MAGNESIUM JET PROFILE MONITOR

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Abstract

The Magnesium Jet Profile Monitor was designed and developed by Budker Institute for Nuclear Physics. The article presents the description and features of this original diagnostic equipment to investigate a beam structure.

1 INTRODUCTION

Measurement of a particles beam density cross structure in accelerators allows to make a set-up of optimum mode operations for accelerator systems and internal target. The basic advantage of a described profilometer is a combination of high sensitivity and weak influence of the space charge of beam on the space resolution [1]. It is reached by use of a thin magnesium atoms jet, which flow density can be changed in large value by small change of evaporator temperature from 400^{0} up to 450^{0} C. Since neutral atoms are not sensitive to electrical fields then there is no need to obtain the electron-optical image during collection and measurement of electrons created by ionization. The electron-optical system should just guide the electrons onto luminophor and measure its light emission. Such system allows to measure small currents down to several electrons per second, that allows to measure a structure of a beam with current about 0.1 μA.

The use of magnesium as a vapor source is defined by several factors. The physical properties of magnesium are those, that it starts to evaporate long before melting point and it allows to use a more simple design for its container. Small nuclear number reduces the scattering of a beam particles. The light condensability of surface allows use the profiler in high-vacuum systems without additional pumps. Moreover, the fresh magnesium film surface serves like sorption pump.

The signal from Mg-Jet Monitor is proportional to the density of ion beam. It gives a lot of opportunities to use the profilometer for measuring of cooling decrement, friction force or evolution of some instabilities at the mode without mechanical scanning.

2 MECHANICAL PART OF INSTALLATION

The schematic image of a physical part of installation is shown in Fig. 1.

During heater operation the magnesium in container is heated up to 400^{0} - 450^{0}C. A magnesium vapor pressure is been developed in the container allows to the vapor to flow through a narrow gap. To obtain a narrow flowing jet the additional collimator gap is mounted. It helps to form a sheet beam. At collision of magnesium

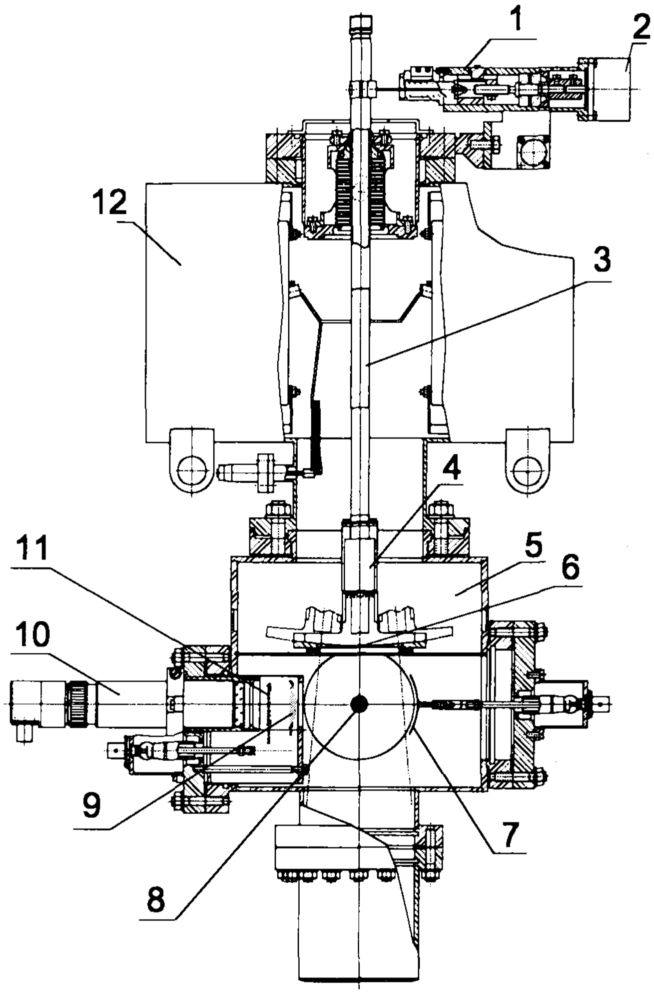

Fig. 1 Cross-section View of Magnesium Jet Profile Monitor (1-drive mechanism, 2-step motor, 3-step motor driven stem, 4-magnesium filled container with heating wires and thermocouples, 5-installation case, 6-collimator gap for outflowing magnesium jet, 7-reflecting (or clearing) electrode (under up to -2kV), 8-beam of charged particles, 9-electrons extracting grid, 10-PMT, 11-collector plate: a glass covered with aluminized luminophor (under up to +15kV), 12-ion pump)

atoms and charged particles beam the magnesium atoms are get ionized. During this process the ionization electrons are formed (in quantity proportional to the beam and magnesium vapor densities) and then are extracted by extracting grid under small positive potential about +1 kV. Further, the passed grid electrons are get additional acceleration by a collector voltage (up to +15 kV) and come the luminophor. The light flow emitted by luminophor goes to the photomultiplier photocathode. Then the current from photomultiplier collector is transformed to a voltage by operating amplifier. This voltage is digitized by use of ADC and stored into computer memory.

While measurements take place the sheet beam of magnesium vapor controlled by microprocessor scans the area of a particles beam and simultaneously PMT current is measured. As a result the obtained data represents the information on a beam structure (the data is transmitted to host computer for further processing).

To swing stem with the container the kinematic schema based on one step motor was chosen. Thus it is possible to solve a few problems at once - flexible management of a range, speed and central point for scanning process by computer.

After Profile Monitor mounted into storage ring or into a channel it is necessary to pump out its vacuum volume. The working vacuum in profiler chamber should not be lower than 10^{-8} torr. There is not its own pump devices on the Mg-Jet Profile Monitor to get a high vacuum except the ion-pump NMD-016 (with rate about 160 liters per sec), which should be used only after achievement of working vacuum ($<10^{-7}$ torr). If it is required to have superhigh vacuum ($<10^{-8}$ torr) in storage ring or channel it is necessary to bake the profiler volume at pressure no more than 10^{-4} torr and temperature no more than 400^{O} C. Baking time - about 2 days, i.e. the standard procedure to develop superhigh vacuum.

2 INSTALLATION MANAGEMENT

The installation management consists of the following problems fulfillment:

- Maintenance of a set temperature of a mg heating;
- Management of the step motor rotation;
- Maintenance of electron-optical system by a high voltage;
- Measurement of a PMT current;

To meet all of these requirements the electronics units mounted in CHERRY-Rack are used. The CPU unit receives instructions from host computer via serial RS232 port and programs the operation mode for Mg-Jet Profile Monitor. Since all of the low level functions are written for and running into CPU unit then host managing program can be run under any OS with use of appropriate I/O and graph libraries. For example the operating Mg-Jet Profile Monitors used at CELSIUS Ring [2] (The Swedberg Lab, Uppsala University, Sweden) and at 2-MeV CW RF Injector (KAERI, S.Korea) are managed by server running under vxWorks in VME create in first case and stand alone program running under Windows in PC in second case. So it is easy to embed the profiler to any accelerator control system.

3 MEASURING EXAMPLES

All the samples submitted below have been obtained during measuring of ion beams circulated in CELSIUS Ring (The Swedberg Lab, Uppsala, Sweden).

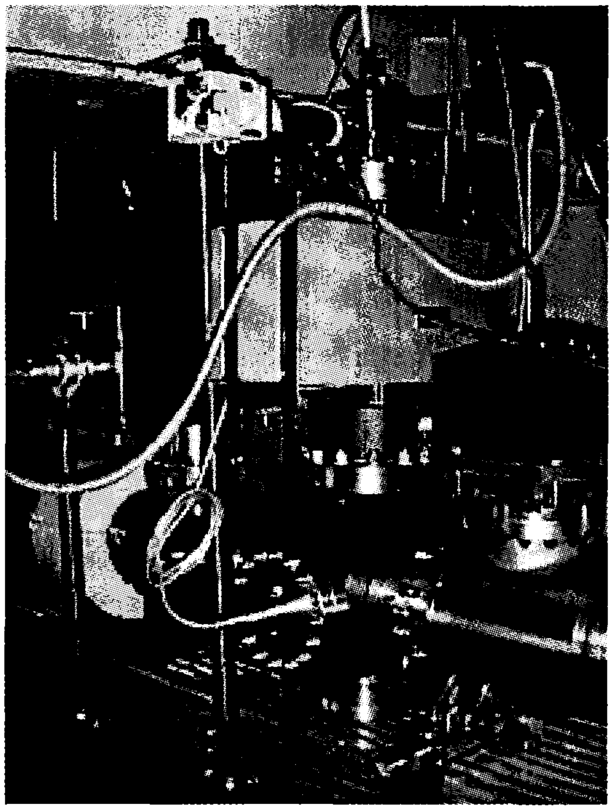

Fig. 2 Mg-Jet Profile Monitor mounted on 2MeV Injector.

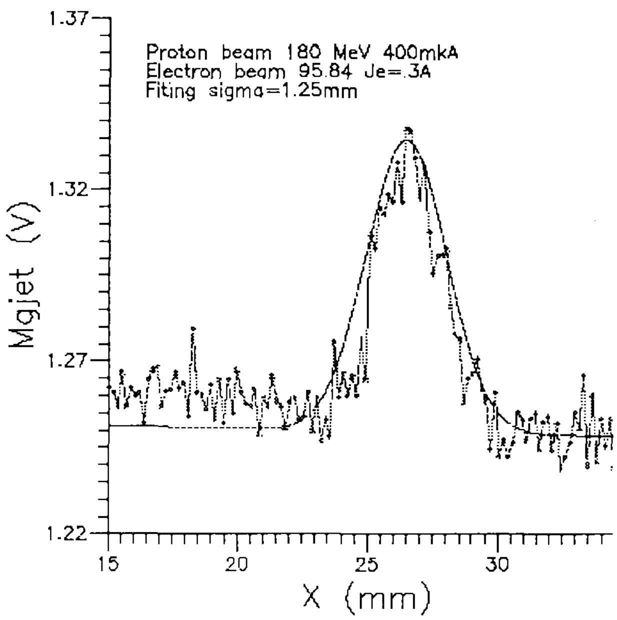

Fig. 3 Proton beam profile along X-axis obtained by Mg-Jet Profile Monitor and its fitting-curve.

The Fig. 3 represents measurement of proton beam cross structure. Determining the coordinate appropriated to maximum density of a beam and have exposed a Mg-jet at the point allows to carry out measurement of beam decay (PMT signal measurement depending on a time).

In Fig. 4 are submitted two measurements of Ar-beam current decay. The top curve has been obtained by

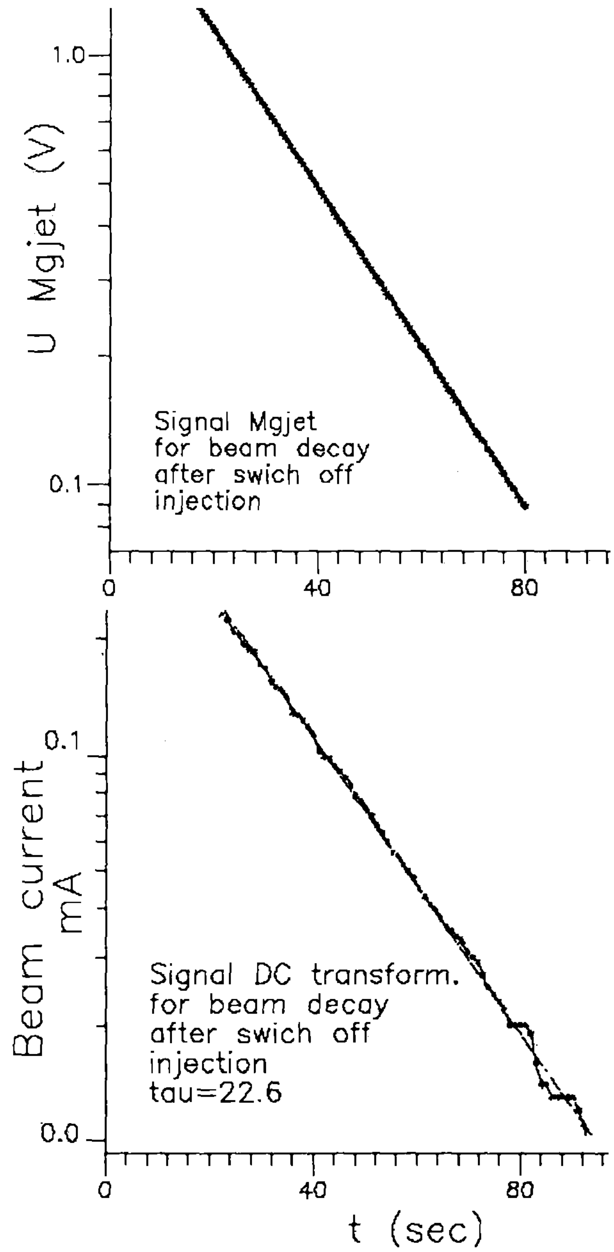

Fig.4 Two plots of decay measurements by Mg-Jet Profile Monitor and by DC transform for low beam current.

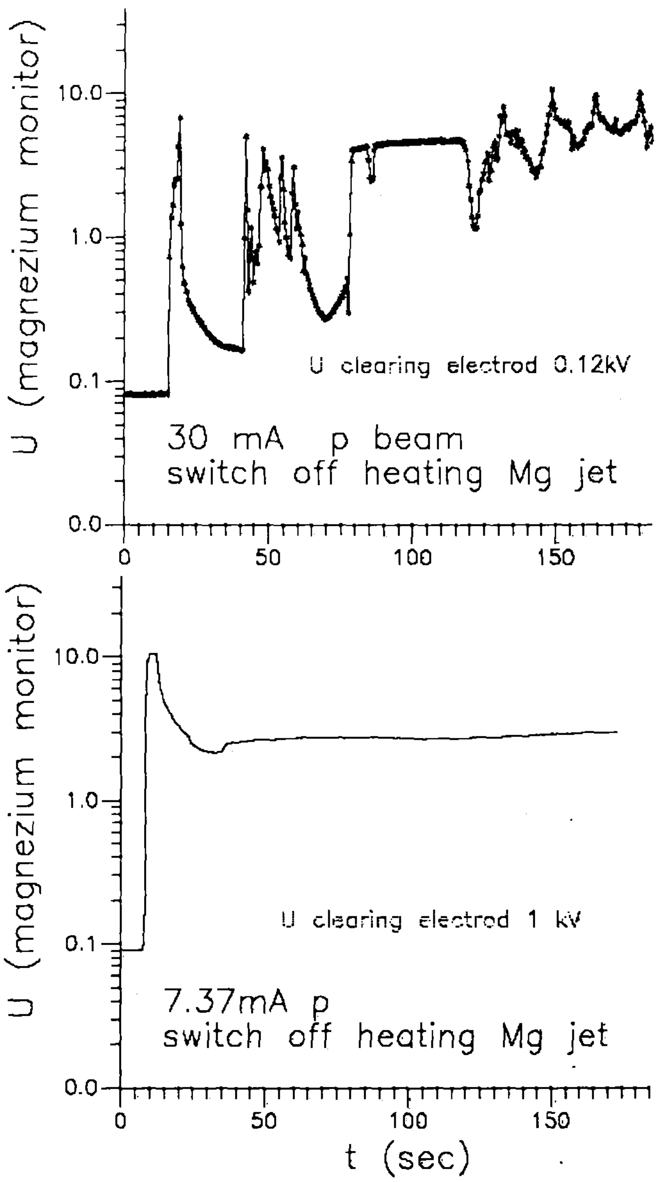

Fig.5 Signals of ionization current. Top and bottom curves are differ by cleaner electrode potentioal.

use of Mg-jet Profile Monitor and is characterized by smaller noise in contrast to second one obtained by use of a DC transform. For Mg-Jet method the root-mean-square deviation equals to $2 \cdot 10^{-4} mA$ and for DC transform equals to $2 \cdot 10^{-3} mA$.

In Fig.5 are shown the changes of signal for ionization current (the heater for magnesium filled container switched off) during CELSIUS Ring operation. At 15 seconds starts the injection and acceleration. During acceleration the energy is increased but the ability to ionize the particles decreases. At 40 sec the acceleration is terminated and RF voltage is switched off. Thus a beam becomes continuous along the orbit and ionization electrons can go significant distances adrift along the beam, getting in a sensitive area of Mg-Jet Profile Monitor. As a result we can see very strong changes of a current caused by changes of the beam conditions. The beam cooling process starts at 70 sec. At 1 kV voltage applied to the "cleaner" electrode, the noise caused by ionization in the chamber decreases and as a result the measurement curve (bottom curve in Fig.5) has more evident kind.

REFERENCES

[1] Particle Accelerators, *1976, V7, №4, pp.197-211;*
[2] T.Bergmark et al, *Transverse cooling time and cooling beam profiles at CELSIUS*, TSL-Note 96-24, July 1996