Electron Beam Pumped UV Light Source for Resonant Ionization Spectroscopy of Atoms ◇

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Resonant photoionization of atomic species is an extremely sensitive and selective method for chemical analysis. Experiments described here aimed at a combined technique using both laser- and incoherent light for photoionization of gadolinium. A two step ionisation was planned starting with an excitation of the $^9D_6$ - $^9F_2$ transition in Gd at 422.7 nm. This transition was driven by a titanium saphire laser to achieve high selectivity. The goal was to replace two infrared lasers for subsequent ionisation into the continuum which requires photon energies on the order of 3.5 eV by a brilliant incoherent light source. The light source uses low energy electron beam excitation of dense gases and has been successfully used for single photon ionization of organic molecules [1]. Single photon ionisation normally requires high photon energies on the order of 10 eV which corresponds to light in the vacuum ultraviolet spectral region. The 3.5 eV photons required for ionizing Gd from the $^9F_2$ level, however, correspond to about 350 nm. Molecular nitrogen emits in this wavelength region. This is well known from the nitrogen laser emitting at 337 nm. There is another strong and narrow transition in the N_2(C-B) band around 358 nm which can be used for ionizing Gd. It is also known from the literature that there is a resonant energy transfer from argon to nitrogen [2,3,4].

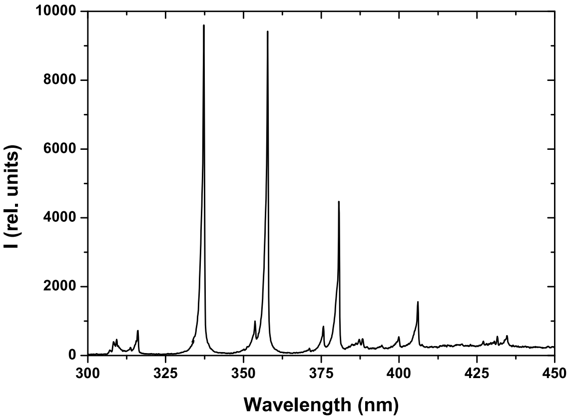

Fig. 1: Emission spectrum from an electron beam pumped Ar-N_2 mixture (6 %N_2) at atmospheric pressure

The electron beam pumped light source used here has been described in detail in previous publications [5,6]. Briefly, an electron beam of typically 12 keV is formed in a vacuum part and sent through a 300 nm thin ceramic membrane into a gas filled part of the setup. The beam is stopped within about 1mm in gases at atmospheric pressure thus depositing its power in a small volume which leads to high power densities. Using a nitrogen or argon nitrogen gas filling leads to intense emission in the 300 to 400 nm region as shown in Fig. 1. It was found that the intensity ratios of the various nitrogen bands does not depend on whether or not pure nitrogen or an argon nitrogen mixture is used. Total light output and efficiency of the light source, however, depend strongly on gas composition. Results of a series of measurements for gas fillings at atmospheric pressure using various percentages of nitrogen in argon are shown in Fig. 2. An increase by a factor of 13 of light output on the 358 nm band was found when pure nitrogen was replaced by gas mixtures containing less than 10 % N_2. A weak maxiumim was found at 6 % and this concentration was used for further measurements.

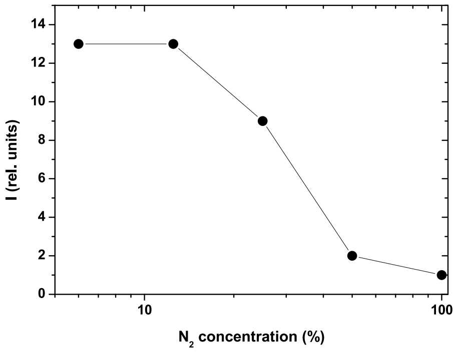

Fig. 2: Output power of the electron beam pumped ArN_2 light source at 358 nm wavelength versus N_2 concentration in the Ar buffer gas

Both absolute efficiency measurements and focusing experiments were performed with the incoherent 358 nm light source in preparation of experiments to detect Gd in an atomic beam. Using an appropriate combination of optical filters (BG39 and U11, L.O.T. company) and the sensitivity and solid angle of a silicon photodetector a conversion efficiency of 2 % from electron beam into light has been measured. Focusing experiments using optics which was available to us at that point led to about 1 efficiency to a spot which could be brought in coincidence with the spot of a Ti-Saphire laser used for excitation of Gd. Since the laser is operated in a pulsed mode the incoherent light source would also be pulsed. In a separate experiment it was shown that pulsing the electron beam which is presently used in the light source leads to an increase of instantaneous light intensity by a factor 100. An upgrade of the light source with a similar and still rather inexpensive electron gun would provide another factor of 10 in output power. In summary, a UV power density of 100 mW in the laser - atomic-beam interaction region could be calculated. If necessary, further increase in pulsed light output power up to the tens or hundreds of Watts level in the interaction region could be achieved by using very intense, pulsed electron beams such as a 1.75 A (20 kW) electron gun which is presently being installed as well as better focusing optics.

References

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