Optical Properties of Liquid Noble Gas Detector Media

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INTRODUCTION

Liquid noble gases are often used as scintillating material in rare event physics. Their primary scintillation light emission is in the vacuum ultraviolet spectral region at about 130 and 170 nm for argon and xenon, respectively. The efficiency for converting power deposited in the material into light is very high, on the order of 30% (Ar) to 40% (Xe) [1] in gas at atmospheric pressure. These values do not change very much for the liquid phase. We have started a program in which we study the optical properties of liquid noble gases, spectrally resolved. Time resolved measurements are also performed for the various emission bands which can be identified. So far the experiments were focused on argon since it has the highest excitation energies from which energy transfer occurs to impurities, including heavier rare gases. So we avoided contamination of our gas system with xenon. Applying careful distillation techniques it is now possible to study also Ar-Xe mixtures and return to clean argon conditions.

SCINTILLATION OF PURE LIQUID ARGON

The basic technology for studying liquid noble gases has been developed in the course of the dissertation of Thomas Heindl (see section THESES and references [2, 3]). Liquid nitrogen is used as the coolant. A copper cell is attached to a Dewar with a copper rod. The temperature of the cell which is filled with the liquid is controlled by a heating resistor. Magnesium fluoride windows and an Al-MgF_2 coated mirror are used to guide the light to a vacuum ultraviolet monochromator. A gas purifier and gas circulation is used in the gas system to remove chemical impurities such as oxygen, nitrogen, and water vapor. Details of the technology are described in ref. [3]. The key technique of the setup lies in the low energy (12 keV) electron-beam which is used for exciting the liquid noble gases. It is coupled into the liquid through a thin ceramic membrane [4]. A spectrum emitted from liquid argon excited by the 12 keV electrons is shown in Fig. 1 together with a spectrum from the gas phase. The main result is that the emission from the liquid is even more strongly dominated by the analogue of the so called second excimer continuum peaking at 126.8 nm. Xenon emission was identified and it has been shown that this gas has to be considered as an impurity which is not removed by noble gas purifiers based on chemical reactions.

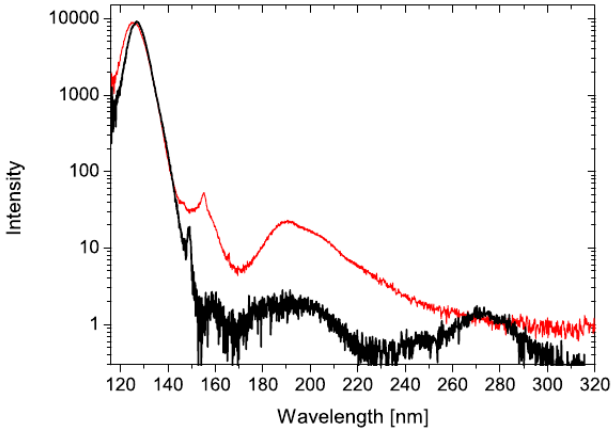

Figure 1: The emission spectrum of electron-beam excited gaseous (red) and liquid (black) argon is shown.

EXCITATION OF ARGON WITH DIFFERENT PROJECTILES

It was known from the gas phase that the so called third excimer continuum which can be seen around 190 nm (spectrum shown in red) in Fig. 1 is stronger for heavy ion beam excitation than for electron-beam excitation [5, 6]. Therefore we have performed a study using proton, sulfur, and gold beam excitation of liquid argon at the Munich Tandem accelerator (see section Theses and ref. [7]). Motivation for this study was the question whether the intensity ratio between the second and the third continuum could be used for particle identification. It was found that this is not the case. But the differences in the time structure of the emission on the second continuum for various particles does have the potential for particle identification.

ATTENUATION OF VACUUM ULTRAVIOLET LIGHT IN LIQUID ARGON

Since particle detectors using liquid argon as scintillating material often have large dimensions it was interesting to measure the attenuation length of the scintillation light in liquid argon, wavelength resolved (see section THESES and ref. [8]). Chemical impurities such as oxygen and water vapor were found to induce deep absorption dips in the spectrum which makes gas purification mandatory. Besides, as in emission, xenon was identified as an impurity in argon which is of course not removed by regular gas purifiers. Distillation was successfully used to remove or at least reduce the absorption by xenon resonance transitions

significantly. It was important to note that the resonance absorption due to xenon at 126 nm lies directly in the middle of the argon second continuum emission. Recently we found that even the remaining short wavelength attenuation in liquid argon below about 129 nm found in ref. [8] was due to residual xenon in the liquid argon sample.

STRONG INFRARED EMISSION FROM XENON-DOPED LIQUID ARGON

There were hints in the literature [9, 10, 11, 12] that there is also an infrared emission from liquid argon. A second emission band can be of importance since it could be used for particle identification on an event by event basis if the intensity ratio with respect to the VUV emission or the time dependence of light emission (or both) depend on the particle which induces the light emission. We have extended our spectroscopic studies into the infrared by replacing the phototube as the detector attached to the monochromator by an InAs detector and by exchanging the grating in the monochromator. Using a lock-in technique the spectra shown in Fig. 2 were recorded. The lower panel shows a spectrum recorded with highly purified liquid argon (chemical purification plus distillation to remove xenon). The result is that we can find no infrared emission from liquid argon up to a wavelength of 3.5 μm. The upper panel shows a spectrum where 10 ppm xenon were deliberately added to the argon sample. The scintillation of xenon doped liquid argon at short wavelengths (VUV) has already been studied in a time resolved but wavelength integrated way [13]. The result of our measurement is that there is a strong emission in liquid argon xenon mixtures in the infrared peaking at a wavelength of 1.18 μm. The width of the emission is 100 nm (FWHM). Placing the InAs detector without additional optics at a distance of 20 cm from the electron-beam excited liquid sample and using the sensitivity of the detector provided by the manufacturer it was found that 10000 IR photons are emitted per 1 MeV particle energy deposited. Infrared spectra emitted from liquid argon doped with different xenon concentration are displayed in Fig. 3. This shows that the energy transfer peaks already around a very low xenon concentration of 10 ppm. Corresponding VUV spectra will be recorded.

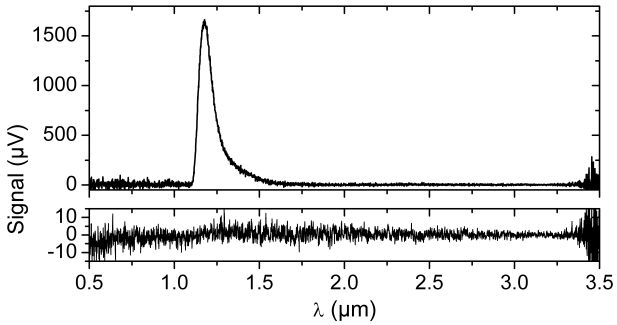

Figure 2: The electron-beam induced infrared emission of liquid argon doped with 10 ppm xenon is shown in the upper panel. For comparison pure liquid argon shows no infrared emission (lower panel).

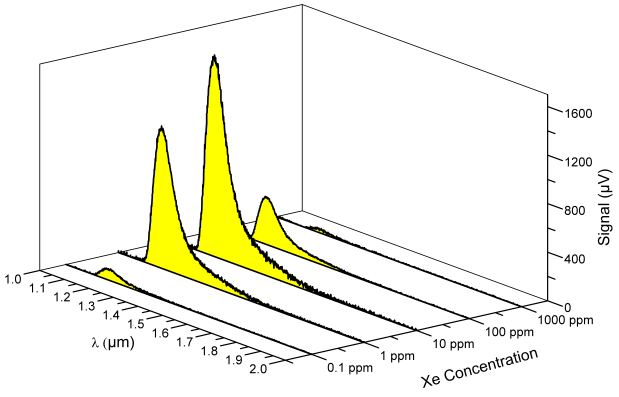

Figure 3: The electron-beam induced infrared emission of xenon doped liquid argon is shown for different xenon concentrations. The broadband emission peaks at 1.18μm, has an asymmetric shape and a half width of approximately 0.1μm.

THESES

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