THE NEUTRON FLUX GENERATED BY THE IREN LINAC DARK CURRENT

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Abstract

The experimental study of the neutron-nuclei interaction based on the time-of-flight spectroscopy using the IBR-30 facility proceeds in the Frank Laboratory of Neutron Physics (JINR). This facility was built more than 20 years ago and needs the replacement.

In accordance with the improvement program the new facility IREN (Intense REsonance Neutron source) is under construction now. The IREN setup [1] includes the driver electron linac LUE-200 and the multiplying target. Two high gradient (35 MeV/m) linac sections will be powered by the SLED power multiplication scheme based on the 5045 SLAC klystrons. Such a high value of electric field results in electron emission from the section walls (the so called dark current) and could increase the neutron pulse duration.

The problem of the dark current influence on the neutron pulse parameters is discussed in this paper. The shape of the neutron pulse taking into account the dark current will be shown. The recommendations on the focusing system of the facility will also be given.

Introduction.

The main goal of the neutron source improvement program is the shortening of the neutron pulse duration (350 ns for the multiplication coefficient 20) and increasing the neutron yield by a factor of two. To satisfy these conditions the average electron beam power (for the electron pulse duration 250 ns) must be up to 10 kW. The LUE-200 particle energy (200 MeV) and the corresponding gradient (35 MeV/m) are limited by the existing room height (12 m). Such a high value of the accelerating gradient could be achieved provided that the corresponding power supply system (SLED power multiplication scheme) will be used. The high value of the surface electric field results in electron RF autoemission from the section walls. These electrons could be captured by the accelerating field and form the dark current. This current depends highly on the surface quality of the accelerating sections, their processing and vacuum properties.

The RF-breakdown process in the room temperature accelerating structures is one of the problems arising in the R&D HEP Program. The problem of the dark current influence on the generated neutron flux is of great importance in the IREN facility too. This paper gives quantitative estimation of the neutron flux generated by the dark current. It is worth mentioning that the IREN accelerating sections were designed in INP (Novosibirsk, Russia) and will be manufactured there as well. They are similar to the sections used in the ϕ-factory project [5]. The linac regime of the project, however, is a single bunch mode while IREN operates in a multi-bunch thus providing an increased average electron beam power. The estimations made in [4] show that the emittance growth for the last bunches of the train (due to the wake field effect) is about 20% in our case (accelerating gradient is 35 MeV/m). So, the bunches could be delivered to the target without considerable loss, but the dark current influence could possibly change this situation.

Method

The dynamics of the dark current electrons produced by the first accelerating section was computed. It is these particles that influence the neutron flux parameters (duration and amplitude). The experiments to measure the dark current were carried out in SLAC [2] and KEK [3]. In the first case the conducted experiments were aimed at studying the RF breakdown in the S-band room temperature accelerating structure. The dependence of the pulse dark current vs. the input RF-power was obtained. It was shown that with a 7-cell accelerating structure at the RF input power of 30 MW the pulse dark current amounts to 20 mA. The KEK measurements were conducted on a 3-meter S-band accelerating structure powered by the klystron with a SLED system. It was reported that the value of the pulse dark current at the input power of 200 MW was 340 mA. On the basis of these results the dependence of the pulse dark current vs. RF input power (for the IREN facility full power range) was extrapolated (see Fig. 1).

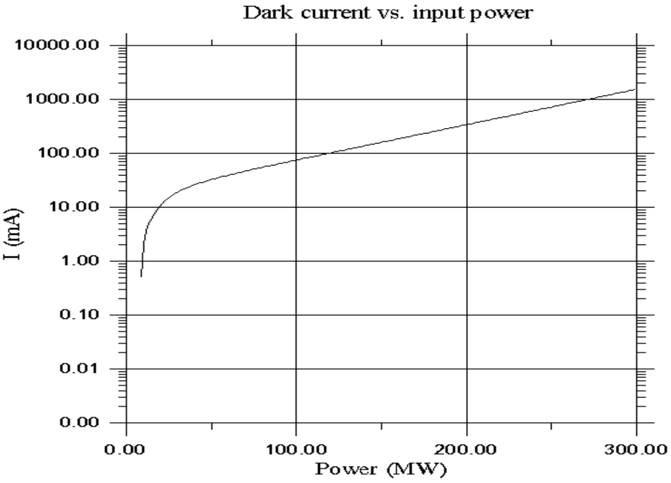

Fig. 1 Dark current vs input power

Before proceeding further some initial assumptions should be made : the quantity corresponding (according to Fig.1) to the integral value of the RF power distribution along the accelerating section was taken as an instantaneous magnitude of the dark current; the bunch space charge, beam loading and wake field effects were not taken into account (space charge does not affect much the particle dynamics for these energies).

The SLED system parameters [1] and the dependence shown above (Fig. 1) fully describe the expected dark current parameters at the end of the first section (taking the channel acceptance for the normal conditions at the end of the first section (0.002 cm rad) as an electron beam emittance). In terms of these parameters the calculations of the beam dynamics in the IREN linac and focusing system have been made using the PARMELA program. About one hundred calculations for a full energy range (35 - 135 MeV at the end of the first section) have been performed.

Results.

The energy acceptance of the IREN facility transport channel was computed. The ratio of the number of electrons delivered to the target to their initial number (channel transparency) is shown in Fig.2. The channel transparency significantly increases (from 0.1 to 0.7) over the electron energy range of 80-90 MeV. The upper limit of the energy acceptance (about 270 MeV) cannot be achieved with the existing power supply.

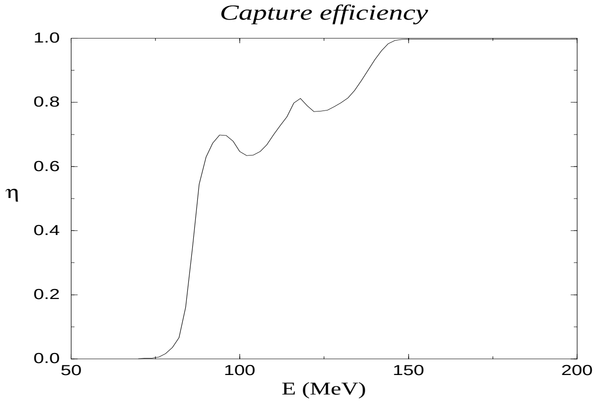

Fig. 2 Channel transparency

The dark current of the second section is not taken into account since the energy of the particles forming the current is not sufficient to reach the target. Beam envelopes for different values of the input electron energy are shown in Fig. 3. The first two cases represent the electron beam envelope for the particles with the energy less than normal (200 MeV). The size of the bunch along the channel exceeds normal about 1.5-2 times. Also the low energy electrons (< 100 MeV) are lost in the second section, so the necessity of the scrapers is obvious.

The characteristics of the dark current for the operation cycle are shown in Fig. 4. The energy gain in the sections is shown in Fig. 4a. After filling the section with RF-energy (at 0.5 μs) the total energy gain in the sections is equal to 120 MeV, which corresponds to the gradient 40 MeV/m (without

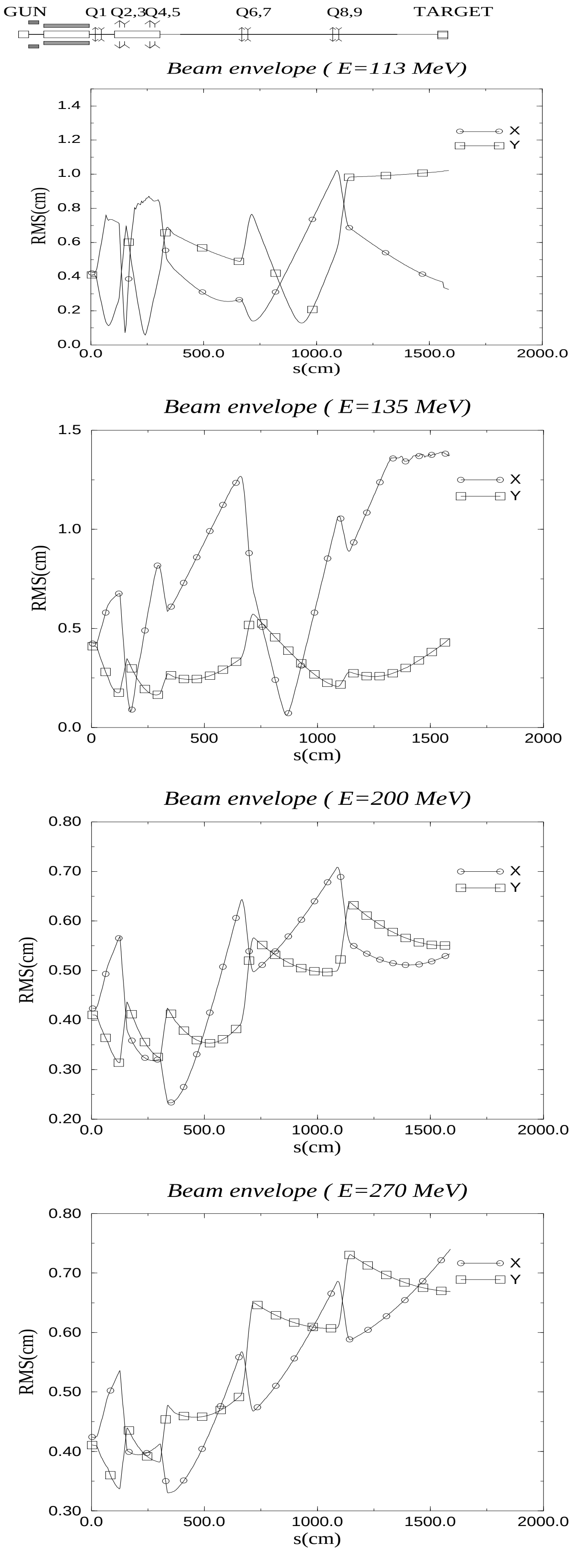

Fig. 3 Beam envelope

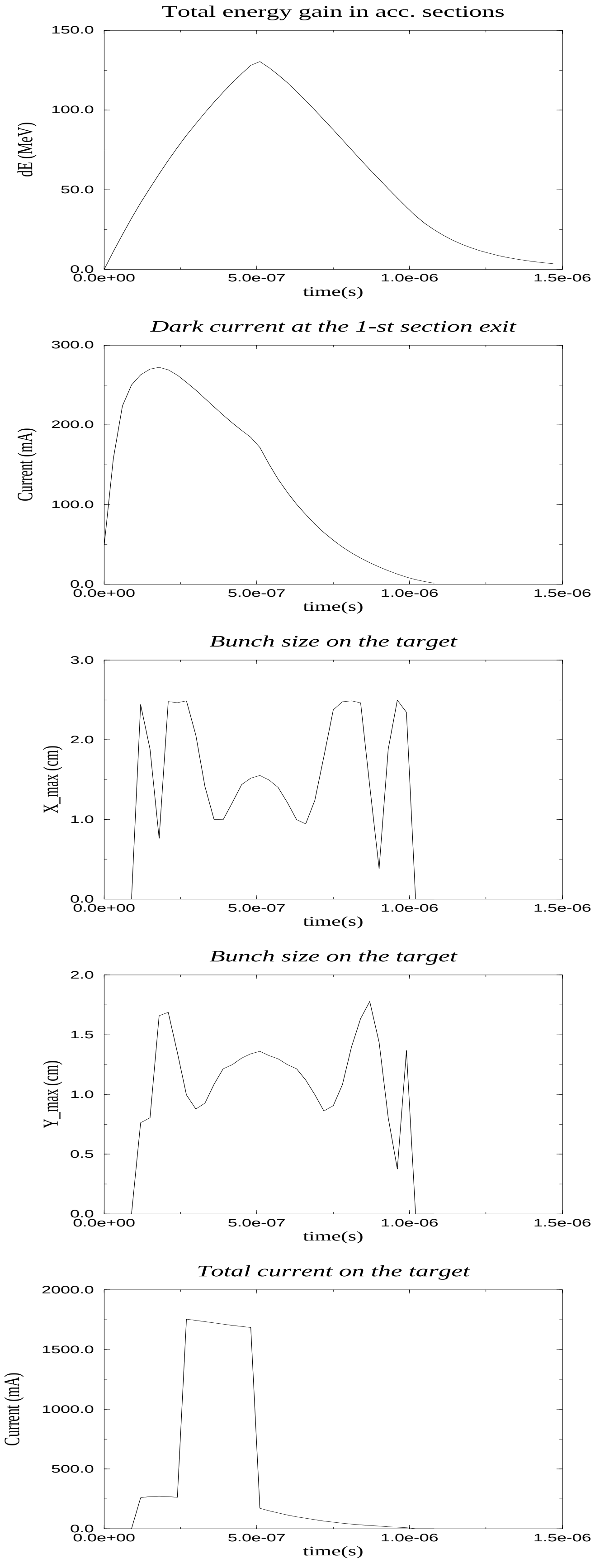

Fig. 4 Beam parameters vs. time

beam loading). The peak value of the dark current at the end of the second section vs. time is shown in Fig. 4b (0.5 T solenoidal magnetic field is applied along the first section so the low energy electrons (below 100 MeV) could be successfully delivered to the end of the first section).

The peak value of the dark current for the operation cycle is about 270 mA. The electron bunch RMS changes vs. time are shown in Fig. 4cd. The first electrons reach the target 100 ns after the RF-power front edge pulse. The size of the electron beam on the target varies in time from normal to double (normal beam diameter is 2 cm.). The total electron current on the target is shown in Fig. 4e. The dark current results in the additional current pedestal with duration of up to 0.6 μs. and magnitude of about 20 % of the normal.

The instant neutron yield dependence could be obtained from the equation $dI/dt \sim I + I_{ext}(t)$ (the constants are neglected), where I is the instant neutron yield, $I_{ext}(t)$ - external neutron flux. The resulting neutron yield is shown in Fig. 5. The total neutron pulse duration also increases up to 0.6 μs with the pre-pulse magnitude of about 20% of the normal pulse one.

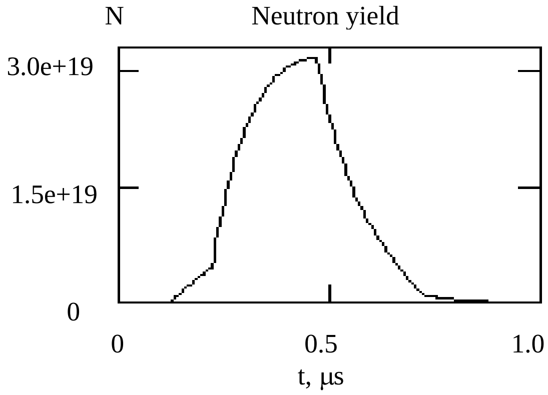

Fig. 5 Neutron yield vs. time

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References

1. A. V. Novokhatski et. al. Linear Accelerator for Intense Resonance Neutron Source (IREN), Proceedings of the 2nd Workshop on JINR Tau-Charm Factory, Dubna, 1994, p. 197.
2. J. W. Wang RF properties of periodic accelerating structures for linear colliders. SLAC-report-339, 1989.
3. H. Matsumoto et al. ATF S-band Linac Regular Accelerator Unit, KEK, JLC, Linear Collider Study Group, Proc. of NLC Workshop, SLAC, Sept 23, 1994, p.13.
4. A. K. Krasnykh et. al. Wake field influence on the transverse particles dynamics in the IREN linac. The IV Charged Particles Accelerator Conference, Protvino 1994, p. 284.
5. M. S. Avilov et. al. Preinjector for electron-positron factories.
IV Linac Conference, Protvino, 1994, p.23.