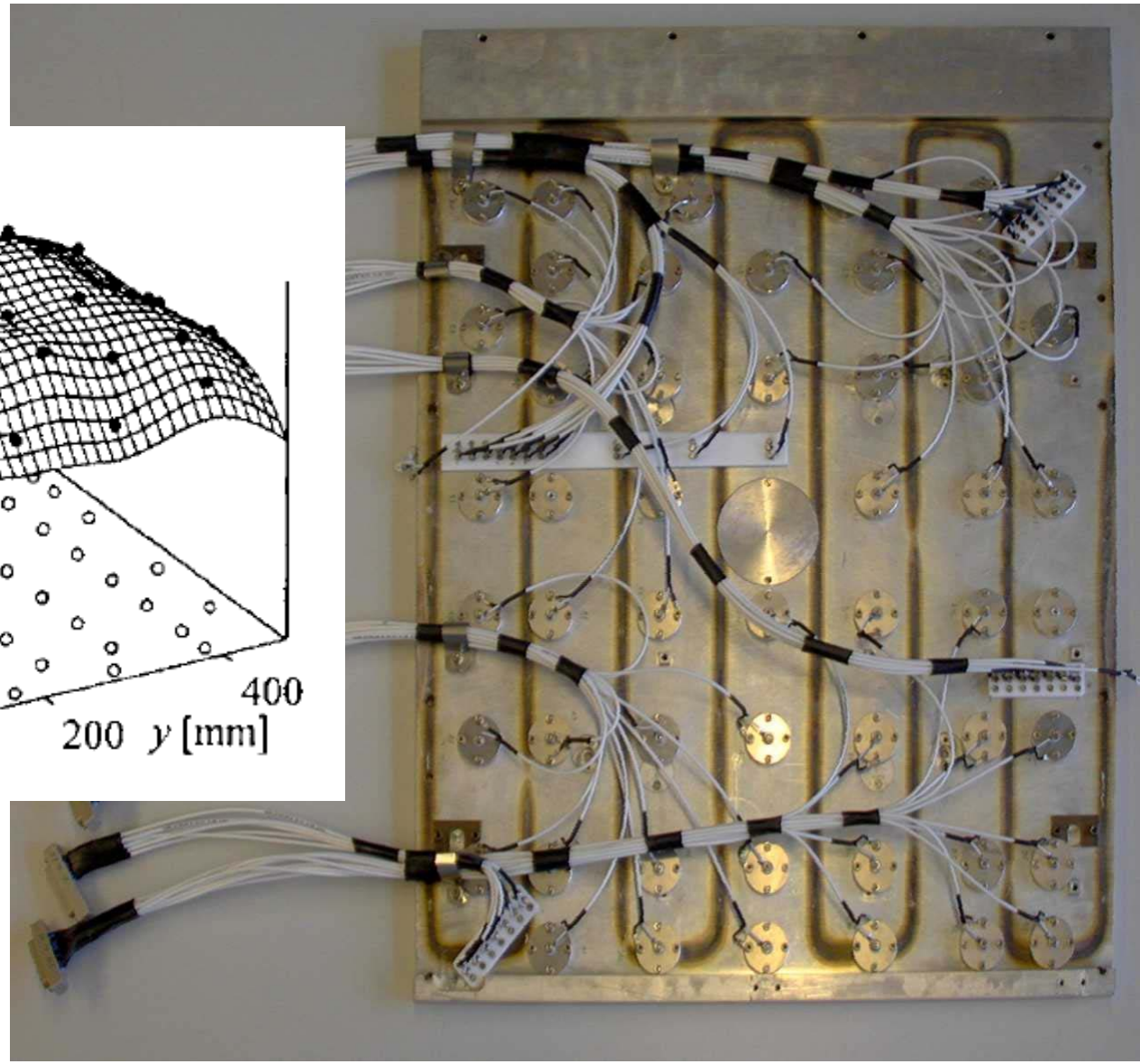


reactor 47 x 57 cm²

surface electrostatic probes: (i) ion saturated current

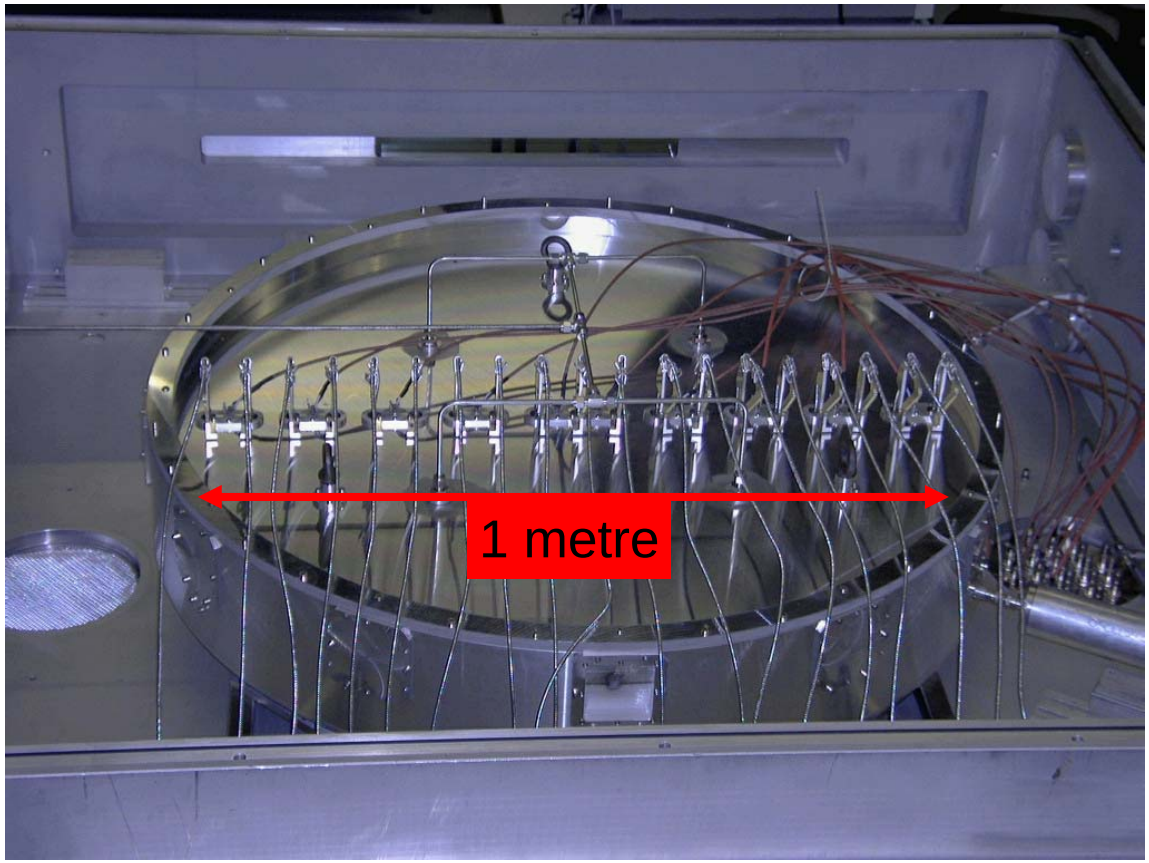
JOURNAL OF APPLIED PHYSICS 97, 123308 (2005)

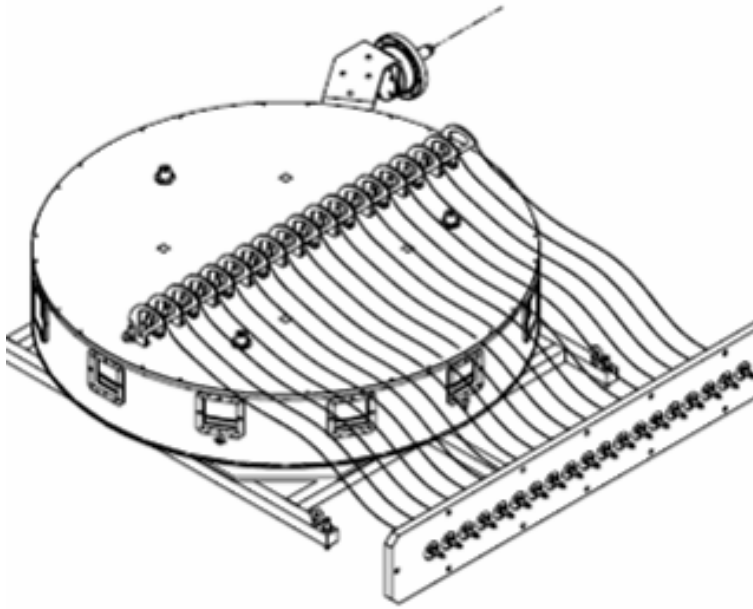




J. Appl. Phys. **95** 4559 (2004)

Cylindrical reactor experiment

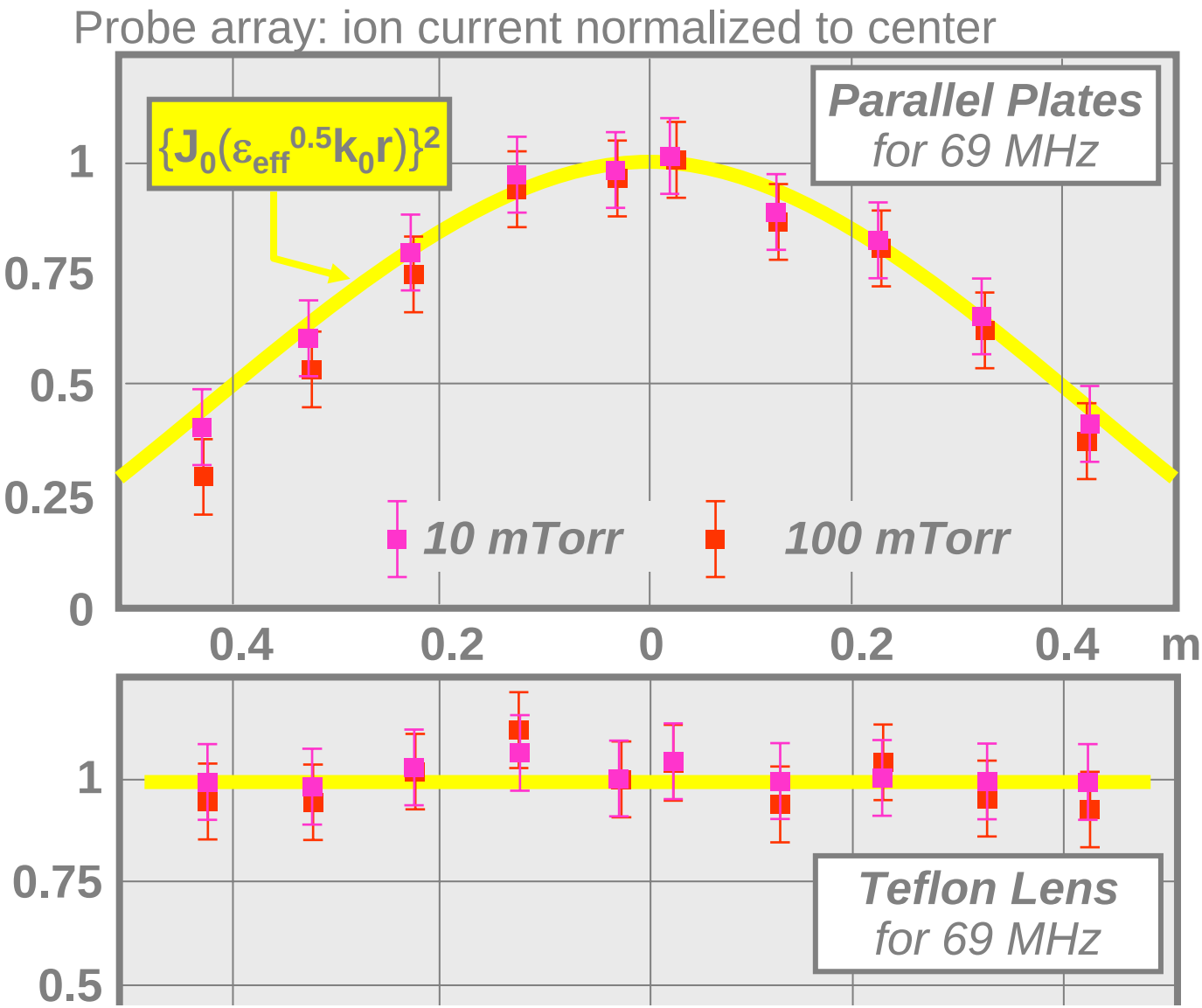




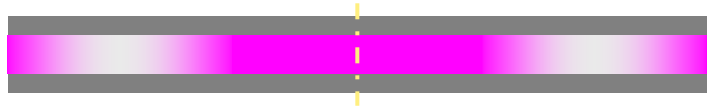
optical emission & surface electrostatic probes

surface electrostatic probes: (i) ion saturated current

J. Appl. Phys. **95** 4559 (2004)

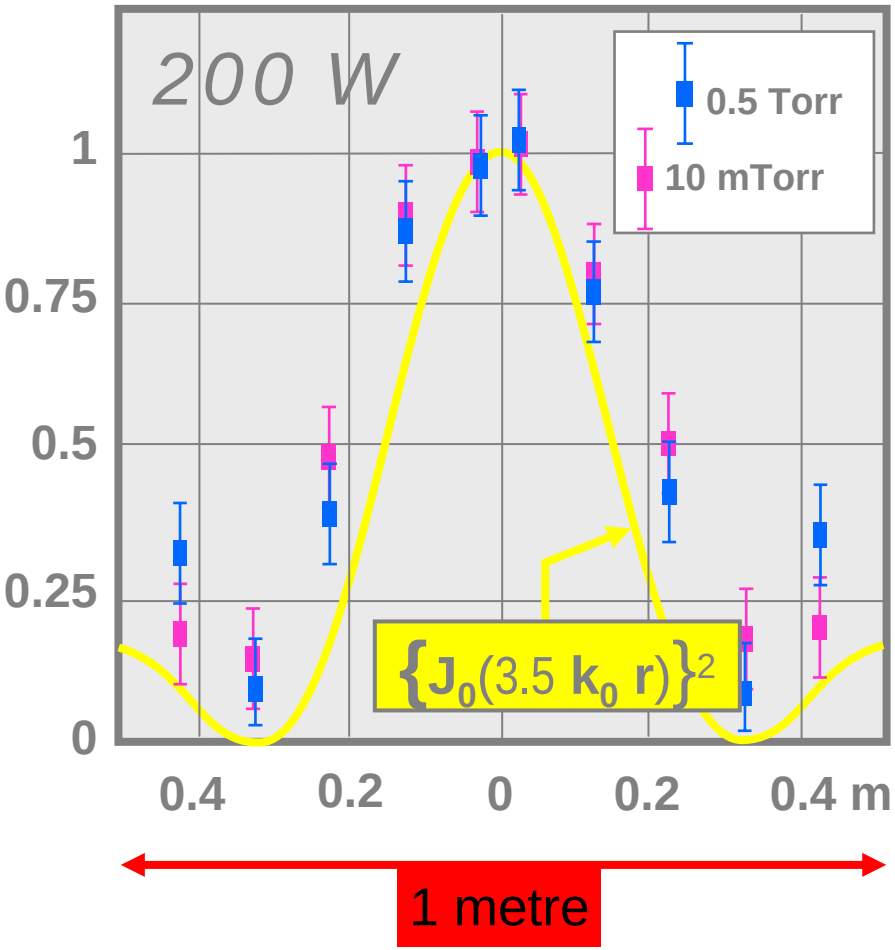


EXPERIMENTS AT 100 MHz



probe array ion saturation currents
(normalized to the central values)

J. Appl. Phys. **95** 4559 (2004)

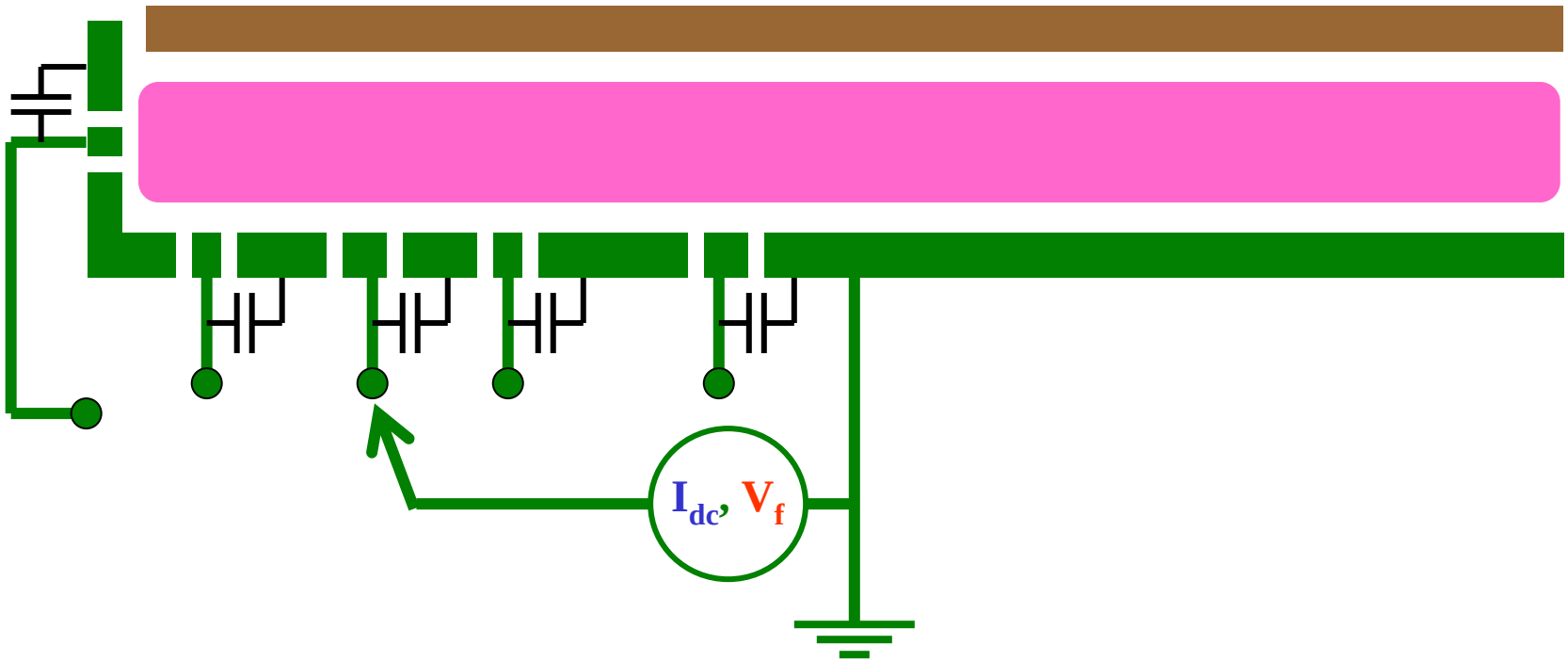


surface electrostatic probes: (ii) DC floating voltage

JOURNAL OF APPLIED PHYSICS 97, 123308 (2005)

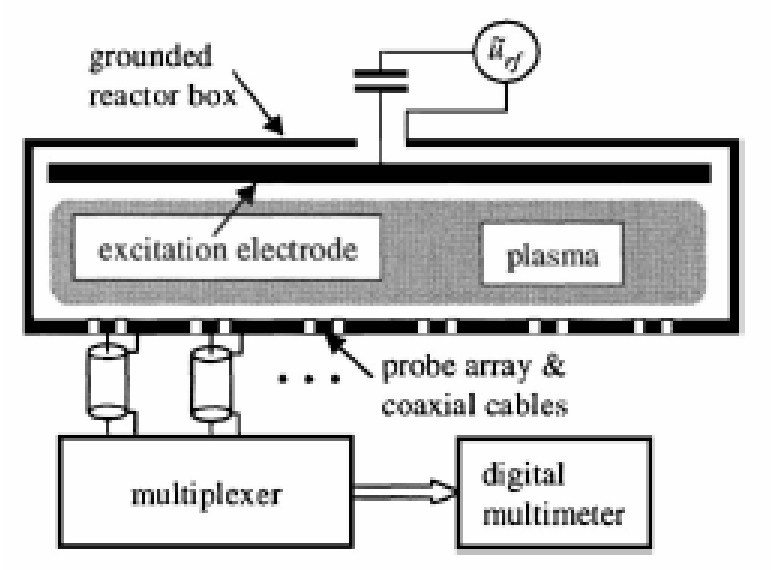
DC floating voltages give approx. variation in RF plasma potential

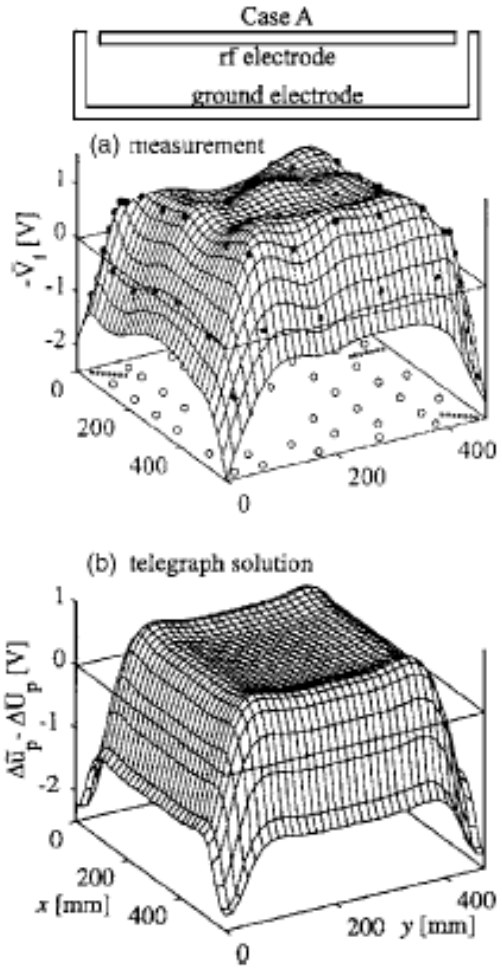
DC currents to grounded probes give DC current density profile,



surface electrostatic probes: (ii) DC floating voltage

JOURNAL OF APPLIED PHYSICS 97, 123308 (2005)





perturbation to plasma RF potential due to sidewall area

surface electrostatic probes: (iii) DC current, zero bias

Small area:

$\overline{U}$ and $\tilde{U}$ constant over the electrode area

Blocking capacitor →

$$\frac{1}{T}\int_0^T (J_e + J_i)dt = 0 \rightarrow \overline{U} = \frac{T_e}{2}\ln\left(\frac{M_i}{2.3m_e}\right) + T_e \ln\left[\mathrm{I}_0\left(\frac{\tilde{U}}{T_e}\right)\right]$$

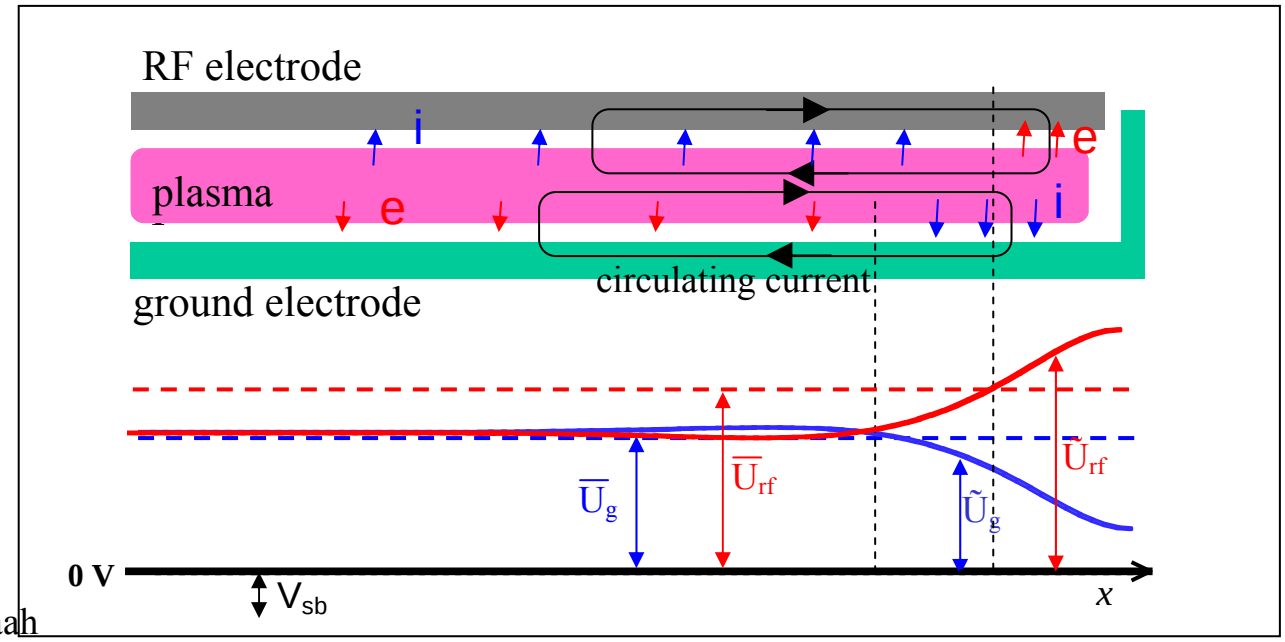
Local ambipolarity for 0 time averaged conducting current on the electrode

Large area:

$\overline{U}$ constant, but $\tilde{U}$ varying according to the telegraph equation →

Equation cannot be satisfied simultaneously over the electrode area

JOURNAL OF APPLIED PHYSICS **97**, 123308 (2005)



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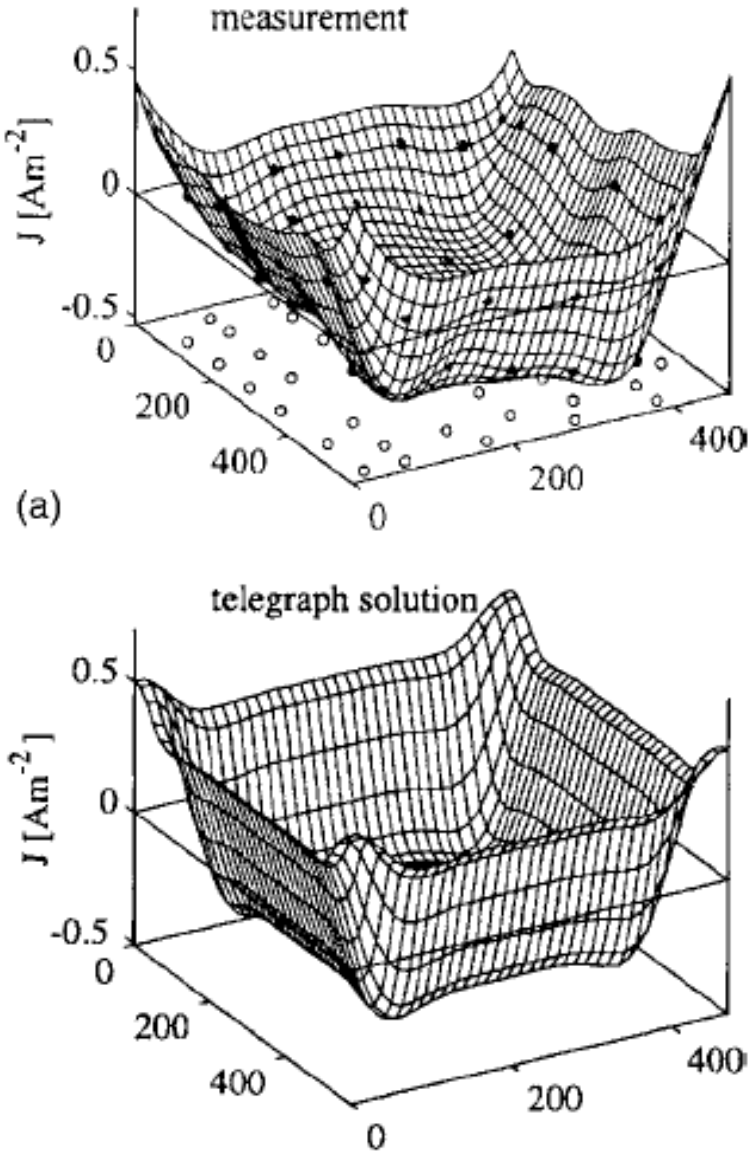
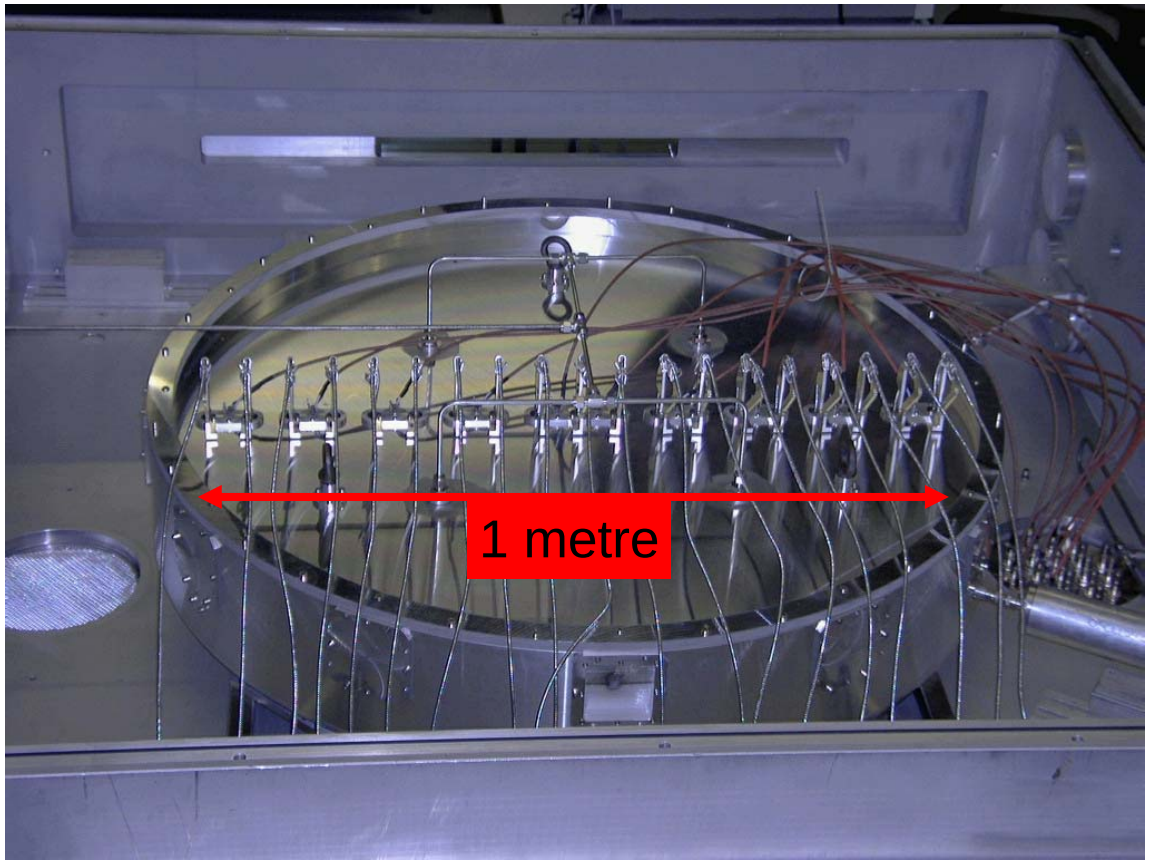
JOURNAL OF APPLIED PHYSICS 97, 123308 (2005)

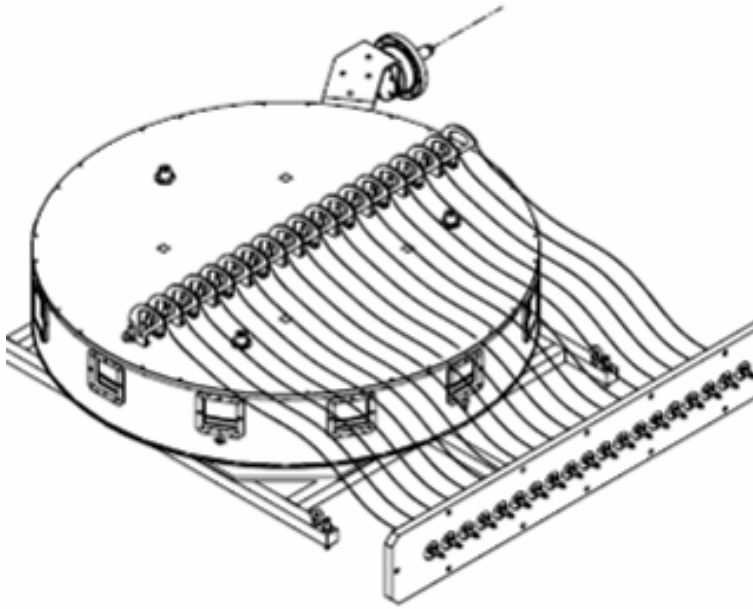


optical emission intensity: fibre optic probes

J. Appl. Phys. **95** 4559 (2004)

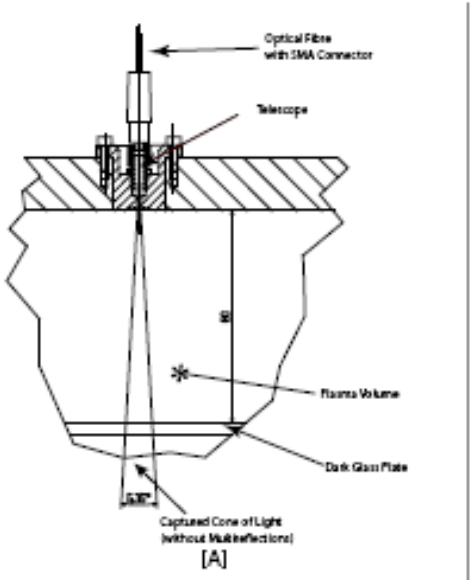
optical emission & surface electrostatic probes





Cylindrical reactor experiment

optical emission intensity: fibre optic probes

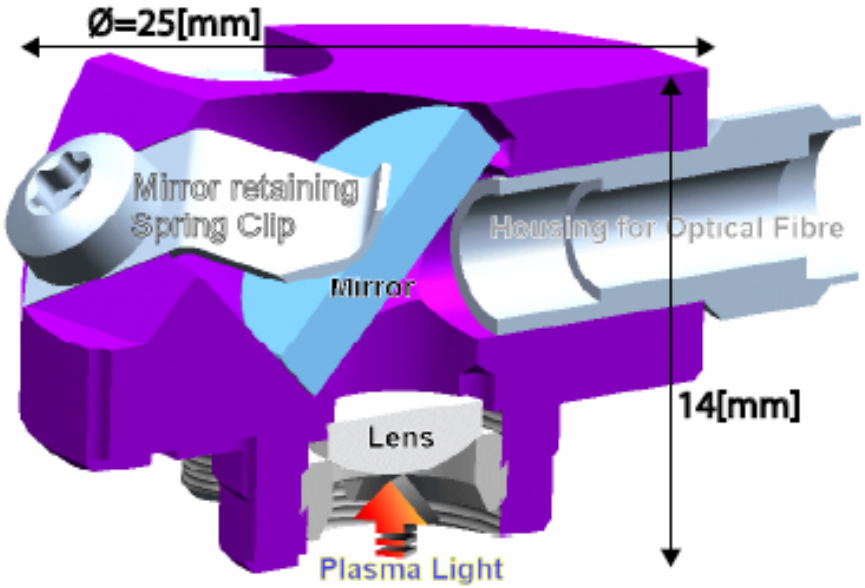


[A]


[B]

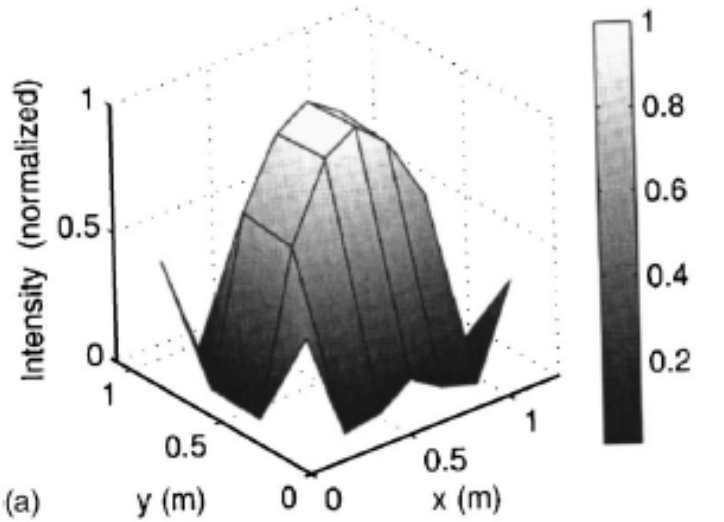
J. Appl. Phys. **95** 4559 (2004)

fibre optic telescope



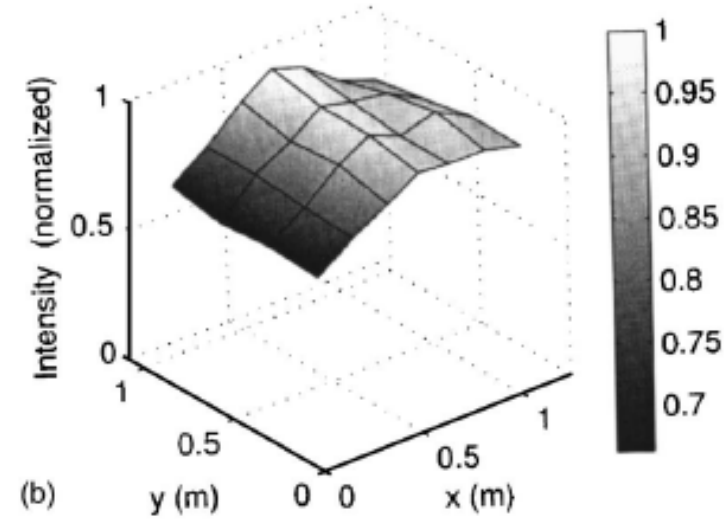
fibre optic telescope,
for right-angle view

optical emission intensity: fibre optic probes



Optical emission 2D profiles
in a rectangular reactor:

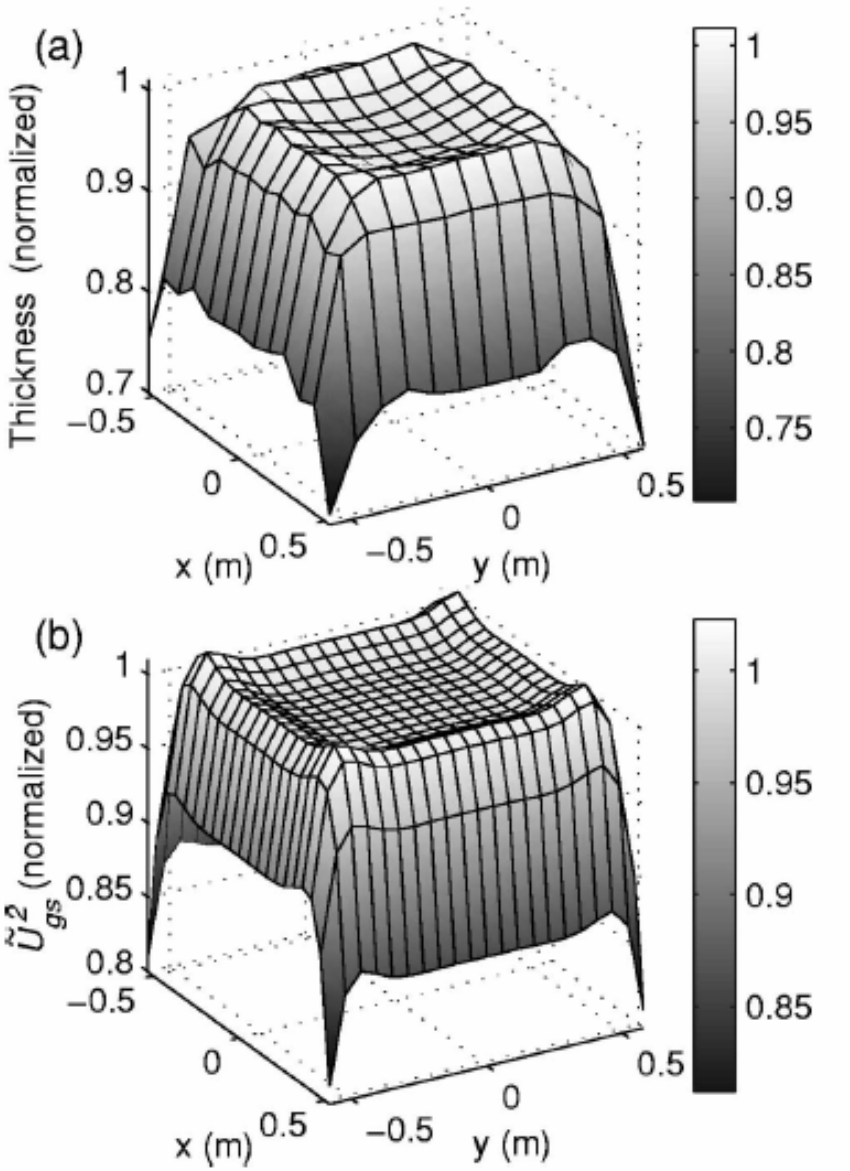
Parallel plates



With lens

FIG. 3. Normalized plasma emission profile averaged over the vertical interelectrode gap for (a) the parallel plate reactor configuration, and (b) the shaped electrode reactor configuration. The plasma conditions are 66.7% argon 33.3% hydrogen gas mixture at 0.132 mbar, 67.8 MHz excitation frequency, and 300 W input power.

ex situ film thickness measurements

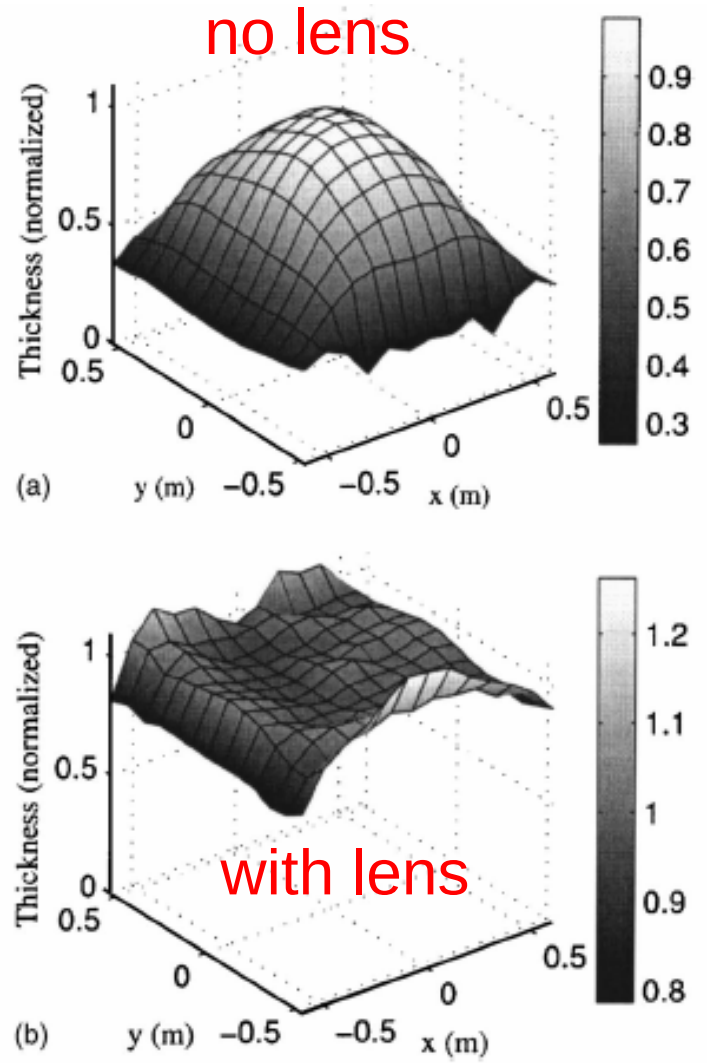


Film thickness measurements, ex situ, telegraph effect

Plasma non-uniformity convoluted with gas flow non-uniformity etc.

telegraph model

ex situ film thickness measurements



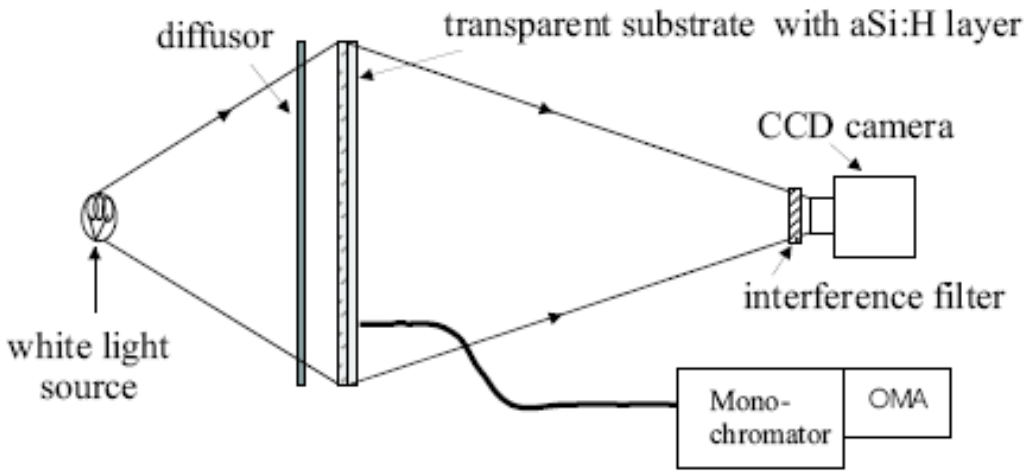
1425 J. Vac. Sci. Technol. A 24(4), Jul/Aug 2006

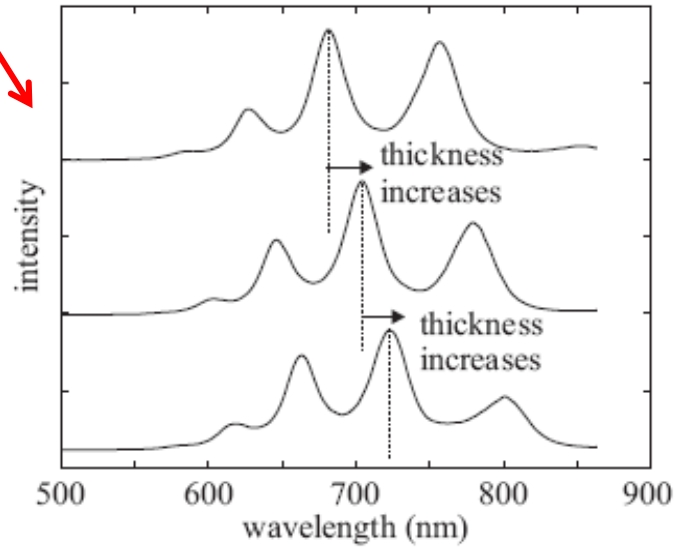
Film thickness measurements, ex situ, standing wave correction

Plasma non-uniformity convoluted with gas flow non-uniformity etc.

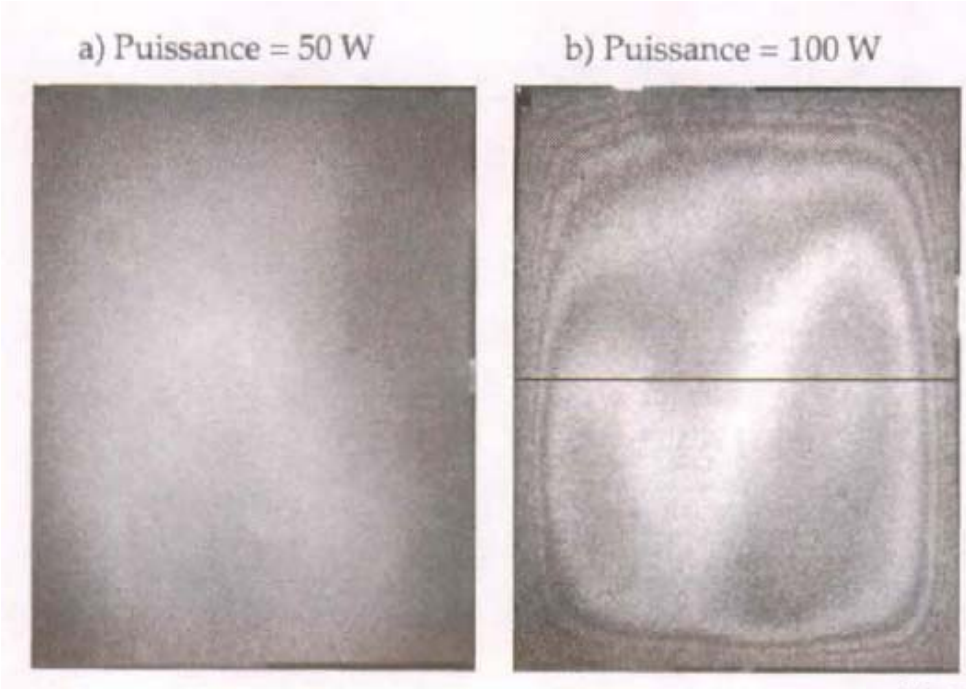
ex situ film thickness measurement: interferogram

Plasma Sources Sci. Technol. **6** (1997) 170–178.





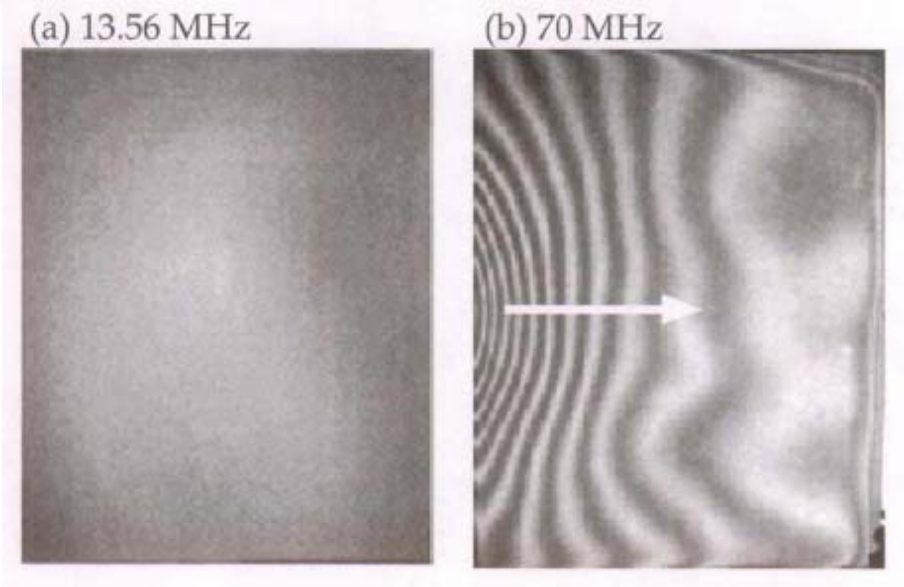
ex situ film thickness measurement: interferogram



non-uniformity due to powder

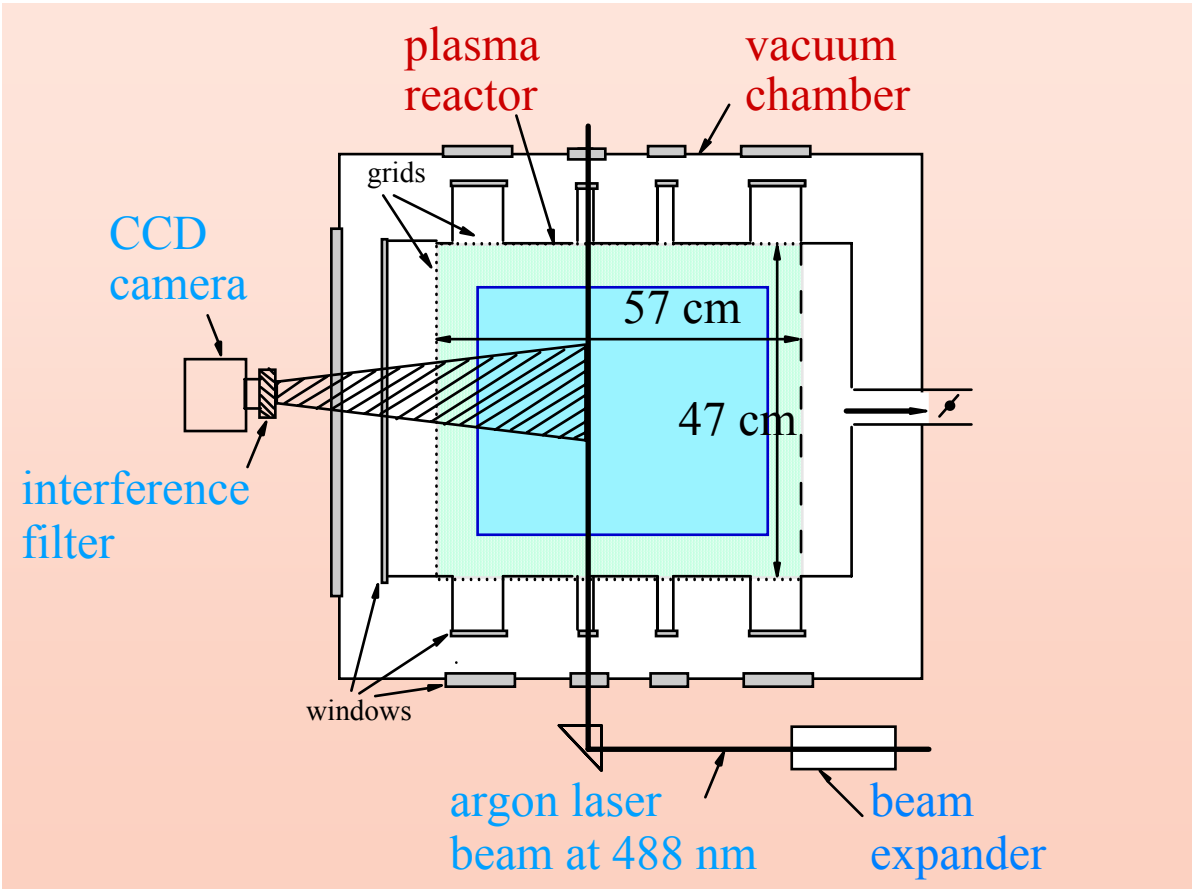
Plasma Sources Sci. Technol. **6** (1997) 170–178.

37 cm x 47 cm

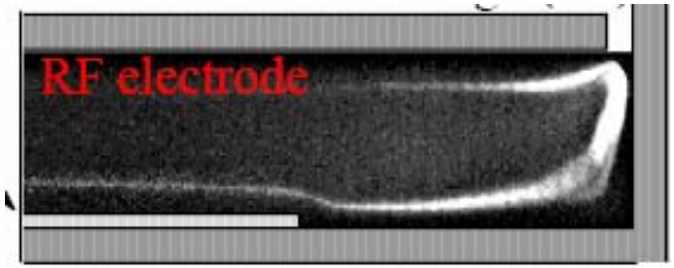


non-uniformity due to standing wave (VHF frequency)

light scattering from powder

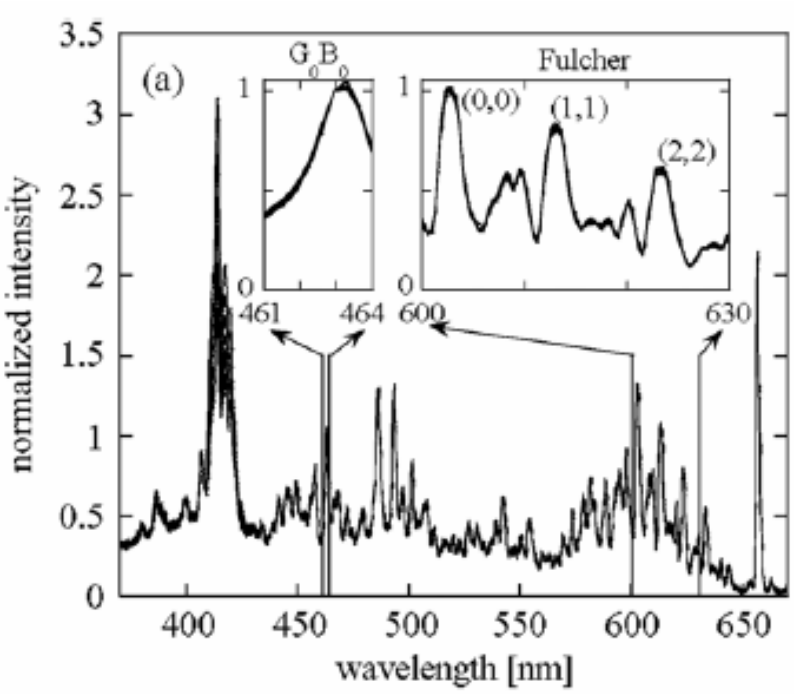


MRS Symp. Proc. Vol. 507
Amorphous and Microcrystalline Silicon Technology,
pp547-557 (1998).

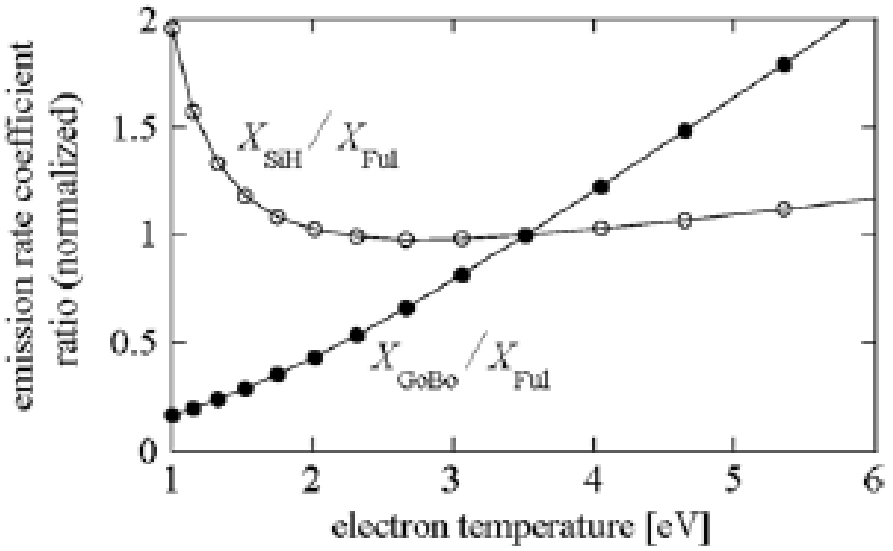


CCD Image

OES and electron temperature *vs* time



Plasma Sources Sci. Technol. **16** (2007) 679–696



H_2* emission is only from e+H_2 collisions, but H* emission has several sources