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HOM POWER LEVELS IN THE BESSY VSR COLD STRING

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Abstract

The BESSY VSR upgrade of the BESSY II light source represents a novel approach to simultaneously store long and short bunches in the storage ring. This challenging goal requires installation of four new SRF cavities (2x1.5GHz and 2x1.75GHz) in one module for installation in a single straight. These cavities are equipped with strong waveguide HOM dampers necessary for stable operation. The expected HOM power and spectrum has been analyzed for the complete cold string. The cold string is a combination of various elements such as SRF cavities, bellows with and without shielding, warm HOM beam-pipe absorbers and UHV pumping domes. The presented study is performed for various BESSY VSR bunch filling patterns with 300 mA beam current. The contribution of each component to the total HOM power is presented.

INTRODUCTION

The BESSY Variable pulse length Storage Ring (VSR) project [1, 2] is a future upgrade of the 3rd generation BESSY II light source. The key feature of the project is the simultaneous storage of long (ca. 15ps) and short (ca. 1.7ps) electron bunches under "standard" user optics. This challenging goal requires installation of SRF higher harmonic cavities of the fundamental 500MHz at two different frequencies. Therefore four new SRF cavities (2x1.5GHz and 2x1.75GHz) are designed [3, 4]. These cavities will operate in CW mode at high gradients of 20MV/m. The combination of these factors with a high beam current (I_b=300 mA) make the cavity design a challenging goal, since stable operation must be ensured. Thus special attention was paid to the damping of HOMs excited by the beam that may otherwise lead to coupled bunch instabilities.

The HOM power levels for different cavity arrangements in the SRF module are presented. A dedicated spectral weighting technique for calculation of RF power propagation due to the HOMs excited by the circulating beam in SRF cavities is used [5, 6]. The method makes use of wakefield simulations using the CST software [7] and an external post-processing of the port signals. Calculations were performed for different bunch filling patterns of the BESSY VSR project. The propagated HOM RF power is obtained by spectral weighting of port signals (calculated with a single bunch excitation) with the bunch train spectrum. In this manner the resonances of the cold string component excited by the periodic bunch pattern will be detected. The evaluation procedure is used for the calculation of the expected HOM powers (broadband) to be absorbed in the RF loads and of the efficiency of HOM dampers in terms of power flow balance between FPC, HOM waveguides and beampipes. The HOM power levels for complete cold string with warm elements outside the SRF module are presented as well.

THE BESSY-VSR FILLING PATTERN

The realisation of the BESSY VSR project implies installation of a single superconducting module with four cavities in one of the straight sections of the existing BESSY II ring (Fig.1). The module integration is a challenging engineering task because of strict space limitations of the ring-straight to ~4.5m. The complete module design is currently in the development stage.

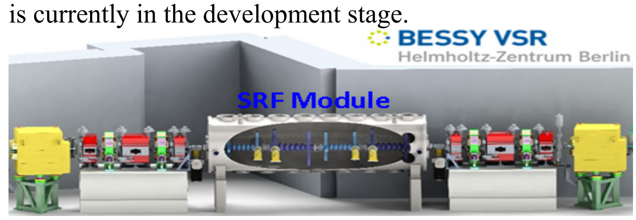

Figure 1: Schematic view of BESSY VSR cavities in ring straight.

The nominal BESSY VSR filling pattern of the 240m circumference ring is shown in Figure 2 where the short and long bunches will be stored simultaneously. In total 400 RF buckets with 2ns bunch spacing are available.

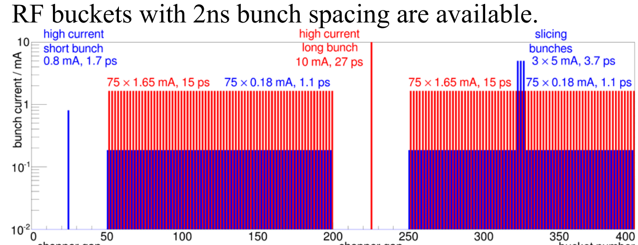

Figure 2: BESSY VSR filling pattern including short (blue) and long (red) bunches.

Two type of bunch filling patterns are considered, so-called "extended" shown in Figure 2 and "baseline" with omission of 150 short-pulse, low-charge bunches.

The repetition rates of 500MHz and 250MHz are defined by the bunch spacing in each pattern, respectively. In the estimated HOM power levels given in this paper we present results for "baseline" pattern as the highest contributor. Note that in case of single bunch operation the bunch repetition rate will be 1.25MHz, defined by ring circumference of 240m corresponding to 800ns revolution time.

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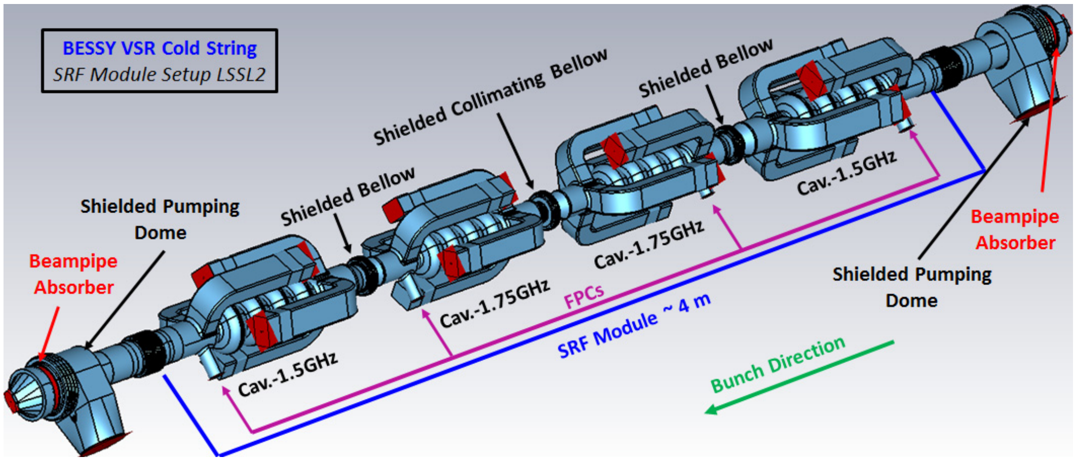

Figure 3: Simulation model of BESSY VSR cold string consisting of superconducting module supplied with warm components necessary for installation and operation.

HOM POWER LEVELS IN BESSY VSR SRF MODULE

In [5], a different cavity arrangement of the SRF module was analyzed. This is a simplified model where cavities are connected by round pipes or tapered transitions. It was shown that LSSL arrangement is the optimum configuration in terms of equally distributed HOM power portions along the module.

In this section different Fundamental Power Coupler (FPC) positions with respect to the cavities in the module for the LSSL arrangement (Fig.4) are presented. This study is motivated by space restrictions in the tunnel of currently operating BESSY II storage ring and offers challenges towards the SRF module design. In this realistic model 1.5 GHz (L) and 1.75 GHz (S) cavities in the SRF module are connected with transition and collimating bellows shown in Fig.3. Both type of bellows are shielded to ensure low-impedance and low heat load from fundamental modes of neighboring cavities. Details on the different bellow designs are given in [8].

In order to analyse the excitation of HOMs in the SRF module, long range (20m) wakefield simulations with σ=9 mm bunch where performed using CST Studio Suite [7]. To ensure realistic HOM propagation and damping in the time domain simulation multi-mode ports have been used. This includes all possible boundaries (cavity waveguide dampers, FPC ports, upstream and downstream beam pipes (BmP)) for accurate extraction of excited HOM energy. Then the port signals from single bunch simulations where spectrally weighted to estimate the power levels and spectrum for BESSY VSR filling pattern. More details on special spectral weighting technique can be found in [5, 6].

In Table 1 the HOM power distribution along different ports is summarized. The presented power levels correspond to the BESSY VSR “baseline” filling pattern. The table component sequence follows the bunch propagation direction.

Three different setups with different FPC locations (Fig. 4) are considered: LSSL1 - all FPCs are on same side and two other setups with full symmetry on central collimating bellow with outer (LSSL2) and inner (LSSL3) positioned FPCs.

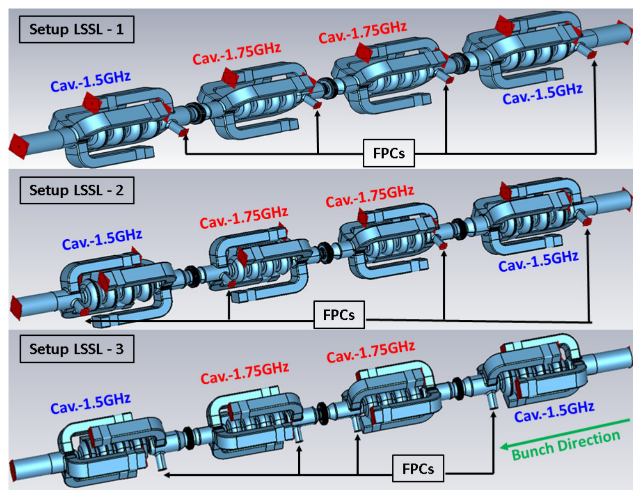

Figure 4: Different FPC positions of the 4-cavity arrangement LSSL in BESSY VSR Module.

As can be seen the LSSL2 setup is optimum in terms of HOM power distribution along the module and reduced reflected power towards the coaxial FPC ports. Low HOM power in the FPCs is important to protect the inner ceramic RF windows. Accordingly optimisation of FPC coax dimensions was performed during the cavity designs [6, 9]. The collimating bellow in the middle of SRF module is a key component protecting the cavities from incident synchrotron light generated in the vicinity (11W). Simulations show that highest HOM power is concentrated at the two end-groups located on both sides of this collimating bellow. Thus having 3-waveguide end-groups as in LSSL2 setup would damp the HOM power more efficient. Simulations for single cavity included complete FPC model have been performed to analyse the expected changes in HOM power balance in the vicinity of RF windows. It was seen that at the higher HOM related frequencies (>2GHz) the powers are mostly reflected back from the first win-

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dows and are coupled to two-waveguide dampers of corresponding end-group. Thus in the module HOM power increase at FPC end-group waveguides is expected. In the Table 1 the ports of each cavity are grouped into to the end-groups and are marked by upper index in the port name.

Table 1: HOM power levels in BESSY VSR module obtained for 'Baseline' filling pattern & different cavity arrangements.

Component	Port	HOM Power [W] LSSL - 1	LSSL - 2	LSSL - 3
Cavity 1.5 GHz	FPC(1)	25	28	61
	WG(1)	115	107	206
	WG(1)	115	107	206
	WG(2)	136	157	74
	WG(2)	136	157	74
	WG(2)	172	193	90
Cavity 1.75 GHz	FPC(1)	66	67	73
	WG(1)	267	265	305
	WG(1)	267	265	305
	WG(2)	204	187	179
	WG(2)	204	187	179
	WG(2)	243	213	220
Cavity 1.75 GHz	FPC(1)	107	72	114
	WG(1)	314	261	316
	WG(1)	314	261	316
	WG(2)	171	245	171
	WG(2)	171	245	171
	WG(2)	203	282	211
Cavity 1.5 GHz	FPC(1)	59	25	74
	WG(1)	208	112	203
	WG(1)	208	112	203
	WG(2)	74	143	80
	WG(2)	74	143	80
	WG(2)	90	184	83
BmP	Upstr.	230	300	230
	Downstr	363	380	290
Total		4534	4693	4515

HOM POWER LEVELS IN THE COLD STRING

In this section the HOM power levels obtained for BESSY VSR cold string with optimum cavity setup LSSL2 in SRF module is presented (Fig.3). The simulation model is directly extracted from the engineering model. It includes additional warm components on both sides of SRF module like module end-bellows, shielded pumping domes, warm beam pipe absorbers and transition to BESSY standard beam pipe. The powers losses in dielectric absorbers are obtained by special spectral weighting evaluation of time monitored electric fields in dielectric [5].

Table 2: HOM power levels in BESSY VSR cold string obtained for 'Baseline' filling pattern.

Port	HOM Power [W] in Each Cavity 1.5GHz	1.75GHz	1.75GHz	1.5GHz
FPC(1)	62	66	69	33
WG(1)	197	255	258	151
WG(1)	197	255	258	151
WG(2)	166	183	249	140
WG(2)	166	183	249	140
WG(2)	202	206	284	176
Warm parts	**Upstream**	**Downstream**		
Absorber*	273	367		
Pump. Dome	20	17		
BmP	54	143		
Total	5186 W = 4531 W (Ports) + 656 W (Absorbers)			

In Table 2 the HOM power distribution along the BESSY VSR cold string is presented. As can be seen the HOM powers at FPC end-groups of 1.5 cavities (located at both module ends) are significantly increased due to the beam interactions with warm components located outside of the module. While the powers at other end-groups are of the same level as for only SRF module (Table 1). The warm beam pipe absorbers are relaxing the SRF module power balance from addition warm component contributions. The calculations of the dissipated power in the absorbers [5] shows that main losses are located at the dielectric borders. Thus, the losses are sensitive with respect to the number of field-probes located near dielectric boundaries. In [5] a field extrapolation is employed for the loss evaluation and currently its consistency and convergence are under investigation. In Table 2 the absorber losses are obtained without any field extrapolation based on sparse field-probes located slightly far from the dielectric borders. This leads to lower power levels in comparison with [5]. More accurate simulation are foreseen with fine field-sampling in the dielectrics and significant increase of dissipated power between 1-2 kW is expected.

OUTLOOK

In this paper we have presented the results on ongoing studies on HOM power levels for BESSY VSR project. The stable machine operation requires HOM impedances not exceeding the threshold defined by the operating BESSY II feedback system [1]. Hence, the power levels for cold string different setups are under investigation. This is directly related to ongoing technical solutions / challenges of cold string design and integration into one of the straight sections of existing BESSY II storage ring.

REFERENCES

[1] A. Jankowiak, J. Knobloch *et al.*, Technical Design Study BESSY VSR, Helmholtz-Zentrum Berlin, 2015.

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-WEPML048

[2] A. Jankowiak, J. Knobloch *et al.*, "The BESSY VSR Project for Short X-Ray Pulse Production", in *Proc. of IPAC'16*, Busan, Korea, 2016, pp. 2833-2836.

[3] A. Velez *et al*, "HOM Damping Optimization Design Studies for BESSY VSR Cavities", in *Proceedings of IPAC'15*, Richmond, VA, USA, 2015, pp. 2774-2776.

[4] A. Velez *et al*, "SRF Developments for BESSY VSR", in *Proc. of IPAC'17*, Copenhagen, Denmark, May 2017, paper MOPVA053.

[5] T. Flisgen *et al.*, "Estimation of dielectric losses in the BESSY VSR Warm Beam Pipe Absorbers", presented at IPAC'18, **,** Vancouver, Canada, 2018, paper THPAF085.

[6] A. Tsakanian *et al*, "Study on HOM Power Levels in the BESSY VSR Module", in *Proc. of IPAC'17*, Copenhagen, Denmark, May 2017, paper MOPVA052.

[7] CST Studio Suite is a trademark of CST GmbH, Bad Nauheimer Str. 19, 64289 Darmstadt, Germany, `www.cst.com`

[8] H.-W. Glock *et al.,* "Design of the Beamline Elements in the BESSY VSR Cold String", presented at IPAC'18, Vancouver, Canada, 2018, paper THPMF033.

[9] E. Sharples, A. Velez, M. Dirsat, J. Knobloch, "Design of the High Power 1.5GHz Input Couplers for BESSY VSR", in *Proc. of IPAC'17*, Copenhagen, Denmark, May 2017, paper MOPVA051.