# The RF - System of the Synchrotron Radiation Source ROSY

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*Abstract*

For the Synchrotron Light Source ROSY [1],[2], the rf-system has to provide a total rf power of 270 kW to meet the design values (energy E = 3 GeV and an electron-beam current of I = 0.1 A). The total energy loss per turn of ROSY fully equipped with four wigglers and four undulators within its straight sections is 1180 keV. To obtain the energy acceptance of better than 1.5 % the overvoltage factor q is 2.92. As result of a comparison of well established accelerating cavity systems the ROSY design is based on two 352 MHz LEP cavities driven by one klystron TH 2089 (Thomson) or YK 1350 (Philips). One rf window per cavity is used to feed 123 kW rf power into each cavity. The acceleration of 250 mA electrons in a future step necessitates to provide each cavity with two rf windows because of the power limit of about 150 kW per window.

## 1. INTRODUCTION

The rf system has to provide sufficient power to compensate the synchrotron radiation loss per turn and to accelerate the injected electrons (injection energy: 800 MeV) to the final energy of 3 GeV with sufficient energy acceptance. The main rf parameters are given in table 1 [3].

Table 1
RF-parameters of ROSY

| | |
|---|---|
| Nominal energy | 3 GeV |
| Electron current | 100 mA,(phase 2: 250 mA) |
| Circumference | 148.1 m |
| Momentum compaction | $6.6\ 10^{-3}$ |
| Radio frequency | 352 MHz |
| Harmonic number | 174 |
| Damping number | -0.61 |
| Damping functions | |
| horizontal | 1.61 |
| vertical | 1 |
| longitudinal | 1.39 |
| Energy loss per turn | 1180 keV |
| Bending magnets | 1003 keV |
| Insertion devices | 177 keV |
| Beam power | 118 kW, (295 kW) |
| Bending magnets | 100 kW, (251 kW) |
| Insertion devices | 17.7 kW, (44.4 kW) |
| Overvoltage factor | 2.92 |
| Stable phase | 20 deg. |
| Energy spread | 1.5 % |
| Natural energy spread | $1.16\ 10^{-3}$ |
| Bunch length | 14.6 mm |
| Synchrotron frequency | 28.6 MHz |

## 2. CHOICE OF THE CAVITIES

The rf power balance is given by:

$$P_{RF} = P_B + P_{Diss} + P_T + P_{HOM} \qquad (1)$$

with:
$P_{RF}$: RF output of the klystron
$P_B$: Beam losses
$P_{Diss}$: Cavity dissipation
$P_T$: Transmission losses
$P_{HOM}$: Higher order mode losses.

A rough estimation of the required rf power can be done by considering 10% higher order mode losses and 10% transmission losses . This leeds to:

$$P_{RF} \approx 1.2\left(P_B + P_{Diss}\right) \ . \qquad (2)$$

The cavity dissipation is given by the shunt impedance $R_S$ of the cavity and the effective cavity peak voltage $U_{Cav}$ :

$$P_{Diss} = \frac{U_{Cav}^2}{2R_s} \ . \qquad (3)$$

The effective cavity peak voltage $U_{Cav}$ is given :

$$U_{Cav} = q \cdot \frac{U_0}{e} \qquad (4)$$

with:
q: Overvoltage factor
$U_0$: Energy loss per turn
e: $1.6022\ 10^{-19}$ C.

For a quantum life time of more than 10 hrs. the energy acceptance of the rf system ΔE/E has to be at least ten times of the natural energy spread δE/E. The rf energy spread depending on the overvoltage factor q is [4] :

$$\frac{\Delta E}{E} = \pm\sqrt{\frac{U_0}{\pi \alpha k E_0} \cdot 2\left[\sqrt{q^2-1} - arccos\left(\frac{1}{q}\right)\right]} \qquad (5)$$

with:
α: Momentum compaction factor
k: Harmonic number.

With $U_0$, $\alpha$, $E_0$ and k from table 1 the wanted energy acceptance of 1.5 % (see equation 5) requires an overvoltage factor q = 2.92. Taken this into account (equation 4) the cavity peak voltage for ROSY has to be 3445 kV. During injection (at 800 MeV) the rf energy acceptance is about 5 %, due to an q of 20...30 because of the much lower synchrotron radiation loss at that energy. Cavity parameters from the projects ALS , ELETTRA , DORIS , APS , PETRA and LEP were checked and compaired for their use within the ROSY project [4]. The main parameters are given in table 2.

Table 2
Cavity Design Parameters [3]

| Cavity | ALS | Elettra | Doris | APS | Petra-7-cell | LEP 5-cell |
|---|---|---|---|---|---|---|
| f /MHz | 500 | 500 | 500 | 352 | 500 | 352 |
| $R_{sh}(1)$ / MΩ | 8 | 7 | 3 | 5.6 | 19 | 28.3 |
| $U_{cav}$ / kV | 574 | 574 | 574 | 862 | 1723 | 1723 |
| $P_{Diss}$/ kW | 21 | 24 | 57 | 66 | 78 | 53 |
| $P_{rf\text{-}Inp}$/kW | 45 | 48 | 85 | 105 | 151 | 123 |
| $P_{klystron}$/kW | 295 | 316 | 558 | 464 | 332 | 270 |
| N (cavities) | 6 | 6 | 6 | 4 | 2 | 2 |

We have chosen two LEP five-cell cavities for ROSY because of its best rf-power efficiency and its compact design within the lattice. A distributed system with single cell cavities has the advantage of better maintainance but one design goal for ROSY is to use as much as possible straight sections for installing insertion devices. The use of two 7-cell PETRA cavities would be an alternaive solution, but the thermal regime of the cavity as well as the capability of the input coupler has to be checked carefully. The further upgrading of ROSY (I = 250 mA) requires two input coupler per cavity. This has been done at the ESRF using the LEP basic design [6]. In table 3 the operational parameters of one LEP cavity, adopted to ROSY, are given [5] :

Table 3
ROSY rf parameters, system equipped with two LEP cavities

| | |
|---|---|
| Number of cavities | 2 |
| Cells per cavity | 5 |
| Shunt impedance | 28.3 MOhm |
| Eff. cavity peak voltage<br>($q = 2.92$, $U_0 = 1180$ keV) | 1723 kV |
| Cavity dissipation | 52.5 kW |
| for I = 100 mA: | |
| Beam power per cavity | 59 kW |
| Forward rf pwr (per cavity) | 123 kW |
| RF window fwd. power | 123 kW |
| Clystron output (+20%) | 270 kW |
| for I= 250 mA: (2 input cpl.) | |
| Beam power per cavity | 148 kW |
| Forward rf pwr (per cavity) | 220 kW |
| RF window fwd. power | 110 kW |
| Clystron output (+20%) | 485 kW |

Fig. 1 shows the implementation of two LEP cavities within the storage ring ROSY.

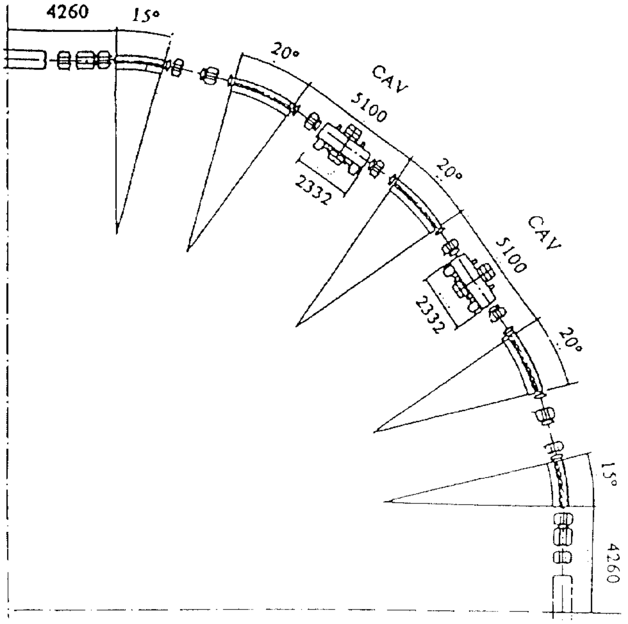

Figure 1. RF-quadrant of the SR-source ROSY

## 3. RF-SYSTEM

The rf-power distribution for both variants (I = 100 mA and I= 250 mA) are presented in fig.2 and fig.3.

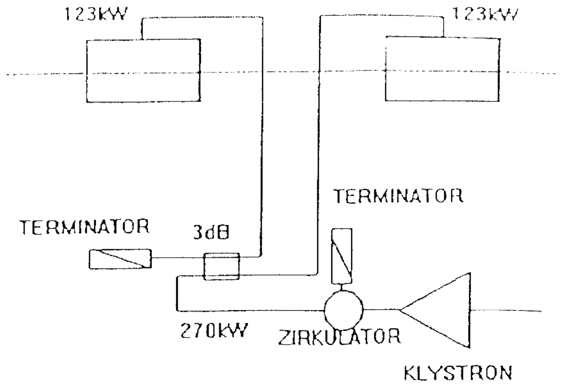

Figure 2. RF-distribution of ROSY phase 1 (I=100 mA)

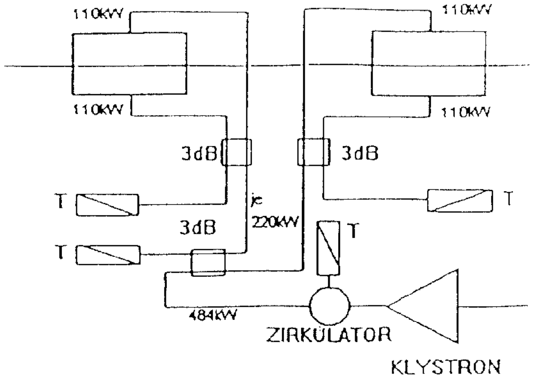

Figure 3. RF-distribution for ROSY phase 2 (I=250 mA)

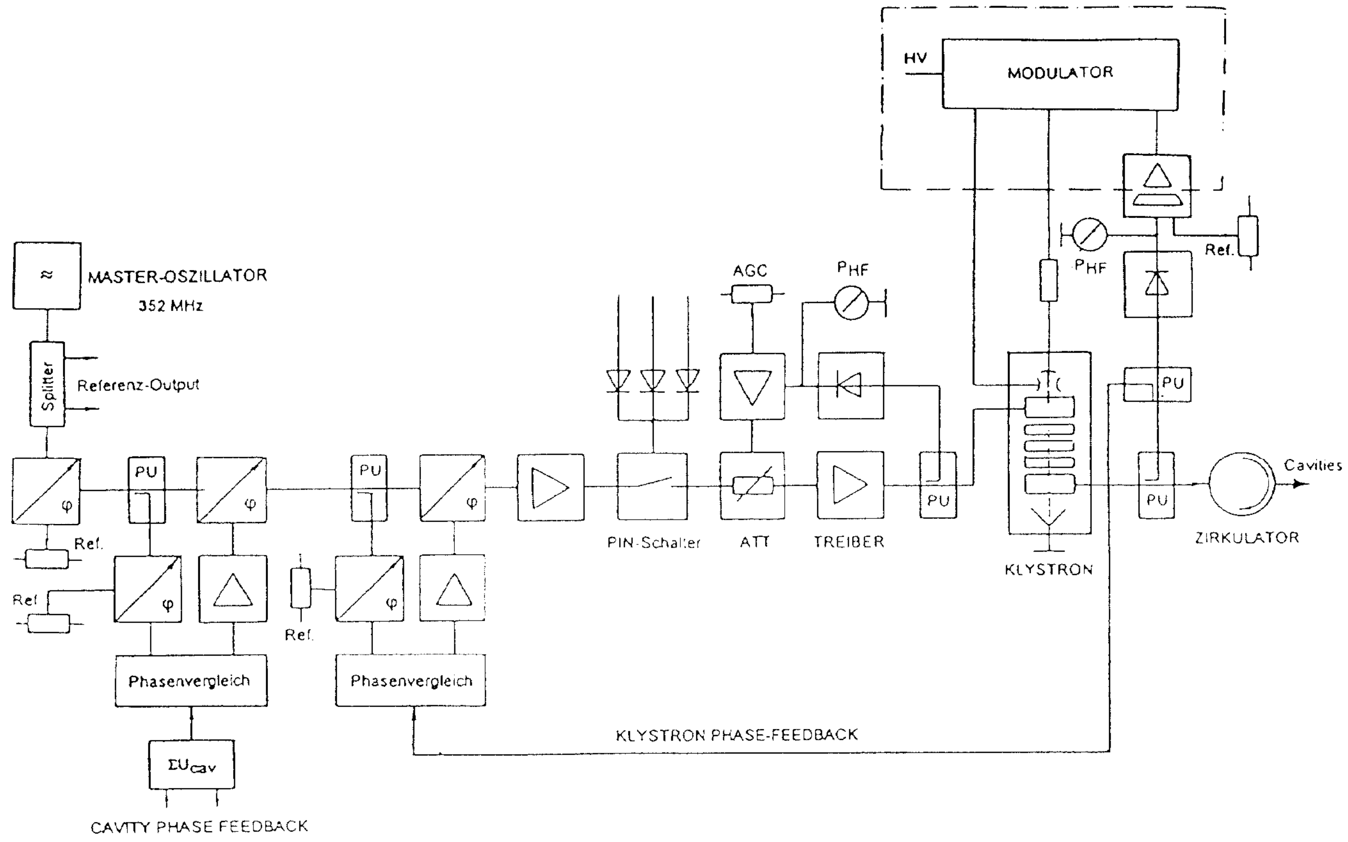

Figure 5. Scheme of the ROSY rf - system

The block-diagram of the rf-system is given in Fig.5. The main power amplifier is a klystron TH 2089 (Thomson) or YK 1350 (Philips), which can deliver twice the output required to run ROSY. The klystron output control is performed by a loop, consisting of the pick-up before the circulator, the insulation amplifier and the modulator. The control of the modulation voltage reduces the dissipation of the power klystron and is more efficient than varying the drive power. Two independent phase feedback loops stabilize the gain and phase of the low-level circuit and the complete rf-system including the cavities. Fast interlocks fire the PIN-diode switch. The phase stable reference signal is generated by a master oscillator. The splitter provides reference outputs to the gun and preaccelerator and the phase shifter that follows allows a phase matching of the rf system relatively to the injection.

## 4. REFERENCES

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