

The Stochastic-Cooling System of COSY

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Abstract

The stochastic-cooling system in the cooler synchrotron COSY is designed for protons in the energy range between 0.8 and 2.5 GeV [1,2]. The layout of both the microwave and the mechanical components is completed. Prototypes of all required kinds of amplifiers, programable attenuators and phase shifters of the 2-band RF system (1.0 to 1.8 GHz, 1.8 to 3.0 GHz) have been fabricated and tested. The final layout as well as results of the prototype measurements are presented.

1. THEORETICAL INVESTIGATIONS

The cooling times, the amplification and phase conditions have been recalculated based on the final technical design and the measured data of the prototypes. A microwave power of 30 W per RF feedthrough of the kickers is sufficient for cooling times less than 50 s for 10^{10} stored protons.

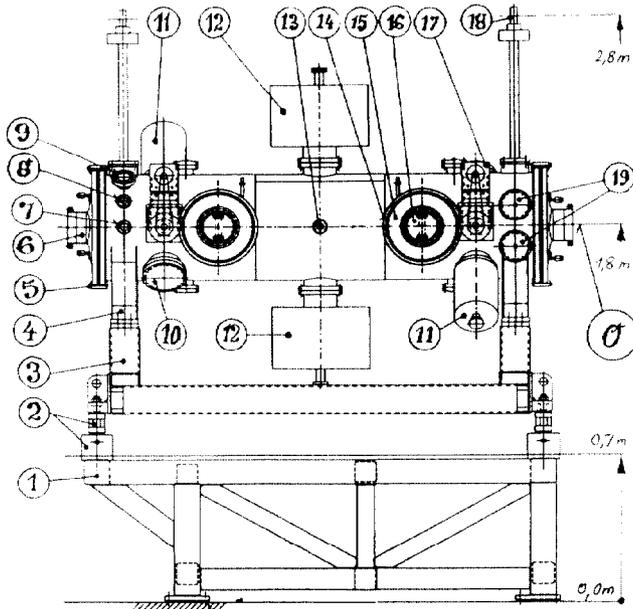


Figure 1: Side view of a horizontal kicker tank.

- | | |
|---|-------------------------------|
| 0: Beam axis | 11: Ti-sublimation pump |
| 1: under support, | 12: ion-sputter pump |
| 2: adjustable foot, | 13: multi-contact feedthrough |
| 3: adjusting support, | 14: RF dome |
| 4: tank foot, | 15: reducing flange 320→150 |
| 5: X seal, \varnothing 500 * 8 | 16: 4 RF inputs |
| 6: reducing flange 500→150 | 17: drive of electrode bar |
| 7-9: flanges for RF and vacuum measurements | 18: Taylor-Hobson sphere |
| 10: assembly port | 19: cooling water feedthrough |

The betatron phase advance over the tank sections is neglectable for the chosen optical parameters [1]. This allows the orientation of band-I and band-II sections within the tanks in that way, that identical mechanical RF elements can be used in the PU and kicker tanks.

2. COOLING TANKS

The engineering of the cooling tanks has been completed in October 1991. Prototype fabrication of RF-relevant parts as the flexible RF transmission lines in the tanks and one complete electrode bar will start in March 1992, in collaboration with the KFA central workshop. These components will be integrated into our RF test setup and optimized according to the measurements. The fabrication of the tanks is splitted into three groups: one horizontal and one vertical pickup tank section are scheduled for end of 1993 for mounting in the ring, the 2 kicker tanks will be ready in spring 1994 and the second horizontal and vertical pickup tanks will be ready in the end 1994. Table 1 lists the main mechanical tank components. Figure 1 shows a side view of a horizontal kicker tank.

Table 1: Tank components and dimensions

	Pickup	Kicker
length of tank section / mm	2 050	2 050
inner diameter of tanks / mm	500	500
number of tank sections per plane	2	1
total length of tank / mm	4 355	2 355
stripline beam coupler pairs per plane	112	56
number of RF feedthroughs per plane	32	16
cooling of electrodes	cryogenic cooling	water cooling

maximum beam aperture / mm	140
minimum beam aperture / mm	20
duration of moving cycle / s	3
tolerance of movements / mm	± 0.1
expected lifetime of moving parts / cycles	10^6

Table 2: List of the RF components for both transverse planes

component		frequency range	number
low noise preamplifiers	VVI	1.0 - 1.8 GHz	32
	VVII	1.8 - 3.0 GHz	32
low power amplifiers	KLV	1.0 - 3.0 GHz	16
medium power amplifiers	MLV	1.0 - 3.0 GHz	12
high power amplifiers	HLVI	1.0 - 1.8 GHz	16
	HLVII	1.8 - 3.0 GHz	16
programmable attenuators	PA	1.0 - 3.0 GHz	4
programmable delay lines	PV1a	1.0 - 3.0 GHz	48
	PV1b		32
	PV2		8
	PV3		4

3. RF-SIGNAL PROCESSING

The scheme of one signal path is shown in Fig.2. 4 paths are required for 2-band horizontal (H) and vertical (V) operation.

The signal combining and distribution within the cooling tanks will be performed using microstrip lines on 2.5-mm alumina (97.6 %) substrates. The strip metallization was made using thick-film pastes. Ag-Pd was used for the ground plane in order to get good thermal matching to the alumina sheet. Test boards with ring resonators of different strip widths were measured and lead to a permittivity value of 9.8 and attenuation values around 1 dB/m at room temperature. This value is small enough with respect to both the noise figure in the PUs and the power losses in the kickers. The fluctuations of permittivity and strip widths cause tolerances in the order of 10^{-3} which is 10 times better than necessary. The final layout of the combiner/splitter boards is adjusted to these measured values and a medium beam velocity of 92% of the speed of light ($T_{\text{protons}}=1.5$ GeV). By this, the largest possible phase error causes an amplitude decrease of less than 0.2 dB between 1.1 and 2.5 GeV and 2 dB at 0.8 GeV.

Table 3: Measured data of the RF prototypes

	VVI	VVII	KLV	MLV	HLVI	HLVII	PA
gain	31.0	29.0	29.5	33.0	38.0	32.0	4.3
	± 1.0	± 1.5	± 0.5	± 1.1	± 1.5	± 2.0	± 0.5
min. S_{11}	10.5	11.0	15.0	14.0	10.0	15.0	13.0
min. S_{22}	13.0	11.5	12.0	11.0	16.0	15.0	13.0
min. S_{12}	65.0	45.0	45.0	57.0	90.0	90.0	37.0
max. noise	0.75	0.80	6.70	5.50	4.80	6.30	15.0
max. power	6	6	6	29.6	44	44	29
delay	1.0	1.0	0.93	1.0	8.3	7.1	1.42
	± 0.2	± 0.2	± 0.03	± 0.15	± 1.2	± 0.8	± 0.06
alimentation	18-30	18-30	18-30	15-25	18-25	18-25	15-30
	/V	/V	/V	/V	/V	/V	/V
	0.1	0.1	0.1	0.7	18	18	0.17
	/A	/A	/A	/A	/A	/A	/A

Table 4: Data for the programmable delay lines

	PV1a	PV1b	PV2	PV3
nb. of stages	1	2	2	13
el. lengths /mm	20	20, 40	80, 160	2.5-10 240

The electronic components are listed in Table 2. Measured data of the prototypes are compiled in Table 3. The characteristics of the programmable delay lines are listed in Table 4.

The variable-delay network has been finally designed. It will enable optimum phase adjustments and amplitude losses of less than 5% for cooling energies between 0.8 and 2.5 GeV using a minimum number of RF switches.

The prototype power amplifiers have been fabricated using four Fujitsu FLL100 FETs per amplifier leading to about 20 W output power. In the next step, a redesign using four FLL120 instead of FLL100 will increase the output power to 30 W and smooth the group delay. Two additional booster modules inside each power amplifier could raise the power to 60 W if necessary.

The following preventive measures have been installed in the power amplifiers:

- separate DC regulating and control circuits for all RF power FETs,
- control of supply voltages and currents,
- control of temperatures of the RF power FETs,
- control of reflected power and symmetry of balanced power paths,
- control of the DC value of the amplifier load.

The control signals will be conjoined in groups and connected to the COSY control system [4]. So, each failure is locatable from a COSY control terminal.

4. TIME SCHEDULE

Prototypes of the critical mechanical parts will be fabricated and integrated into our RF test setup in autumn this year. One horizontal and one vertical pickup section will be mounted in the ring in the end of 1993, the two kicker tanks in June 1994. Delivery of the second horizontal and vertical tank section in the end of 1994 will complete the mechanical components.

One complete signal path including the air filled RF transmission line for test measurements and optimization will be installed in the test area in autumn this year.

Delivery of all preamplifiers (VVI and VVII) is envisaged for autumn this year. Attenuators (PA) and delay lines (PV1,...,PV3) as well as the low and medium power amplifiers (KLV and MLV) will be ready in April 1993. By this, sensitive beam diagnosis with the stochastic cooling pickups will be possible in the end of 1993. Delivery and installation of the high power amplifiers (HLVI and HLVII) until summer 1994 makes stochastic cooling in both transverse planes with reduced performance possible. Full performance will be achieved in the beginning of 1995.

