EXPERIENCE WITH A BROADBAND CAVITY AT COSY

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Abstract

We describe the integration of a broadband cavity based on the material VitroPerm into COSY [1]. The electrical characteristics of the 12 cores arranged in two half-cavities allow the application of a fundamental from 400 kHz to 1.6 MHz together with 2 higher harmonics. The second harmonic can be driven at up to 50 % amplitude, the third or fourth harmonic at 20% amplitude of the fundamental. The impedance is a function of the magnetic material and also of the cooling medium. We measure the impedance with tap water, low conductivity water and Fluorinert FC_77. Like colleagues from KEK [2] we obtained at least 400 Ω. The acceleration voltage requirements of COSY allow beam tests with this cavity by semiconductor amplifiers in the kW power range. We plan an upgrade to a tube amplifier with 50 kW RF power, to compare different schemes of γ-transition crossing.

1  FIRST ASSEMBLY

In 1999 we measured the impedance of each half of the cavity structure loaded with VitroPerm [3], [4]. With water of different quality as cooling medium we noticed that the impedance is related to the water purity, e.g. tap water resulted in about half the maximum impedance, compared to low conductivity water, see Fig. 1. The lower impedance explained as a reduced Q with tap water could be an advantage for broadband operating, because the impedance variation vs. frequency is lower. We do not fill both cavity sides with tap water, to prevent contamination of the low conductive water cooling system.

We experienced problems with corrosion of the cores, because the coating, comparable to resin used for transformer metal sheets, was not perfect waterproof. The manufacturer of the cores [5] removed the coating and the corrosion and made tests to improve the water protection. The final solution is to bandage the cores with glass-fiber to increase the adhesion and then to apply the resin. As a finish the cores were painted with a waterproof color.

These tests of different coatings resulted in a reduction of the impedance value of the cores due to thermal stress when heating up the cores with the resin.

2  SECOND ASSEMBLY

When the cores were returned, we measured the impedance of each core with a single turn winding. The absolute value is plotted in Fig. 2. The 12 cores were sorted in two groups to get almost equal impedance as a function of frequency on both cavity sides. The result of the optimization – both cavity sides loaded with VitroPerm and no cooling medium, e.g. only air, is demonstrated in Fig. 3.

![Fig. 1: Impedance as function of cooling medium, measured on both cavity sides 1 and 2 separately](image1)

![Fig. 2: Impedance distribution of 12 cores](image2)

![Fig. 3: Impedance of both sides of VitroPerm cavity filled with air](image3)
3 SMALL TEST CAVITY

The impedance as a function of cooling medium is measured with a test-cavity representing one cavity side. The impedance of a group of 3 small sample cores (outer dia. 76 mm, inner dia. 50 mm, height 25mm) of the same material grade and coating is plotted as a function of coolant in Fig. 4. This confirms [2], that Fluorinert FC_77 [6] with its dielectric constant of $\varepsilon_r = 1.86$ does not affect the impedance compared to air. With water as coolant, it is important to use low-conductivity water instead of tap water to obtain a high impedance value. This is appropriate for operation with a fundamental and higher harmonics, which are lower than the fundamental. With tap water the lowered impedance is less sensitive to frequency, so increased power allows operation at different fundamental frequencies.

4 OPERATING CONDITIONS

For operation at COSY (500 kHz to 1.6 MHz), the VitroPerm cavity is filled with low conductive water. The impedance shown in Fig. 5 is lower than in Fig. 1 (first assembly). The value of ≈200 $\Omega$ per cavity side in the COSY range matches to 200 $\Omega$ custom-made transmission lines. The outer part of the coax is standard 4 1/2-inch [7]. Inside it is modified to 4mm inner diameter.

In 100 mm diameter size, 2 VitroPerm cores are used for impedance transformers/combiners at the end of the transmission lines. The 50 $\Omega$ output impedance of one transistor amplifier is transformed (1:9) to 450 $\Omega$. Two amplifiers are combined on one core and thus matched to 225 $\Omega$. This layout is shown in Fig. 6. For higher power we will drive the cavity with a push-pull tube amplifier via the transmission lines.

The voltage plotted in Fig. 7 is high enough to operate COSY with only 2 kW delivered by 4 amplifiers.

So, the cavity was installed in COSY and brought into operation with beam. First we demonstrated, that the performance of the VitroPerm cavity, measured as ratio of accelerated beam in flat top over injected particles compared to the ferrite cavity is at least the same when we operate it with the fundamental only. By adding the second harmonic [8] in the VitroPerm cavity the bunching efficiency [9], [10] increases as shown in Figs. 8a-b. This results in about 10% more particles in flat-top.
From operation of the cavity we learned, that the
cooling water for the cavity should not be too cold to pre-
vent condensation of humidity. We also inserted a relay in
the signal path to the amplifiers: In flat-top we program
zero amplitude to de-bunch the beam. The synthesizer
output is “quiet” at the generated harmonics, but there is
some crosstalk of the digital clock at 16xf rev. This affects
the beam via the broadband amplifiers and cavity. We
observed and corrected this.

5 SIGNAL SYNTHESIS

For signal synthesis of the higher harmonics we pro-
gram signals with a predictable amplitude - an example is
given in Fig. 9. For real operation amplitude and phase of
the higher harmonics are adjusted to the fundamental. This
relation is shown for (h=2) to (h=1) in Fig. 10.

We will compare the VitroPerm cavity with beam ex-
periments at COSY, where we cross γ-transition (see
Fig. 11) without using the Q-jump-system – only by
applying a phase program to the digital phase loop of the
RF-system. We will need more power for the VitroPerm
cavity, and therefore we plan to drive it with a push-pull
tube amplifier, which was used for the VitroVac cavity

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