NEW SCHOTTKY- PICKUP FOR COSY - JÜLICH

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Abstract

A new Schottky-pickup for the Cooler Synchrotron COSY [1] at the Forschungszentrum Jülich was developed, tested and installed. The new pickup with four diagonally arranged plates replaces the two 1 m long Schottky–pickups used until now in COSY. The previous ones were removed mainly to gain space for new installations (e.g. rf-cavity, experimental devices), but also to increase the horizontal aperture. The available space for the new pickup is only 0.8 m. The pickup plates can be combined by means of relays to measure either in the horizontal or in the vertical plane. The pickup can also be used either as a sensitive broadband beam position monitor or as a tuneable narrowband pickup for Schottky-noise analysis with ultahigh sensitivity. A new method for resonant tuning of the Schottky-pickups for transversal measurements was developed. The differentially excited resonant circuitry enhances the sensitivity by about a factor of 30. The pickups are also used for dynamical tune measurements (tune meter) in the acceleration ramp [2].

1 INTRODUCTION

The Schottky-noise is preferably measured in the 10 to 60 MHz frequency range. This is due to the fact that the line widths in the Schottky-noise spectrum are proportional to the harmonic number with equal noise power per line. The narrow longitudinal lines are measured in the upper part of this frequency range, but the generally much broader transversal lines at lower frequencies because here the line structures do not yet overlap and, in particular at higher frequencies, the amplitudes can vanish in the noise level.

Because of the low power of the transversal signals an especially sensitive monitor is required whose sensitivity will be enhanced further by resonant tuning. Despite of the gain of 20 to 30 dB by resonant tuning, the sensitivity itself is very important and also its frequency dependence. Both sensitivity and frequency dependence are influenced by the layout and the mode of operation.

Three monitor types are at disposal: inductive, capacitive and stripline monitors. In the frequency range of 10 to 60 MHz the capacitive monitor is well suited, but the inductive monitor less so. This is due to the fact that the azimuthal magnetic field of the beam and hence the induced signal power is proportional to $ß^2$, and Schottky-noise measurements at COSY also must be performed at low ß-values. The stripline monitor can be operated at high frequencies and it is able to separate the signals of particles travelling opposite to each other (directivity), a very useful feature in storage rings. This cannot be used at COSY, however, the great disadvantage is the sinusoidal frequency dependence. The maximal sensitivity, obtained at frequencies with $\lambda/4$ corresponding to the monitor length, would be with 0.8m length at 94 MHz. In the 10 to 60 MHz range the sensitivity diminish drastically.

The amplitudes of the transversal Schottky signals are dependent on the square root of the ß-function. A suitable position in COSY with high ß-function values should therefore be chosen. In monitor design, attention must be payed to save the total aperture. For this reason the electrodes must be arranged far outside, at best with beam tube diameter.

2 MONITOR DESIGN AND TRANSFER IMPEDANCE

The capacitive monitor with high impedance preamplifier has the particular advantage of a flat frequency response within a pass band. The lower cut-off frequency is determined by the electrode capacity and the preamplifier input impedance, and can be realized to 10kHz. The upper cut-off frequency is determined by the bandwidth of the preamplifier and is larger than 100MHz, the proper frequency range.

The sensitivity or transfer impedance of one electrode with beam centred is given by

$$Z_{tr} = \frac{A_{el}}{2\pi r} \cdot \frac{1}{\beta c \cdot C_{el}} = \frac{\alpha_{el}}{2\pi} \cdot \frac{L}{\beta c \cdot C_{el}}$$

where: A_{el} = electrode plane, r = beam tube radius, L = monitor length and α = azimuthal angle of electrode. The first term is a geometrical factor, corresponding to the ratio of electrode plane to total monitor cylinder plane. The transfer impedance is maximized if all electrodes together entirely enclose the beam, i.e. if $\Sigma\alpha_{el} = 2\pi$. For high sensitivity the electrode capacity C_{el} must be small, i.e. the distance to the beam tube cannot be too small.

Therefore the vacuum tube should be enlarged and the electrodes positioned in extension of the beam tube.

For the longitudinal or Σ- signal follows: $\Sigma(t) = n \cdot Z_{tr} \cdot i(t)$ where: n = number of electrodes and i(t) = beam current. Important for the transversal or Δ- signals is the coupling capacity C_c between the electrodes that reduces the amplitude, because

$$\Delta(t) = \frac{\Sigma(t)}{a/2} \cdot \frac{C_{el}}{C_{el} + 2C_c} \cdot \left(x - x_0\right)$$

where: a = electrode distance, x = displacement of beam from centre and x_0 = monitor displacement from optical axis. The coupling capacity must be small in comparison to the electrode capacity. This also means, that the electrode capacity cannot be made as small as possible.

The geometry of the new Schottky-pickup has the schematic layout as shown in Fig.1. The apertures in horizontal (150mm diameter) and in vertical (60mm, rectangular) directions remain free, if the pickup diameter is made slightly larger.

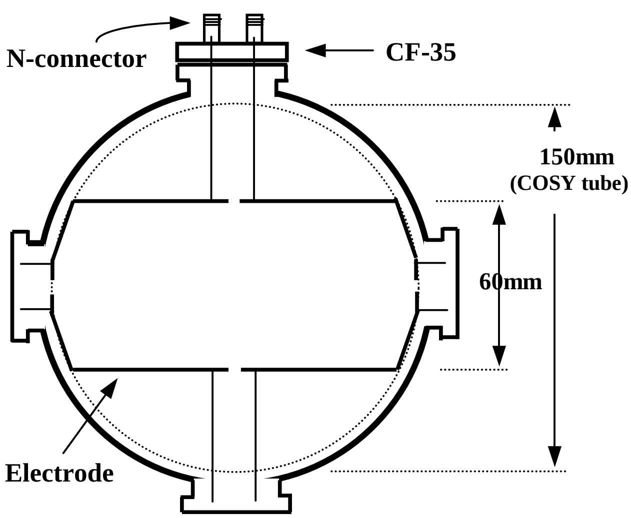

Figure : Layout of the new Schottky-pickup for measurements in horizontal and vertical plane (after proper switching of coax-relays).

The structure is split into four electrodes that together surround the beam. By proper switching of coax-relays, Schottky-noise measurements become possible both in horizontal and vertical planes. To achieve a small coupling capacity (e.g. $C_c < C_{el} / 10$), the separating slits cannot be made too narrow, thus an azimuthal range of about 95% must be tolerated.

Before installation, measurements of the pickup sensitivity (also called transfer impedance) were carried out using a special test set-up. A well defined RF-current is coupled into a matched inner conductor (diameter 1 mm) for simulation of the beam current. The response in the time domain of the Schottky- pickup is shown in Fig. 2. The output signal is attenuated because of damping in the matching networks.

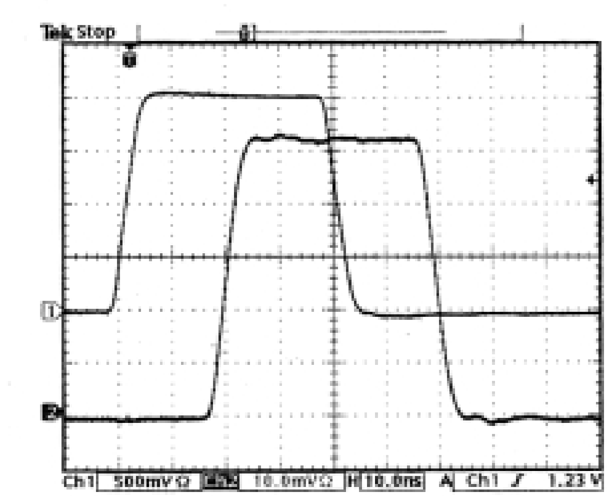

Figure 2: Time response of the Schottky-pickup (Ch1: input; Ch2: output, BW = 70 MHz).

The pickup electrodes can be combined by means of relays for horizontal, vertical or longitudinal broadband measurements as is shown in Fig. 3. An example for broadband measurements is shown in Fig. 4.

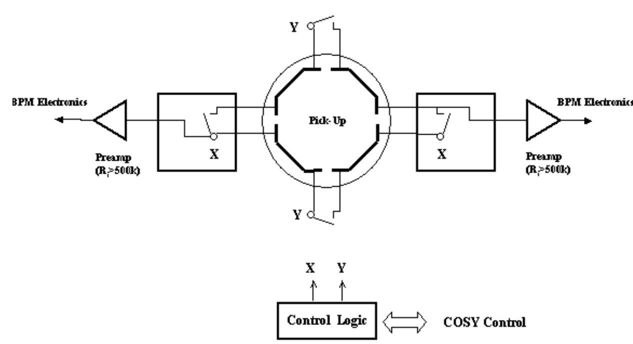

Figure 3: Broadband application of the Schottky-pickups.

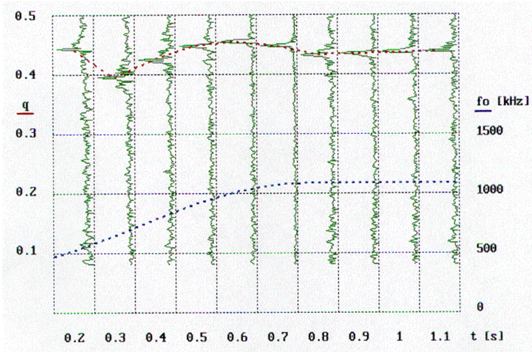

Figure 4: Display of a tune measurement in the acceleration ramp consisting of ten FFT-spectra. The sideband lines are clearly seen. In the lower part (dashed curve) the frequency ramp is shown [2].

3 RESONANT TUNING

For Schottky-noise analysis, special narrowband electronics consisting of two critically coupled LC resonant circuits were developed (Fig. 5.). The first one is connected between two sectors of the properly combined electrode pairs. In this configuration the resonant circuitry will be excited only by the differential current, i.e. by the transversal component of the beam charge. With a coupled additional resonant circuit a band bass filter was formed. To avoid unwanted tuning effects by the strong magnetic fields at COSY, ironless coils with fixed inductivity were used. The centre frequency of the filter and the coupling factor can be tuned by means of double-diode aviators. Three Dace's operated from the control room of COSY generate the tuning voltages using stored arrays for centre frequencies between 8 and 13 MHz and coupling factors for flat pass band response. The bandwidth is about 200 kHz.

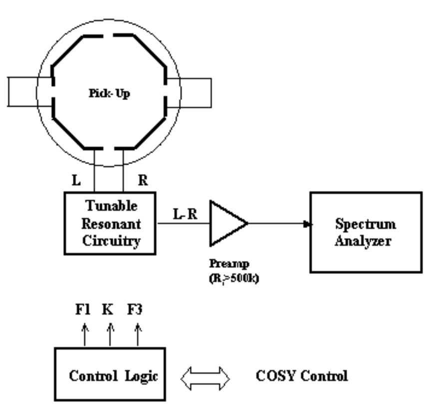

Figure 5: Schottky- pickups with resonant circuitry for horizontal transversal measurements.

The output of the band pass filter corresponds to the transversal beam current. No further subtracting (hybrid) circuitries are necessary for extracting the differential signal component. The filter enhances the pass band sensitivity of the Schottky-pickup and thus it the signal to noise ratio by about a factor of 30 in comparison to the broadband configuration. The small signals of the pickup are amplified by a programmable gain broadband amplifier.

REFERENCES

[1] Maier, R., "Cooler synchrotron COSY – performance and perspectives," Nucl. Instrum. and Methods A **390**, 1- 8 (1997).

[2] Dietrich, J. et al, "Real-time betatron tune measurement in the acceleration ramp at COSY- Jülich", DIPAC, Chester (1999).