The Sealed Beam Intensity Monitors

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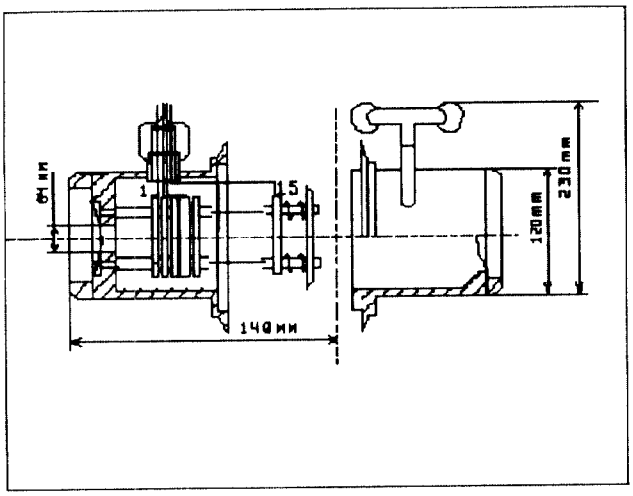

Figure 1: The SEC design.

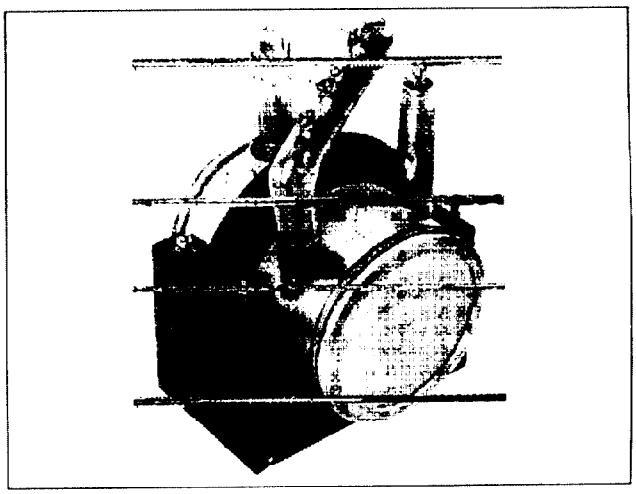

Figure 2: The SEC view.

1 INTRODUCTION

Second emission chamber (SEC) and its argon-filled modification (Argonion) are widely used for intensity monitoring of slowly extracted proton beams around the world. They complete very conveniently one to another, because the ratio of their specific sensitivities is about 10^3. They may be implemented on the one compact mechanical design and thus conveniently used together in the assembly covering the wide range of the beam intensities. Because of the limited necessity in quantity of such devices they are commercially unavailable and are usually self-made. The work on creation of the own SEC has been carrying on at IHEP for several years. Our experience in the creation and exploitation of these devices, the obtained results and some recommendations are summarized in this article.

2 THE SEC DESIGN AND PRODUCING TECHNOLOGY

As the only way to guarantee the SEC stability is to prepare the atomically clean surfaces of emission electrodes and then to conserve them in the hydrocarbons-free vacuum above 10^{-7}-10^{-6} Torr [1, 2], we decided to create a compact sealed device with a necessary static vacuum not needy in additional pumping during the device operation. According to [3] we define that the atomically clean sur-

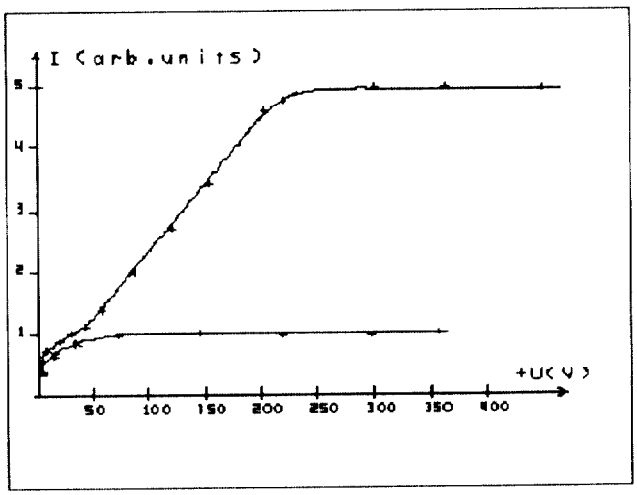

Figure 3: The SEC bias curves: (*) - the typical self-normalized SEC bias curve obtained on the $5 \cdot 10^{12}$ ppp fast extracted beam; (+) - the anomalous bias curve normalized to the first one and obtained on the $0.8 \cdot 10^{12}$ ppp slowly extracted beam (beam spill - 0.5 s) after the SEC irradiation with the high intensity (above $2 \cdot 10^{13}$ ppp) fast extracted beam.

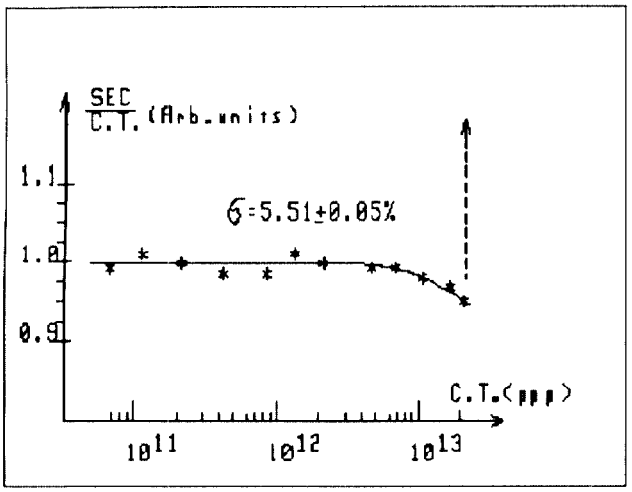

Figure 4: The SEC linearity on the fast extracted beam. U_{sec} = +200 V

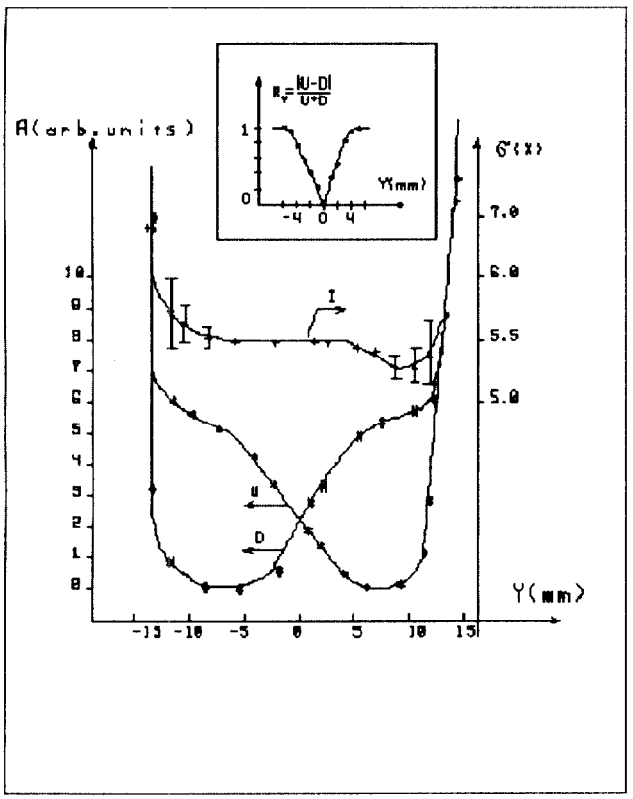

Figure 5: The SEC (I)-foil zone characteristic and the split foils U and D signals, obtained on the $5 \cdot 10^{12}$ ppp fast extracted beam when the SEC was scanned across the beam in Y direction with a constant displacement in X direction about 10 mm. The calculated ratio R_y is shown in the window. The errors on the (I)-curve reflect the E/I ratio.

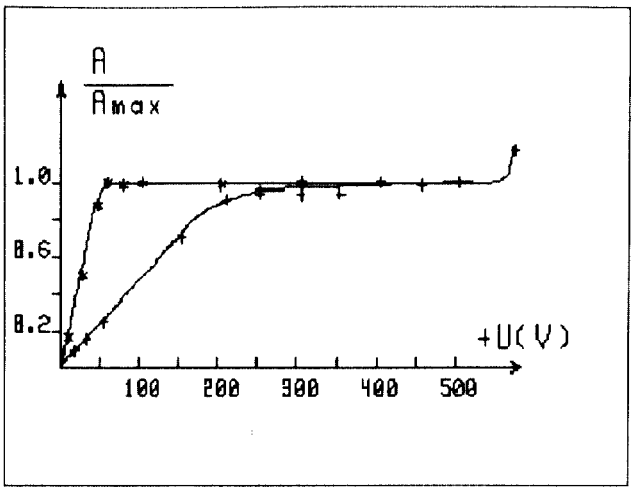

Figure 6: The Argonion self-normalized bias curves for different slowly extracted beam intensities: (*) - at 10^7 ppp and (+) - at 10^{11} ppp.

faces in our case are those which integral outgassing rate due to the thermal or/and beam irradiation effects leads to the worse of the static vacuum in the sealed device volume less than 10^{-6} Torr. It correspondes to a few per cent of a single monolayer of foreign atoms sorbed on the surfaces. We limited the device aperture and designed SEC as compact as possible to make it more convenient and flexible in using and to simplify our task by decreasing the total surface to be cleaned.

The SEC design and view are shown in fig.1,2. It is the all-welded stainless-glass vacuum lamp with 50 μm Ti windows, the glass multi-feedthrough socket, ionization gauge and an evaporated getter. It contains the collector and emission electrodes assembly from 15 electrodes. Electrodes are the 5μm Al foil fixed in the 2 mm stainless holder with aperture 64 mm. The total mass introducing in the beam with SEC is 65 mg cm^{-2}. The standard set of the SEC emission electrodes includes: the main intensity electrode (I), the galo electrode (G) with central hole 5-15 mm, to estimate the beam size and quality of beam passing through the monitor, the complementary split electrodes (U), (D), (L) and (R) to measure the beam displacement in both directions and the error electrode (E) which is the empty holder to estimate the measurements accuracy when beam is passing close to the edge of the SEC aperture or when the beam size is comparable with the SEC aperture. To decrease a hydrogen diffusion rate, Ti windows were improved through surfaces Al implantation.

The detail prescription how to get the stable SEC is given in [2], but it is too complicated and requires a lot of special equipment unavailable to us. We tried to do it in a more simple way . All stainless components were chemically precleaned according to [3] and baked in vacuum at 1000°C for a 10 hours. The glass details were chemically cleaned and dried in a hot air. As to the treatment of the

Al-foil electrodes, we also used [3] recommendations (with treatment conditions between B and C) to deplete the carbon based species binding states, decrease their sorbtion ability and get a sponge-like surface of the emitters for increasing of their efficiency. After assembling SECs were pumped with heating to 350°C for 40–50 hours. The maximum vacuum level of used oil-free stainless-glass vacuum station was about 10^{-7} Torr. During the pumping we carried out the in-situ glow discharge cleaning in 0.1 Torr Ar atmosphere with a current density about 0.1 mA cm^{-2} and total argon ion dose about 10^{18} cm^{-2}. In the case of the leakages absence, after 40–50 hours of pumping we usually get the saturation vacuum level about 10^{-7}–10^{-6} Torr. After that we sealed SEC and pumped the additional outgassing rate from the hot glass feeder with SEC's getter to the equilibrium vacuum level about 10^{-7} Torr.

In some devices we couldn't neither get this vacuum level, nor find leakages. The residual vacuum in this devices was usually about 10^{-3} Torr. We installed these devices at the pumping station again, pumped them, filled with pure Argon at pressure 0.5 kg cm^{-2} and sealed. Thus we took the Argonions. The additional mass of Ar is 15 mg cm^{-2} and the total mass introducing in the beam with Argonion is 75 mg cm^{-2}.

3 MEASUREMENTS AND RESULTS

For calibrations and measurements we used both analog and digitizied current integrators [4] which provided about 2% measuring accuracy and current transformer with about 1% accuracy. We found our SEC are really needy in the individual calibration. The emission coefficients σ obtained at the calibrations varied for different devices in the range 5.4%–5.7%. It was, we think, due to the producing treatments uncontroled variances. But they remained stable within the calibration accuracy 2% through all the SEC operation time for the integral proton fluxes to $5 \cdot 10^{18}$ cm^{-2} . The σ values obtained was a bit higher than might be expected, we think due to the emission electrodes sponge-like surfaces obtained through the etching in the alcaline solution.

The problems began with increasing the accelerator beam intensity above $2 \cdot 10^{13}$ ppp. The anomalous bias curve in fig.3 is the result of the SEC irradiation in a such high intensity fast extracted beam. The transition of the normal bias curve to the anomalous one was jump-like and irreversible. We think it is a result of the Ti windows overheating from the beam. We saw heat-induced discoloration spots on the windows. It is known that Ti becomes a hydrogen generator when is heated above 500°C. Thus we got a low pressure (about 0.5–1 Torr) hydrogen ionization chamber + SEC (at 20% – 30% level of total saturation signal) as a result of this beam treatment. On the fast extracted beam this new device showed the significant saturation effects starting from $2 \cdot 10^{12}$ ppp. But it does not mean that device useless for the same slowly extracted beam intensity measurements, because one can see the excelent plateau at about the same intensity of slowly extracted beam on fig.3. We observed the normal SEC saturation like performance at very high intensities of the fast extacted beam – see fig.4. Unfortunately we couldn't investigate this effect in details because our SECs transformed as was described above. We explain this feature of the SEC performance also as thermal effect of the emission coefficient temperature dependence: $\sigma(T) \sim (1 + \beta T)^{-1}$, were β is about $2.5 \cdot 10^{-3}\ K^{-1}$, which is approximately the same as the corresponding resistance coefficient [6].

The downfall at the one edge of (I)-foil zone characteristic – fig. 5 was not typical. We explaine it as the residue of cleaning solution in the ring holder split difficult to be removed. The real SEC aperture was found significantly lesser than mechanical one and the large errors of measurements were observed close to the aperture edges. To indicate them and correct, if necessary, the (E)-signal may be used.

The Argonion parameters were in a good agreement with the expected ones from [5]. Its transformation coefficient was found 10^{-5} pC prot.$^{-1}$ within 5% accuracy. The linearity region extends to $2 \cdot 10^{11}$ ppp.

We are going to replace outer glass components to the ceramic ones, the 50 μm Ti windows to the 20 μm stainless or 60 μm Al-Be alloy. We'll also try to reject the evaporated getter and to use the stainless housing covered inside with Ti as an effective non-evaporated getter.

We can recommend be careful with carring out the devices calibration and avoid the incorrect calibration procedures. In the SEC case it means that calibrations should be done under the same with working thermal conditions and for gas ionization devices under the same beam current densities, where the plateau on the bias curve remains.

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