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Study of crystal extraction of a circulating beam from the U-70 at the injection energy

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A B S T R A C T

Phenomenon of the deflection of charged particle beam due to channeling in a bent crystal is good investigated and successfully applied for extraction of the beam in high-energy accelerators, at the energies of about 10 GeV and higher. However, a significant practical interest presents the problem of deflection and extraction of charged particles with energies below 1 GeV, for example, production of ultrastable beams of low emittance for medical and biological applications. That's why two novel crystal techniques, namely: thin sequential straight crystal targets, and array of short bent crystal strips were investigated in this report as elements for extraction of the beam from U-70 accelerator. Experimental results were obtained for extraction of 1.3 GeV protons.

1. Introduction

Phenomenon of the deflection of charged particle beam in a bent crystal is well investigated and successfully applied for beam extraction in high-energy accelerators at energies of about 10 GeV and higher (see, e.g., [1–3]). However, the problem of deflection and extraction of charged particles with energies below 1 GeV presents a significant practical interest, e.g. for example for the production of ultra stable beams of low emittance for medical and biological applications. There is a big experimental problem in steering such energy beams, which is connected with the small size of the bent crystal samples. The efficiency of particles deflection is determined by the ratio of the critical channeling angle θ_c to the beam divergence φ and drops exponentially with the crystal length L: $\mathrm{Eff} \sim (\theta_c/\varphi) \times \exp(-L/L_d)$, where the characteristic parameter L_d, is known as dechanneling length, and it is relatively small for low energy. For example, at E = 500 MeV we have $\theta_c = 0.24$ mrad and $L_d = 0.4$ mm. In the case of usual channeling in bent crystals (about 1 mm in length) only 10% efficiency was achieved for the deflection of sub – GeV energy particles in beam line [4]. There are still more problems at extraction of a circulating beam from the ring accelerator because the significant sizes of a crystal cross-section exceeding its length are required.

Thus the bend angle of a crystal should be more than 1 mrad so that the deflected beam would be separated from circulating one. Potentially suitable tools in this case can be the bent quasimosaic crystals such as in [5] or thin straight crystals [6–9], but in the both these cases it is necessary to increase the deflection angle of particles once and again in few times. For low energy we propose the novel crystal technique, which can effectively work in the wide energy range and is especially perspective for low energy below 1 GeV.

The first option is based on use of an array of shot bent channeling crystals (Fig. 1) with one millimeter length (special thin silicon wafers about 200 μ thickness were used for the production of such samples). Thus the bend of array occurs also, as a bend of the single well investigated silicon strip [10].

The second option is based on the reflection of the particles in thin straight crystal plates with thickness, which is equal to an odd number of half-lengths of channeling oscillation waves $L = \lambda(2n+1)/2$ where $\lambda = \pi d/\theta_c$, $d = 2.3\ A^0$ is the interplanar distance in silicon. It means, for example, that the optimum length of a crystal should be 10 microns for particles with energy of 50 GeV. The reflection angle in one silicon plate should be equal to twice the critical angle $\theta_c = (2U_o/pv)^{1/2}$, where: $U_o \sim 22$ eV – is the value of the potential of planar channel in silicon; p, v are the momentum and speed of incident particle. For the enhancement of the deflection angle, the few aligned plates placed like a fan (see Fig. 2).

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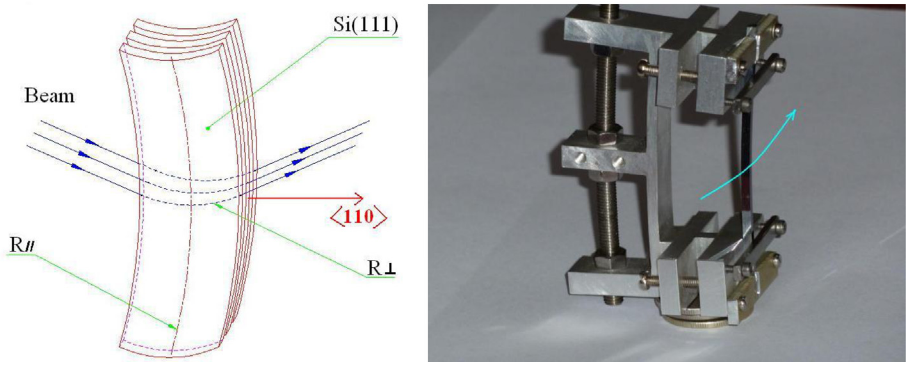

Fig. 1. The crystal device number one. a – Scheme, b – photo.

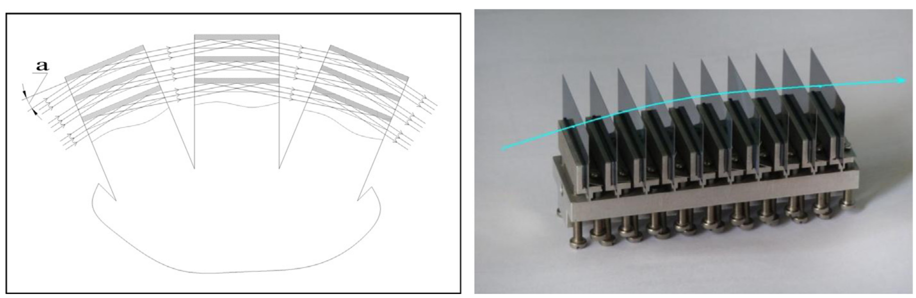

Fig. 2. The crystal device number two. a – Scheme, b – photo.

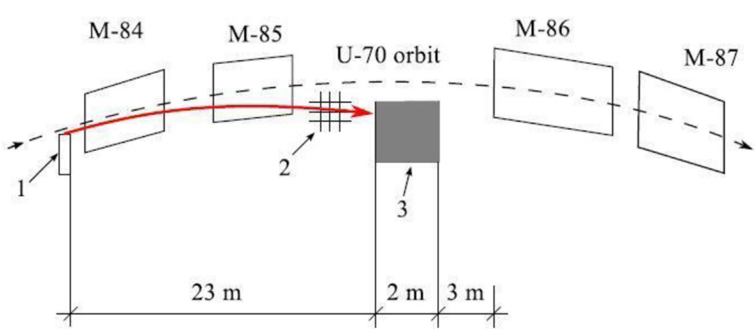

Fig. 3. The scheme of experiment on beam extraction by crystals: 1 — goniometer with a crystal, 2 — multiwire detector, 3 — absorber, M — magnetic blocks of the accelerator.

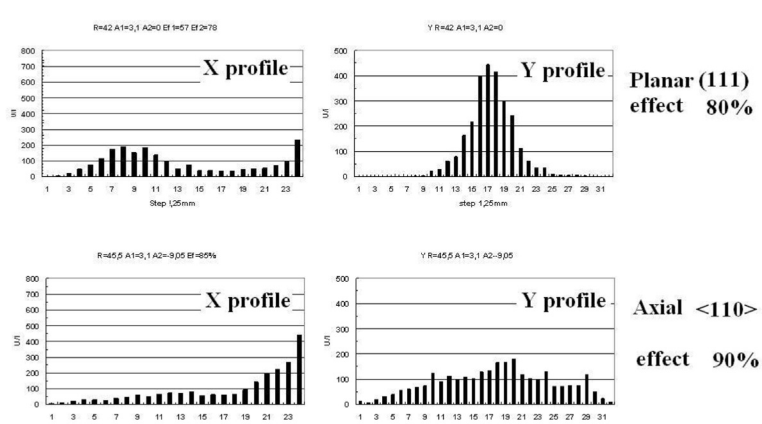

Fig. 4. Beam profiles at 50 GeV energy.