VA characteristics @GOLEM

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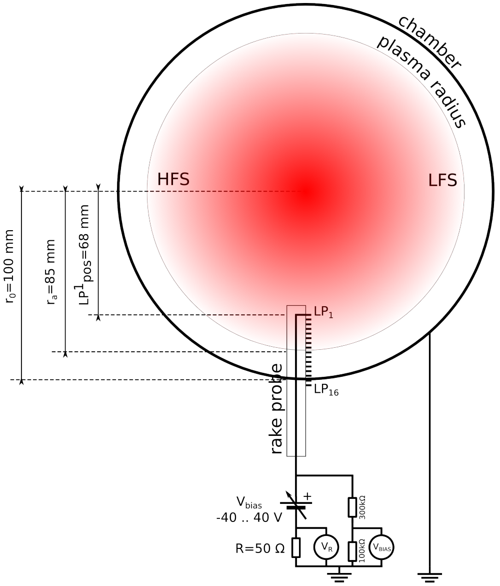
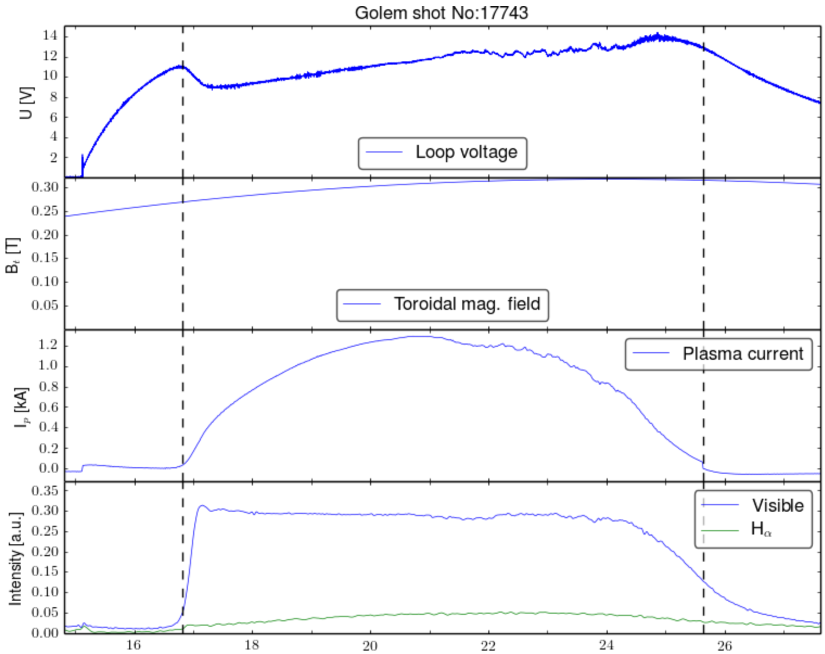
2015

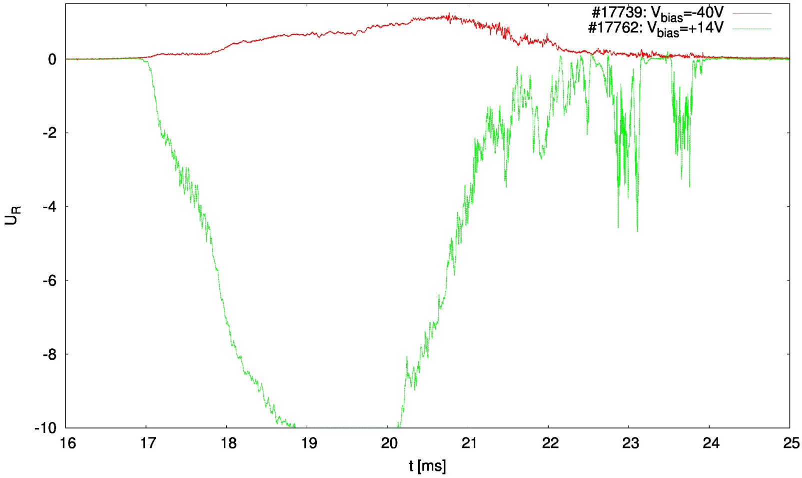
Experimental setup



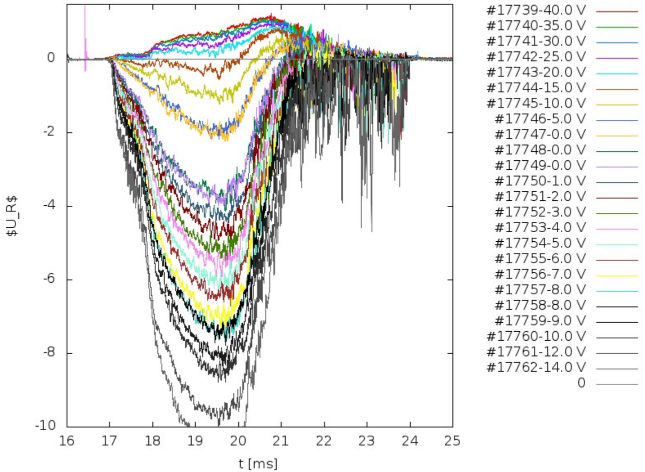
Reference discharge #17743



Raw signals: electron & ion signal

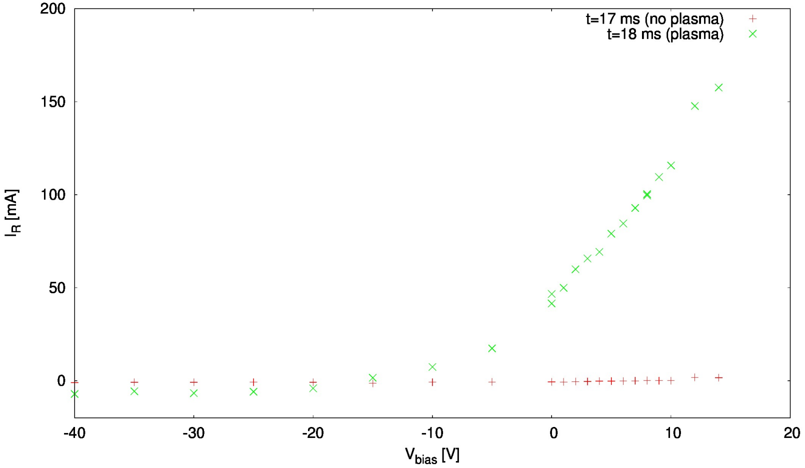


Raw signals alltogether

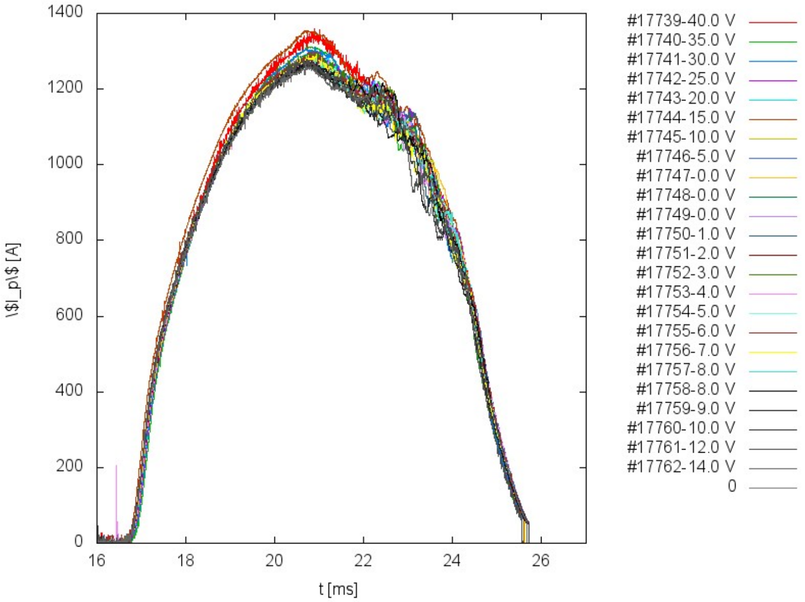


Let's make cut @17ms & @18ms →

VA characteristics



Discharge reproducibility @GOLEM



LP theory - use 3 parameter fit

How to extract plasma parameters

The knee of the I-V characteristics identifies the plasma potential V_{pl}.

V_f: the "floating potential" → no current driven to the probe.

Plasma potential: $V_{pl} = V_{fl} + \Lambda T_e$

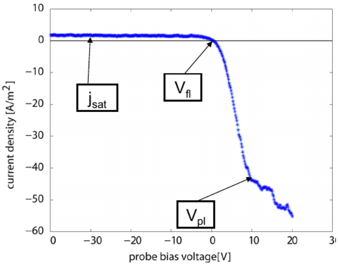
I_{sat}: ion saturation current. Often we work directly with $J_{sat} = I_{sat}/A_s$, with A_s the particle collection area – this is identified with $A_\perp$, the projected area when $B \neq 0$ (see later).

Once I_{sat} and T_e are known, the density at the sheath edge follows:

$n_{se} = I_{sat}/Z_i e c_s A_s$

However, the knee it is not well defined (see practicum III).

Usual way to extract information from LP characteristic is to use a 3 parameter non-linear least square fit to obtain I_{sat}, V_f and T_e.



$$I = I_{sat}\left[1 - \exp\frac{V - V_{fl}}{T_e}\right]$$

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Furno et al.:Theory of electrostatic probes

LP theory - empirical parametrization

$$I(a, V_{bias}) = \exp[a_1 \tanh(V_{bias} + a_2)/a_3] + a_4$$

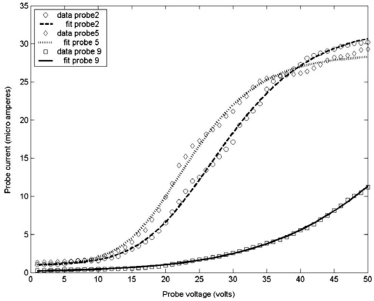


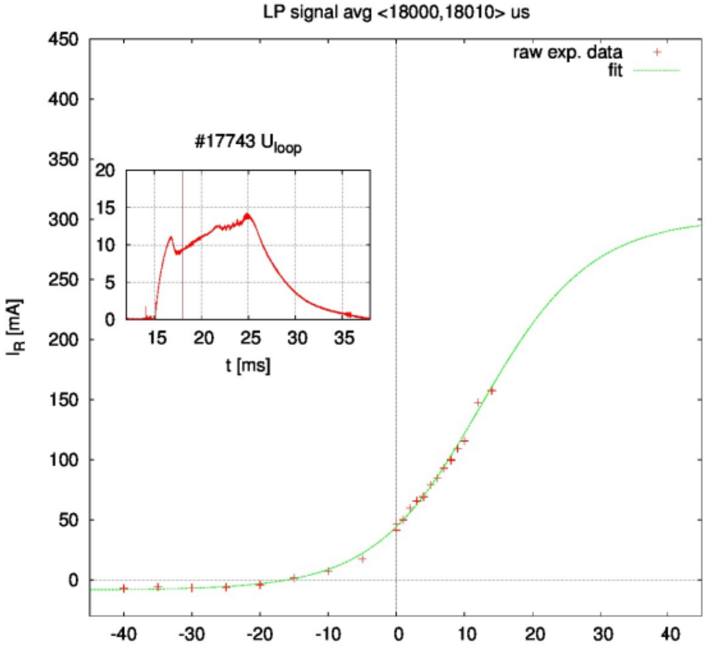
FIG. 8. Experimental and fitted *I-V* characteristics for three probes.

are much similar to probes 2 and 5. The current scale of probe 9 is lower than those obtained for other probes. This probe is very close to the glass discharge vessel where wall effects are dominant. Evaluation of the second differential d^2I/dV^2, plasma potential V_p, the EEDF, and thus the plasma electron temperature T_e are carried out using both the fitting method and ac differentiating signal data. Typical plot of d^2I/dV^2 and the EEDF using both methods for one of the probes are shown in Fig. 9.

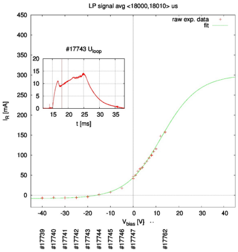
It can be said that there is an acceptable agreement between values of the plasma potential and the general shape of the EEDF obtained using the two methods. Part of the discrepancies between the two may be associated with some of the limitations associated with ac differentiation. One of these limitations is connected to the experimental difficulty of measuring very small differences in probe current for the ac on and ac off cases. This is particularly true at higher probe dc probe biases that correspond to the higher electron energy tail of the EEDF. A second limitation associated with ac differentiation is the effect of instrument convolution

Azzoz@RevSciInst(2008) + code@matlab

Empirical parametrization on the GOLEM data



Extracted parameters



- Ion saturation current: $I_{is} = I(a, 2 * min(V_{bias}))$
- Electron saturation current: $I_{es} = I(a, 3 * max(V_{bias}))$
- Plasma potential: $V_p = a_3 * \mathrm{atanh}(((\sqrt{1 + a_1^2}) - 1)/a_1) - a_2;$
- Floating potential V_{fl} from the condition $I(a, V_{fl}) = 0$
- Electron energy distribution function (EEDF): $N(\epsilon) = \frac{2}{Ae}\sqrt{\frac{2m\epsilon}{e}}\frac{d^2I}{dV^2}$
- Electron energy distribution function (EEPF): $P(\epsilon) = \frac{2}{Ae}\sqrt{\frac{2m}{e}}\frac{d^2I}{dV^2}$
- Electron density

$$n_e = \int_0^\infty P(\epsilon) d\epsilon$$

- Ion density $n_i = \frac{|I_{is}|}{0.52 * A * e^{2/3}}\sqrt{\frac{M_i}{T_e}}$
- Electron temperature

$$T_e = \frac{2}{3} < \epsilon > = \frac{2}{3n_e}\int_0^\infty \epsilon P(\epsilon) d\epsilon$$

LP theory - EEDF

Harmonic method for EEDF measurements

$$\frac{d^2 I_e}{dV^2} = \frac{2\pi e^3}{m_e^2} A_p f[\mathrm{v}(\varepsilon)]$$

$$\varepsilon = \frac{1}{2} m\mathrm{v}^2 \qquad \mathrm{F}(\varepsilon)d\varepsilon = 4\pi\,\mathrm{v}^2 f(\mathrm{v})d\mathrm{v}$$

$$f(\mathrm{v}) = \frac{m_e^2}{2\pi e^3 A_p}\frac{d^2 I_e}{dV^2}$$

Druyvesteyn formula $F(\varepsilon) = \frac{4}{e^2 A_p}\sqrt{\frac{mV}{2e}}\frac{d^2 I_e}{dV^2}$

Practically, a modulation δ(t) is superposed on the biasing voltage and the second harmonic component is measured which is proportional to the EEDF.

$$I(V) = I[V_0 + \delta(t)] = I(V_0) + \delta(t)\frac{dI(V_0)}{dV} + \frac{1}{2}[\delta(t)]^2 \frac{d^2 I(V_0)}{dV^2} + \ldots$$

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M. Druyvesteyn and F. Penning, Reviews of Modern Physics, vol. 12, no. 2, 87, (1940).

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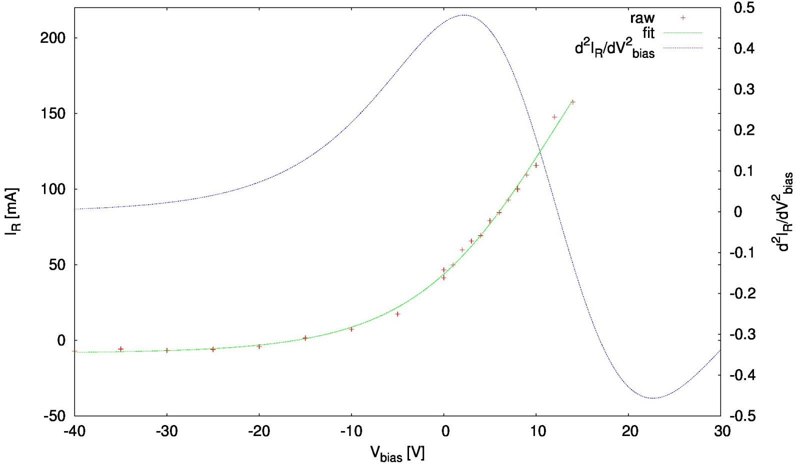
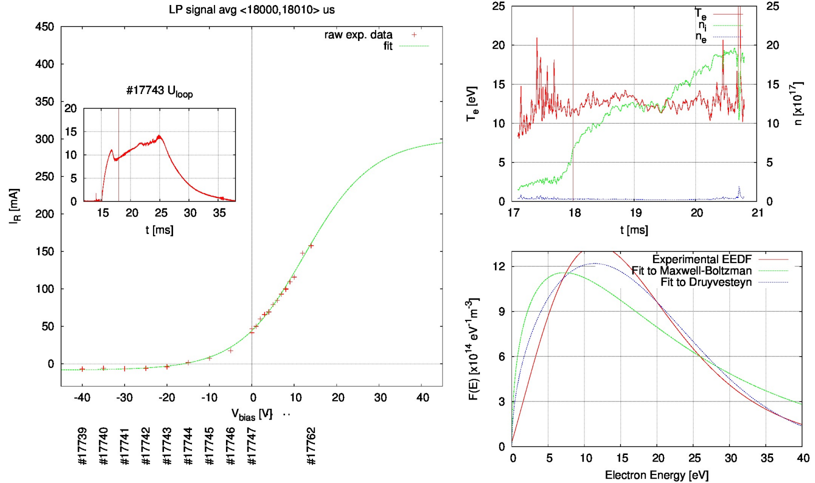
The second derivative of VA characteristics

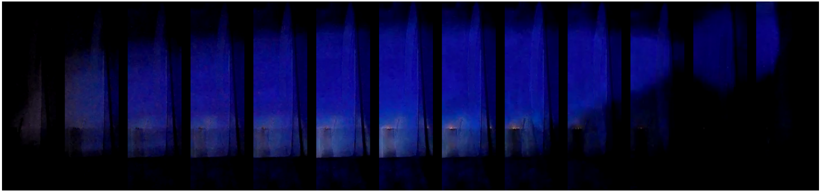


Final video frame



https://www.youtube.com/watch?v=yd54Cy2tFT4

Signal vanish



Summary

- VA characterictic measured on the shot to shot base
- unique data obtained