In-situ diagnostics for plasma based extreme ultraviolet light sources

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Introduction

Most sources for extreme ultraviolet (EUV) radiation are based on line emission from high temperature, high density plasmas. The obtained conversion efficiency from input power to the collected in-band EUV power will, among others, depend on the achieved plasma parameters.

We believe that in order to further increase the EUV output, it is vital to accurately measure these plasma conditions.

Currently, only limited diagnostic information from the plasma is available due to the harsh operating environment. For this we have designed and built a small, versatile plasma characterization sensor box that can be flexibly placed and orientated inside a vacuum vessel. This sensor box can also operate stand-alone without any modifications, when no vacuum feedthroughts are available.

Design of sensor box

The sensor box comprises of a sensor head and an electronics unit for sensor read out, data logging and power supply. Figure 1 shows the sensor head which incorporates five sensors: Langmuir probe (a), PT100 (b), photodiode (c), heat flux sensor (d) and Faraday cup (e).

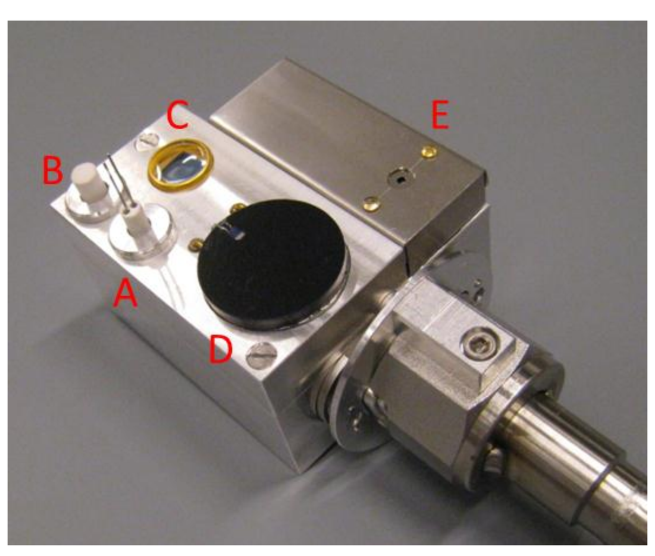

Figure 1: *Sensor head with Langmuir probe (a), PT100 (b), photo diode (c), heat flux sensor (d) and Faraday cup (e).*

Heat flux sensor: Developed by TNO and used to measure heat flux on a pre-defined surface area.

Langmuir probe: Using a sweep voltage, the langmuir probe is used to measure electron temperature, electron density and plasma potential.

Faraday cup: An absolute measurement of the ion or electron flux can be performed using either a negative or positive bias.

Photo diode: A silicon photodiode is used to measure light intensity in UV/VIS/IR (200-1100nm). Additional band pass filters can be installed to select a wavelength band of interest.

PT100: The PT100 is installed to measure the temperature of the plasma/environment. It is has been enclosed in a Al_2O_3 housing to protect it against the harsh conditions of the plasma.

All five sensors are operated simultaneously at a standard readout frequency of 900Hz. The electronics unit is shown in figure 2. Sensor head and electronics unit are both placed inside the vacuum vessel.

Measurement protocol

The head of the sensor box was positioned close to one of the plasma setups available at TNO. All experiments where done with a microwave induced H_2 plasma at 0.3 mbar.

During the experiment we varied the microwave plasma input power between ~200 and 600 watt (CW). Besides power we also varied the distance of the sensor head to the microwave cavity in which the plasma was ignited.

Results

Figures 3 to 7 show a selection of the results of our measurements. The black curves in these figures are with the sensor head at 6 cm from the microwave cavity, the red curves with the sensor head at 12 cm from the microwave cavity.

As expected there is an increase of all sensor readings when the power of the microwave source is increased and when the sensor head is placed closer to the microwave cavity.

Figure 5 shows Langmuir probe data for a voltage sweep from -48 to +48V (blue curves). From the Langmuir probe data the plasma electron density and temperature can be calculated (see figures 6/7) .

Conclusions

A small, stand alone sensor box for in-situ plasma diagnostics has been realized successfully, measuring several plasma parameters simultaneously.

Future work

Future developments are aimed towards performing a long-duration test in an EUV source environment and expanding the set of available diagnostics.

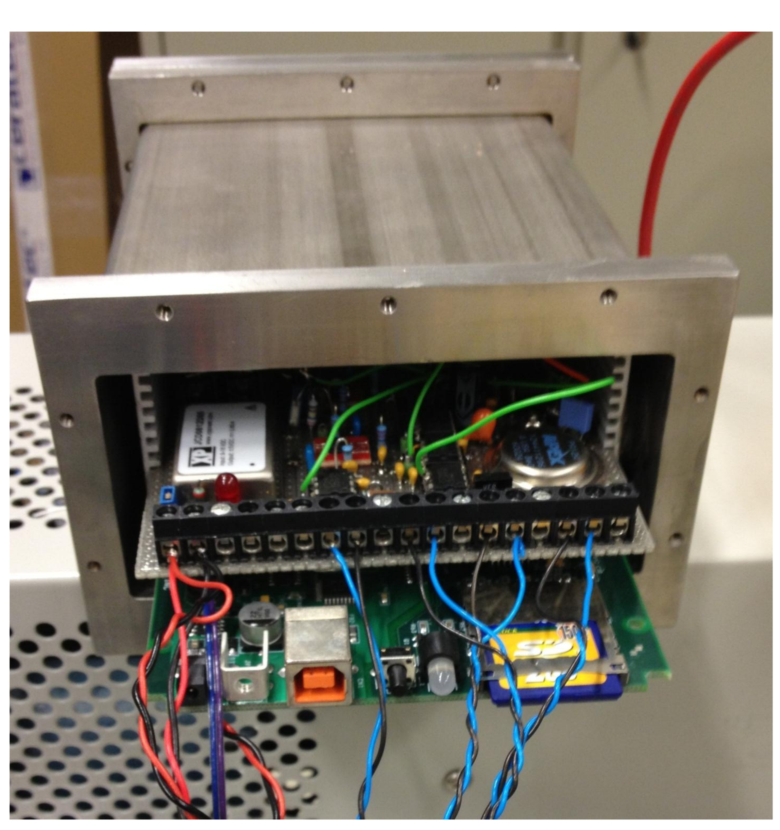

Figure 2: *Opened sensor electronics unit for sensor read out, data logging and power supply.*

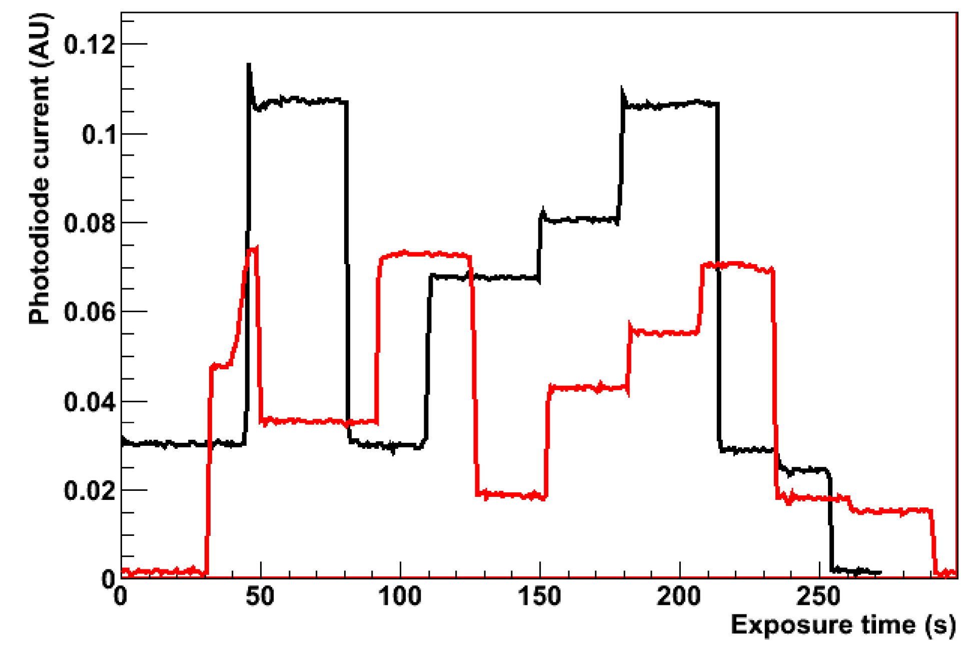

Figure 3: *Photo diode signal, following the stepped microwave input power (200W, 400W, 500W and 600W)*

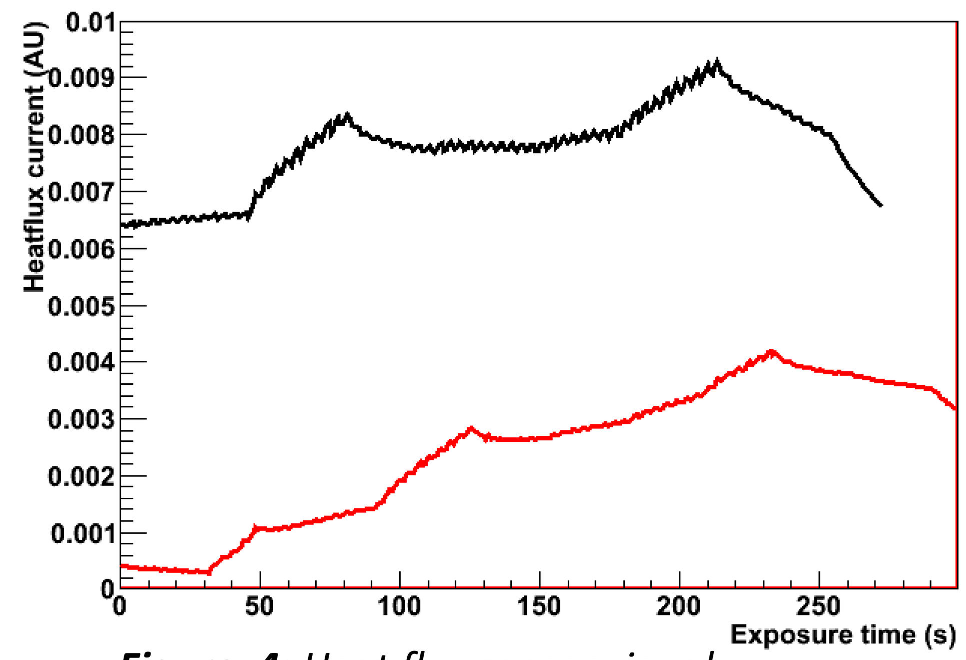

Figure 4: *Heat flux sensor signal*

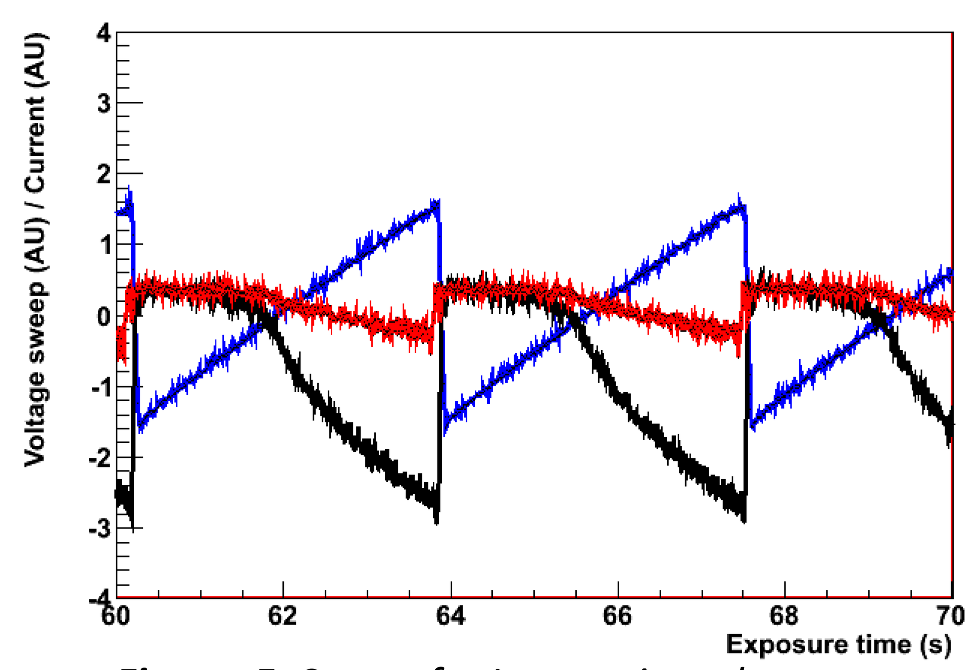

Figure 5: *Sweep for Langmuir probe*

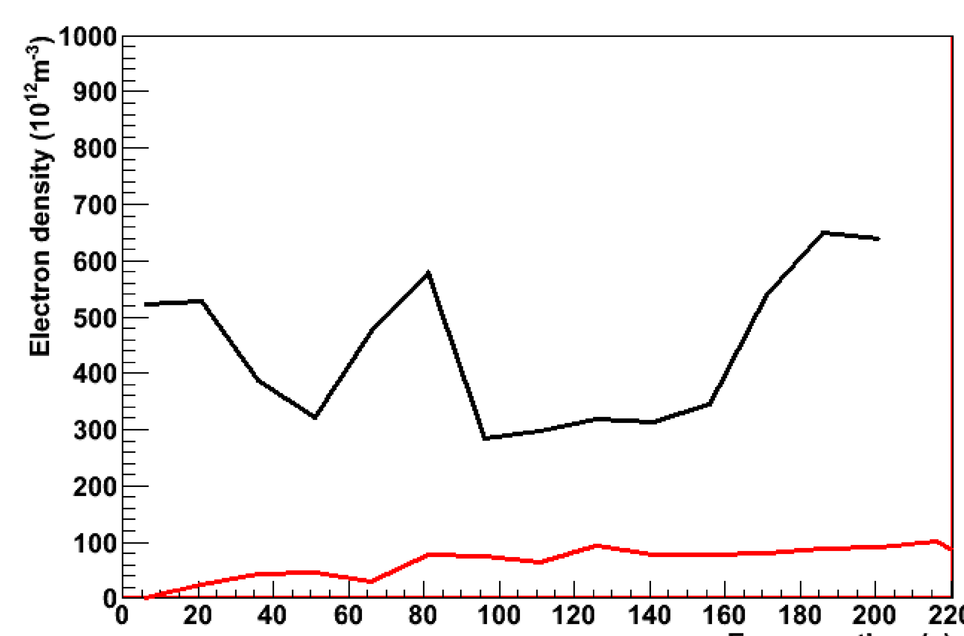

Figure 6: *Plasma electron density*

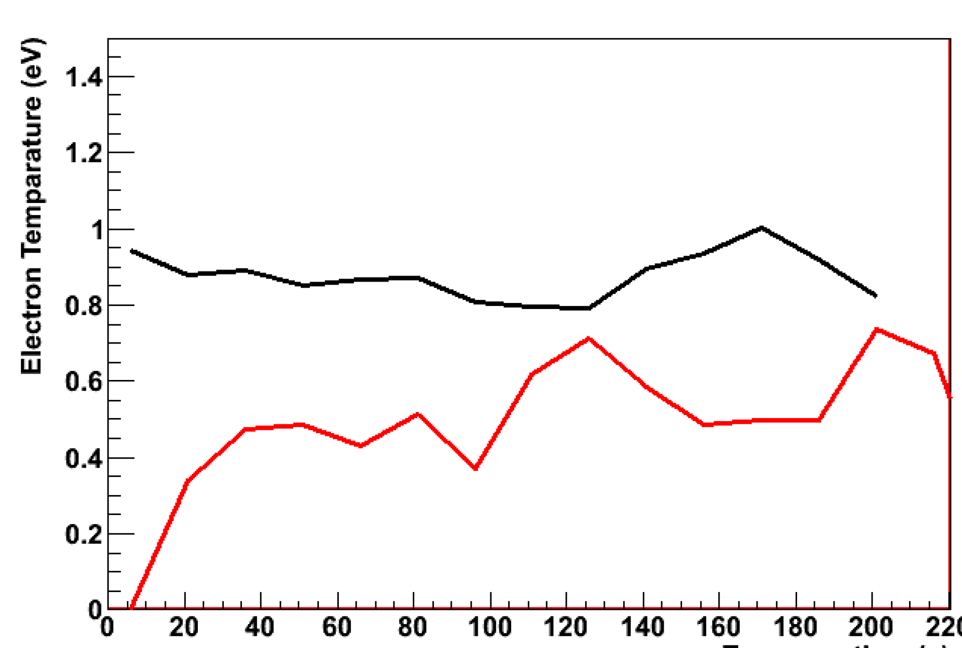

Figure 7: *Plasma electron temperature*