Application of $^{235}U^+$ Ion Beams for Increasing the Safety of Operation in Nuclear Reactors for Atomic Power Station (APS).

A.V.Demyanov, *INR, Ukraine, Kiev.*

The application of an $^{235}U^+$ ion beam for providing a safe operational mode of APS with a subcritical reactor is discussed. The problem of increasing the operational safety of nuclear reactors used in APS can probably be solved by a simpler and essentially less expensive way, if a beam of single-charged heavy ions is used, instead of a proton beam, for example $^{235}U^+$ ions which experience an induced fission due to the effect of the neutron flux n_r in the reactor while moving through the active reactor zone in a vacuum chamber.

For experimental nuclear physics and technological processes high intensity single-charged heavy ion beams, accelerated to a low energy (50÷200KeV) are necessary.

From a PIG ion source with the seit of about 0,1cm^2 (1cm×0,1cm) an ion beam of U^+ with an intensity of ~ 10mA (20mA) can be extracted.

A radiofrequency high -current ion source for heavy elements was developed in our laboratory. In this ion source spherical are cylinder shape grid electrodes are used. This electrodes define the plasma boundary, provide effective extraction and beam focusing (Fig.1). The window in grids electrodes equals the Debay radius in plasma, the transparency of these grids is about 0,9 (90%). The extraction and focusing properties of these electrodes were investigated on the test-bunch. In the experiment with an industrial laser (Wave length λ=1,06μm, pulse duration t=10ns, energy in the pulse q=0,04j, frequency f=25Hz) and a solid Mg target the value of the ion current in the direction of the central detector increased with the growth of the extracting potential and beam focusing was observed (Fig.2). For the investigation of the structure of the beam, extracted from laser plasma and focused by cylinder-shape electrodes a multichannel detector is used. The diameter of the outlet aperture of the radiofquency high current ion source for the current I is the following:

I_1=1A, D_1 ≈3,5cm (s~10cm^2)

I_{10}=10A, D_{10} ≈11,5cm (s~ 100cm^2)

I_{100}=100A, D_{100} ≈36cm (s~ 1000cm^2)

This ion source may be used, for example, for in-beam chemical preparation with a solid or gas target, for the on-line production of radioactive isotopes (Fig.3), for the intensive neutrons generator (Fig.1), for the implantation and surface modification of solid material, for increasing the safety of operation in nuclear reactors for APS.

It is a well-known accelerator breeding process, in which the chain reaction is restored by an external powerful neutron flux, generated in uranium or lead targets by means of high energy protons. A transition of an APS to operation with deep subcritical reactor manes it possible to avoid a possibility of emergency siruations connected with the probability reactor of transition to the overcritical state and its runaway. The drawback of this method is excessive complexity, power-consumption and high cost of development of an accelerator, for example, a proton accelerator with a protone energy of about 0,5 GeV and beam current of about 100 μA. In addition, it may be noted that it is also a complex and ixpensive task to build a target (or targets), which is arranged in the active zone of the nuclear reactor. There are also some other difficulties [2, 3]. The problem of increasing the operational safety of nuclear reactors used in APS can probably be solved in a simpler and essentially less expensive way, if a beam of single-charged heavy ions is used, instead of a proton beam, for example $^{235}U^+$ ions (E≈ 50÷200keV, I≈ 100×10A) which experience an induced fission due to the effect of the neutron flux n_r in the reactor while moving through the active reactor zone in a vacuum chamber. The neutron flux n(^{235}U$^+$) of the fission in the presence of n_r in the reactor is given by n($^{235}U^+$)=I($^{235}U^+$) $\cdot n_r \cdot \sigma \cdot \nu$, where I($^{235}U^+$) is the beam current of $^{235}U^+$ ions, σ the cross-section of fission of ^{235}U for neutrons, and ν the number of neutrons released in one fission event of ^{235}U. If I($^{235}U^+$)=10^3A, $n_r = 10^{14} cm^{-2}$, $\sigma = 600 \cdot 10^{-24} cm^2$, $\nu = 2.5$, we obtain n($^{235}U^+$) $\sim 10^{15}$sec^{-1}, which is approximately equal to the neutron flux, produced by the interaction of a proton beam at accordingly energy and a current with a uranium or lead target (see table 1). As in case of APS operation with subcritical reactor with an external neutron flux, produced by a proton beam, in our case the shut-down of the reactor is made by the switching of the U^{235+} ion beam, which is carried out by the automatic systems during the time of ~1msec.

The cost and complexity of the injector of U^{235+} ions development may be considerebly smaller thana proton accelerator of respective energie and the beam current (table 1).

Moreover, in this case the target problem is absent. The $^{235}U^+$ beam is the target.

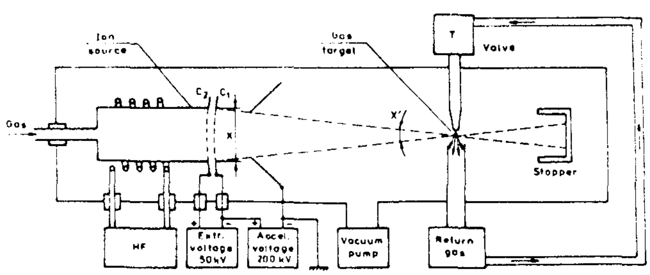

Figure 1: High current radiofrequency ion source

Table 1

E_p GeV	n/p	I_p, μA	n, s^{-1}	I(^{235}U$^+$) A
0,2	1	1,0	$6 \cdot 10^{12}$	1
		10	$6 \cdot 10^{13}$	10
		100	$6 \cdot 10^{14}$	100
		1000	$6 \cdot 10^{15}$	100 × 10
0,5	10	1	$6 \cdot 10^{13}$	10
		10	$6 \cdot 10^{14}$	100
		100	$6 \cdot 10^{15}$	100 × 10
		1000	$6 \cdot 10^{16}$	
1,0	20	1	$6 \cdot 10^{14}$	100
		10	$6 \cdot 10^{15}$	100 × 10
		100	$6 \cdot 10^{16}$	

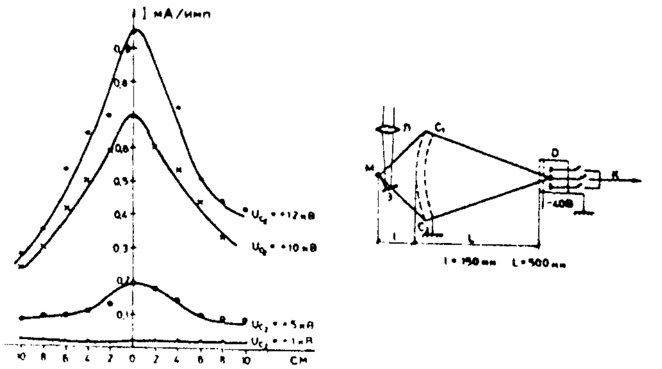

Figure 2: Distribution of the ion current in the focus of grid electroded at different potentials of grid electrode $C_2(U_{11})$

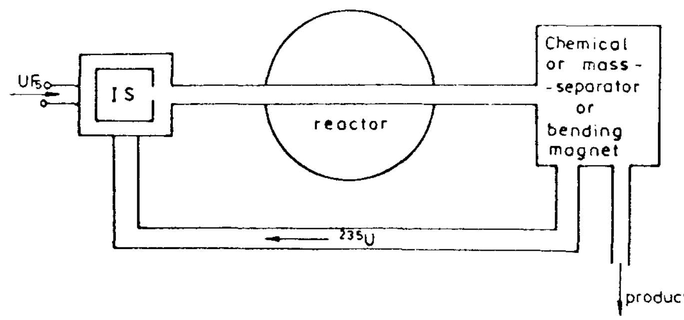

Figure 3: Application of ^{235}U+ ion beams for Increasing the Safety of operation in nuclear reactors for APS

References

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