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NEW SCHEME OF LONGITUDINAL BEAM COMPRESSION FOR HIF DRIVER

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NEW SCHEME OF LONGITUDINAL BEAM COMPRESSION FOR HIF DRIVER:
Preprint ITEP 9-98/

D.G.Koshkarev, A.V.Barkhudaryan, A.N.Talyzin - M., 1998 - 8p.

The longitudinal compression of a bunched beam in the final transport line with two high frequency Alvarez RF sections as effective method to attain high current for the heavy ion driver, based on the charge-symmetrical scheme, has been proposed. The bunched beam consists of 160 bunches with spacing of 4 ns (pulse frequency f=250MHz). The first RF section rotates the beam in the phase space relatively to the central bunch by RF field with the negative frequency shift Δf. RF voltage of 300MV is required to get 17-fold momentum spread increase for ions with energy of 10GeV. The significant rise of the compression efficiency has been obtained by addition of the second harmonic of RF field (37MV). The second RF section with 18MV provides the rotation of each bunch relatively to own center. In the final transport line of 4km length the beam is compressed into single bunch with the pulse duration of 10ns. The bunch peak power is 200TW according to the peak current 20kA (10kA for species Au^{+1} and Au^{-1}).

Fig. - 3, ref. - 4 name.

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Introduction

The concept of the charge-symmetric driver had been submitted to Frascati HIF Symposium in 1993 [1]. The idea is based on acceleration of eight different species of platinum ions (four different isotopes, each in two states of positive and negative charge) in one linear accelerator complex. Negative ion beams are merged with the positive ones in the final stage of the transport channel in order to reduce space charge and increase total beam current. Beams of different ions arrive the target simultaneously and provide the irradiation energy of 9.6MJ and power 960TW ([1],[2]). But this driver design was rather complicated and expensive because of the need for a system of storage and compression rings for each ion species.

Now we use HIF driver design [3], based on idea to keep the beam bunch structure up to the collision of ions with thermonuclear target. Together with new ring system this driver needs in two ion species only, namely, Au^{+1} and Au^{-1}.

Beam Bunching and Accumulation

The main specifications of the proposed driver are listed in Table 1. The driver layout and the beam parameters evolution are described in ITEP preprint [3].

Table 1: Driver parameters

Ion mass (Au)	197
Pulse duration at linac entry	1.96 ms
Energy of ions	10 GeV
Pulse duration at linac exit	40 μs
Quantity of beams	10
Beam energy	1 MJ
Peak beam power	200 TW
Beam spot diameter on target	2.2 mm

The beam is bunched beforehand at the entry of each first RFQ-linac sections by RF field (6.25MHz) and the beam bunch structure is kept up to the collision of ions with thermonuclear target. In this bunched beam each fifth bucket is an empty one. As a result the beam will have "holes" with duration 160ns and period 800ns. Therefore all operations of beam ejection and injection between driver elements will not lead to any ion losses in the vacuum chamber walls. Eight positive ion and eight negative ion current lines are planned with 40mA in each line. As a whole the linac complex is similar to the "classical" scheme of HIF driver. But so called "accumulation" rings (two for positive and two for negative ion current) are inserted in the linac structure (the point of transition from Wideroe to Alvarez linac). In these rings the beam bunch structure is provided by the small RF voltage with the frequency of 100MHz. The beam circulates in accumulation ring 7 turns up to obtain the energy of ions 600MeV. As a result the beam duration is reduced by 49 times.

The total longitudinal compression factor is equal to 2560. The mean beam current increase in linac by a factor of 8 both for Au^{+1} and Au^{-1} ions is provided.Then the further increase of ion current by a factor of 5 is realised at five turn injection in

the third accumulation ring (AR in Fig. 1) The injection is provided by use of the periodic orbit bump that consists of two deflectors with the distance between them equal to half of the betatron wavelength. The frequency of deflectors voltage is tuned to the bunch frequency at the injection point (F=50MHz). The following condition for the ring circumference,

$$L=\beta c/F(n\pm 1/5)$$

is matched exactly with the time shift between adjoined revolutions equal to 0.2/F. Such a technique is described in detailes in the paper [2] and, partly, in [4].As a result we get 20 ion current pulses (10 of Au^{+1} ions and 10 of Au^{-1} ions) with a mean current of 4A in each pulse, duration of 640ns and spacing 4ns. These 20 pulses are ejected by kicker magnets into 20 transport channels, where they are compressed by two Alvarez sections with distance between them equal to 230m.

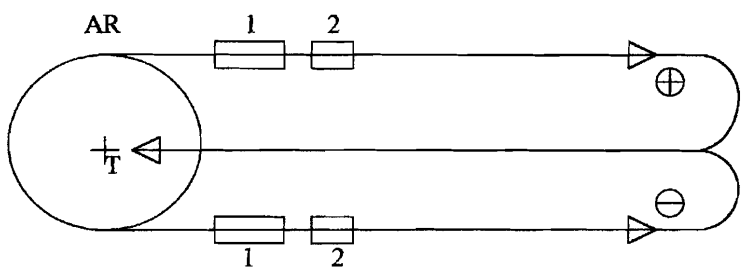

Figure 1: Sketch of final transport line

Beam Compression

The full length of each transport channel is 4250m. After half of this distance the positive and negative ion beams are bent on 180° and merged by dipole magnets. Then ten neutral beams propagate up to the thermonuclear target (point T in Fig. 1). 64-fold final compression is realized in the transport channels and each beam is compressed into a single current pulse. The final compression has been investigated numerically.

The beam ejected in transport channel consists of 160 short bunches with spacing of 4ns (frequency f=250MHz). Each bunch has duration of 0.4ns and relative momentum spread of $\pm 4.7 \cdot 10^{-4}$. The beam compression is provided by two RF Alvarez sections in the first part of the final transport line (respectively, rectangles 1 and 2 in Fig. 1)

The first RF section rotates the beam in the phase space relative to the central bunch, so that the front bunches are decelerated and the back ones accelerated. The beam rotation is caused by RF field with frequency shift Δf opposite to pulse frequency f. 300MV RF voltage with shift $\Delta f = -f/480$ are required to get 17-fold increase of momentum spread for ions having energy of 10GeV. The significant rise in compression efficiency has been obtained by the addition (37MV) of the second harmonic of RF field.After the phase rotation bunches are lengthened in the transport line of 230m length, so spacing approaches 2ns. In the second Alvarez section rotation of each bunch relative to own center is provided by RF voltage of 18MV.

In the final transport line of 4km length the beam is compressed into single bunch with the pulse duration of 10ns. For the initial beam duration equal to 640ns the phase volume dilution is near to 50%. The bunch peak power is 200TW according to the peak current 20kA (10kA for species Au^{+1} and Au^{-1}). The shape of

the pulses for the distance 2000m, 800m, 400m from the target (see Fig. 2) and for 200m, 100m, 0m (Fig. 3) are given.

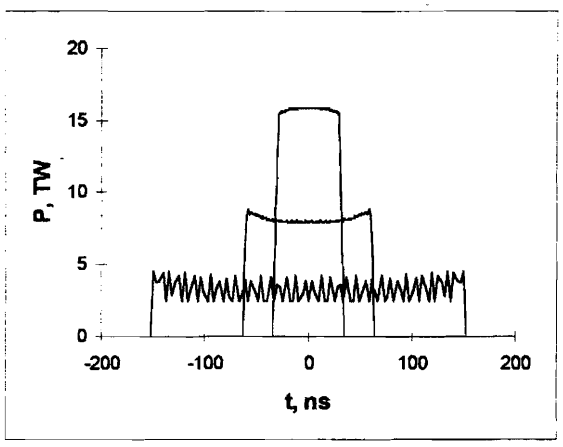

Figure 2: Pulse evolution on distance from the target 2000 *m*, 800 *m*, 400 *m*

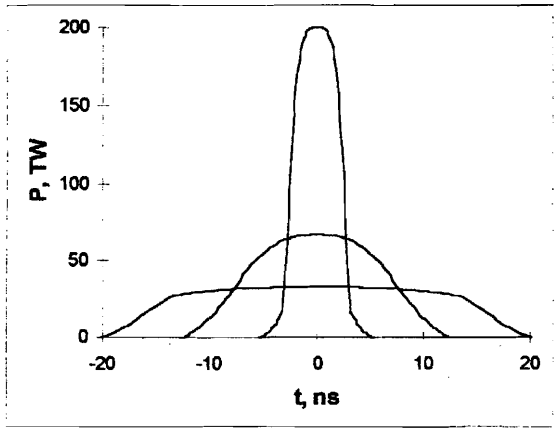

Figure 3: Pulse evolution on distanse from the target 200 *m*, 100 *m*, 0 *m*

Conclusion

In conclusion note some questions which should be additionally considered during the further studies.

- The influence of the beam coupling on the beam emittance value during accelerating process and for opposite signe beams merging in the final channel should be calculated more precisely.
- The value of chromaticity of final beam transport channel (for beam momentum spread $\pm 8 \cdot 10^{-3}$ and beam spot radius on target 1.1mm) is intolerable high.The possibility to create the achromatic transport channel should be considered.

Acknowledgements

Authors would like to thank INTAS for the support this work in frame of the INTAS grant 93-2571 and ISTC grant 154.

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