# *EFFECT OF THE COUPLING SLOTS ON BEAM DYNAMICS IN ACCELERATOR STRUCTURE OF MOSCOW CW RTM*

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We detected strong coupling slots effect on the transverse beam dynamics for on-axis coupled accelerator structure. This effect is explained by the transverse magnetic field exited on the axis of coupling cells and providing intercell coupling. We suggested method to compensate coupling slots effect with the external magnetic field. Transition radiation was used to get beam size and position in the course of experiments presented below.

## I. INTRODUCTION

Effect of coupling slots on the transverse beam dynamics for on-axis coupled accelerator structure was first detected in [1] and investigated in details in [2-4]. The main manifestation of this effect is quadrupole beam focusing in one plane and defocusing in the other, which was explained by quadrupole field asymmetry in accelerating cells introduced by coupling slots. To compensate this effect coupling slots in accelerating cells should be aligned with the pair of slots at one accelerating cell web exactly against the pair at the other web.

One of the Moscow CW RTM accelerator structure peculiarity is that only one coupling slot is placed at each cells web [5]. So instead of quadrupole effect one should wait phase dependent dipole effect leading to the beam position shift during its acceleration.

## II. EXPERIMENTAL SET-UP

Experiments were conducted with the accelerator sections of Moscow CW RTM injector described elsewhere [6]. Injector consists of the graded-$\beta$ capture section and five $\beta$ = 1 sections, each powered by its own klystron exited by the reference signal. Every section provides about 1.1-1.2 MeV maximum energy gain, so 6.7 MeV beam can be obtained at the injector output with the bunch phase length about 5$^{o}$, energy spread 0.3% and normalised transverse emittance 5mm$\times$mrad. Intercells coupling slots were positioned in vertical plane, in the lower web part at accelerating cell entrance and upper at exit.

To investigate coupling slots effect we measured dependence of the beam size and position on the last accelerator section phase at the 1 m distance from the injector output. Experimental set-up is shown in Fig. 1.

Accelerating field phase with respect to the reference signal were changed by phaseshifter $\Phi$ and measured by phasemeter $\Phi$M. Beam energy can be measured with the analysing magnet M.

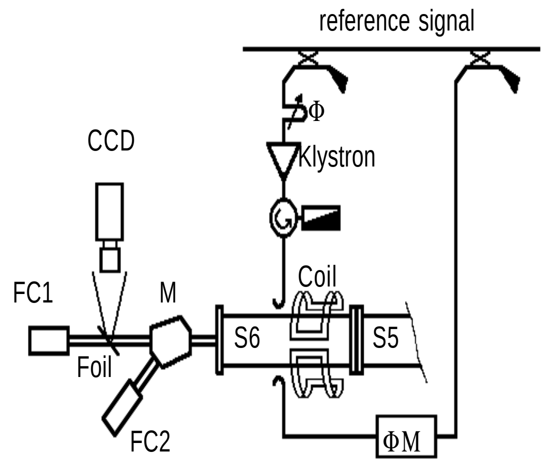


Figure 1. Schematic view (from the top) of the experimental set-up. Shown are: accelerator sections S5, S6, analysing magnet M, phaseshifter $\Phi$, phasemeter $\Phi$M, Faraday's caps, FC1, FC2, CCD TV camera, reference signal line, klystron, correcting coils.

For exact measurements of the beam centre gravity position and current distribution we used transition radiation [7-8] from 9 mkm Al foil placed at 45$^{o}$ to the beam axis. Signal from CCD camera with magnification 14:1 at 51cm TV screen was analysed with digital TV system and stored in computer memory. An example of beam current distribution obtained by this method for 6.7 MeV, 40 mkA beam is shown in Fig. 2.

To compensate slots effect correcting coils shown in Fig. 1 with the effective length about 0.35m were placed at external part of section. Coils produced magnetic field on section axis in horizontal plane with the induction about 3 Gauss per 1 A of current.

## III. RESULTS AND INTERPRETATION.

We have measured dependence on the accelerator section phase of (a) beam energy, (b) beam centre gravity position, and (c) value of correcting coils current returning beam to the reference position which is the beam position with the last section field switched off (beam energy 5.5 MeV). Results of this measurements are shown in Fig. 3. Accelerating field phase was arbitrary taken to be zero at maximum acceleration.

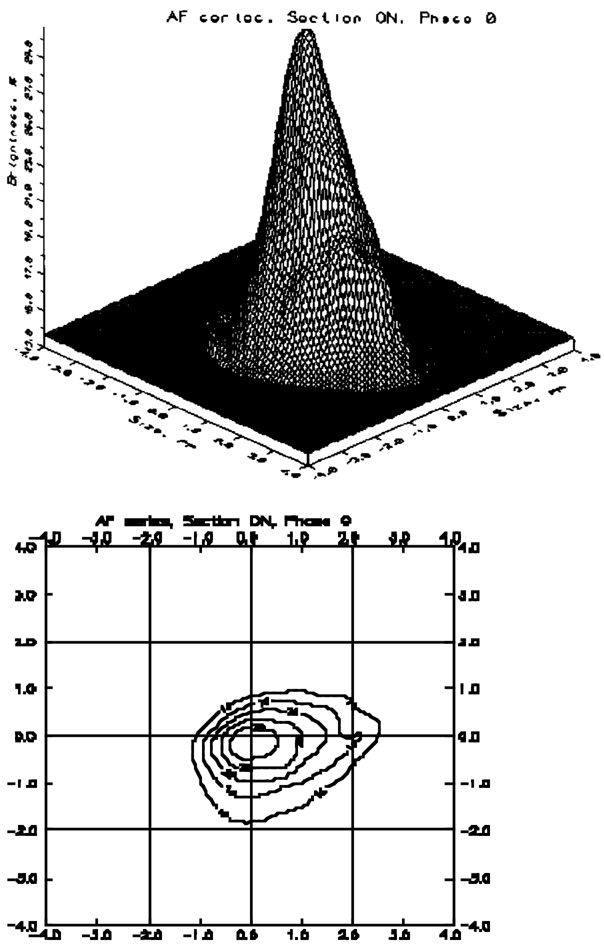

Figure 2. Current distribution in the beam (3D view and contours plot) measured by means of transition radiation.

One can see that in the accelerating phase (6.7 MeV energy) beam is shifted for about 4.5mm upwards with respect to the reference position, and in the decelerating phase (4.3 MeV energy) downward for about 7.2mm. In horizontal plane beam position was practically unchanged. Beam form changed slightly, reflecting mainly dependence of section focusing properties and beam energy on the phase. By applying current +0.8 A and -0.9 A to the correcting coils, respectively for accelerating and decelerating phases, beam can be shifted to the reference position.

To explain obtained results different possible reasons of the beam shift were considered and first of all accelerating cells field asymmetry due to the coupling slots. Electromagnetic field distribution inside the accelerating cell was calculated with the MAFIA code [9]. Calculations were made with one full accelerating cell and two coupling half cells at the ends with magnetic walls boundary conditions. In this case we neglect possible influence of the coupling cells magnetic field on beam dynamics. Radial electric and azimuthal magnetic field asymmetry of the order of $10^{-3}$ were investigated, and beam dynamics with RTMTRACE code [10] were calculated. Calculations showed depending on phase beam shift but with opposite sign as compared with experimental one, and about 5 times less in magnitude.

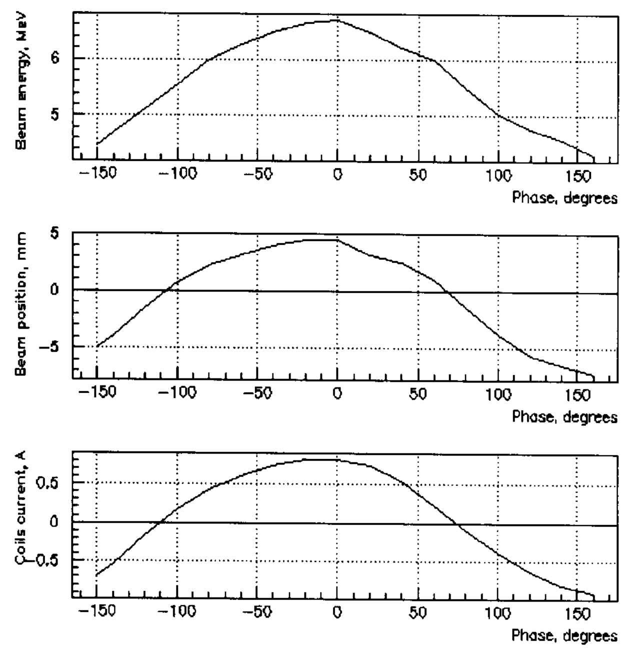


Figure 3. Dependence on the section 6 phase of beam energy (upper), beam position (middle), and correcting coils current (lower).

Influence of external parasitic magnetic fields and accelerator section misalignments on the transverse beam dynamics were analysed - this influence was found to be order of magnitude less than investigated effect.

After that we made new set of MAFIA calculations, but with one full coupling cell and two accelerating half cells at the ends with electric type boundary conditions. Results of this calculations appeared to be extremely interesting. Though in simplified models of biperiodic standing wave accelerator structure, such as lumped circuit model, coupling cells stay unexcited for $\pi/2$ mode in tuned structure (neglecting the power flow owing to finite quality factor), MAFIA calculations showed strong transverse magnetic field on the axis of coupling cells. Magnetic field distribution in the central plane of coupling cell is shown in Fig. 4.

Magnetic flux is propagating from one accelerating cell to the other through coupling slots creating near the coupling cells axis field parttern resembling TM11 mode field distribution. Electric field components, both longitudinal and transverse are close to zero near the axis. Presence of the strong field in the coupling cells correlating in spatial distribution with position of coupling slots was investigated in [3].

Calculated by MAFIA code integrals show that vertical transverse momentum obtained by the relativistic particle in coupling cell is about $6x10^{-3}$ of the longitudinal momentum obtained in the accelerating cell - value corresponding to experimental one. Taking into account, that magnetic field reaches its maximum when particle in accelerating phase passes the centre of coupling cell and that the sign of transverse momentum obtained by the electrons corresponds to that obtained in experiment we can conclude that investigated beam shift is practically totally explained by influence of this field.

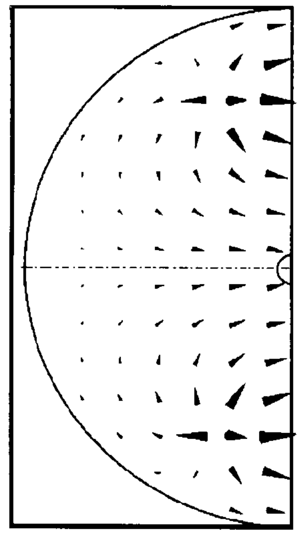

Figure 4. Magnetic field distribution in the centre of coupling cell for biperiodic on-axis coupled accelerator structure with one coupling slot per web.

## VI. CONCLUSION.

We investigated strong phase dependent beam shift for on-axis coupled accelerator structure with one coupling slot per web which can not be explained by the accelerating cells field asymmetry nor for the value of beam shift not for its sign. Calculations made with MAFIA code showed existence of the strong field in the coupling cells providing intercell coupling with transverse component of the magnetic field on the cells axis. Taking into account this field we explained our experimental data. For the accelerator structure with two coupling slots per web additional effect of coupling cells field also should be taken into account.

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