Diagnostics for large area RF plasma reactors

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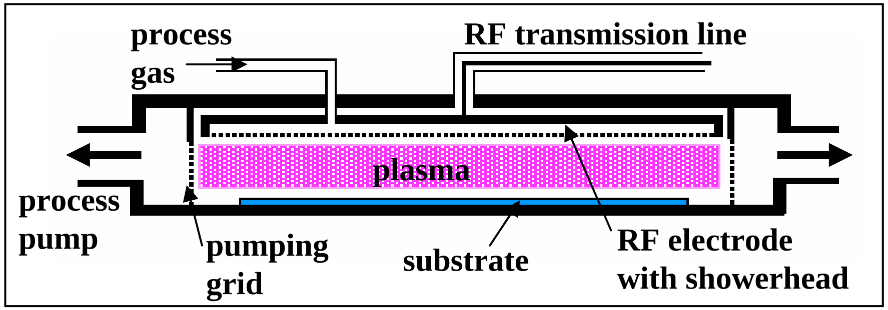
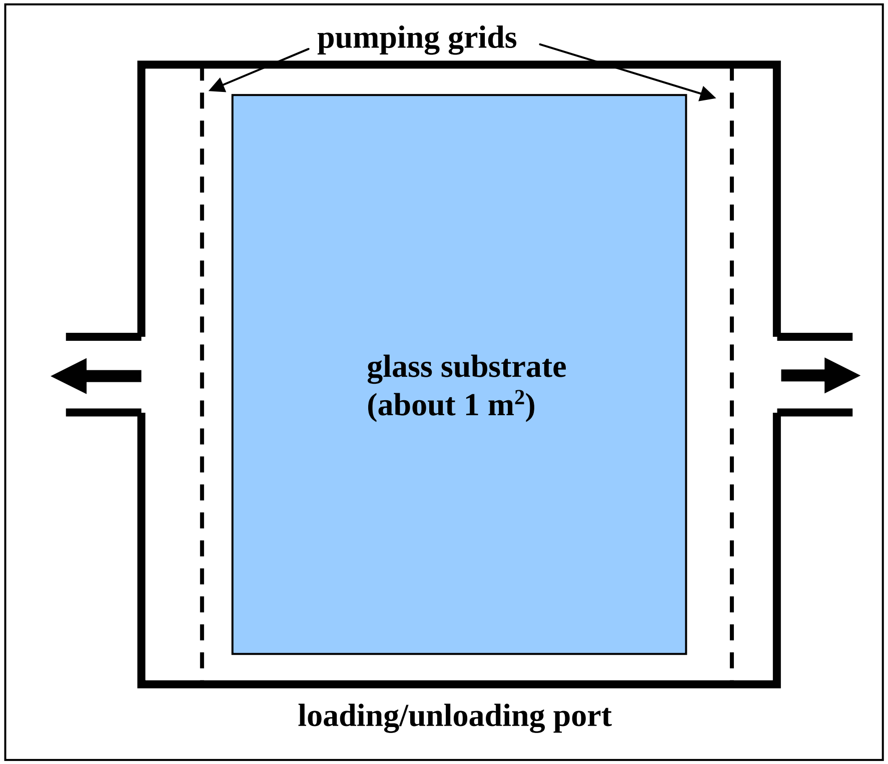
Center for Research in Plasma Physics (CRPP)

start by acknowledging:

Christoph Hollenstein, Laurent Sansonnens, & co.

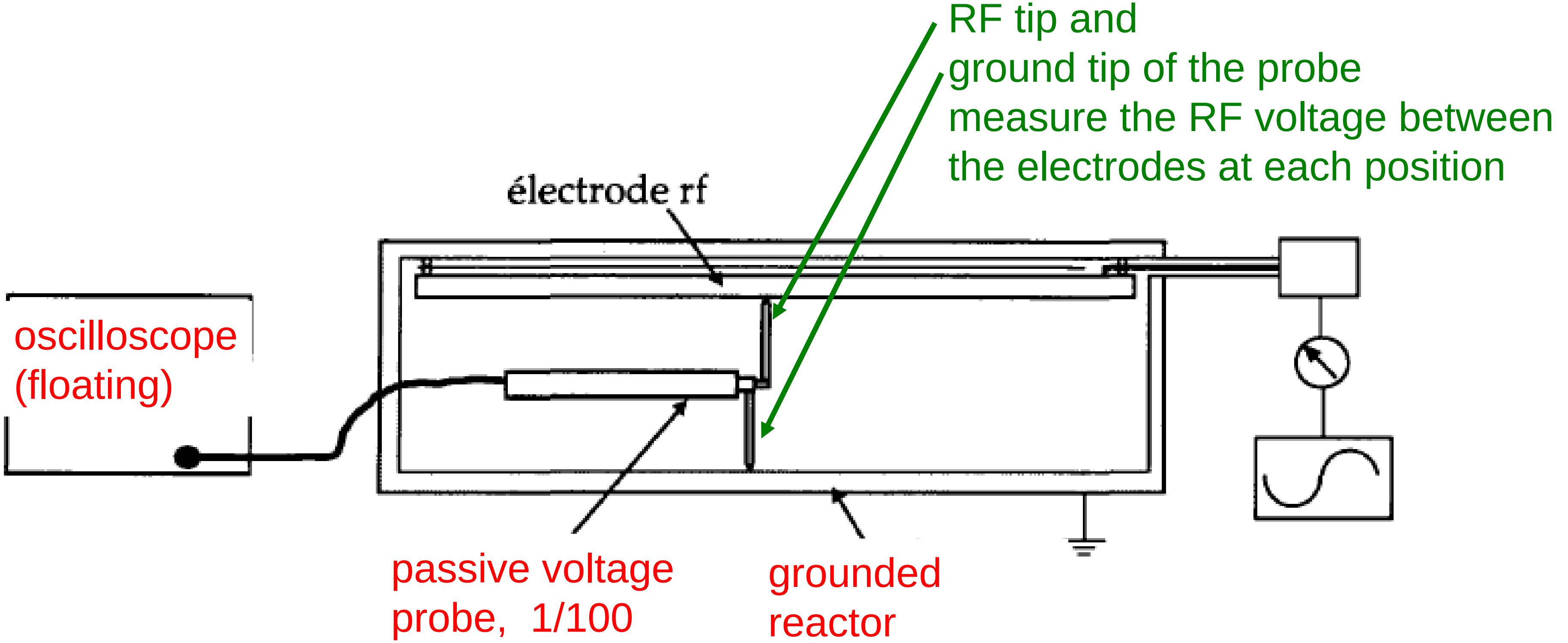
Schematic drawing of a rectangular parallel plate RF capacitive plasma reactor:





RF inter-electrode voltage in vacuum

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



RF inter-electrode voltage in vacuum

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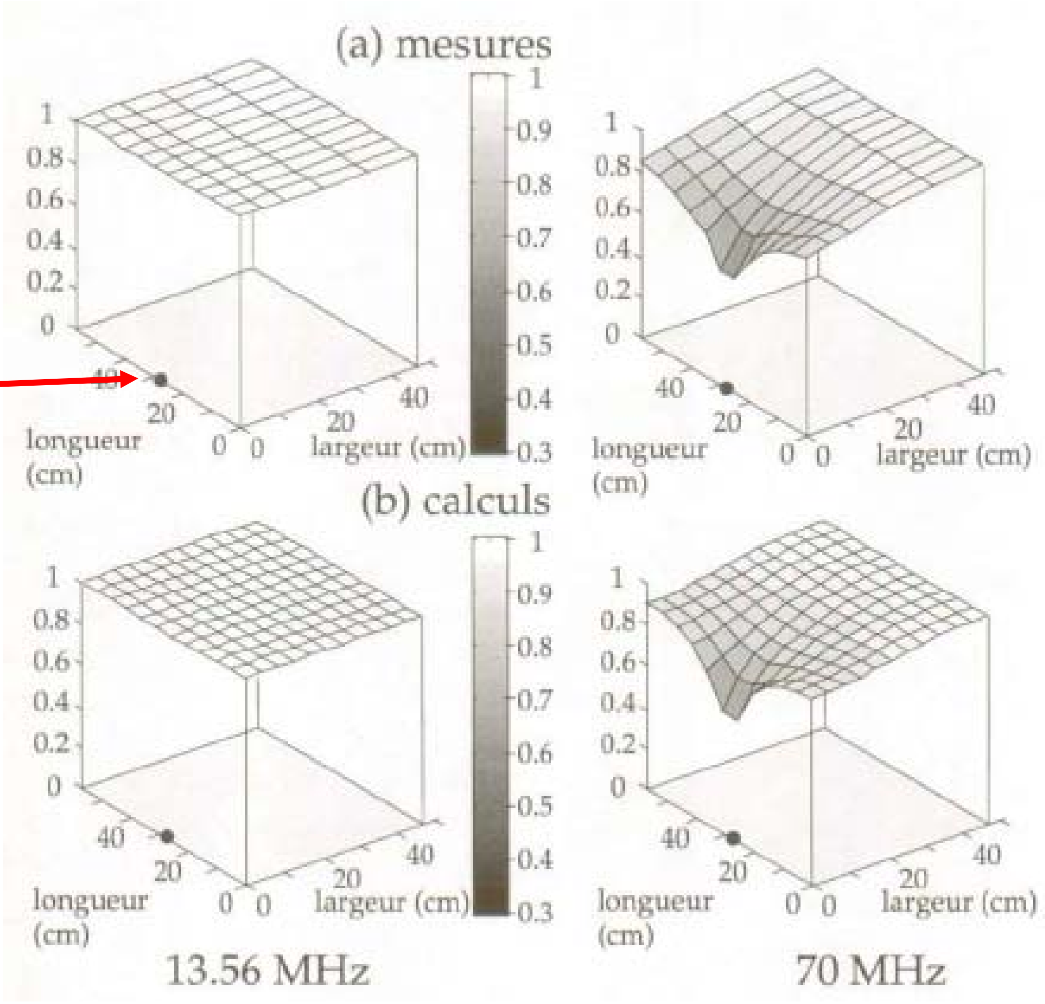
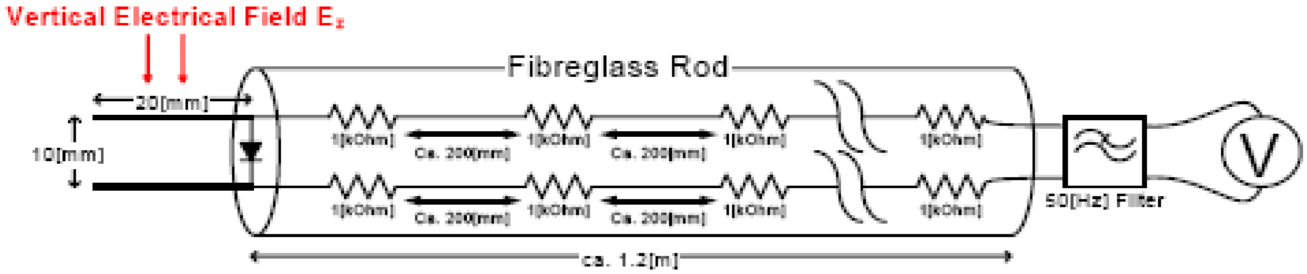
RF power
side connection

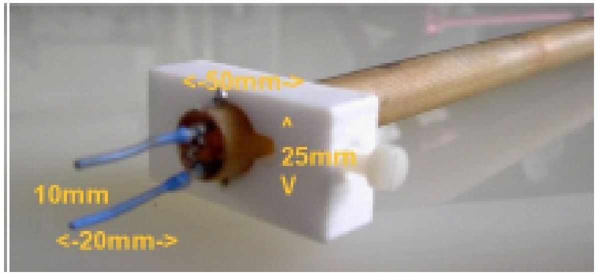


RF inter-electrode electric field in vacuum using a diode probe

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



[A]



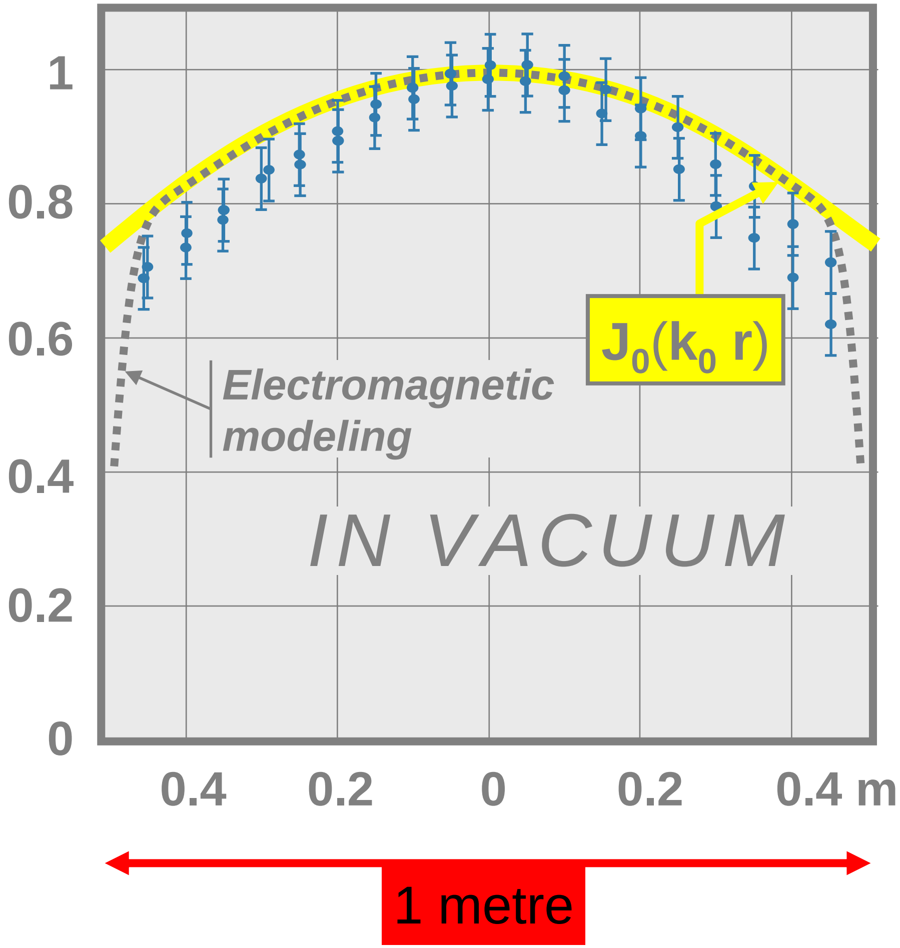
[B]

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)

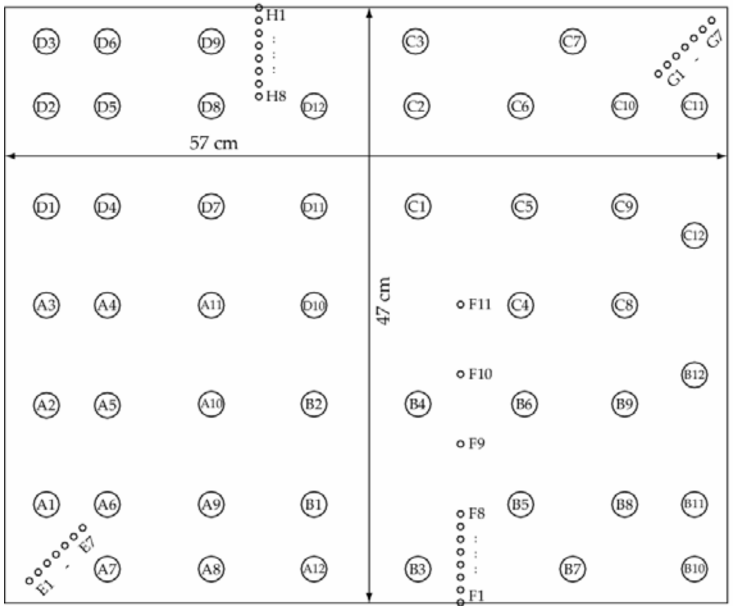
E-field relative profile at 100 MHz
(bench test with scanning probe)



surface electrostatic probes: (i) ion saturated current

JOURNAL OF APPLIED PHYSICS 97, 123308 (2005)

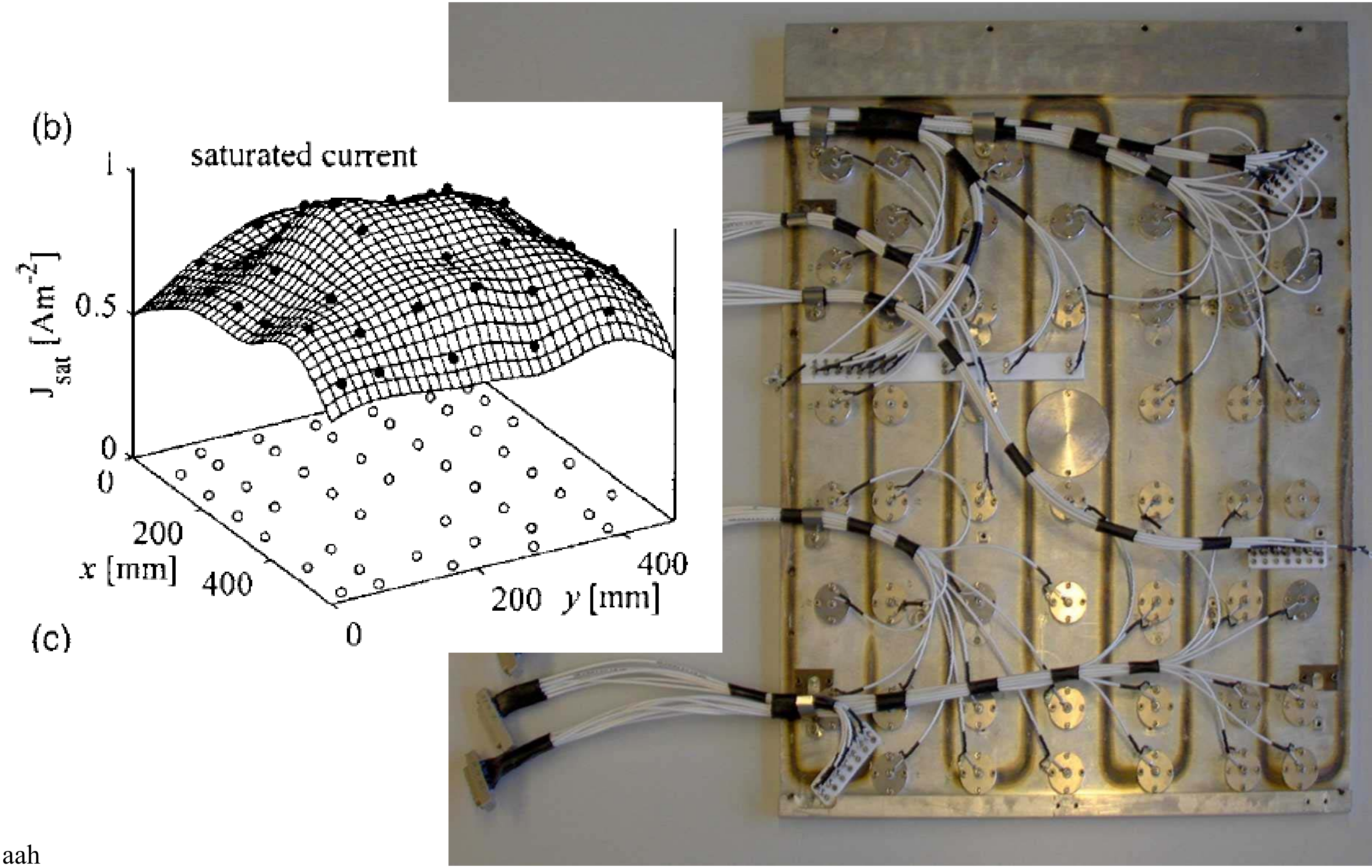
81 surface probes for DC voltage and current measurements



reactor 47 x 57 cm^2

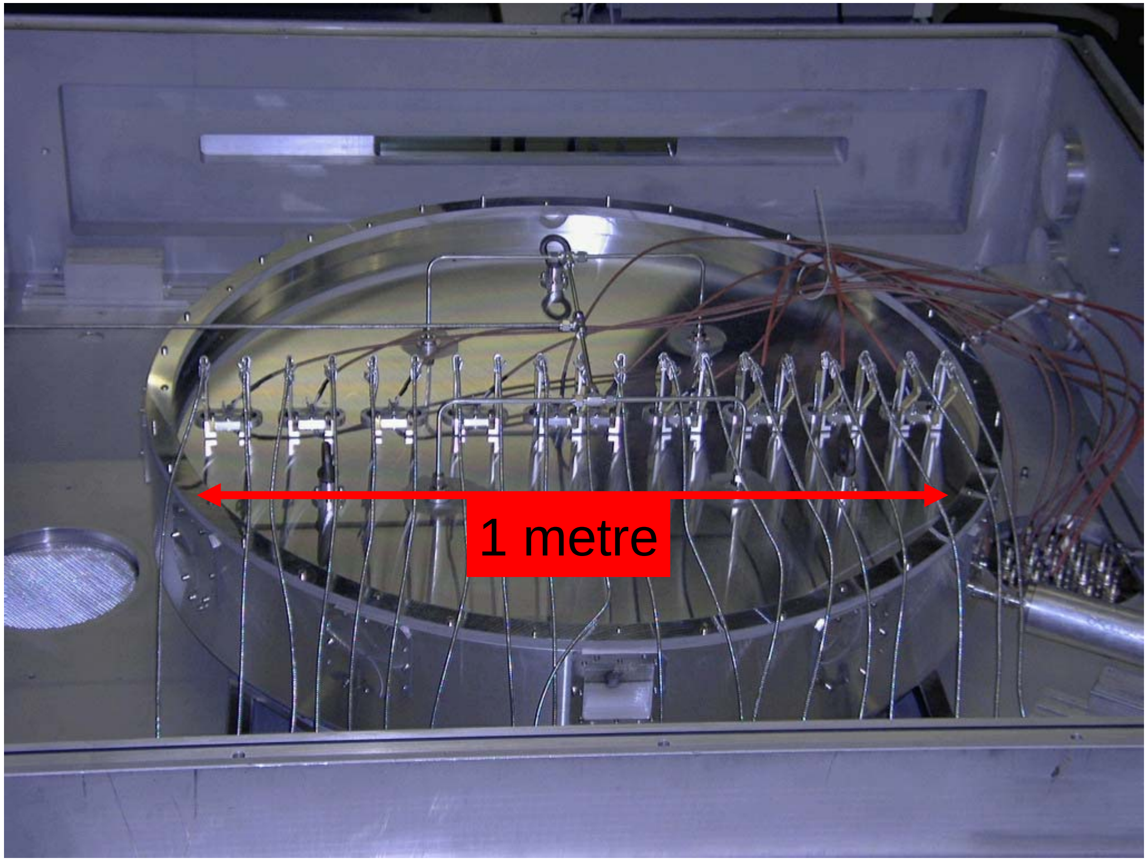
surface electrostatic probes: (i) ion saturated current

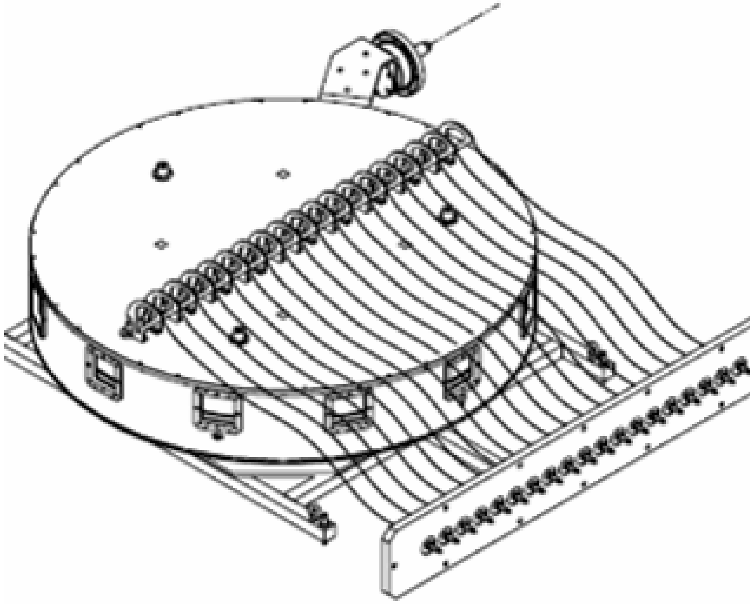
JOURNAL OF APPLIED PHYSICS 97, 123308 (2005)



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

Cylindrical reactor experiment



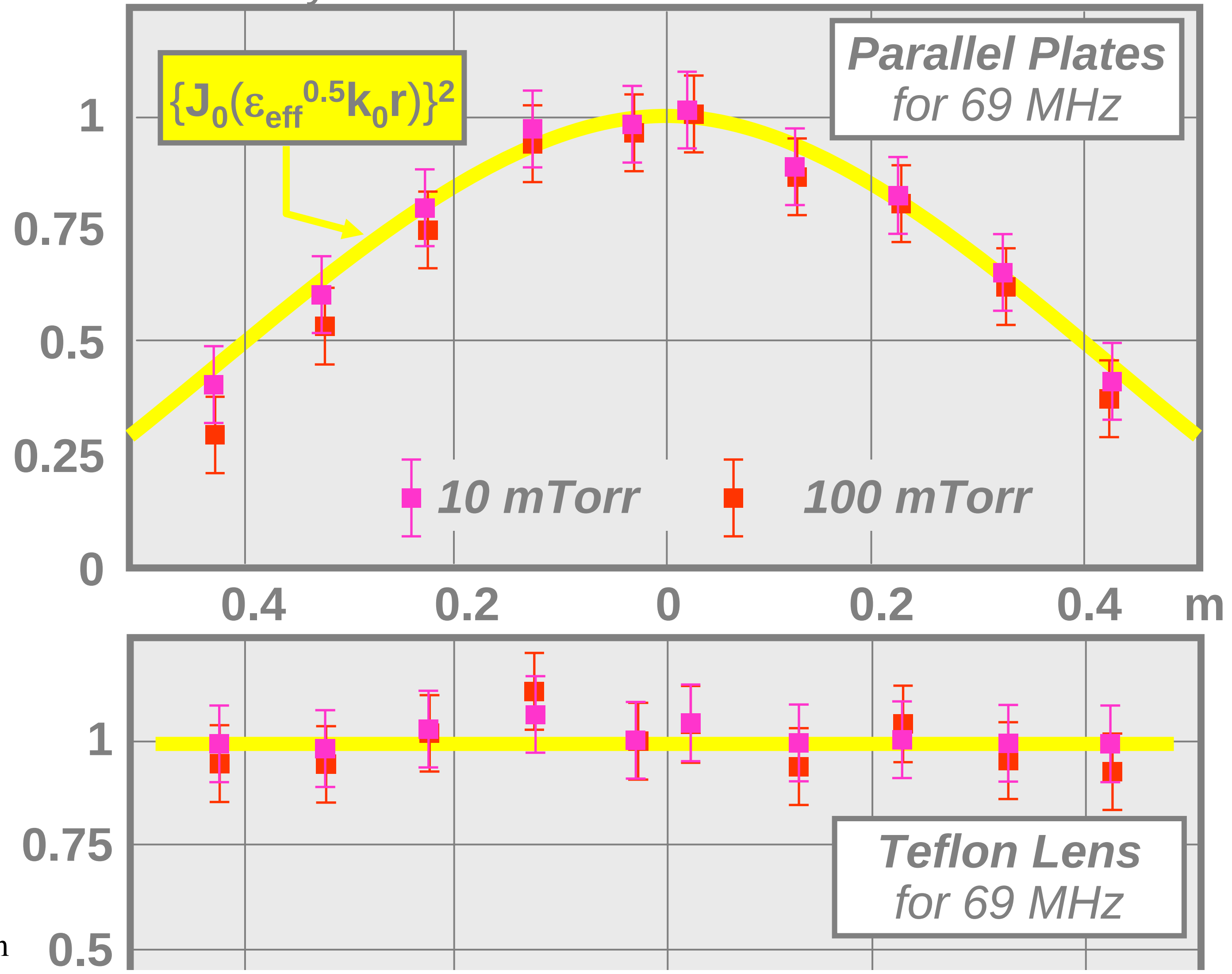


optical emission & surface electrostatic probes

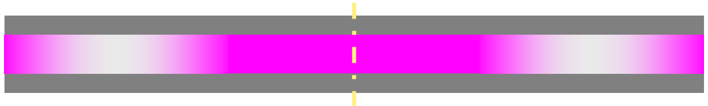
surface electrostatic probes: (i) ion saturated current

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

Probe array: ion current normalized to center

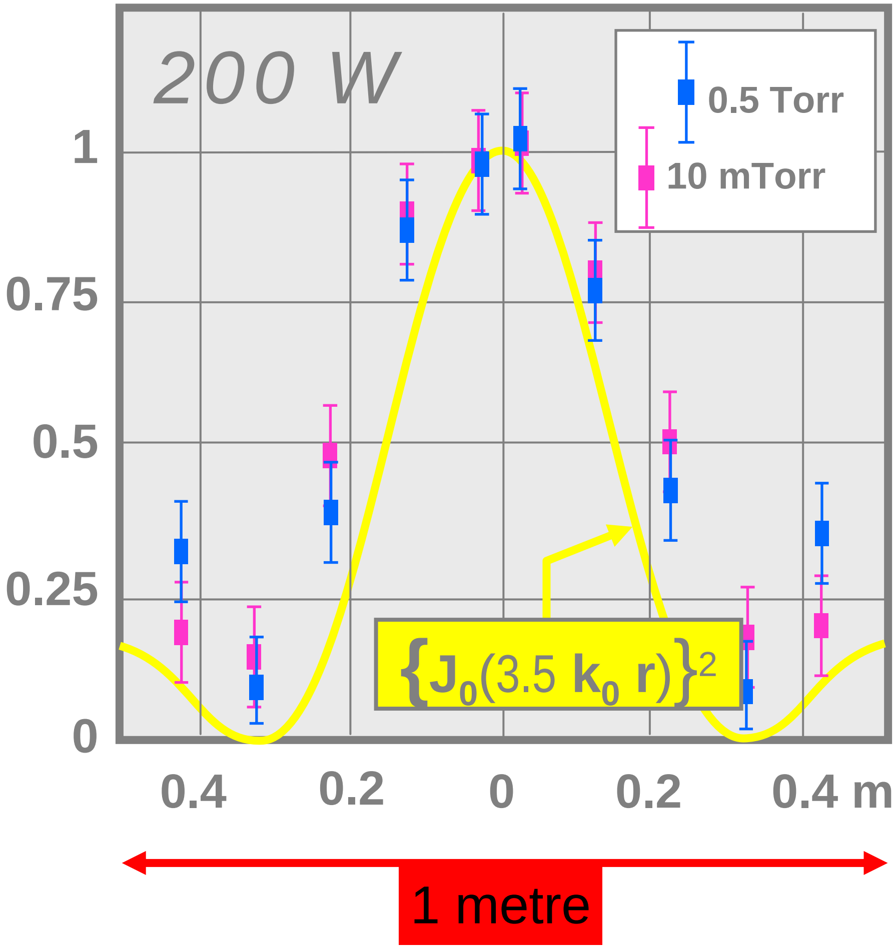


EXPERIMENTS AT 100 MHz



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

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

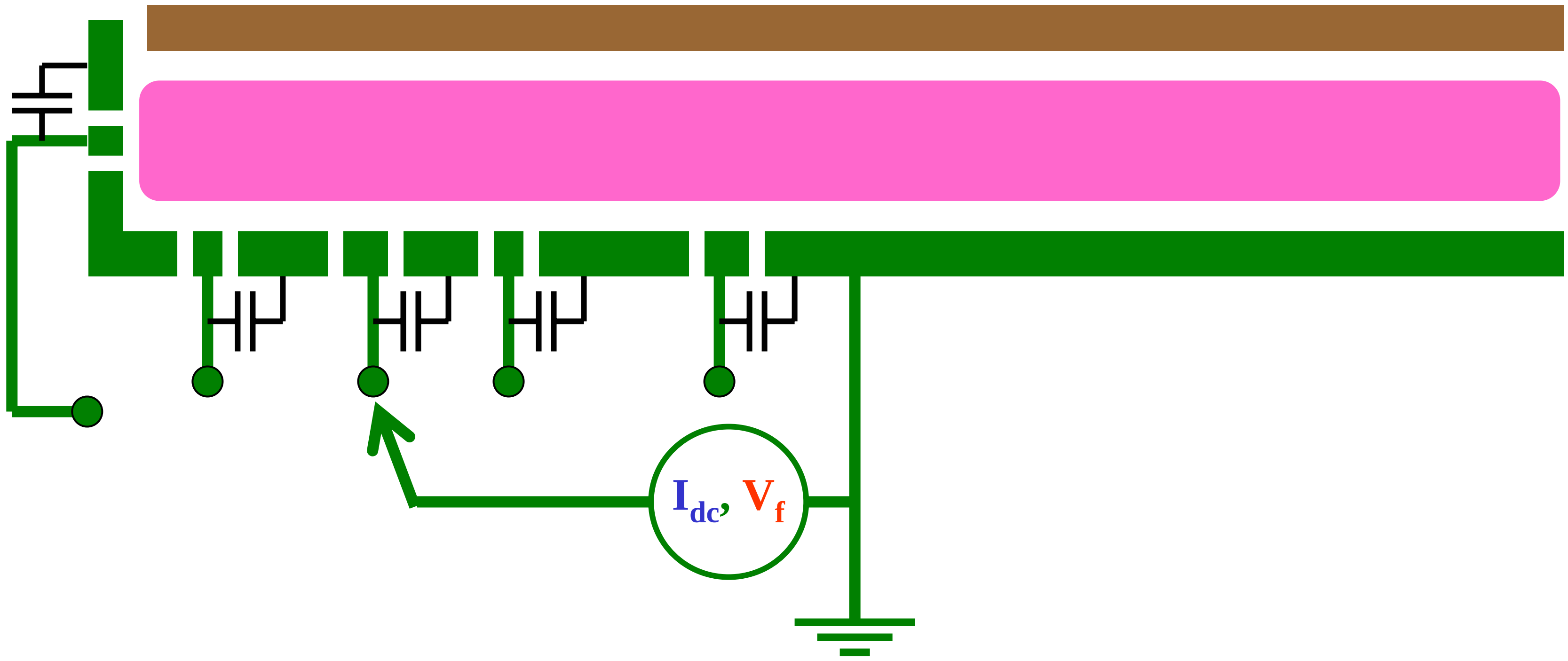


surface electrostatic probes: (ii) DC floating voltage

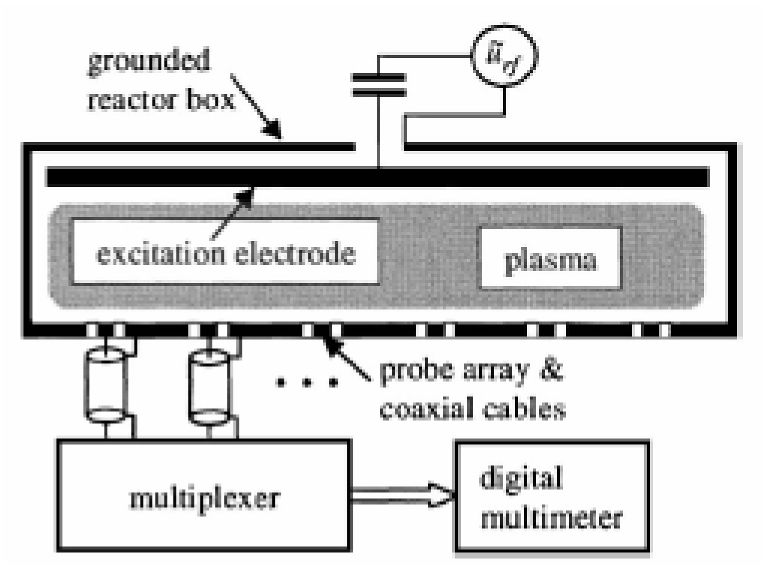
JOURNAL OF APPLIED PHYSICS 97, 123308 (2005)

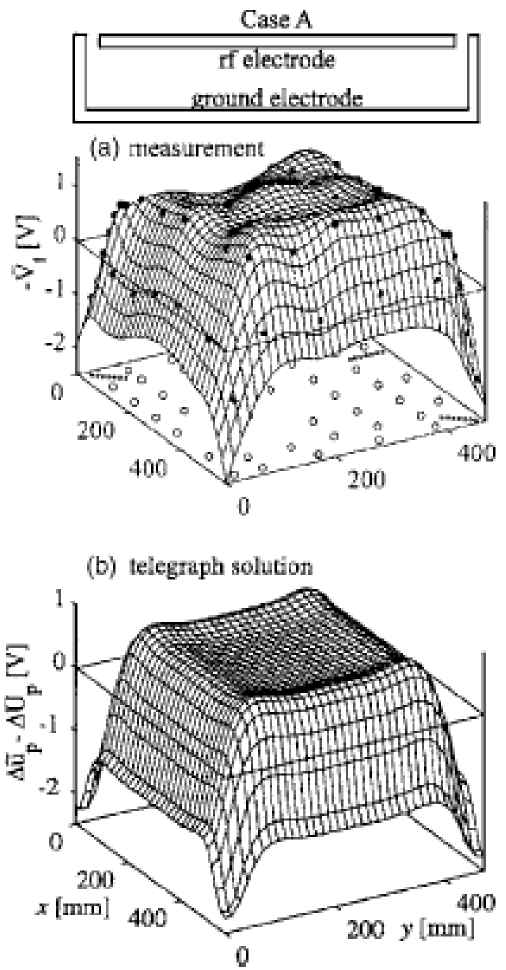
DC floating voltages give approx. variation in RF plasma potential

DC currents to grounded probes give DC current density profile,



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:

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

Blocking capacitor →

$$\frac{1}{T}\int_0^T (J_e + J_i)dt = 0 \rightarrow \bar{U} = \frac{T_e}{2}\ln\left(\frac{M_i}{2.3m_e}\right) + T_e \ln\left[I_0\left(\frac{\tilde{U}}{T_e}\right)\right]$$

Local ambipolarity for 0 time averaged conducting current on the electrode

Large area:

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

→ Equation cannot be satisfied simultaneously over the electrode area

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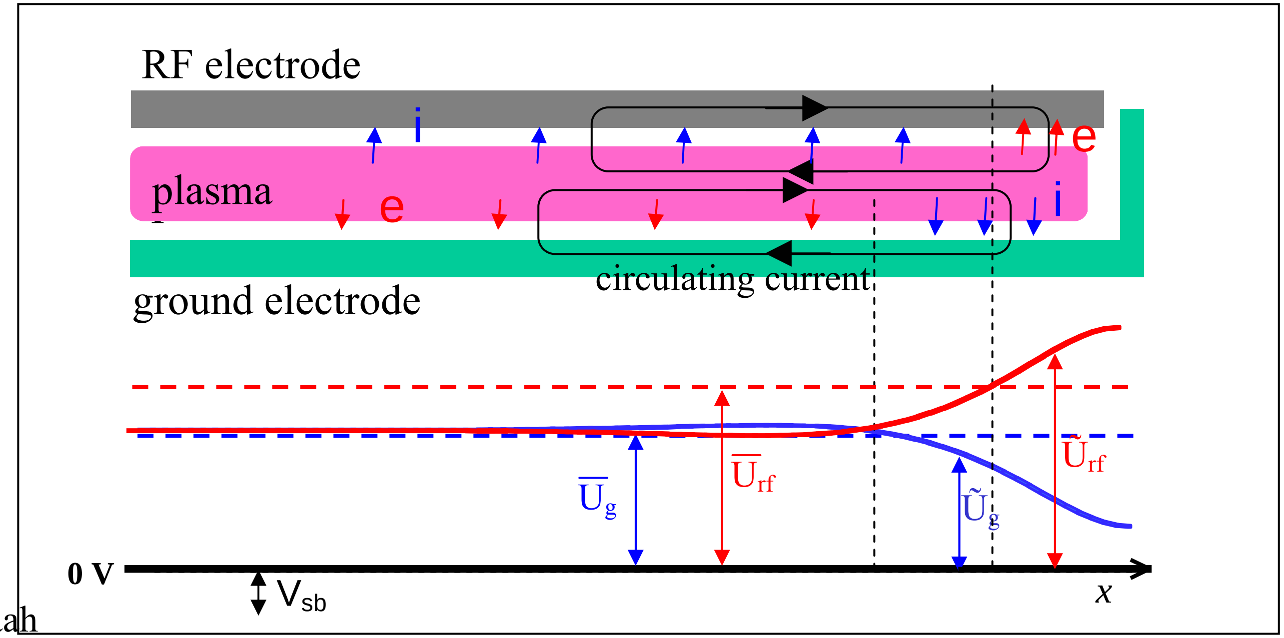

surface electrostatic probes: (iii) DC current, zero bias

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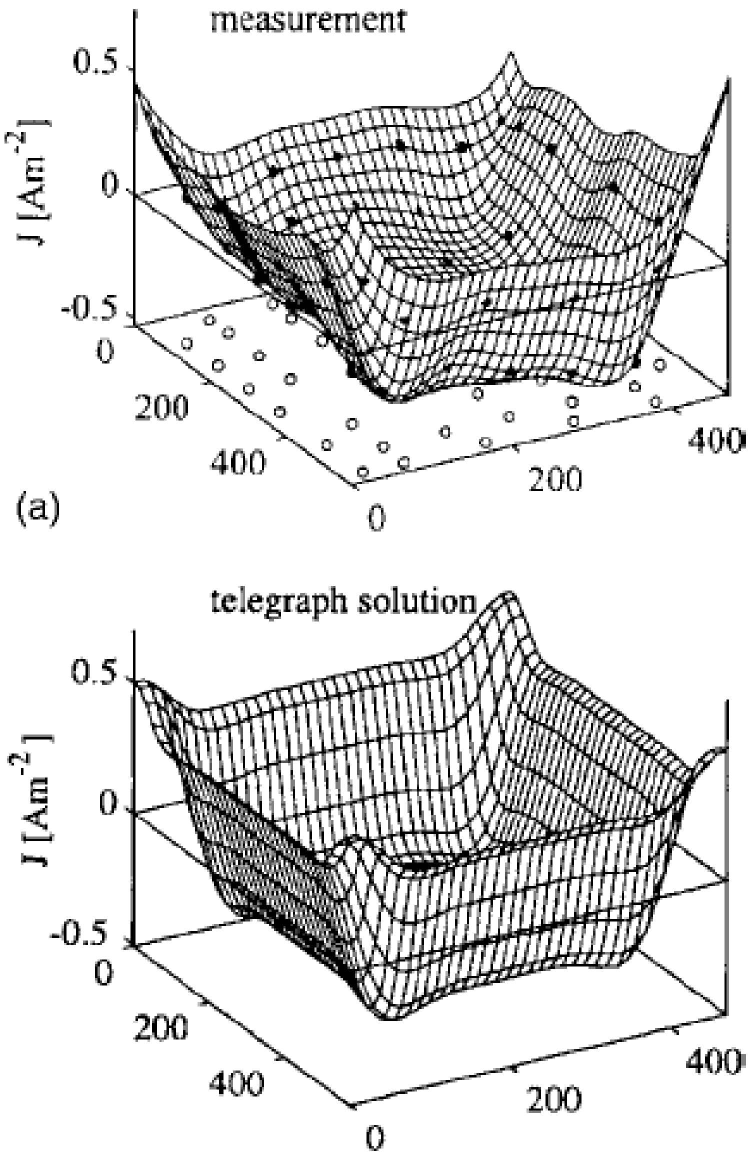

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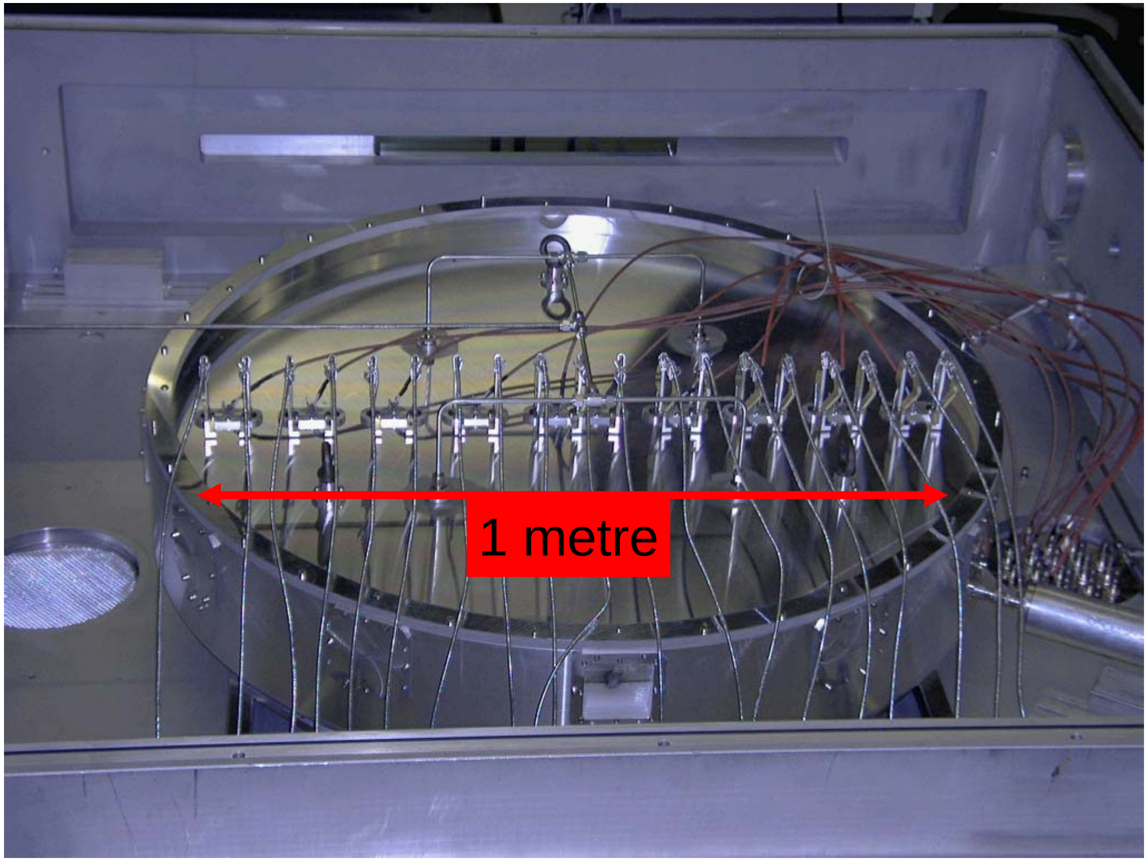
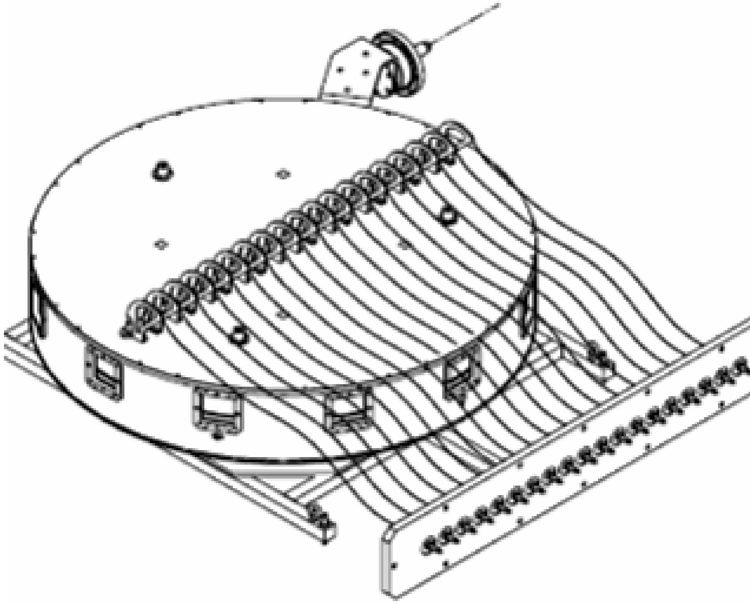
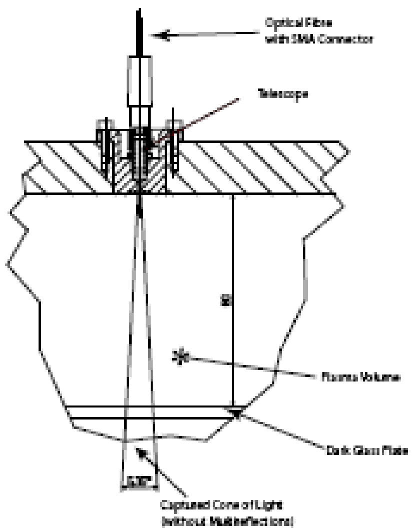
optical emission & surface electrostatic probes





Cylindrical reactor experiment

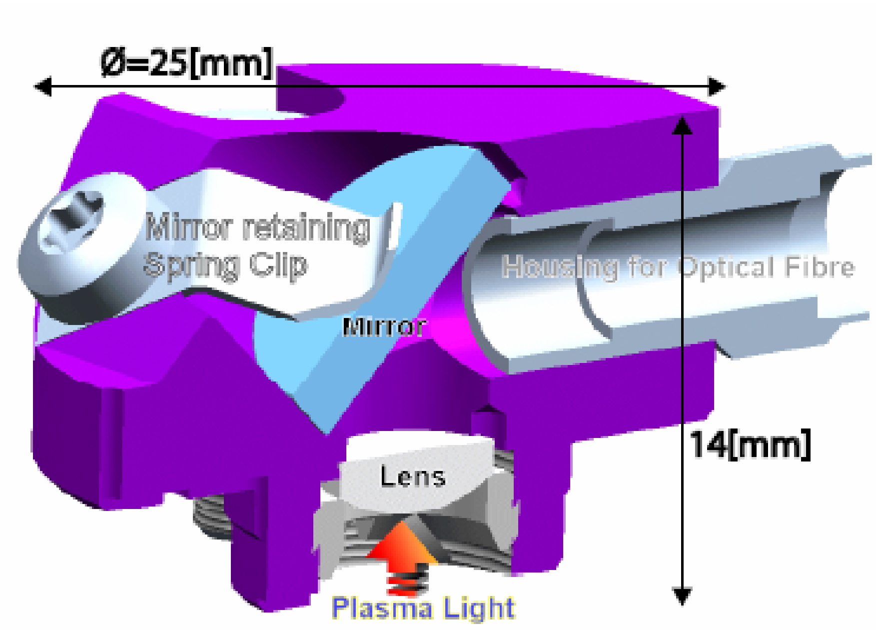


[A]

[B]

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

fibre optic telescope



fibre optic telescope, for right-angle view

optical emission intensity: fibre optic probes

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

Optical emission 2D profiles
in a rectangular reactor:

Parallel plates

With lens

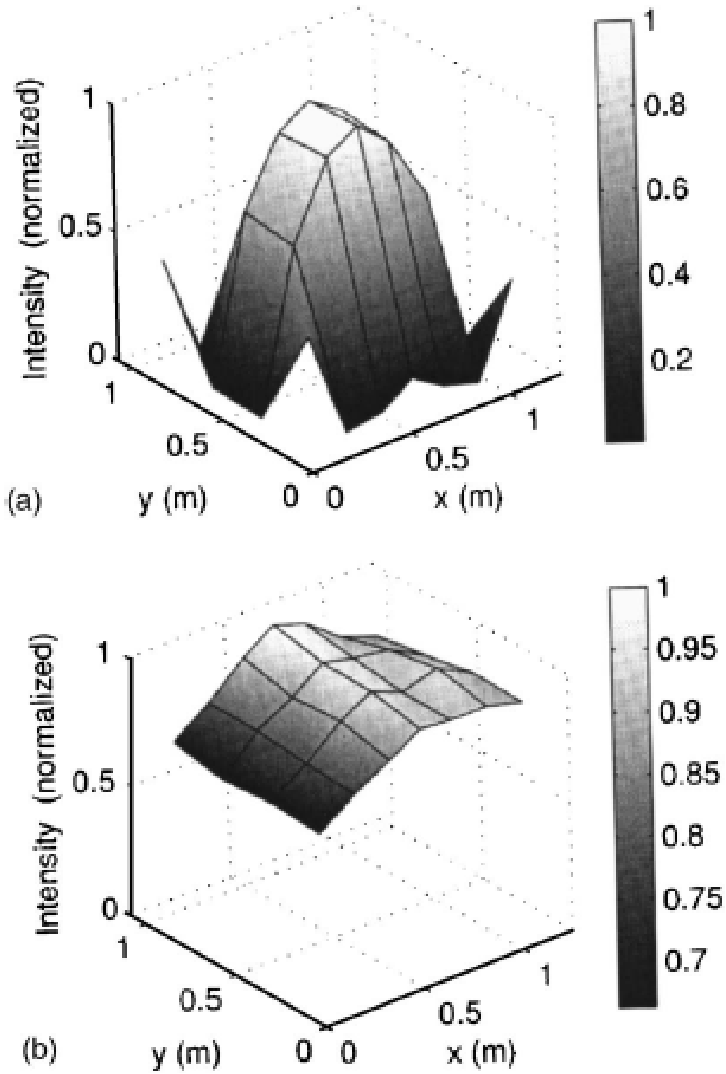
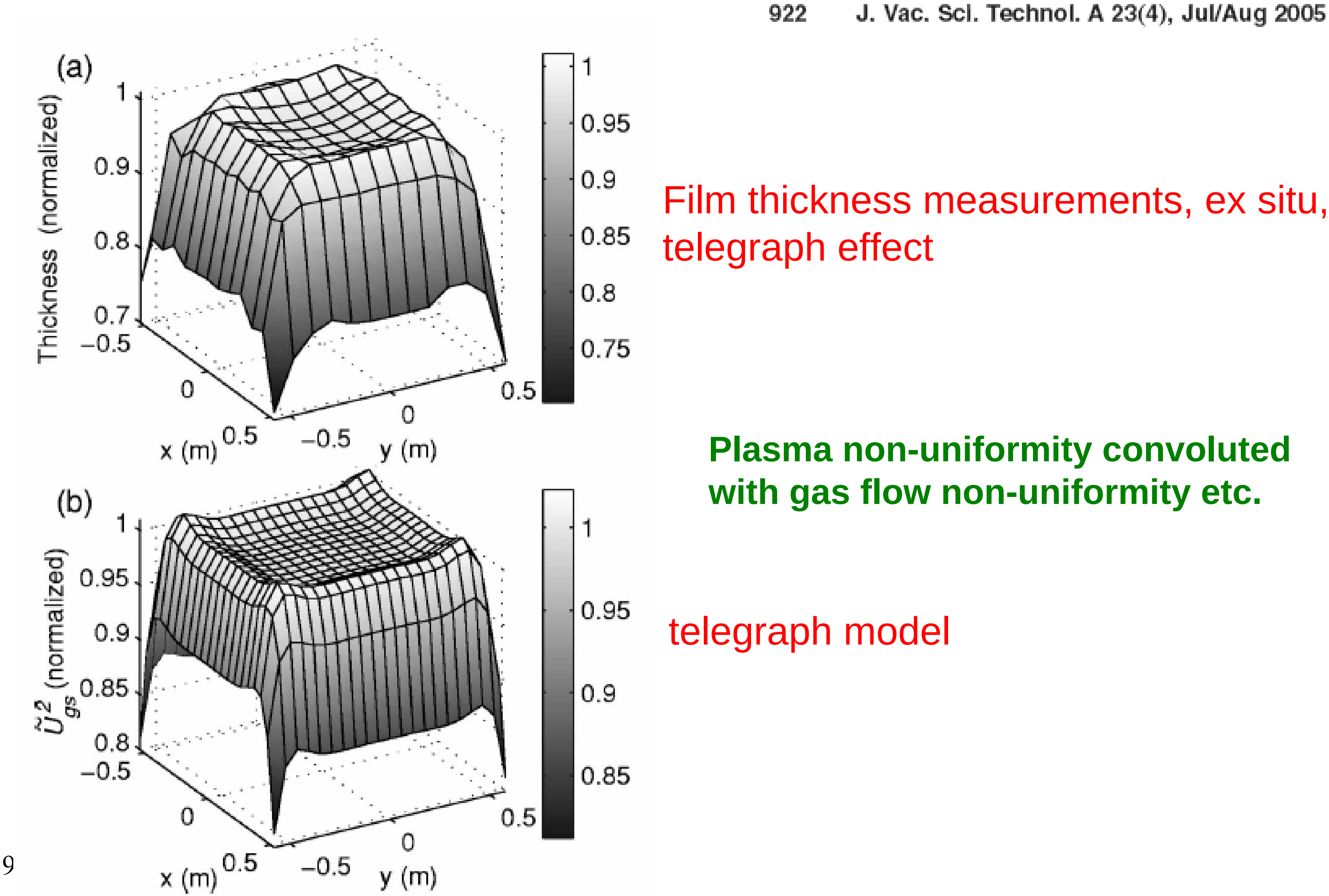


FIG. 3. Normalized plasma emission profile averaged over the vertical interelectrode gap for (a) the parallel plate reactor configuration, and (b) the shaped electrode reactor configuration. The plasma conditions are 66.7% argon 33.3% hydrogen gas mixture at 0.132 mbar, 67.8 MHz excitation frequency,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

ex situ film thickness measurements

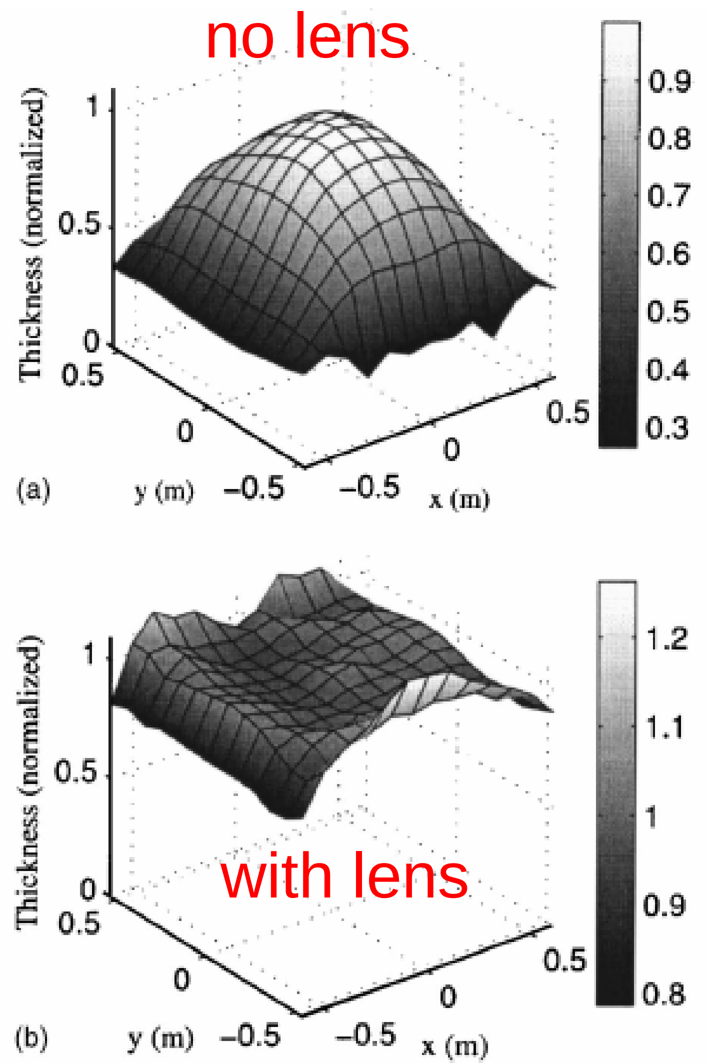


Film thickness measurements, ex situ, telegraph effect

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

telegraph model

ex situ film thickness measurements



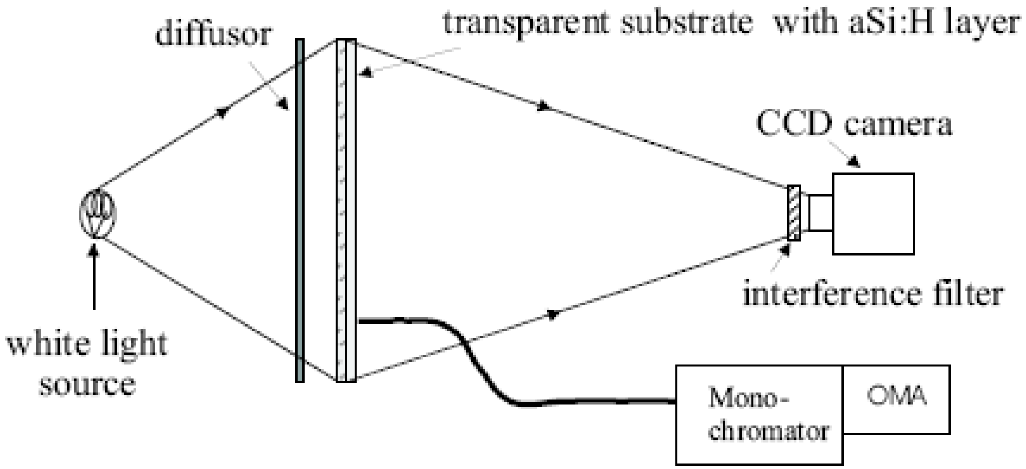
1425 J. Vac. Sci. Technol. A 24(4), Jul/Aug 2006

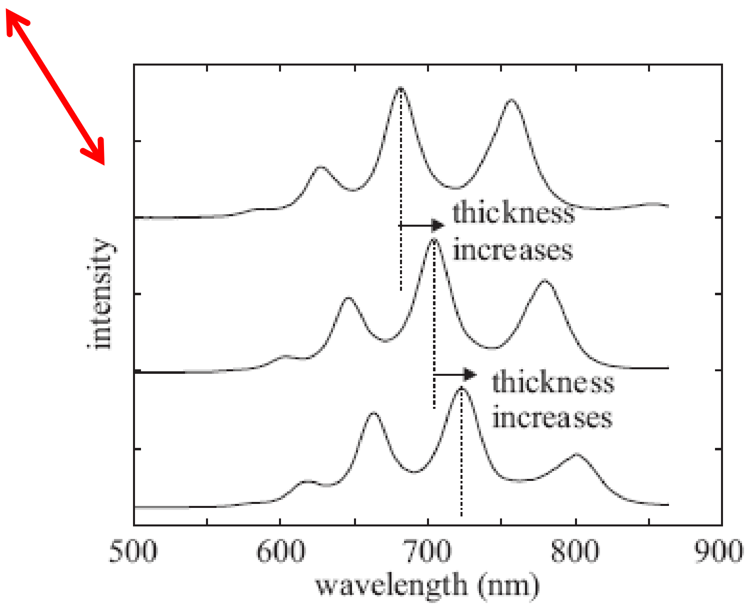
Film thickness measurements, ex situ, standing wave correction

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

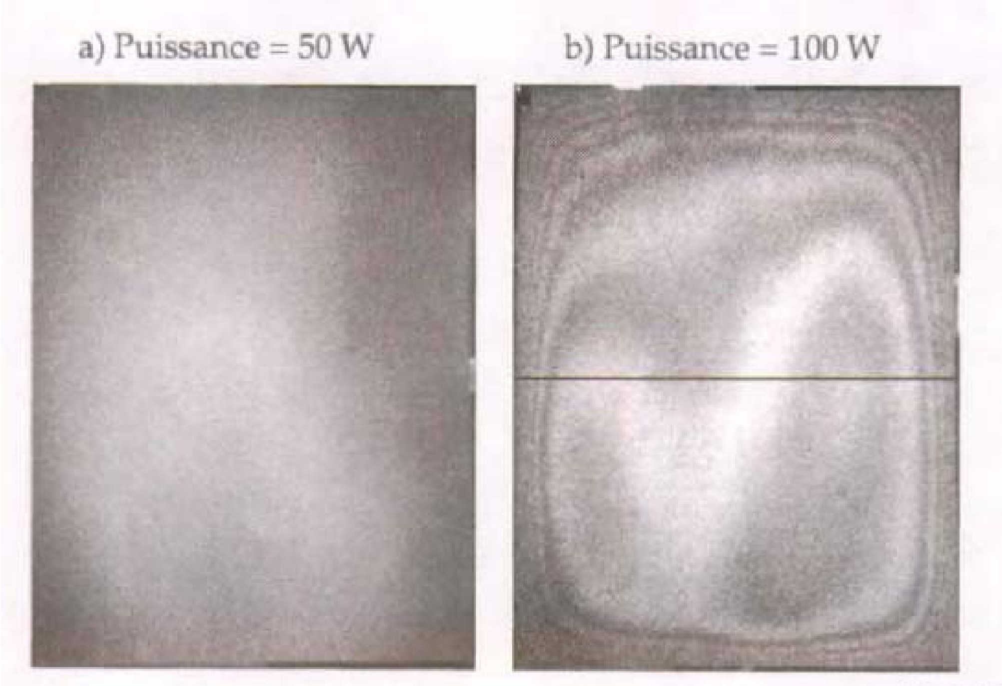
ex situ film thickness measurement: interferogram

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





ex situ film thickness measurement: interferogram



37 cm x 47 cm

non-uniformity due to powder

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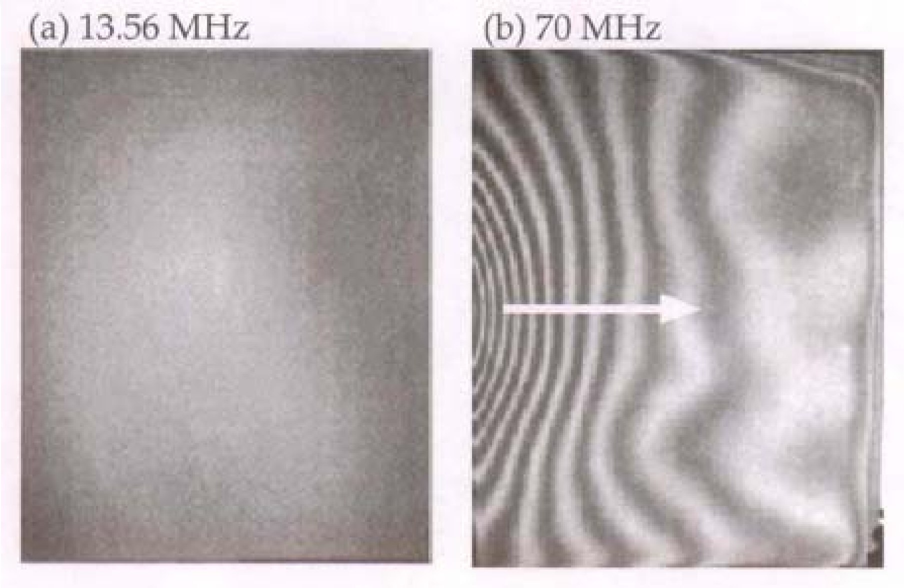
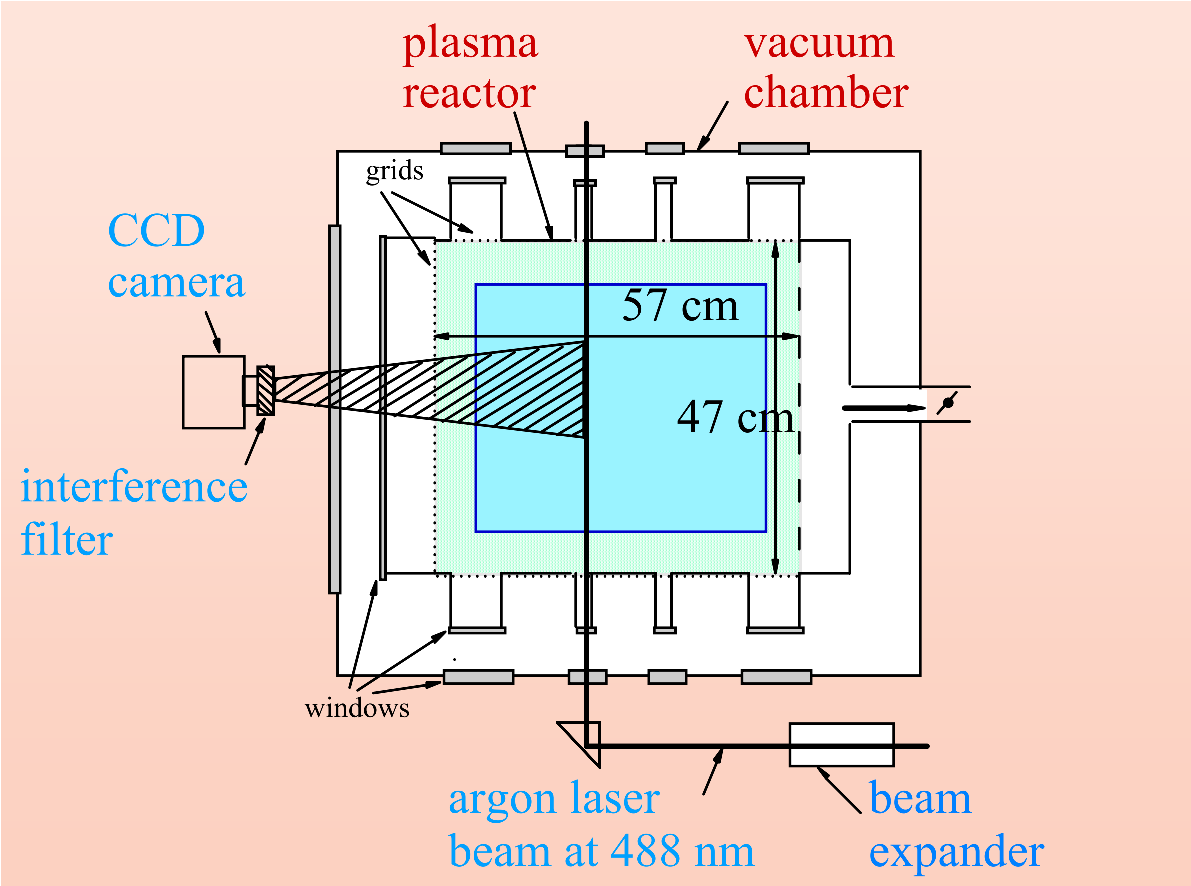
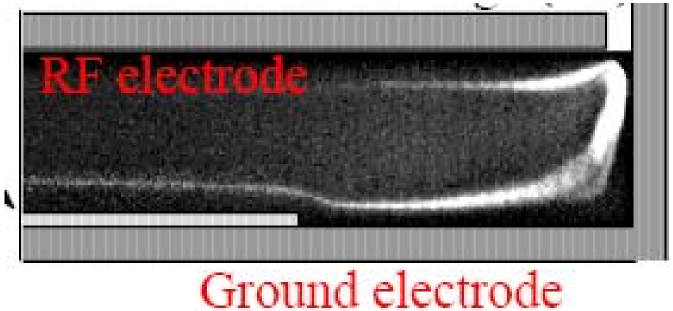


non-uniformity due to standing wave
(VHF frequency)

light scattering from powder

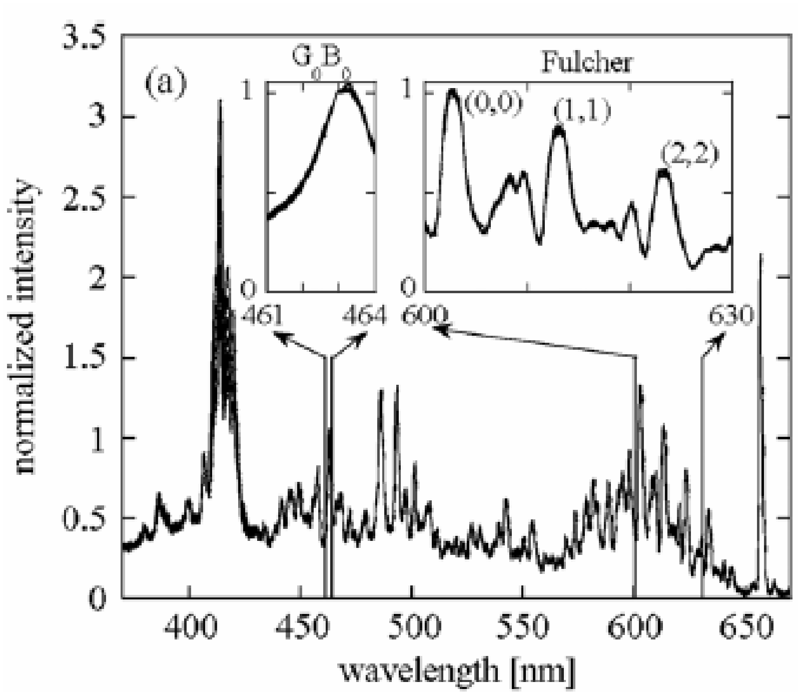


MRS Symp. Proc. Vol. 507
Amorphous and Microcrystalline
Silicon Technology,
pp547-557 (1998).

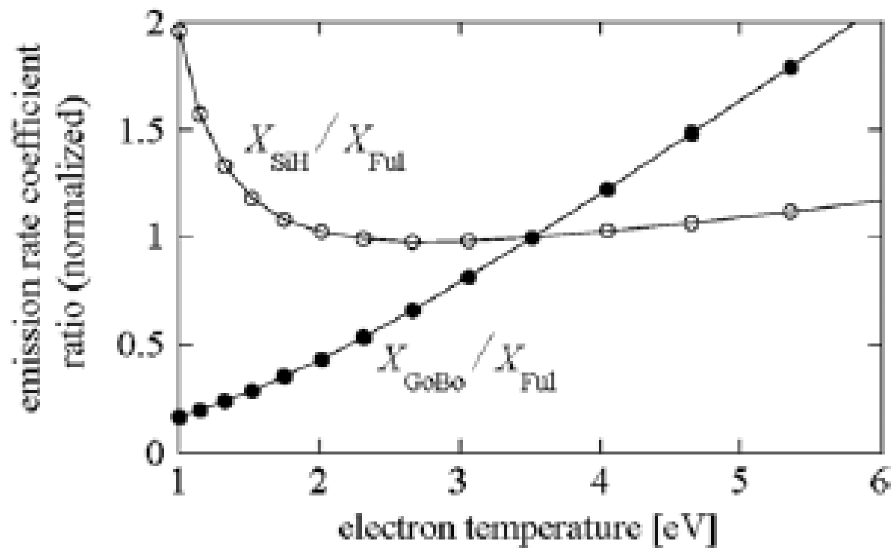


CCD
Image

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