Time resolved measurements of spectral radiant flux from VUV to NIR (160 nm < λ < ≈ 1000 nm) on Xe excimer lamps

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Abstract A radiometric set-up is presented to measure the radiant efficacy of pulsed Xe excimer lamps. It allows time and spectral resolved radiant flux measurements from the VUV to NIR region. The results will provide a better understanding of the plasma processes in Xe excimer lamps. We measure the Xe excimer emission λ_{Xe2*} = 172 nm in the VUV and spectral lines at λ_{XE*} ≈ 828 nm. We use two different monochromators with fast photomultipliers because the duration of Xe excimer micro discharges is only several 10 ns. To determine the total flux of the lamp, we choose a goniometric set-up.

Xe excimer lamp

Recent papers show that its possible to increase the radiant efficacy of dielectric barrier discharges (DBD) by using very fast pulse excitation. Improvements by a factor of 3.2 in comparison with the AC excitation were reported (Mildren et al. 2000).

The authors measured the VUV output indirectly by means of phosphor conversion from VUV into the VIS. Furthermore up to now, the radiant flux of excimer lamps has been determined by interpolation from a single determined radiant value. So the reported flux values have big experimental uncertainties and are difficult to be compared. (Falkenstein et al. 1997). The large differences between reported efficacies of Xe excimer lamps would be better understood if the VUV measurements were less uncertain. The absence of reliable standard lamps in this spectral region might be the reason why commercially available Xe excimer lamps are used to calibrate UV sensors. (Carman et al. 2004)

The Xe_2^* excimer molecule emits the main part of its radiation by spontaneous decay of Xe_2^* into an emission band in the VUV around a wavelength of λ = 172 nm (10 nm FWHM). For a better understanding of the plasma processes, it is also very interesting to measure lines from higher energy levels. Here lines in the NIR are of special interest, e.g. λ = 823 nm and λ = 828 nm. They fill the excimer levels. This is why the ratio between the VUV emission and these lines is an indicator for the radiant efficacy of a Xe_2^* plasma. Time-, wavelength- and angle- resolved measurements on cylindrical lamps from the VUV λ = 120 nm up to the NIR λ = 1000 nm have been performed.

VUV - NIR goniophotometer

In air, radiation with wavelength below λ < 200 nm is nearly totally absorbed by oxygen. To measure such wavelengths it is necessary to eliminate the oxygen out of the optical path. Either you use an non-absorbing atmosphere like N_2 or Ar, or you evacuate the hole path. We use a vacuum chamber to make long term measurements affordable. Figure 1 shows the set-up with two monochromators, one for the VUV-UV region (120 nm < λ < 320 nm) and another for the UV to NIR region (200 < λ < 1000 nm) and a turning arm which supports the lamp in the vacuum chamber.

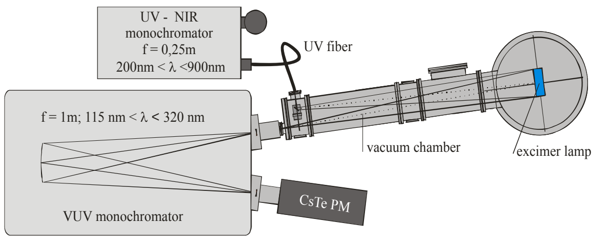

Figure 1. Set-Up with vacuum chamber, one Monochromator for VUV and one for UV to NIR and the turnable lamp at the right.

To determine the radiant intensity, a diffuser made of MgF_2 is placed in front of the VUV monochromator entrance. As the distance between lamp and diffuser was chosen ten times of the largest radiation field dimension the photometric distance law can be applied. So it was possible to calibrate the irradiance on the diffuser with a deuterium lamp, though this lamp is only a standard of radiant intensity.

The timescale of the DBD is in the range of several 10 ns. To dissolve the time dependent behavior of the plasma fast photomultipliers are used. In the lower spectral range (120 nm < λ < 320 nm) a solar blind CsTe PM is used. This PM is mounted at the exit port of a 1 m monochromator with normal incident grating. The longer wavelengths are detected with an f = 0.25 m Czerney-Tuner monochromator with multi alkali PM. The radiation is guided through a special UV fiber to the entrance slit. At the entrance of the fiber a quartz diffuser is used.

Stray light reduction

The vacuum chamber is made of stainless steel and reflects down to the VUV. For absolutely calibrated measurements it is necessary to have a special focus on stray light reduction. For this reason we put in both optical paths three apertures. We experienced out that carbon black gives a good and cheap absorbing coating for the wall behind the lamp. The disadvantage of this coating is that carbon black should not be touched anytime. Carbon black hardly adsorbs oxygen so that the vacuum will not be reduced.

To measure the stray light ratio we put a shutter in front of the lamp so that only the rear reflected part of the lamp output is detected. (Figure 2) To reduce the stray light fraction we also coated the rear absorber with carbon black. At the moment we analyze how the carbon in the vacuum influences the transmission of the MgF_2 in the VUV.

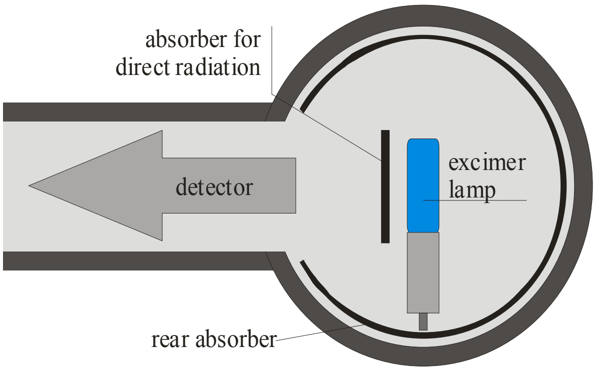

Figure 2. Set-up for stray light measurement.

Calibration

We calibrate our set-up with an deuterium lamp of known radiant intensity. For wavelengths below 160 nm this is the only available calibrated lamp. Unfortunately the spectrum of the Deuterium lamp is as shown in Figure 3. The spectrum exists of many lines. So it is indispensable to measure with the same resolution as it was done during calibration.

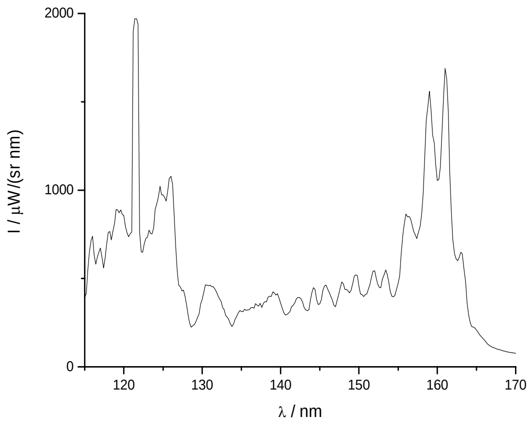

Figure 3. Spectrum of an deuterium lamp in the VUV region

To specify the spectral resolution of our monochromator we measured the lines of Hg low pressure lamp (PenRay®) in dependence of the slit width.

References

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