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Photostimulated phosphor based image plate detection system for HRVUV beamline at Indus-1 synchrotron radiation source

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ABSTRACT

A high resolution vacuum ultraviolet (HRVUV) beamline based on a 6.65 m off-plane Eagle spectrometer is in operation at the Indus-1 synchrotron radiation source, RRCAT, Indore, India. To facilitate position sensitive detection and fast spectral recording, a new BaFBr:Eu^{2+} phosphor based image plate (IP) detection system interchangeable with the existing photomultiplier (PMT) scanning system has been installed on this beamline. VUV photoabsorption studies on Xe, O_2, N_2O and SO_2 are carried out to evaluate the performance of the IP detection system. An FWHM of ~0.5 Å is achieved for the Xe atomic line at 1469.6 Å. Reproducibility of spectra is found to be within the experimental resolution. Compared to the PMT scanning system, the IP shows several advantages in terms of sensitivity, recording time and *S/N* ratio, which are highlighted in the paper. This is the first report of incorporation of an IP detection system in a VUV beamline using synchrotron radiation. Commissioning of the new detection system is expected to greatly enhance the utilization of the HRVUV beamline as a number of spectroscopic experiments which require fast recording times combined with a good signal to noise ratio are now feasible.

1. Introduction

Spectroscopy in the vacuum ultraviolet (VUV) region has always posed a challenge due to scarcity of suitable sources and detection methods. With the advent of dedicated synchrotron radiation (SR) sources, highly intense and tunable beams of VUV photons are now available which have facilitated a variety of experiments which were either impossible or very difficult to perform with traditional laboratory sources [1–3]. Detection of VUV radiation in the early years was carried out using specially prepared gelatin-free photographic glass plates like Kodak make short wavelength radiation (SWR) plates [3,4]. Due to some inherent disadvantages like fragility, aging problems, cumbersome dark room procedures for loading and developing, etc. these plates were gradually phased out and replaced by electronic detectors like photomultiplier tubes (PMTs), microchannel plates (MCPs) and charge coupled devices (CCDs). While VUV PMTs with MgF_2 windows are available for direct detection of radiation down to 1100 Å, for lower wavelengths, one has to use a scintillator. Most commonly used is a sodium salicylate film which absorbs in the VUV and emits fluorescence in the visible region, which is then detected by a visible PMT [3]. In cases where position sensitive detection or imaging is desirable, MCPs and CCDs have been used. However, besides being much more expensive, these have limited wavelength coverage and resolution as compared to photographic plates. PMTs, MCPs and CCDs are also prone to electrical noise. Typically, in high resolution spectrometers, photographic plates have been replaced with PMTs using a precision scanning mechanism along the Rowland circle to cover the wavelength region of interest. This means that for achieving high resolution and good signal to noise ratios small step sizes and long integration times have to be used. Due to these reasons, SWR plates are still in use for a number of spectroscopic applications. However, since the manufacturing of these plates has been recently discontinued, an urgent necessity is created to find alternative position sensitive detectors.

The photostimulated phosphor based image plate (IP) detector is one such alternative which is inexpensive and offers many advantages over both PMTs and traditional photographic plates. This detector consists of a film of BaFBr with trace amounts of Eu^{2+} coated on a flexible plastic substrate and works on the principle of photostimulated luminescence (PSL) [5]. Although phosphor based IPs had been in wide use in the X-ray region for crystallography and medical diagnostics for quite some time, their

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usefulness for detection in the VUV region was first demonstrated by Reader et al. [4] who used special autoradiographic plates mounted in a 10.7 m grazing incidence spectrometer to record spectra in the 50–550 Å region from a low inductance vacuum spark source. At about the same time, Ben-Kish et al. [6] also demonstrated the use of similar IPs for extreme UV (XUV) spectroscopy by recording spectra from a fast capillary discharge Z-pinch source using a 2 m Schwob–Fraenkel spectrometer in the 5–1700 Å region. IPs used by them were modified to have thinner phosphor layers than standard X-ray image plates and no protective plastic coating in order to render them useful in the VUV region. These experiments concluded that the PSL based IP has sensitivity comparable with that of photographic plates, along with a better linear response over a wider dynamic range. Subsequently, Nave et al. [7] showed that the usefulness of these plates can be extended to the longer wavelength side (UV region) up to 2300 Å, with some sensitivity retained even up to 3000 Å. It may be noted that all the papers cited above are on VUV emission spectroscopy. Despite the capability and advantages of IPs as VUV detectors, we do not find much literature reporting their use in synchrotron radiation source based VUV photoabsorption studies. Here, a mention must be made to the paper by Katto et al. [8] where they have compared the photoluminescence intensity from BaFBr:Eu^{2+} films irradiated by synchrotron radiation and pulsed VUV lasers.

In this paper we report the implementation of an IP based detection system on the high resolution VUV (HRVUV) beamline [9] at the Indus-1 synchrotron radiation source (SRS), Raja Ramanna Centre for Advanced Technology (RRCAT), Indore, India and its application to photoabsorption studies using SR. We have augmented the 6.65 m spectrometer to enable use of an IP based detection system interchangeably with the existing PMT based detection system. The IP is mounted on the focal plane of the spectrometer and the performance of the new system with respect to the PMT based technique is compared, especially with respect to recording time, sensitivity, reproducibility, dynamic range, resolution, etc. Details of the design of the new system and test experiments performed are discussed in what follows.

2. Experimental setup

2.1. Brief description of beamline and PMT scanning mechanism

The Indus-1 SRS is a 450 MeV electron storage ring with a peak photon flux of 7.2×10^{11} photons/s/mrad/0.1% bandwidth [10]. The HRVUV beamline at Indus-1 which has been in operation since 2011 is designed for photoabsorption studies of atoms and molecules using SR in the 1150–3500 Å wavelength range [9]. A schematic layout of the HRVUV beamline is shown in Fig. 1. Details of the design and development of this beamline have been reported earlier [9]. Briefly, this indigenously developed beamline utilizes a 6.65 m off-plane Eagle mount normal incidence spectrometer for wavelength dispersion. The spectrometer houses a single optical component, viz. an Al+MgF_2 coated concave grating with groove density 1200 l/mm, blazed at $\lambda = 1500$ Å giving a first order reciprocal linear dispersion of 1.24 Å/mm in the wavelength range of 1150–3500 Å. With this grating mounted in the spetometer, one can record a scanning range of 160 mm corresponding to ~200 Å for a given central wavelength setting. A 4800 l/mm gold coated grating which covers a wavelength range of ~50 Å for each central wavelength setting with reciprocal linear dispersion of ~0.3 Å/mm is also available for higher resolution measurements. The wavelength range of interest is set by rotating the grating about the horizontal axis of the spectrometer to select a particular central wavelength (λ_0) and then translating it along this axis to focus the dispersed light onto the exit slit [11]. The angle of rotation α_0 and translational position X are given by the relations $\alpha_0 = \sin^{-1}(\lambda_0/2d)$ and $X = R(1 - \cos\alpha_0)$ where d is the groove spacing and R is the radius of curvature of the grating. The entire spectrometer chamber is maintained at a vacuum of 1×10^{-6} mbar obtained using a roots blower and two 500 l/s turomolecular pumping stations.

For photoabsorption studies, a 0.5 m stainless steel absorption cell (cf. Fig. 2) is placed between the entrance slit of the spectrometer and beamline fore-optics. The broad band SR beam from the Indus-1 source passes through a three cylindrical mirror fore-optics system and subsequently through the absorption cell before getting focused

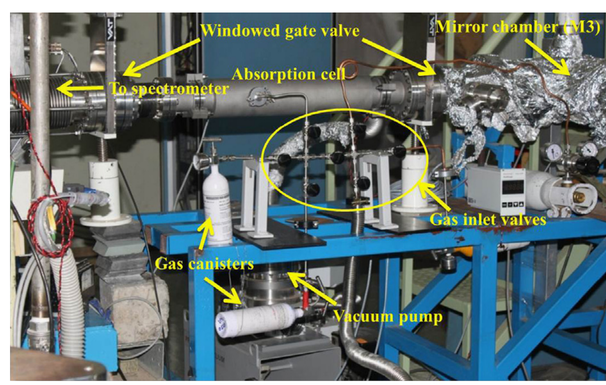

Fig. 2. Gas phase absorption cell with sample introduction system.

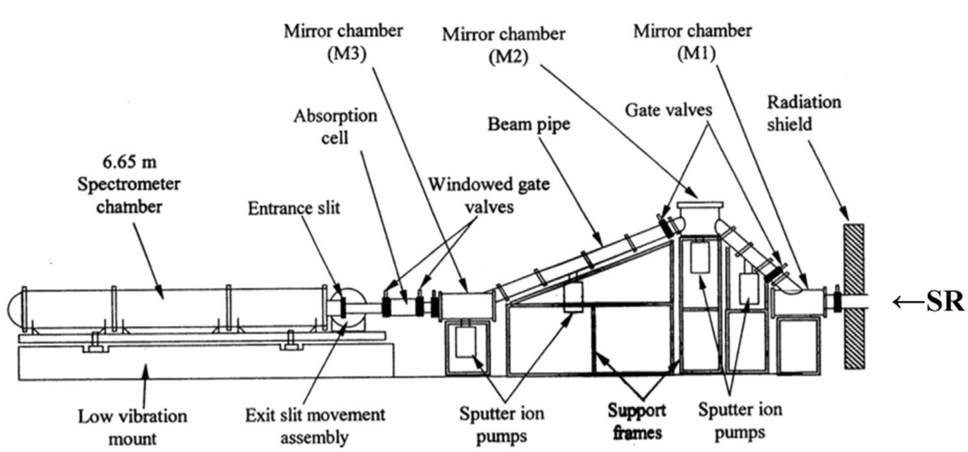

Fig. 1. Schematic layout of the HRVUV beamline at Indus-1.