Calibration source based on capillary discharge

E Baronova[1] and A Stepanenko

National Research Centre "Kurchatov Institute", Kurchatov square, 1, Moscow, 123182, Russia

E-mail: baronova04@mail.ru

Abstract. A source of ultraviolet radiation based on capillary discharge was made. Alignment and calibration of focusing spectrograph using this source is described.

Capillary discharge is one of the simplest type of Z-pinch discharge. It is thoroughly studied due to its lithography applications. The modes with minimal scattering of ceramics and electrodes materials as well as with maximal output of shortwave radiation (e.g. radiation in the vicinity of 135 Å for which Mo-Si mirrors are used) are of particular interest. These modes are achievable in capillaries filled with Xe at relatively small current which would be sufficient for generation of radiation in the vicinity of 135 Å. It is necessary to note that in capillary discharges filled with Xe radiation with wavelengths 110-120 Å is the more intensive than that with 135 Å. However, mirrors for 110 Å contain Be, forbidden in industrial facilities.

In this work we obtained the spectra (100-700 Å range) of the capillary discharge, which was used for the alignment and calibration of UV spectrograph. Focusing spectrographs with small incidence angles are very sensitive to alignment, i.e. localization of a precise positions of the detector and the dispersive element. Capillary discharge is chosen for alignment procedure since it is cheap, reliable (capillary withstands tens and hundreds of thousands of shots without replacement of its parts) and easy to operate. Along with that, the radiation source is fixed in space and small, and its radiation is intensive.

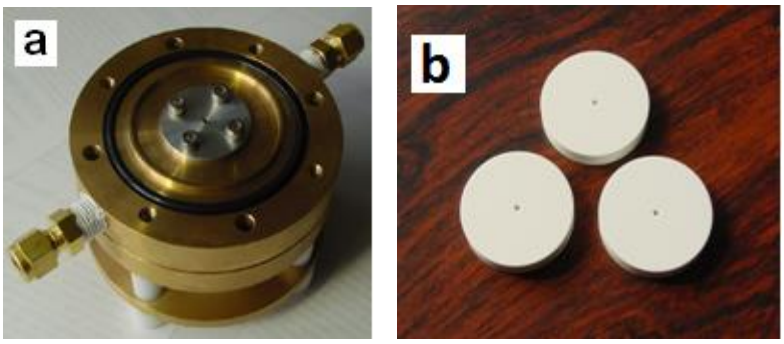

Figure 1. a – capillary discharge chamber, b - insulator.

[1] To whom any correspondence should be addressed.

Figure 1a shows a capillary discharge chamber. The capillary is 1 ÷ 2 mm in diameter, the length of cylindrical channel of the capillary is 6 mm. The capillary is designed as a small channel inside a ceramic disk 6 mm in thickness and 30 mm in diameter. The voltage within 3 ÷ 10 kV range is applied to two ring-shaped electrodes. The high negative voltage is applied to the top flange while the bottom flange is grounded. The outlet flange of capillary has a cylindrical aperture for collimation of radiation. The exterior surface of the flange has a leak-proof mounting unit for the filter. Figure 1b shows the photographs of ceramics used in the capillary chamber.
In our experiments the working) gas (Xe) was puffed into the capillary through side tubes. Turbomolecular pumps were used to achieve high vacuum. The pressure of Xe was of 0.2÷0.5 Torr. Figure 2 shows the experimentally obtained current waveform. The maximum current was 3.7 kA, half-period of the current was 1200-1300 ns.

Figure 3 shows the spectrograph used for spectrum registration. The spectrograph was equipped with spherical holographic grating (30mm x 40mm, 4200 lines per mm) covered with gold, grazing angle was 10°. The measurements were conducted in the 1st diffraction order, DEF film was used as a detector.

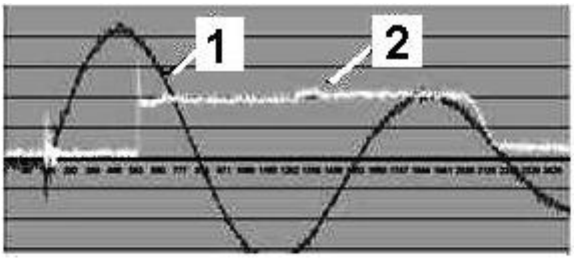

Figure 2. 1 – shape of the current, 2 – voltage shape.

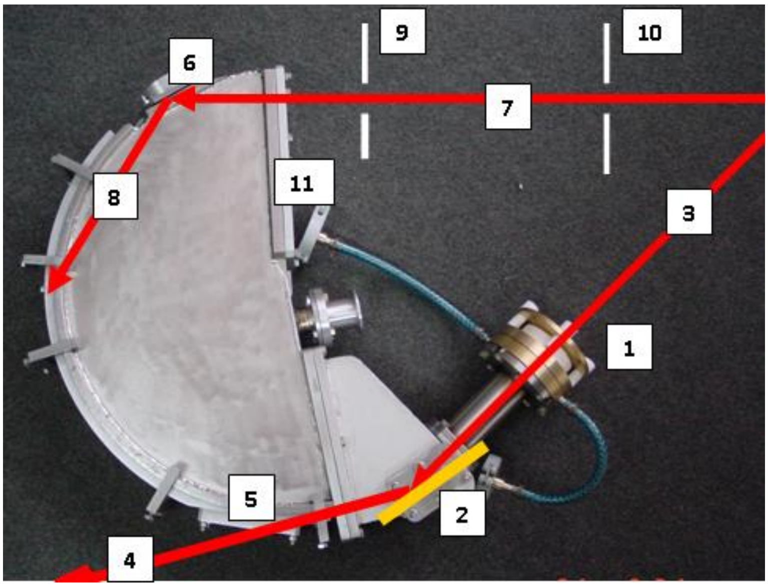

Figure 3. 1 – capillary chamber, 2 - grating, 3 – incoming laser beam for alignment of EUV, UV channel, 4 – reda laser beam reflected from grating, 5 – position of detector (film, CCD,MCP, etc.) 6 – grating position , 7 – incoming laser beam for alignment of second EUV,UV channel, 8 – reflected laser beam, 9, 10 - diaphragm, 11 – second input flange for EUV,UV radiation.

Width (1.5 mm) and height (7 mm) of the slit were determined by sensitivity of spectral channel. A 250 Å thick carbon filter deposited on the wire grid (cell size of 250 micron, wire diameter of 15 micron) was installed on the slit. The filter is transparent for the visible radiation, so it was possible to perform initial optical alignment of the spectrograph by red laser.

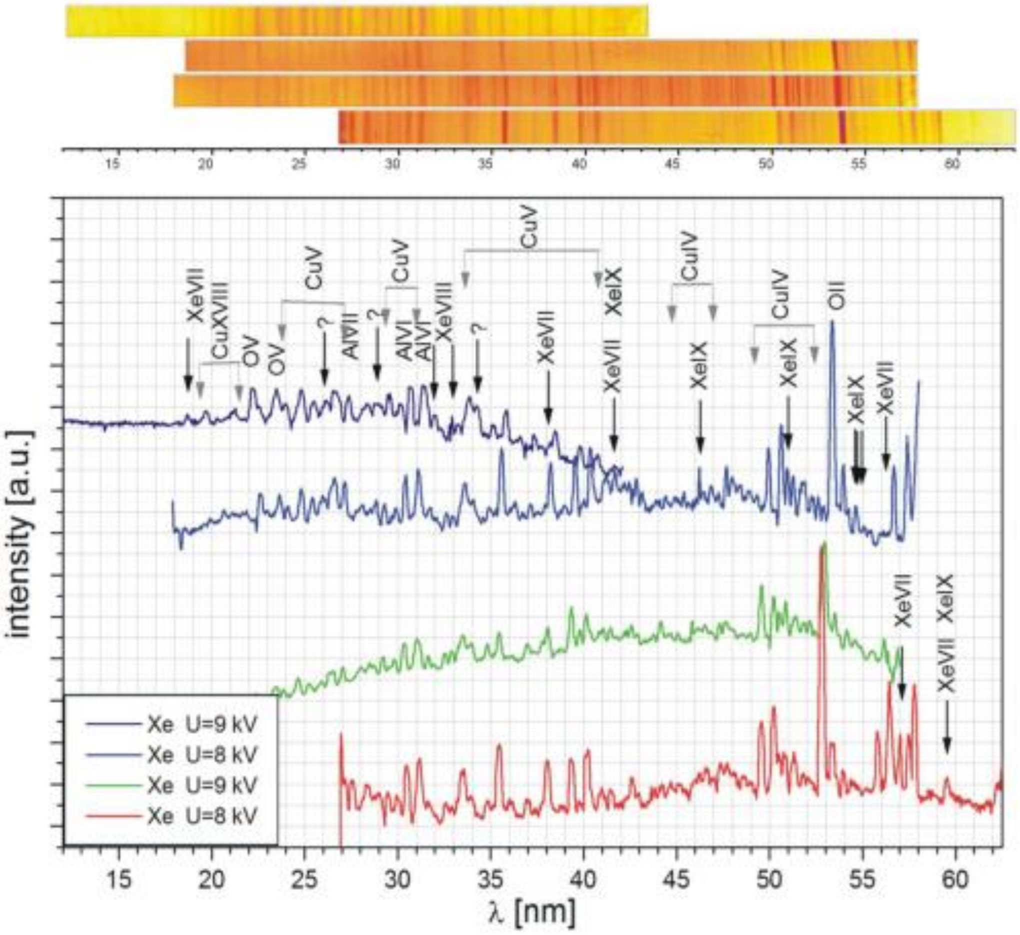

Figure 4. Spectrum registered from capillary discharge and the corresponding densitogram.

Reflection coefficients of mirrors and dispersive elements for EUV, UV radiation at large grazing angles are pretty low, so it forces us to work at small grazing angles. This makes alignment of the device more complicated. At the first stage of the alignment detector and dispersive elements are put in calculated positions (so called geometrical alignment) and then an optical alignment by checking precise positions of elements using visible light sources (red lasers) takes place. The last stage is the final adjustment using EUV, UV calibration source (capillary).

Spectrum of calibration source within given wavelength range is registered by spectrograph with further evaluation of half-widths and relative intensities of lines and repositioning of spectrograph units for achieving optimal parameters. Optimally focused spectrum obtained by 4200 lines per mm grating and corresponding densitograms is shown in figure 4. The spectrum contains lines of ions of Al, Cu, O and Xe with various degrees of ionization. Registered spectra shows_that the contribution of lines of electrode material to plasma radiation must be taken into account when simulating the processes in capillary discharges.

Thus, the capillary discharge was created, and its spectra including lines of working gas, electrode material and ceramics were registered. The designed source was successfully applied for alignment and calibration of focusing spectrograph. Presence of intensive spectrum containing lines of electrode (cathode) material testifies that it is reasonable to deposit the corresponding material on the inner surface of electrode to obtain higher radiation yield within the desired wavelengths.