Langmuir probes for low temperature plasma diagnostics

An analysis of laboratory results

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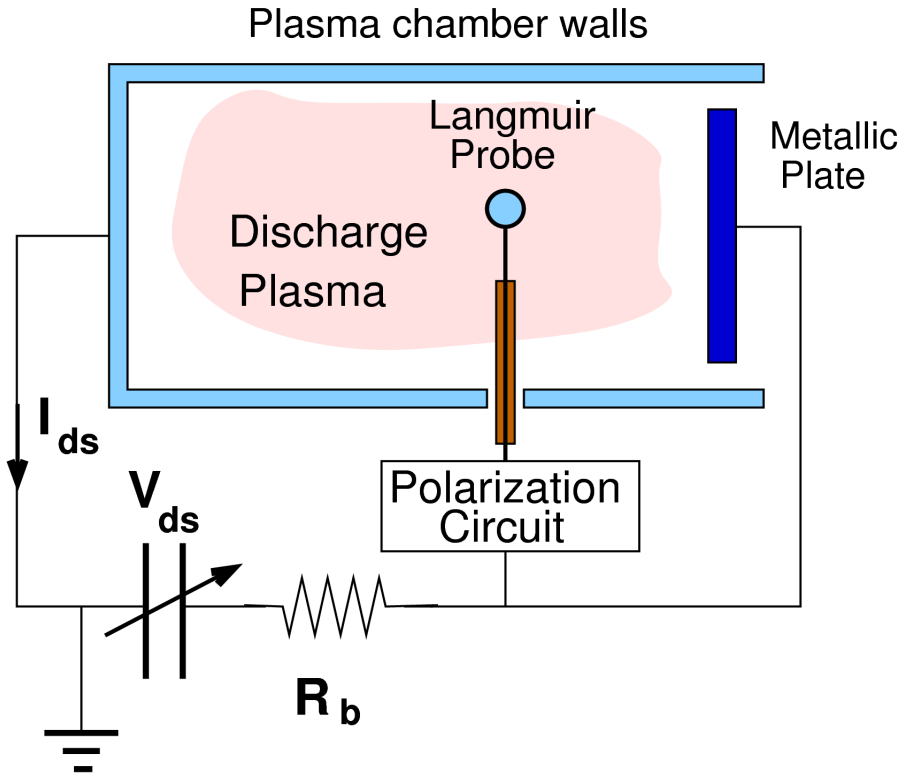
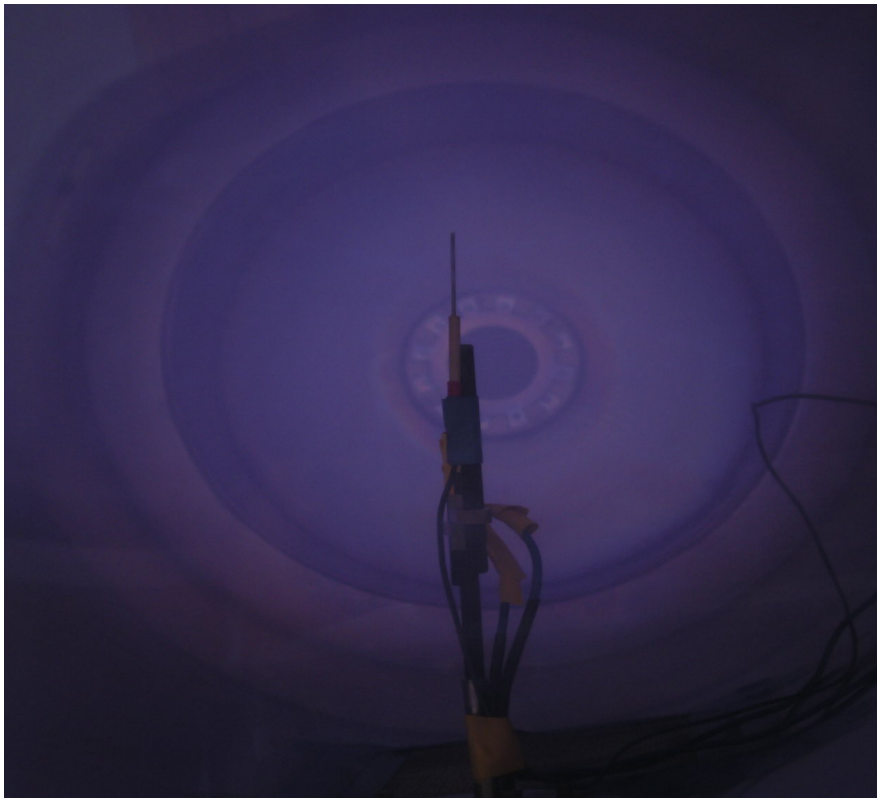
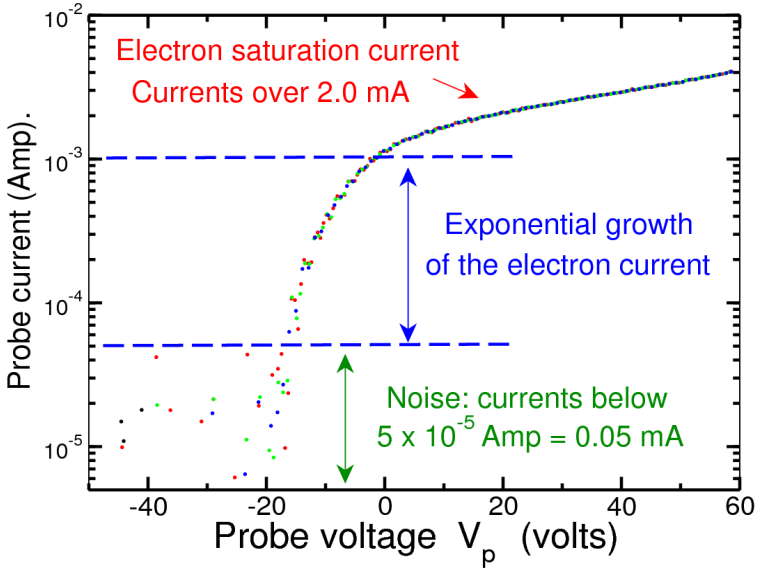
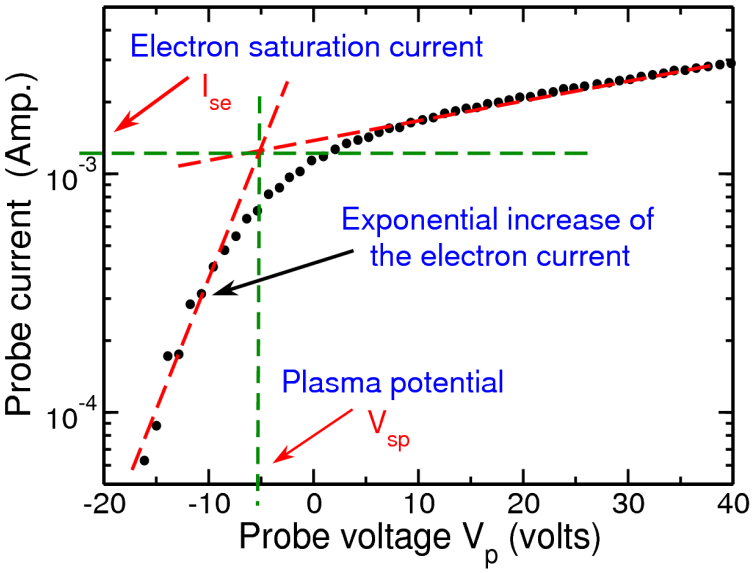
The plasma was produced by a glow discharge

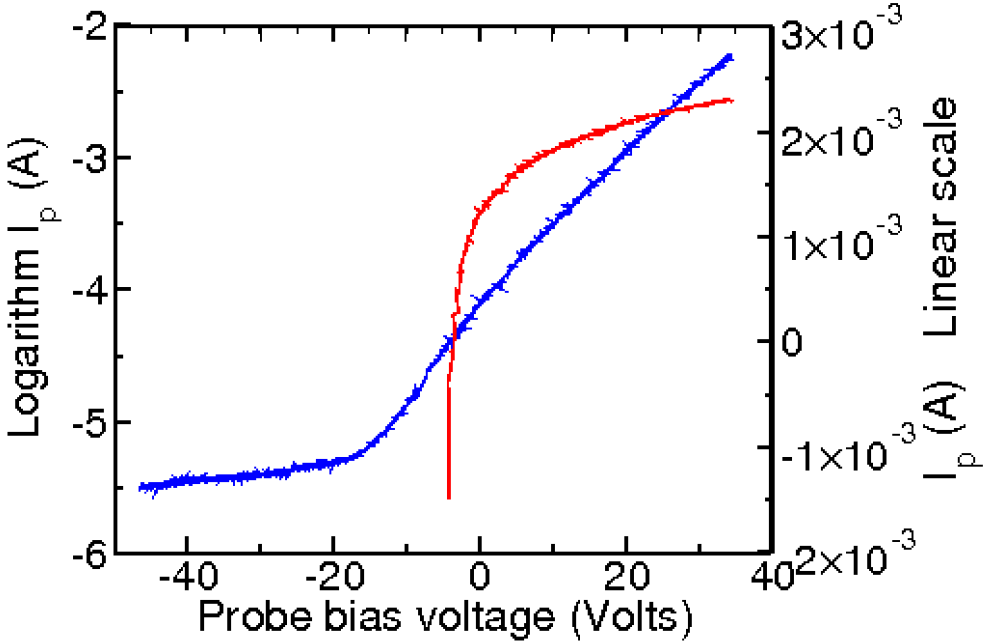




The classical analysis requires few linear fits of data, ...







The comparison of the characteristic curve in linear (right) and logarithm scale (left) of the same data.

The results from the simplified theory

The elementary theory applies for collisionless and unmagnetized plamas and assumes that, both electrons and ions, have a Maxwellian energy distribution function with finite temperatures: $K_B T_e >> K_B T_i \approx K_B T_a$

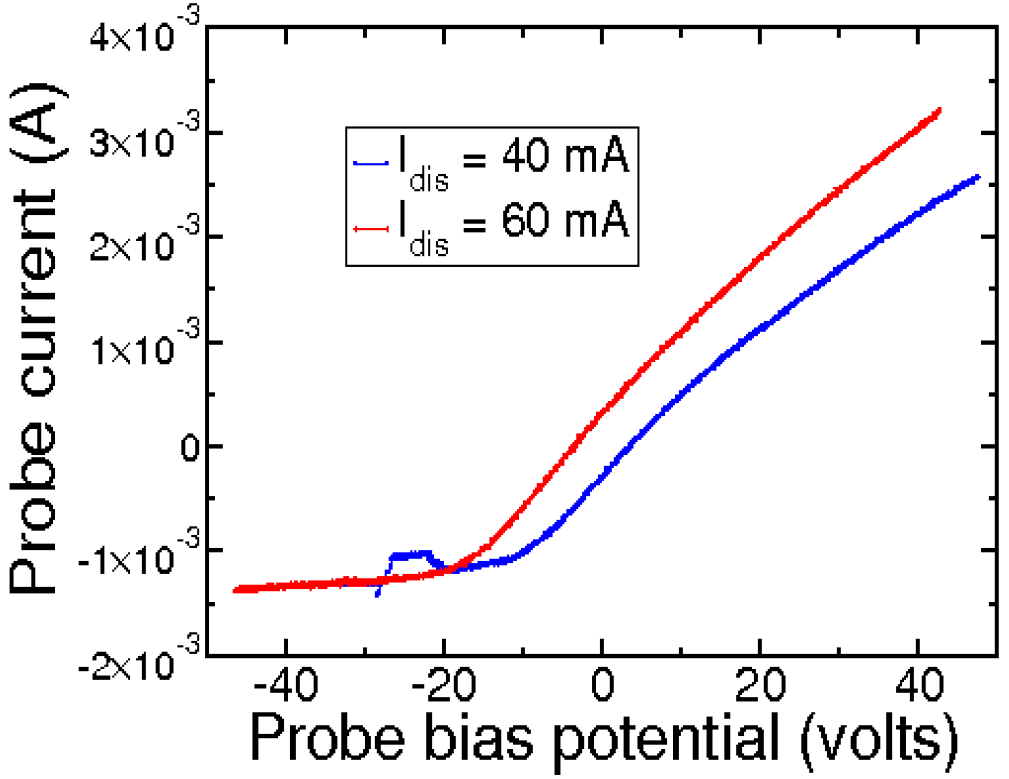
$$I_{BC} = I_s \exp\left(\frac{e(V_p - V_{sp})}{K_B T_e}\right)$$

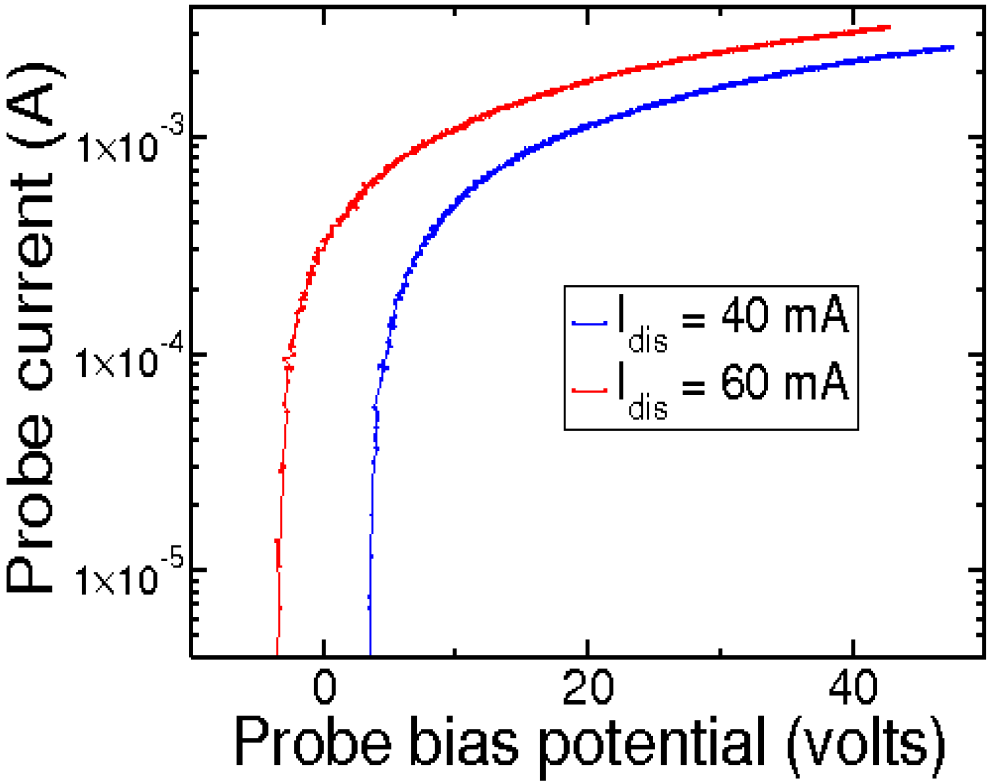
$$v_{th} = \left(\frac{8 K_B T_e}{\pi m_e}\right)^{(1/2)} \qquad I_{es} = \frac{1}{4} S n_e v_{th} \qquad \begin{cases} S = 4\pi r_p^2 \\ S = 2\pi r_p \ L \end{cases}$$

The second derivative of the current for *repelled* particles is proportional to the electron energy distribution function *g(E)*

$$\frac{d^2 I}{dV_p^2} = -(e^2 \pi r_p^2) g(E) \sqrt{\frac{2e}{m_e V_p}}$$

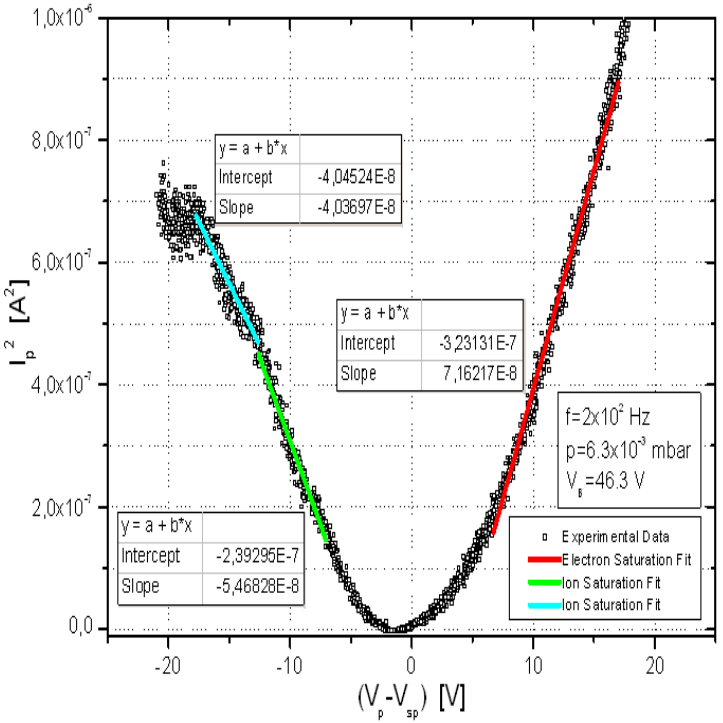
How much the discharge current changes the plasma?

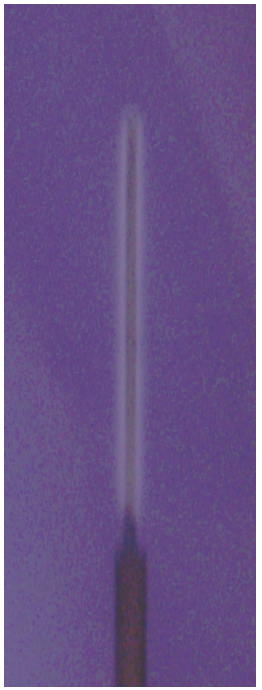


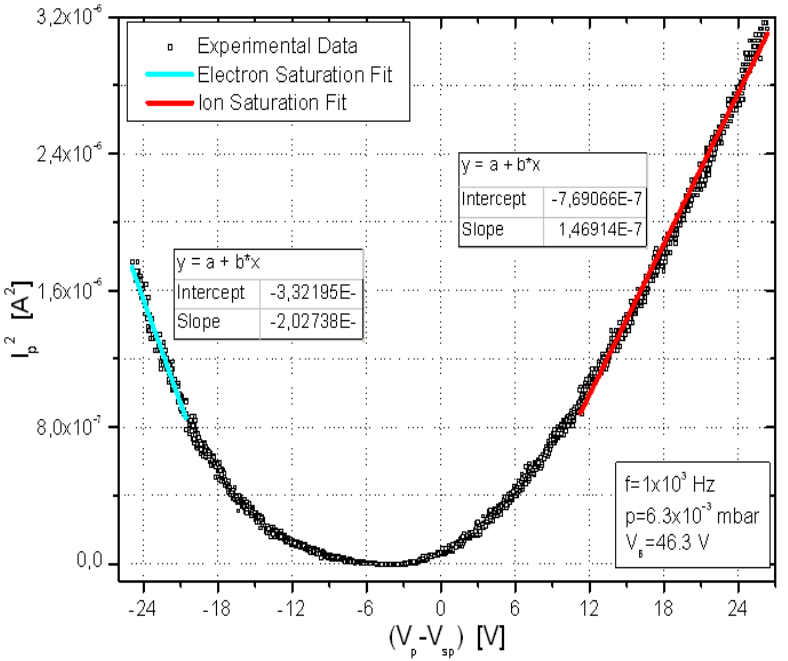


The plasma potential changes but the plasma electron density and electron temperature remain unaltered by the increment in the discharge current

How reliable is the thick sheath (OML) approximation?

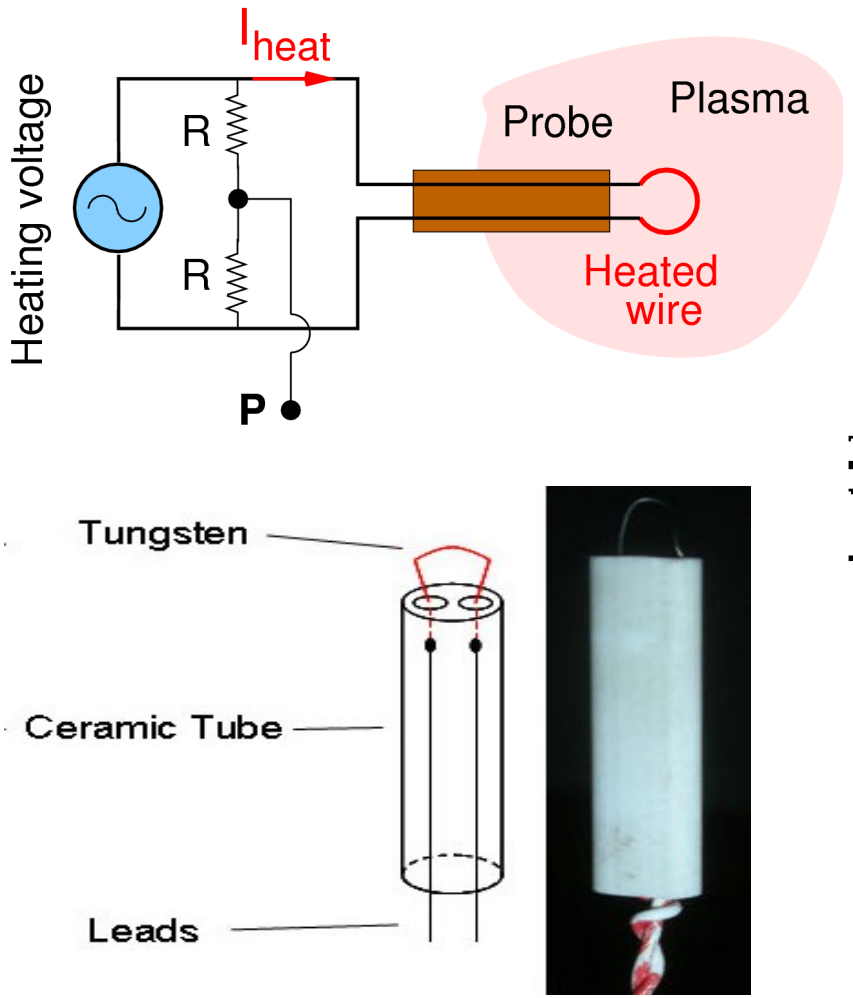


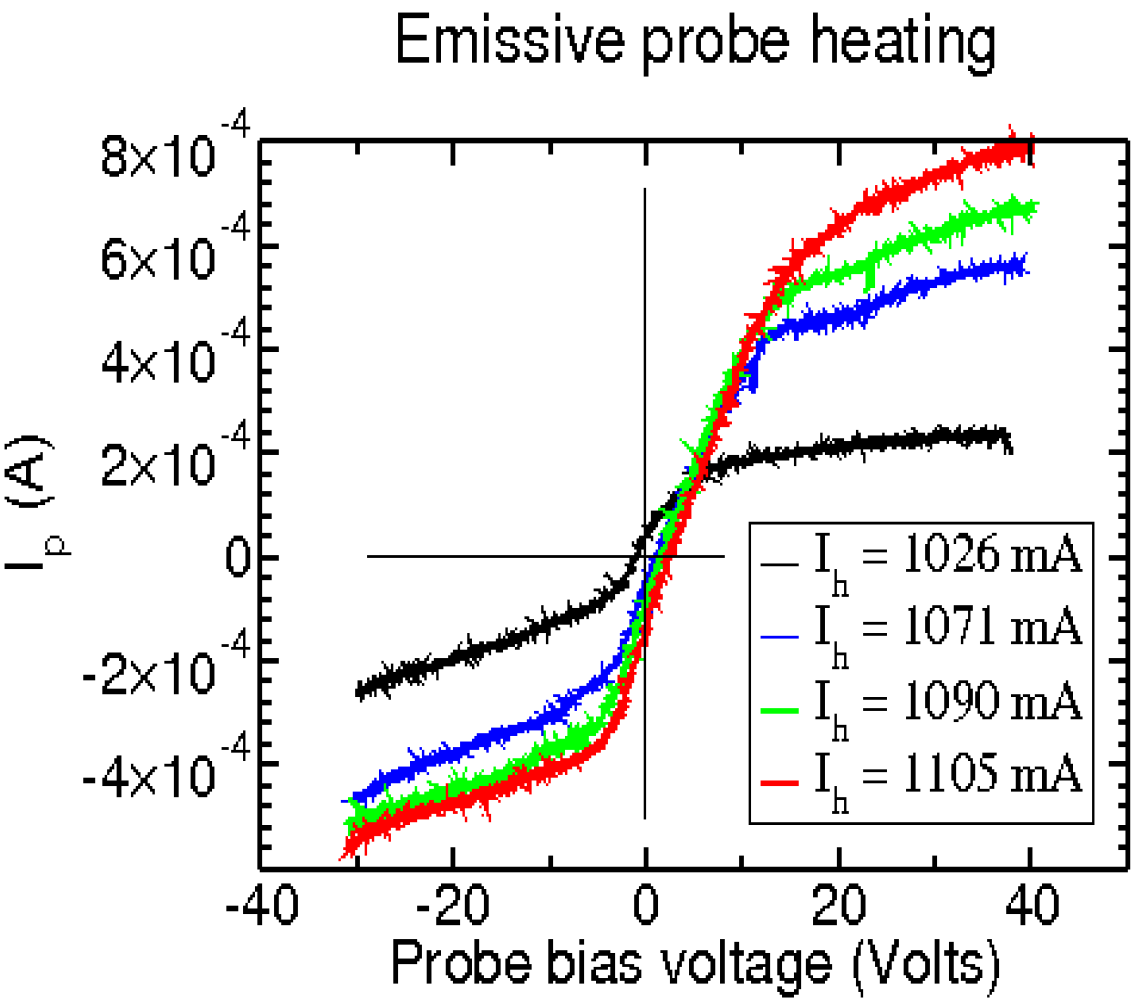




The dependence with V_p-V_{sp} is more or less correct, but the plasma parameters are wrong by about an order of magnitude.

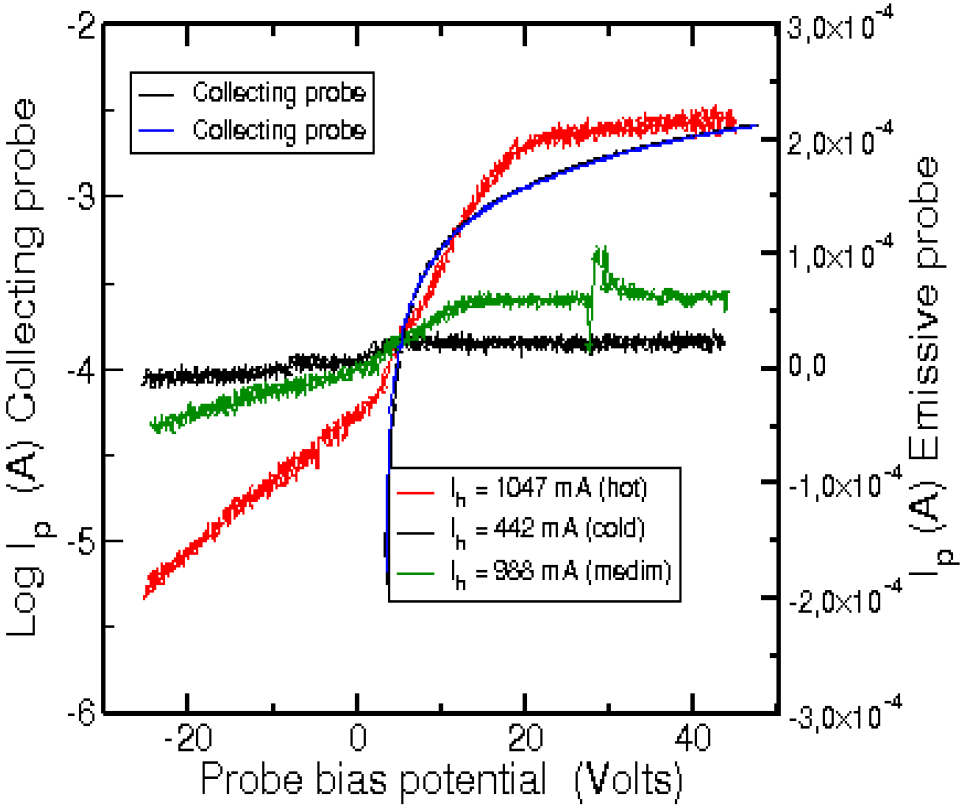
How emissive probes work?

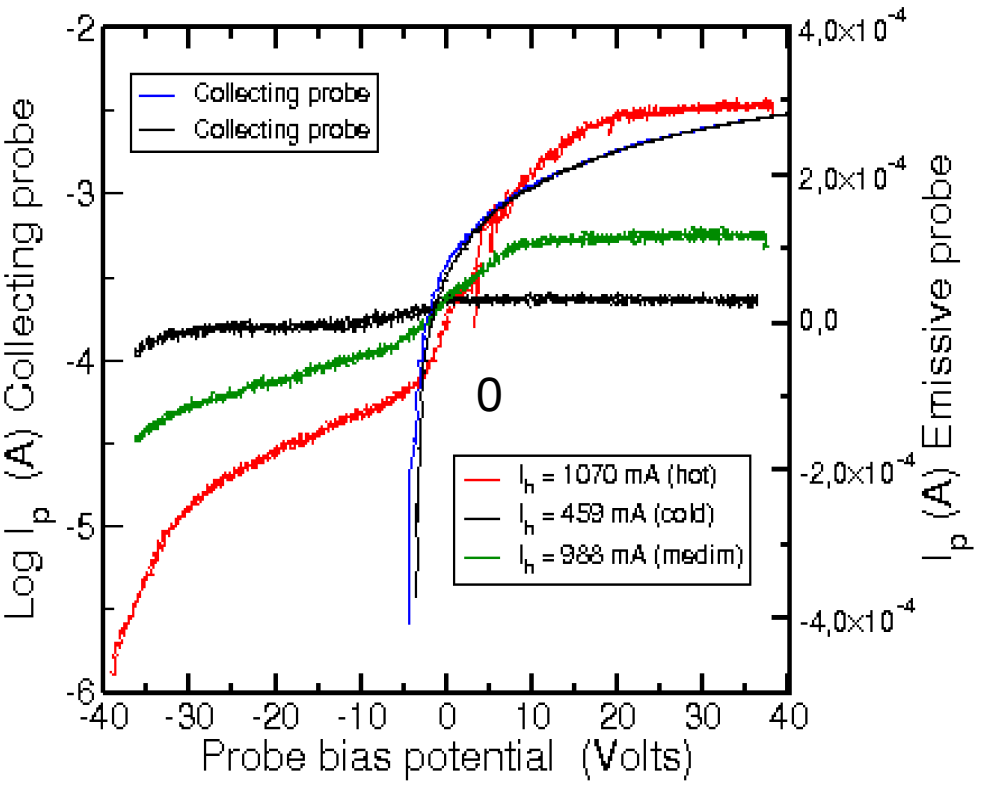




The emissive probe is heated up to the strong electron emission by a DC current ...even over 1 ampere !. Then, the floating potential of the probe approaches the plasma potential

Are emissive probes reliable to determine the plasma potential?

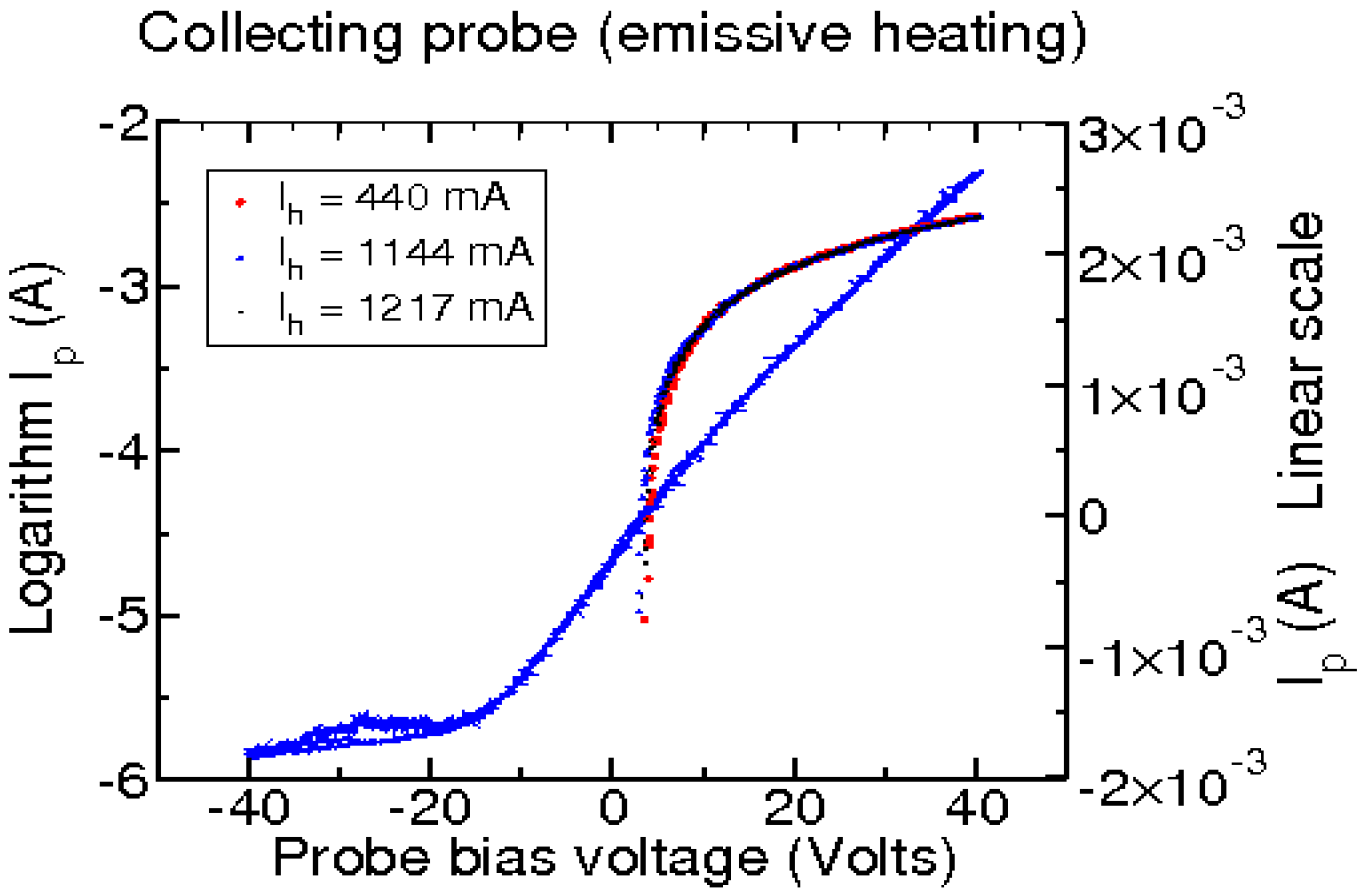




The these results evidence that as the electron emission increases, the floating voltage of the emissive probe (linear scale right) approaches the value of the plasma potential indicated by the knee of the characteristic curve of the collecting probe (log scale, left).

The error involved in the measure of Vp depends on the noise, the lower surface, ..etc.

Is the local plasma affected by the emitted electrons?



The data of collecting probes (linear scale, left) and also in log scale (right) superpose while the emissive probe is heated. No noticeable changes are observed and these curves Also demonstrate how difficult is to determine V_p at a first glance.,

Laboratory Project: answers and conclusions.

1) The increment in the discharge current produces little effect in the plasma parameters. The plasma remains basically unchanged.

2) The *thick sheath* approximation (OML) do not work with these data. The dependence wit the plasma potential is not bad, but the predicted values of the plasma parameters differ from those obtained with the classical analysis .

3) The floating point of an emissive probe approaches the plasma potential predicted by collecting porbes. The involved errors depend on the effective electron emission by the probe, the noise / signal ratio, ... etc.

4) There is not an accepted explanation for this increase of the electron saturation current: all ideas are welcome.

5) In accordance to the experimental results the floating emissive probe not perturb the surrounding plasma, even in the strong emission regime. When Biased, accelerated electrons mya produce ionizations, plasma instabilities, ...etc.