RECENT DEVELOPMENTS FOR THE HESR STOCHASTIC COOLING SYSTEM

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Abstract

Two cooling systems will be installed in the High-Energy Storage Ring (HESR) of the future international Facility for Antiproton and Ion Research (FAIR) [1] at the GSI in Darmstadt: an electron cooler (1.5-8 GeV/c) and a stochastic cooling system from 3.8 GeV/c up to the highest momentum of the HESR (15 GeV/c). Both coolers are mandatory for the operation of the HESR with the PANDA pellet target. The relative low aperture (89mm) of the HESR suggests fixed structures without a plunging system. An octagonal layout was chosen to increase the sensitivity of the electrodes. Two different types of electrodes were built and tested. We will report on the comparison of printed lambda/4 loops and new broadband slot couplers.

HESR STOCHASTIC COOLING

The modified (2-4GHz) AC CERN [2] loop pairs with a distance of 20mm [3] are basis for the simulations of the HESR stochastic cooling system. For practical reasons and costs reduction aspects we prefer fixed pickup loops without plunging system. One loop pair with a distance of the HESR aperture will give a poor response. The loss of particle image current is not tolerable. The coupling impedance can be increased by combining several rows of electrodes arranged in an octagonal array.

Printed loop Coupler

Printed loops [5] are a cost saving alternative to the mechanical complex structures like the CERN AC structures [2] or the COSY pickups [4]. The first design of the HESR stochastic cooling pickups uses 50-Ohm printed loop couplers containing rectangular electrodes with rounded corners. Each loop ends at a 50-Ohm SMD resistor. These loops are combined via several impedance transforming networks and are located at the combiner side, whereas the coupling is done through the dielectric material of low permittivity (ε_r=3.27). Only simple through-holes are needed to connect the terminating resistors at the electrodes. Loops and combining network are located on the same board. This simplified the whole structure and minimized the fabrication costs. New structures can be easily exchanged. The relatively high bandwidth of 2-4 GHz requires at least two-stage transforming networks. Compared to Wilkinson couplers these combiners are a little bit more space consuming but have lower losses. The printed loop boards have been constructed as a part of a universal modular octagonal structure (fig. 1). Different modes of signal combinations outside the vacuum envelopes will allow to pick up different transversal beam positions as a part e.g. of a core or a halo cooling system.

We compared the transversal sensitivity of the new printed loops to that of the COSY-loop structure of 1.8 to 3 GHz [6] simulating the beam by an air microstrip line.

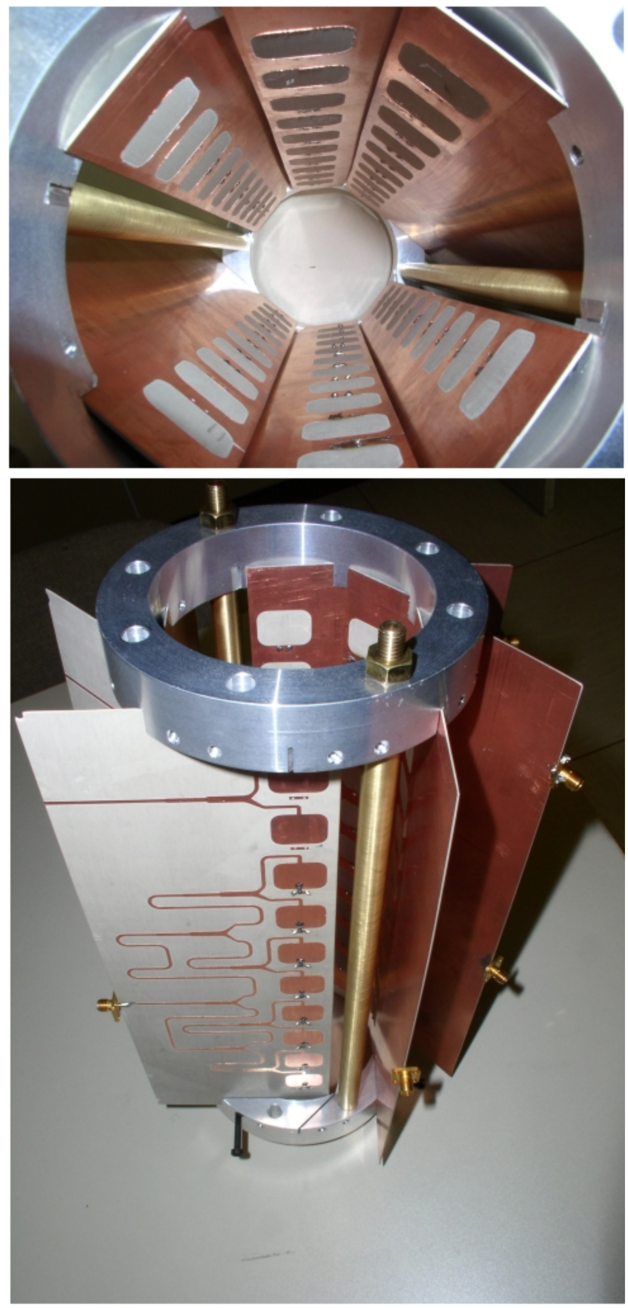

Figure 1: Octagonal pickup structure, equipped with 6 λ/4-electrode rows.

The width of the COSY loops, which were adapted from the CERN AC structures, is the same as in the first layout of the printed loops. Even the number of combined loops are the same, thus a direct comparison is possible. The results of the measurements are presented in fig. 2. The printed loops show the same transversal sensitivity as the COSY-loops and can be used even at frequencies below 2GHz. Thus, a 1-2GHz precooling system seems possible with the same coupler loops.

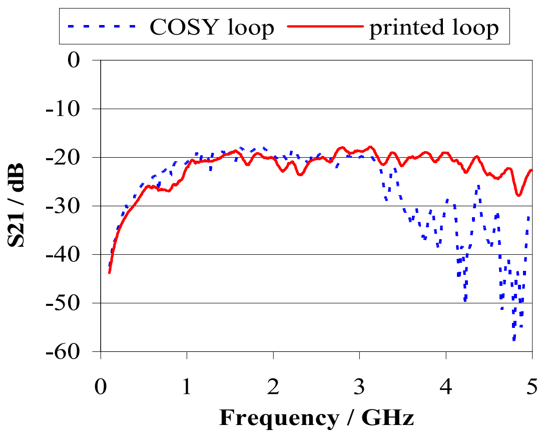

Figure 2: Comparison of COSY-loop and printed loop structures.

A new support structure closes the gaps between the electrode boards (fig. 3) and integrates high power water cooled resistors for kicker operation. Through-holes are no longer needed.

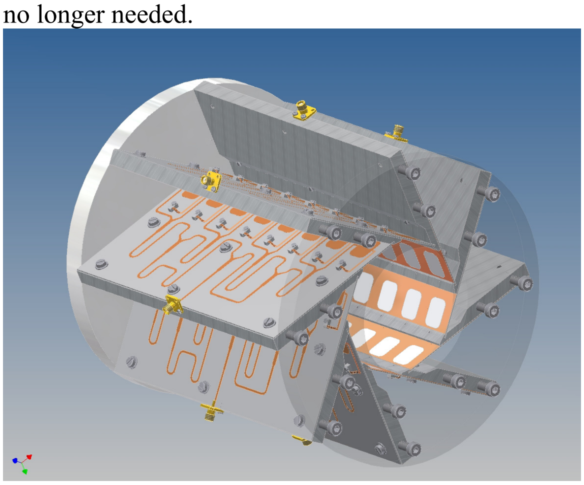

Figure 3: modified support with high power resistors to operate the structure as pickup and as kicker.

The sensitivity of the octagonal structure is sufficient for a transversal stochastic cooling system both as pickup and as kicker structure, but first HFSS [10] simulations [7] show that the sensitivity of the printed loops for longitudinal signals is nearly a factor of four lower than the AC loops.

Ring Slot Coupler

Starting with slot couplers like [9] we found that a ring structure with octagonal arrangement of shorted electrodes will give significant higher longitudinal impedance than any lambda/4 structure [7]. We analysed a slot coupler with the same HESR aperture of 89mm. The structure consists of AlMg4,5Mn rings with 8 shorted electrodes (Fig. 4). The total image current passes the surrounding uninterrupted gap formed by two adjacent rings. The round cell is somewhat like a classical iris-loaded linac cell which is heavily loaded with the eight 50 Ohm coaxial lines to obtain the octave bandwidth. HFSS gives more than two times higher longitudinal coupling impedance per unit length than comparable lambda/4 structures. A TM10 mode enhancement has been found. The field uniformity is good. This round structure offers the most compact solution. With about 2m total active length it satisfies the initial specification of the HESR longitudinal cooling. Different ring slot coupler designs have been analysed including the producibility.

The modular design of this structure allows an easy increase of the number of rings. Two following octagonal rings are centred together by circumferential steps of 3mm length and fits of the diameter within 0.05mm; pivots provide the angular fits.

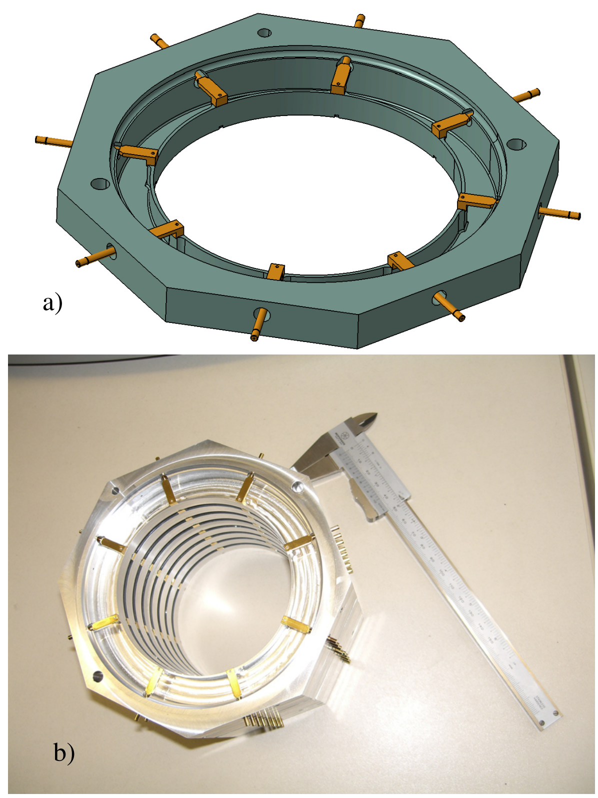

Figure 4: a) single ring with 8 50Ohm electrodes, b) Photo of stack with 8 rings.

A similar combiner board as the simple transforming network used for the lambda/4 coupler cannot be used in this case because of great influence of neighbouring low-impedance electrodes. A good decoupling has been reached by using Wilkinson couplers instead of impedance transforming networks. The 33mm inner conductor of a 31/8" RF transmission line has been used to measure the longitudinal sensitivity of both structures. Together with 90mm inner diameter of the structures we get a 60 Ohm coaxial system. Both ends of this system are completed by commercial 31/8” to N-norm transitions. Using one transition to excite the TEM measurement mode the other transition will be terminated. 60 Ohms are close enough to the 50 Ohm of the network-analyzer impedance that reflections will not influence the TEM field very much.

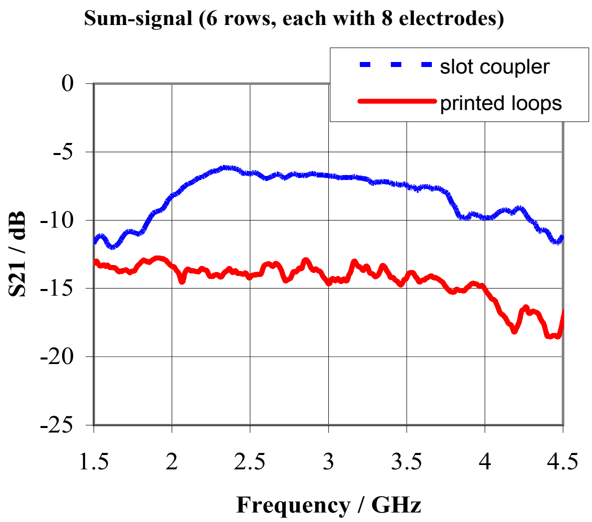

Figure 5: Transmission form 60 Ohm coaxial beam simulation to combined electrodes output.

The slot coupler is not as wide-banded as the printed loops, but shows much higher coupling impedance than the printed loops, although the length in beam direction is only halved. The measurements are comparable to the simulations taking into account the small losses of the combiner boards.

SC TEST-TANK

A cooling tank has been designed to test the different structures with real beam (fig. 6). This tank is already under construction and will be installed in the COSY ring end of this year. In advance, modified gaskets were installed at the chosen place to check whether the aperture reduction to the HESR size (89mm) will influence the number of injected protons.

Two cold heads cool down the structures to about 20K. The whole inner part including the structures can be moved in vertical and horizontal direction to centre the structures according to the beam. The signals of each electrode row are feed through the vacuum system. Thus any combination of signal combining can be tested.

OUTLOOK

The beta functions at different energies are well known in COSY. So the output signals of the new structures can be very easily compared to the existing cooling system in sum-mode as well as in difference mode. First results are expected in 2008 during the first proton beam time.

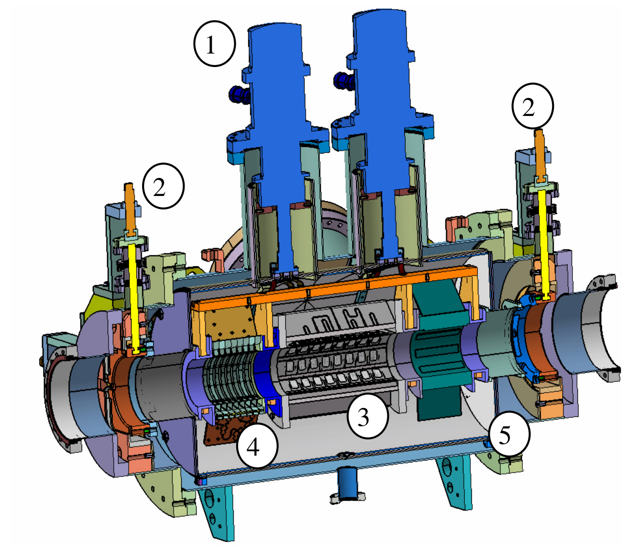

Figure 6: Cooling structures test-tank: (1) cold heads, (2) x-y support, (3) printed loops, (4) ring slot coupler, (5) thermal shield, tank length: 1.15m flange to flange.

ACKNOWLEDGEMENT

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