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New results on a laser heated emissive probe for direct measurements of the plasma potential

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1. Introduction

Direct measurements of the plasma potential are still a difficult task for plasma diagnostic, and the best and least expensive tools for localized direct measurements of this parameter with sufficient temporal resolution are certain forms of electric probes. Since the 1960-ies emissive probes were used in laboratory plasmas for measuring the plasma potential Φ_{pl} directly [see e.g. 1]. However, only during the last years emissive probes were applied for the first time also in the edge plasma region of fusion experiments for measuring Φ_{pl} and related parameters such as the electric field and fluctuations of the potential and electric field [2,3,4,5].

2. Experimental set-up

The experiments were performed in a test chamber and in the VINETA machine at the Max-Planck-Institute for Plasma Physics in Greifswald, Germany [6]. In the test device (20 cm length and 14 cm diameter) the temperature of the probe tips and the current to the wall for different background pressures and heating times were measured.

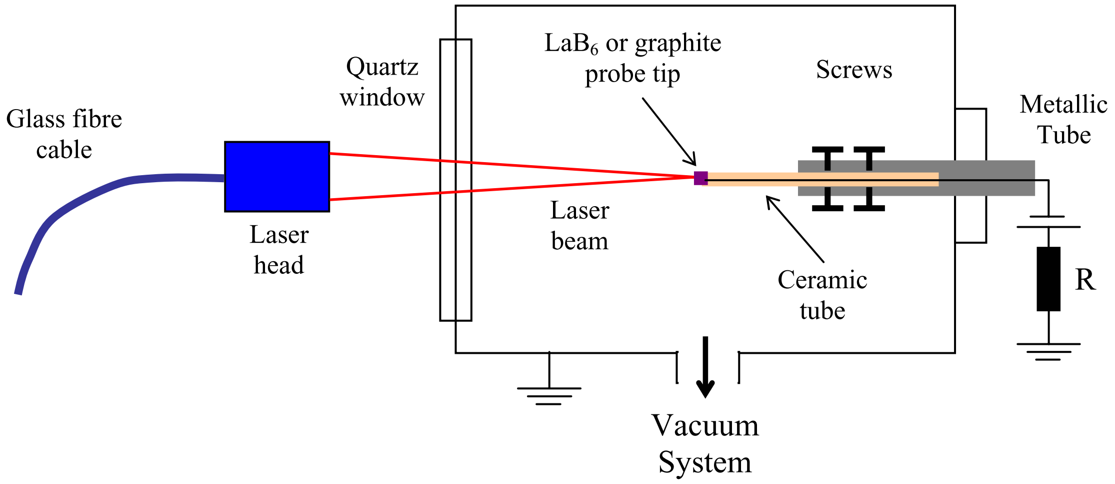


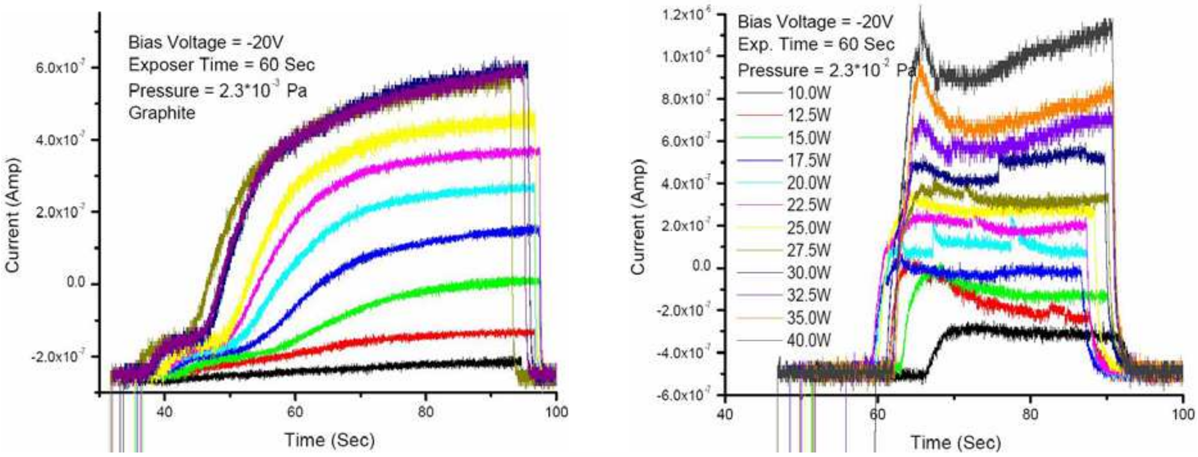
Fig. 1. Experimental set-up for the laser-heated emissive probe.

Cylindrical pieces of 2 mm diameter and heights of about 4 mm were used as probe tips. These were fixed on a Mo-wire of 0.2 mm diameter which was inserted into a fitting ceramic tube. The work function of LaB_6 is low and therefore we get a high electron yield even for low temperatures. Graphite, on the other hand, has a higher work function, but its absorption coefficient is much higher, wherefore it absorbs the laser light much better. Thus it attains higher temperatures for lower laser powers also producing a very high electron emission.

In both experimental set-ups, the test chamber and VINETA, the probe tips were heated from the front side through a quartz-glass window by an infrared high-power diode laser JenLas HDL50F from JenOptik, Jena, Germany, with a maximum laser power of 50 W at a wavelength of 808 nm. The laser beam is coupled into a fibre cable of 3 m length terminating in an output head, with which a focal spot of 0.6 mm diameter is produced in a distance of 20 cm. The temperature of the probe tips was measured by means of a PV11 Mycro-Pyrometer and a thermo graphic camera. The experimental set-up is presented in Fig. 1.

3. Experimental results

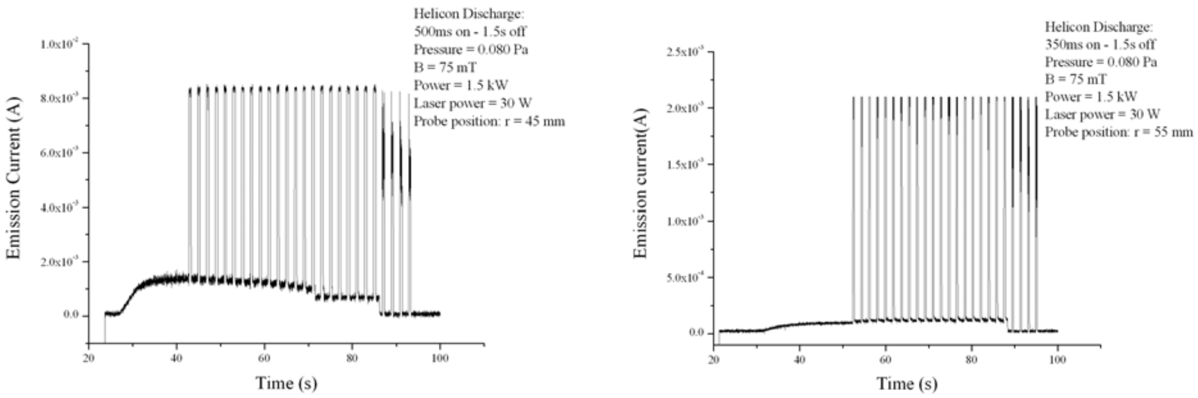
The temporal evolution of the emission current has been measured for different laser heating powers in the test chamber. The results are presented in Figs. 2a and 2b. In all cases, the emission current increases rapidly and reaches saturation after about 20 s. As we see, the behaviour of the graphite probe is stabler than of the LaB_6 probe, which was interpreted as an indication for some sputtering from the polycrystalline LaB_6 probe surface. As for the long-term behaviour we have come to the result that a real thermal equilibrium needs about 5 min heating time to establish.



(a) (b)

Fig. 2. Evolution with heating time of the electron emission current to the test chamber wall for a graphite (a) and a LaB_6 (b) laser-heated emissive probe for a bias of $V = -20$ V and different laser powers. The scale for the laser powers is valid for both parts.

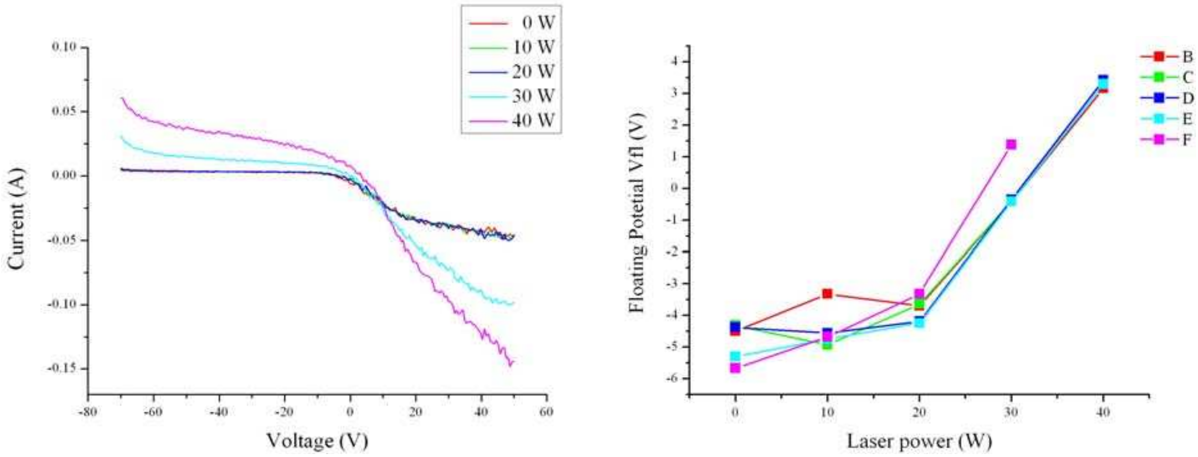
The same measurements were performed at different radial positions in the VINETA plasma column with plasma. A cylindrical argon plasma was produced by a pulsed helicon discharge with a diameter of 10 cm. For the graphite probe the results are presented in Fig. 3. The figure gives a first hint on the fast time response of the probe.



(a) (b)

Fig. 3. Evolution of the electron emission current of the graphite probe at radial position r = 45 (a) and 55 mm (b) from the axis of the plasma column versus heating time in case of pulsed helicon discharges with the duty cycles indicated. Laser power was 30 W, the probe bias –100 V.

For each position we have recorded different sets of current voltage characteristics for each laser power. Typical characteristics and the floating potential as a function of the laser power for each set of data are presented in Fig. 4.



(a) (b)

Fig. 4. Typical current-voltage characteristics (a) and the dependence of the floating potential (b) on the laser power for r = 45 mm from the centre of the plasma column.

The characteristics show the typical behaviour of emissive probes, as also seen in the previous experiment [7], namely that the emissive current superimposes on the ion saturation current and that the floating potential increases. However, astonishing is the strong change of the electron saturation current, which should in principle not vary at all with increasing emission since the electron emission becomes observable only on the left side of the characteristic. We note here that this is a pending problem since on one side there are other experimental observations of such a variation [3,7], whereas in a recent work [5] no such change was seen.

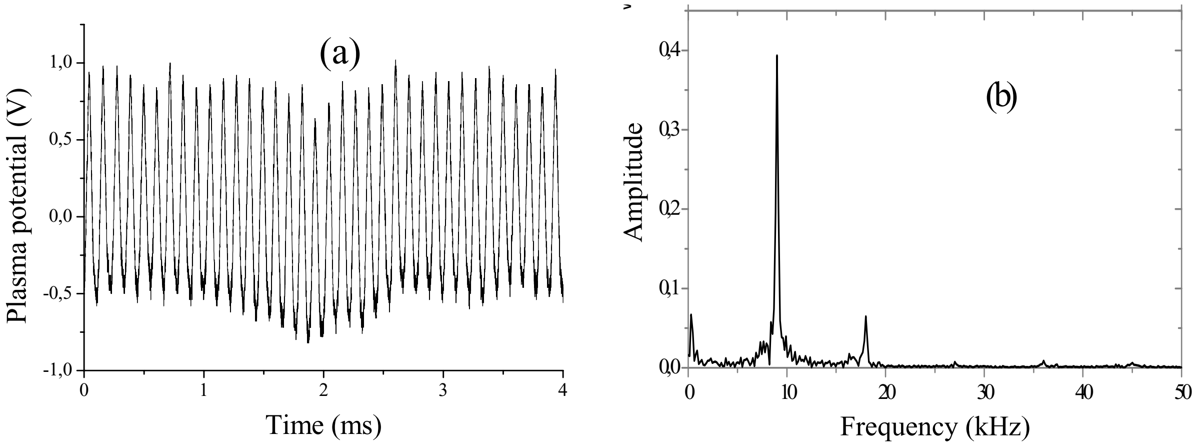


Fig. 5. (a) Times series of a plasma potential oscillation taken by the emissive probe in the edge region of the VINETA plasma column. (b) Amplitude FFT of the same signal.

In order to test the basic frequency response of the probe, we have measured the fluctuations in the edge region of the VINETA plasma column in the helicon regime at an argon pressure of 0.22 Pa. Fig. 7a shows the time series of the oscillations, from which we discern that the oscillation occurs between about –0.5 V and +1.0 V, thus has an amplitude of 0.75 V approximately. Fig. 7b shows the FFT of the same signal. We see that the first harmonic has a frequency of about 9 kHz, since the governing instability in the VINETA device is the drift-wave instability.

4. Conclusion

We have succeeded to construct a laser-heated electron emissive probe which can produce a much higher emission current than a conventional emissive wire probe. It has also a much longer life time since we have observed no evaporation or sputtering of the LaB_6 piece even after many hours of constant strong irradiation with the infrared laser. The probe has also a better time response since no electric heating system with a high internal capacity is necessary.

References

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