Low-Energy Electron-Beam-Induced XUV Excimeremission

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Particle beam excitation of dense rare gases is an efficient method for producing excimer molecules. Radiative decay of these excimers to the repulsive ground state is a source of vacuum ultraviolet light which has received great attention over the last years [1,2,3]. So far, only the heavier rare gases Ar, Kr, and Xe emitting at 128, 150 and 172nm, respectively were used in excimer light sources since there is no material for optical windows for the shorter wavelength light emitted by He and Ne excimers. Here we describe an experimental setup which overcomes these practical problems and can be seen as an example for systems which can be used down to 60nm. This is approximately half the wavelength which is routinely used in VUV optics, except in large synchrotron facilities.

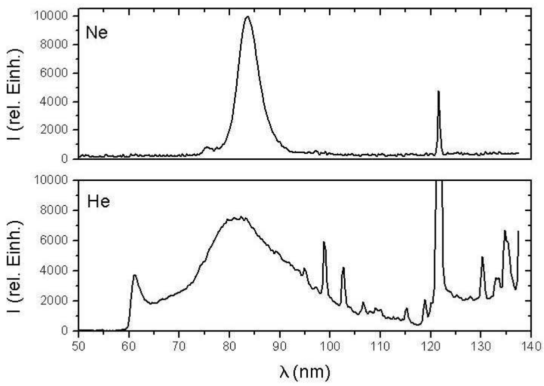

Fig. 1: Electron beam induced emission spectra from Ne and He at 1bar

Ion beam induced formation of neon excimers had been studied at the Tandem accelerator [4]. In these experiments we needed the high energy of the ions to couple the beam power into a dense gas through a $1\mathrm{mg/cm}^2$ titanium foil. Complex differential pumping and a channeltron detector were used for light detection.

Over the last years we have developed a novel technique using electron beams for the excitation of dense gases [3,5,6,7,8]. A thin (300nm) ceramic entrance foil allows a low energy (typ. 15keV) electron beam excitation of dense gases and therefore for the first time portable electron beam pumped light sources and lasers. A helium and neon excimer light source of that type is described below.

A cw 10keV, $10\mu A$ electron beam was formed by an electron gun and focused through a 300nm thick, $1 \times 1mm^2$ silicon nitride membrane into gas samples. The electron beam was formed in a 30cm long tube in which a permanent vacuum was maintained by a getter pump. A 15cm focal length Seya Namioka type XUV- monochromator was used to analyse the electron beam induced radiation and a solid state detector mounted on the exit slit was used for light detection. The whole monochromator was filled with the helium and neon gas, respectively. The gas next to the entrance slit was excited by the electron beam. It was purified using a hot titanium rare gas purifier and circulated through the system. Emission spectra were measured by scanning the monochromator and simultaneously recording the current of the photodiode detector.

Neon and helium spectra at 1 bar and in the wavelength range from 50 to 140nm are shown in Fig. 1. The main neon emission is the second excimer continuum centered at $83.8nm$. It shows a width of $4.48 \pm 0.06nm$. The short wavelength shoulder is the first continuum which is emitted by not fully relaxed excimer molecules. Although care was taken to remove hydrogen from the target gases by adsorbing it in the titanium in the purifier, 121.567nm HI $Lyman-\alpha$ light appears due to minute hydrogen impurities [9]. Interestingly, the so called third excimer continuum, which is a significant feature centered at 99nm using ion beam excitation of dense neon [4] is missing in Fig. 1. This supports its assignment to doubly ionized molecules [10].

A conversion efficiency of 13% has been determined for the conversion of electron beam power into neon second continuum light in a separate experiment using the absolutely calibrated photodiode detector but no monochomator. Instead, a MgF_2 filter was used to discriminate the XUV emission from light emission at longer wavelengths.

The second continuum intensity in the 1bar helium spectrum was significantly lower than for neon. This is most likely due to an activation energy necessary for excimer formation in the case of helium [11]. However, the broad emission from helium is of interest e.g. for testing optical elements with cutoff wavelengths near 100nm such as LiF or MgF_2. This region is difficult to reach by other techniques.

Systems similar to the one described here may also be used for applications such as surface treatment or photolithography. Note, that reflective optics can still be used below 100nm.

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