COSY AS IDEAL TEST FACILITY FOR HESR RF AND STOCHASTIC COOLING HARDWARE

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Abstract

The COoler SYnchrotron COSY at the Forschungszentrum Jülich is operating now since 1992. Up to $5*10^{10}$ protons can be delivered over a momentum range of 300 MeV/c to 3.7 GeV/c. The prototype of the HESR barrier bucket cavity was installed into COSY and many measurements have been performed. Especially the co-operation of barrier bucket with stochastic cooling has been studied. During the measurements the internal WASA Pellet target was available which is similar to the PANDA target at the HESR. A 1.2 m long cryo-tank was designed and installed to measure the sensitivities of new pickup structures for the HESR stochastic cooling system. Tank design and structures arrangement correspond to the projected HESR stochastic cooling layout. The recent results will be presented.

INTRODUCTION

The cooler synchrotron COSY [1] accelerates and stores unpolarized and polarized protons and deuterons in the momentum range between 300 MeV/c to 3.7 GeV/c. To provide high quality beams, an Electron Cooler at injection and a Stochastic Cooling System from 1.5 GeV/c up to maximum momentum are available.

Table 1: COSY-HESR Parameters

	COSY	HESR
Particles	$p, d, \vec{p}, \vec{d}$	$\bar{p}$, p
Number of particles	$5*10^{10}$	$1*10^{10}$–$1*10^{11}$
Momentum range /GeV/c	0.3 – 3.7	1.5 – 15
Particle velocity	0.3 – 0.97	0.84 – 0.998
Rev. frequency / MHz	0.48 – 1.58	0.44 – 0.52

Velocity range, revolution frequency range and available particle numbers favourite COSY as ideal test facility for the HESR. A lot of experiments have been done and will be done to test equipments for the HESR [2] under realistic conditions at COSY.

STOCHASTIC COOLING HESR

Numerical and analytical simulations of the stochastic cooling process in the HESR have shown that experiment requirements can be reached by using a 2-6 GHz cooling system [3]. Two different cooling structures for a 2-4 GHz system have been analysed to build a stochastic cooling system without movable electrode bars [4]. The first structures consist of λ/4 electrodes (wavelength $\lambda_{co} = 0.1$ m) with printed loops (Fig.1 a)). The compact layout allows an arrangement of eight electrode-boards to catch most of the image current without any movement of the electrodes. On the other side the printed-loop arrangement with the 20 mm wide electrode has the disadvantage that an important part of the image current misses the loops passing over the ground plane.

The second structures are the slot ring couplers [5]. First investigation was done using a slit geometry as foreseen for the stochastic cooling system of the CR ring [6] and led to an classical linac cell design where each iris is heavily loaded by eight 50 Ohm connections (Fig. 1 b).

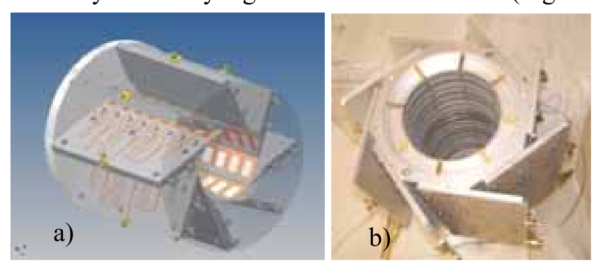

Figure 1: Lambda/4 structures in an octagonal arrangement (a) and stack of slot ring couplers with 16 rings (b).

A test-tank was built at the central workshop of the FZJ. The design of this tank includes already many details for the final cooling-tank layout like the two cold-heads to cool down the structure to a desired value of about 20 K and the x-y support to centre the structures according to the beam.

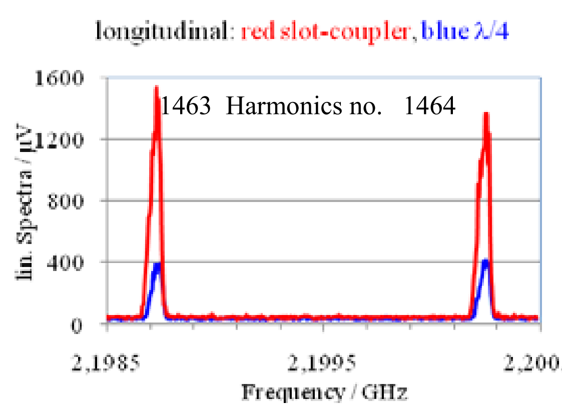

Figure 2: Harmonic number 1463 and 1464 of a 2.2 GeV/c proton beam measured with new slot couplers and new λ/4 structures.

A momentum of 2.2 GeV/c has been chosen for the first tests, which is close at γ_{tr} ($\eta = -0.03$). Thus, even at a low sensitivity and low beta-functions at the test-tank position, the signal strengths of the betatron sidebands exceed always the noise level. Fig. 2 shows the measured harmonic number 1463 and 1464 of $2*10^{10}$ protons.

Although both structures have the same length in beam direction the slot couplers show significant higher coupling impedances than the λ/4 structures. This is expected from the simulations [5].

To detect the transverse sensitivities of the structures the three upper and three lower electrode rows of the λ/4 structures have been combined before a 180°-hybrid generates the vertical transverse response. In the case of the slot-ring couplers two electrode rows were combined, thus the same structure can be used to detect all three cooling planes. Even for the transverse mode the slot couplers show a significant higher sensitivity (fig. 4). Besides the betatron sidebands strong longitudinal signal parts were found in the transverse mode. These signals are visible when the beam is not centred according to the focus of the structure.

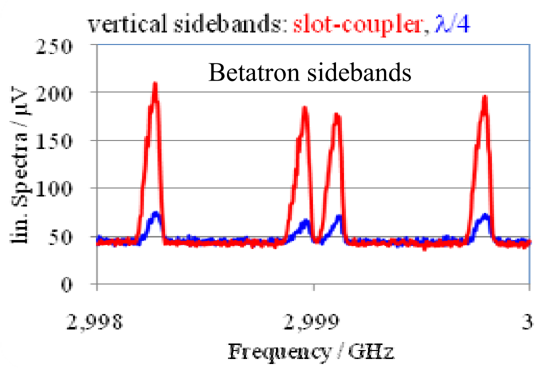

Figure 3: Comparison of transverse sensitivities between new slot ring couplers and new λ/4 structures.

The existing cooling system at COSY operates in the frequency range of 1-3 GHz divided into two bands.

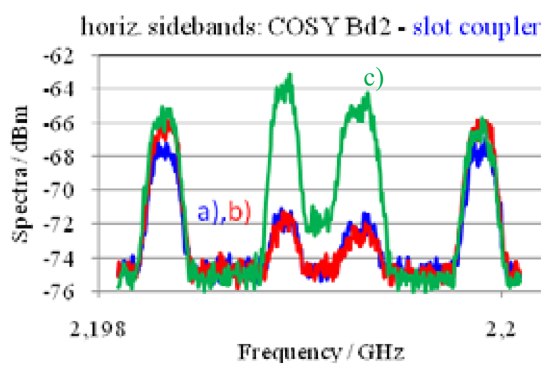

Figure 4: Horizontal betatron sidebands measured with a) new slot couplers (blue), b) COSY lambda/4 structures with aperture 90 mm, c) with aperture 40 mm

The band 2 system was used to compare standard λ/4 structures (wavelength λ_{co} = 0.125m) with the new slot-ring couplers. The system was adjusted to the same aperture of 90 mm. The horizontal beta-functions at the new momentum of 3.2 GeV/c were comparable (Horizontal COSY pickup: 10.6 m, HESR test-tank: 9.5 m). The signal strengths of the horizontal sidebands are nearly the same, but the structure lengths of both pickups are different. The COSY pickup structures have an active length of 1m combining 32 λ/4 electrodes while the length of slot couplers is only 0.2 m. Thus the sensitivity of the slot couplers is approximately a factor of 5 higher. The great advantage of the old λ/4 structures is the possibility to move towards the beam after the acceleration and adiabatically shrinking of the beam size. This is shown in Fig.4 c). The signal level of the betatron sidebands is increased by a factor of 6 when the aperture is reduced to 40 mm. The sensitivity of the slot couplers is not only a factor of 5 higher (at equal structure lengths); another factor 2 is obtained because the same structure can be used for both transverse directions simultaneously. Equal or even better results are expected, although no plunging system is needed. Thus the new slot ring couplers are the first choice of the HESR stochastic cooling system.

The longitudinal parts in the transverse mode were significantly reduced by moving the whole structure with the x-y-support of the test-tank. Fig. 5 shows the transverse mode of the vertical direction at different positions. The longitudinal part is minimized when the structure is positioned according to the nearby located BPM reading of 4 mm.

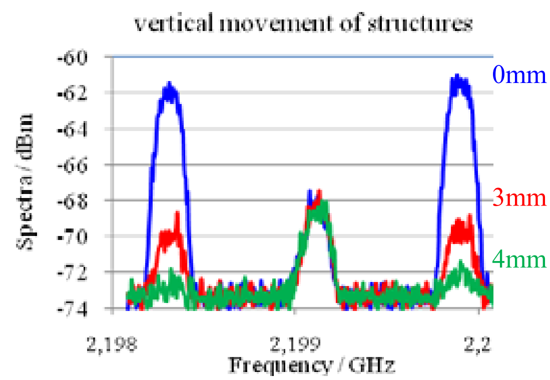

Figure 5: Minimizing longitudinal parts in transverse mode by moving the structures.

One uncertainty was the coupling behavior between the horizontal and the vertical direction within the rings.

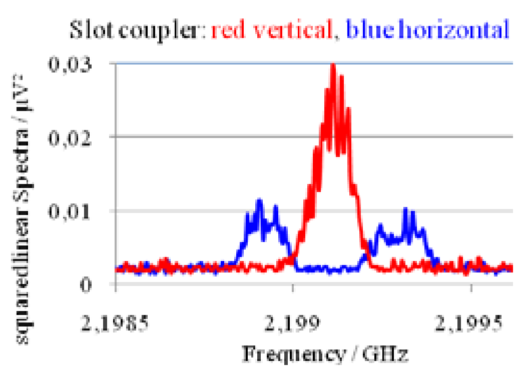

Figure 6: Vertical and horizontal sidebands measured with the same slot ring structure: no coupling was found.

The different tune settings for the vertical (close to 3.5

thus band-overlap occurs) and horizontal plane allowed an easy measurement. Even at higher beta-function in one direction (20 m in the vertical direction had been reached) no coupling was found.

BARRIER BUCKET AND STOCHASTIC COOLING

The high density of the PANDA pellet-target in the HESR leads to a high energy loss of the antiprotons. The stochastic cooling itself is not strong enough to compensate the mean energy loss. A broadband barrier bucket cavity will be used in the HESR to improve the antiproton lifetime by building a 10%-20% time gap. The first prototype of this cavity was built and installed in the COSY ring.

Figure 7: The barrier bucket cavity with its asymmetric layout is installed in one arc of COSY. In this figure, the shielding of the gap is dismounted to make it visible.

An arbitrary waveform generator (AWG) was used to generate a barrier bucket signal, which was applied to a solid-state amplifier driving directly the barrier bucket cavity. After measuring the corresponding gap-voltage the Fourier series of the transfer-function were calculated and a pre-distorted barrier bucket signal was determined, which gives the desired sinusoidal gap-voltage. This method was successfully tested at injection energy at COSY, where the revolution frequency corresponds to the operation frequency of the HESR. The BB cavity is now routinely in operation for many experiments even at higher momentum, although it is not optimized for the three times higher frequencies.

The interaction of barrier bucket, stochastic cooling and pellet-target was measured during a WASA beam-time. The momentum distribution is presented by the Schottky spectra measured at the 1000^{th} harmonic. Fig. 8a shows the distribution at beginning of the 160 sec cycle and fig. 8b the final distribution without stochastic cooling and barrier bucket. The energy loss and longitudinal heating by the target is clearly visible. The target thickness was estimated by the frequency shift and amounts to about $N_T \approx 3.6*10^{15}$ atoms/cm², which corresponds to the expected HESR PANDA target. Even with the relatively low numbers of particles $N = 8*10^8$ the stochastic cooling (band 2: 1.8-3 GHz) alone is not able to compensate for the whole energy loss by the target (curve c)). The momentum spread is significantly reduced by the stochastic cooling, when the mean energy loss is compensated by the barrier bucket system (Fig. 8d). Nevertheless some particles were lost due to the barrier height of +-175 V limited by the available RF-power.

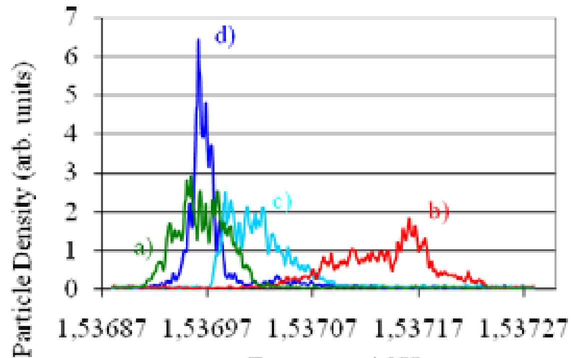

Figure 8: Schottky spectra of COSY beam measured at the 1000th harmonic: a) starting distribution, b) final distribution after 160sec only pellet-target, c) final distribution with longitudinal stochastic cooling and d) final distribution with cooling and barrier bucket.

Besides these activities many additional HESR-relevant tests have been made, like a new rest-gas monitor [8] in collaboration with GSI and beam-lifetime optimization for the PAX experiment [9]. The new projected 2 MeV electron cooler at COSY will allow testing new features for the HESR high energy electron cooler [10].

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