Status of the Barrier-Bucket system for the ESR

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Introduction

In combination with beam cooling, Barrier-Bucket operation allows an intensity increase of particle beams by concentrating particles in one bucket, while creating an empty bucket for the next injection ("longitudinal stacking"). This can be achieved by generation of two RF voltage single-sine waves as barrier pulses, of which one is shifted in time to compress the beam (Fig. 1).

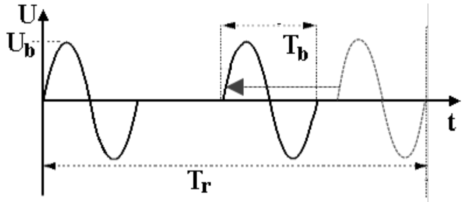

Fig. 1: barrier pulses of duration T_b and amplitude U_b are shifted to compress the beam revolving with period T_r

The generation of Barrier-Buckets in the ESR has been successfully demonstrated with existing ferrite cavities [1], but beam-dynamics requirements regarding barrier-voltage and –frequency made the design of a new cavity based on magnetic alloy (MA) ring cores necessary.

Design of the cavity

Since the power amplifier for the cavity is a solid-state device with 50 Ω output, the cavity as its load should have a similar impedance to enable matching. Impedance measurements of a ring core (FT-3M, 290x660x25 mm³) were used to find a frequency-dependent ring core model in PSpice. A design including four ring cores with four coupling loops connected in parallel (Fig. 2) and parasitic capacitances was then evaluated in PSpice and later compared to measurements from a prototype cavity [2].

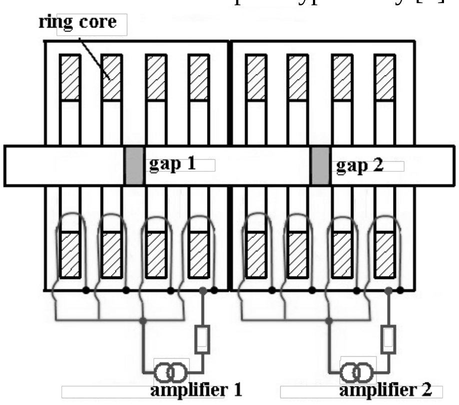

Fig. 2: at each gap, one barrier pulse is generated

Pre-distortion of signals

In order to enable a precise termination of the single sine wave, pre-distortion of the signal is necessary. For linear, time-invariant systems this can be achieved by Fourier-analysis of the system under consideration.

Periodic signals can be expressed as a Fourier series:

$$U(t) = \sum_{n=-\infty}^{\infty} \underline{c}_n e^{in\omega_r t} \quad (1)$$

The desired single-sine signal has Fourier coefficients:

$$\underline{c}_n = \frac{1}{2iT_r}\left(\int_{-\frac{T_b}{2}}^{\frac{T_b}{2}} e^{i\omega_b t} e^{-in\omega_r t} dt - \int_{-\frac{T_b}{2}}^{\frac{T_b}{2}} e^{-i\omega_b t} e^{-in\omega_r t} dt \right) \quad (2)$$

When the transfer function $\underline{H}$ of the system under consideration is measured, its inverse $\underline{H}^{-1}$ can be calculated and the Fourier coefficients of the pre-distorted signal are:

$$\tilde{\underline{c}}_n = \underline{H}^{-1} \underline{c}_n \quad (3)$$

Transformation to time-domain delivers the pre-distorted signal $\tilde{U}(t)$, which is applied to the system´s input in order to produce the single-sine signal at the gap.

Experimental results

The procedure described above has been applied to a prototype system consisting of two ring cores (VitroVAC, 355x700x30 mm³), one amplifier AR 1000A225 and a 1:800 gap voltage divider. It yields a barrier amplitude of U_b=454 V with about 1% ringing after the pulse. The high signal quality measured at the prototype (Fig. 3) is a proof of principle for the planned system.

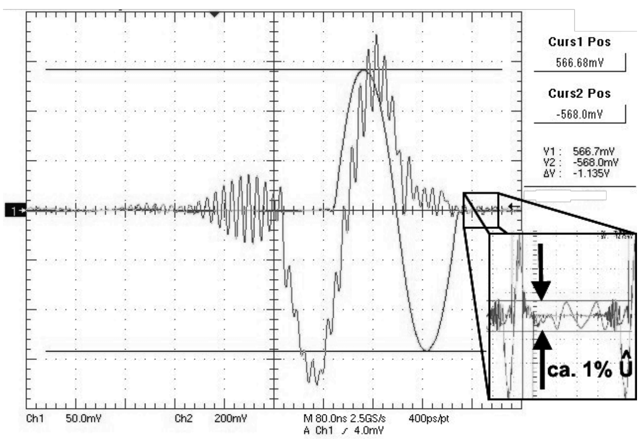

Fig. 3: pre-distorted input (jagged) and gap signal (smooth)

References

1. **Schreiber, G.** *Barrier-Buckets am Experimentierspeicherring der Gesellschaft für Schwerionenforschung.* 2006. Dissertation.

2. **J. Harzheim, D. Domont-Yankulova, H. Klingbeil, R. Königstein.** *Modeling of broadband cavities with P-Spice.* GSI scientific report 2015 (this publication).

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