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Stacking of a Bunched Proton Beam in DORIS

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by

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The bunched beam ejected from the synchrotron is transferred to DORIS where it is captured into the buckets of the 500 MHz-high power electron position rf-system.

The captured bunches are compressed adiabatically raising the rf power according to the maximum available power[1].

Since a bunched beam is injected into the 500 MHz-rf buckets the accumulation is done by stacking in the horizontal betatron phase space , using the equipment for electron positron injection. The procedure runs as follows:
The protons ejected from the synchrotron are injected into DORIS with help of a matched D.C. beam bump (DC) and a pulsed kicker (PK) which shifts the aperture so that it covers the septum area (fig.1).

When the first pulse is captured the maximum D.C. beam bump is provided. The additional kicker pulse then allows to place the injected pulse into the center of the aperture. When the second pulse is injected the DC beam bump is reduced. The additional kicker pulse then allows to place the injected beam on a trajectory around the first pulse.

During the cycle time of the synchrotron which is about 5 sec the second injected pulse smears out over the trajectory due to nonlinearities.

When the third pulse is injected after the DC beam bumps is further reduced only a fraction of the second pulse is scraped off while a new pulse is stacked. If Δ denotes the intensity of the injected pulse and S_k the intensity in the trajectory ring after k pulses and $\frac{1}{n}$ the fraction which is scraped off during an injection cycle we have

$$S_k = S_{k-1} \left(1 - \frac{1}{n}\right) + \Delta \qquad (1)$$

Since $S_1 = \Delta$ we find

$$S_k = n\,\Delta\left(1-\left(1 - \frac{1}{n}\right)^k\right) \qquad (2)$$

After n cycles the injection efficiency into an trajectory ring becomes unefficient since the particle loss reaches the intensity of the injected pulse. The stacked intensity after n cycles in the trajectory ring becomes

$$S_n = n\Delta\ (1-(1-\frac{1}{n})^n) \sim n\Delta\ (1-1/e)$$

Since the total injected intensity is $n \cdot \Delta$ the total injection efficiency according to the described procedure is

$$\eta = \frac{S_n}{n\Delta} \approx (1 - 1/e)$$

When a trajectory ring has been filled after n cycles the DC beam bump is further reduced for filling the next trajectory ring.

The calculations of bunch compression due to an adiabatic increase of the rf-voltage is based on the following adiabatic invariant[2]

$$I = \hat{U}^{1/2}\ F(\lambda/2)$$

$\hat{U}$ = rf peak voltage

λ = bunch length in radius

The function $F(\lambda/2)$ is plotted in fig.2. So for $\lambda > 2$ the function is proportional to λ while $\lambda <$ the function behaves as λ^2.

References:

(1) H. Gerke, R.D. Kohaupt, DESY H-73/5 1973

(2) A.H. Kolomensky, A.N. Lebedev, Theory of CYCLIC accelerators
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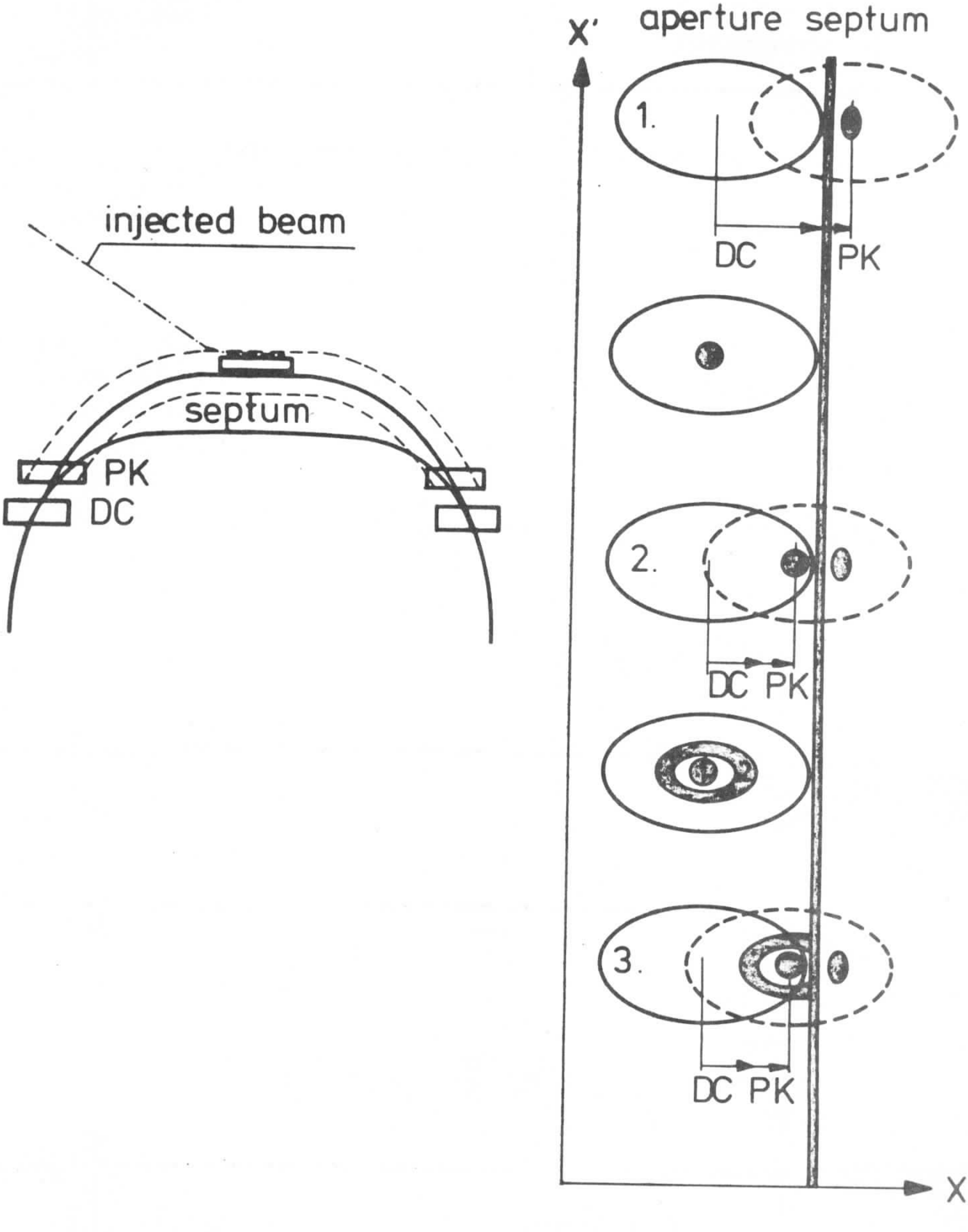
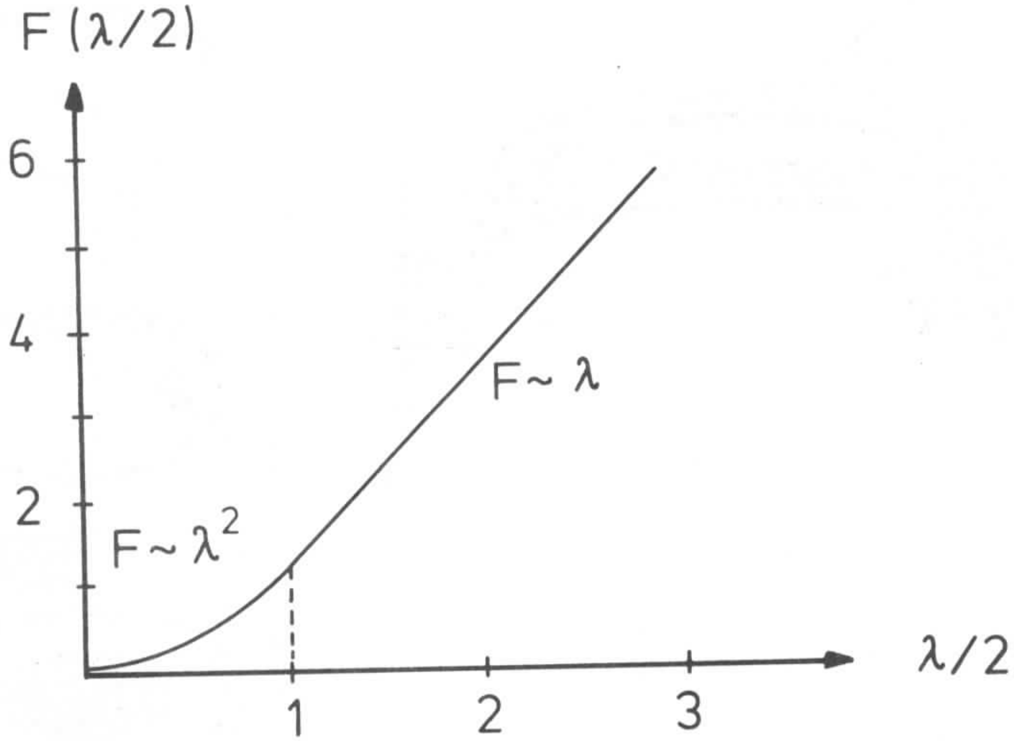

injected beam
septum
PK
DC
X'
aperture septum
1.
DC
PK
2.
DC PK
3.
DC PK
X

fig. 1

$$\text{Invariant}: I = \hat{U}^{1/2} \cdot F(\lambda/2)$$

λ bunch length in radians



$$\lambda \sim 1/\sqrt{\hat{U}} \quad \text{for} \quad \lambda > 2$$

$$\lambda \sim 1/\sqrt[4]{\hat{U}} \quad \text{for} \quad \lambda < 2$$

$$\lambda \sim \left(\frac{\hat{U}}{|\eta|}\right)^{-1/4} \gamma^{-1/4}$$

fig. 2