L-BAND ACCELERATOR SYSTEM IN INJECTOR LINAC FOR SuperKEKB

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Abstract

In order to improve the capture efficiency of the positron produced at the target in present KEKB Injector linac, a new project has just started to utilize L-band (1298MHz) RF. The present S-band (2856MHz) capture cavities and successive RF units are to be replaced by those of L-band. The specifications of the L-band system should fulfill the demands of a positron damping ring downstream which is also to be under study for SuperKEKB project. Besides the whole design work of the system, our present ongoing work is rather concentrated on establishing L-band RF source and accelerating structures.

NEW POSITRON SYSTEM

A new upgrade phase of KEK positron/electron Linac will start soon in order to fit our next project, SuperKEKB, in which we reconfigure the present KEKB accelerator complex into the ultimate luminosity frontier machine of the high energy electron (e-) and positron (e+) collider for B meson physics [1]. The life times of the stored beams in the collider rings are to be very short (typically several hundreds sec) since the beams are extremely squeezed at the interaction point. Thus KEK e+/e- Linac, the injector for superKEKB, should provide intense e- and e+ beams to compensate the rapidly exhausting beams in the rings. The Linac beams should have small emittances enough to be injected efficiently into the rings. To fulfill these requirements, we will employ a new RF Gun system for the e- beam while for the e+ beam we will prepare a new capture section to enhance its intensity and a damping ring to improve its emittance [2]. In the present paper the new capture section based on L-band RF is described.

Table 1: Positron beam Specifications

	Present	superKEKB
Charge/bunch at the target (nC)	1	4
Bunch / RF pulse	2	2
Emittannce normalized (m^{-1})	$2.1x10^{-3}$	$10x10^{-6}$
Rep rate (pps)	50	50
Energy(GeV)	3.5	4

Currently, the positrons are generated at the tungsten target located at sector 2 of Linac (with 4GeV primary e- beam of 10nC per bunch), collected and accelerated in the capture cavities downstream of the target to form an e+ bunch of 1nC. As shown in Table 1, we need to intensify the e+ beam by factor four. We expect the introduction of a stronger focussing magnet at the target can give us factor two and another factor two can be earned by enlarging the acceptance for positrons. A natural solution to do this is use of lower frequency capture cavities which have larger aperture and longer wavelength instead of the present S-band cavities. To be specific, we will use L-band cavities, whose frequency is 1298MHz.

The reason of choosing this particular frequency is a little intricated. Note that Linac uses three frequencies: 114MHz for SHB1, 571MHz for SHB2 and 2856MHz for the main linac respectively. These frequencies are from a single frequency f0=10.385MHz (The harmonic numbers are 11, 55=11×5 and 275=11×5×5 respectively.) The frequency of accelerating cavities in the collider rings is 508.9MHz (49th harmonic of f0). In principle, the multi-bunch acceleration and injection are possible if these bunches are separated by 96.3ns= 1/f0, and actually this is true for the positron beam in present Linac, where the e+beam consists of two bunches separated by the timing above.

These basic relations will be kept in SuperKEKB accelerator system also. In order to fit the capture cavities in this framework, one can choose the frequency of 1298MHz, 125th (=5×5×5) harmonic of f0. Thanks to these rational relations, the 2-bunch operation is still valid. Note that this frequency is very close to 1300MHz, which is the most popular frequency in L-band. We may share the established technologies or even purchase various devices which are commercially available.

PROPOSED L-BAND SYSTEM

The whole layout of the L-band system is shown in Fig.1. In the present design, it is supposed that four of the S-band units in sector 1 of Linac are replaced with those of L-band. (The number of replaced units depends on the detail study of the beam dynamics downstream of the target, however, it is detrmined at least two S-band units will be replaced into L-band as shown in Fig.1.) The first L-band unit consistes of two 2m long accelerating structures while other units by four of those. Between the target and the first strucuture, there is a strong solenoidal magnet to focus the positrons generated at the target. The structures of first two units are the travelling wave type immersed in the soelnoidal focussing magnetic field (~3kG). The target position is moved upstream from the present position in order to have a sufficient energy

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margin for e+ beam to 1.1GeV, which is the injection energy of the damping ring which will be located in the middle of Linac.

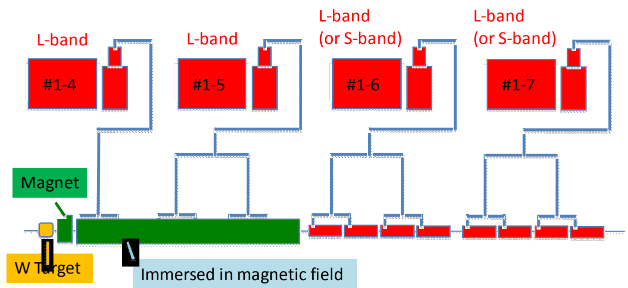

Figure 1: Layout of new positron capture section

RF distribution system

We adopted WR650 waveguide for the high power transmission (a=165mm, b= 82.6mm). Note that the typial power to be handled in our L-band system is a few tens MW peak with its pulsewidth being a few micro seconds. Thus those waveguides to transmit the high power should be kept in vacuum or filled with the gas such as SF6 to avoid electrical discharge. We have decided the whole system to be kept in vacuum.

One concern is that the weights of those system components: For example, one needs to use waveguides strong enough to sustain ambient atomospheric pressure. Suppose we use copper waveguides with 10mm thickness, their unit weight is about 50 kg /m. Cares should be paid in this respect since the weight of those components give some impact on the actual work for construction. We may use Aluminium alloy for some of the waveguides once we convince ourselves that they work fine under vacuum condition. We will do the gas emission test for a sample Al alloy waveguide.

There are some vacuum flanges commercially available for WR650. Among these, we will adopt MO Flange [3], MOF-650. The MO flanges are unisex. We have confirmed MOF-650 made from SS to be usable in our system.

Most of the RF components necessary for our project such as directional couplers, vacuum ports, dummy loads, or 3dB hybrids, are commercially available. We have ordered those components.

Accelerating structure

The electric design work for the regular section of the structure has almost done. The design parameters are listed in Table 2. It is a disk loaded 2m-long constant gradient travelling wave structure of 28 cells operated with $2\pi/3$ mode. The design work is focused now to the couplers based on the Kyhl method and TW simulation with HFSS. The preparation for its test fabrication has started. The whole structure will be made from OFC class1. To allow the insertion of solenoid magnet after the completion of the structure, the maximum transverse dimensions of the structure are specified to be within 350mm in diameter around the beam axis.

Table 2: Accelerating structure Design parameters

Freqeuency	1298 MHz
Input power	15 MW
Gradient	12 MV/m
2a	39.4 ~ 35.0 mm
t	10 mm
vg/c	0.61-0.39 %
Filling time	1.32 μs
Attenuation	0.261
Q	~20000
Length	2 m

Klystron

There is no commercial klystron to fit perfectly with our required specifications. We ordered to constract a new L-band klystron baced on a 40MW S-band klystron (2856MHz) in such a way that we share its gun design while the RF circuits are newly designed. This brings us advantages not only to save the design effort of the klystron but we need not to modify the modulator which supplies the pulsed power to the klystron. The whole length of the L-band klystron will be slightly increased to fit the lower operating frequency. One needs to optimize the solenoidal focussing field and a new magnet will be prepared. The desgin work for the klystron is its final stage and its delivery will be in the end of this August.

Table 3: Klystron

Freqeuency	1298 MHz
Output power	40 MW
Pulse width	4 μs
Rep rate	50 pps
Gain	>50 dB
Efficiency	>40 %
Cathode Voltage	350 kV
Perveance	2 μP

LLRF

It is simply supposed that LLRF for our L-band system should be as stable as S-band system and it can be. There is no further requirement on LLRF in our system. However, in order to handle the L-band RF signals in more sophisticated way, we have a plan to introduce a compact LLRF unit based on IQ modulator/demodulator with an FPGA controller instead of our traditional IϕA module. See Fig.2. This new unit handles the RF signal for a driver amplifier (600W solid state amplifier) as well as the monitor signals from the klystron output for the interlock (VSWR) and feedback.

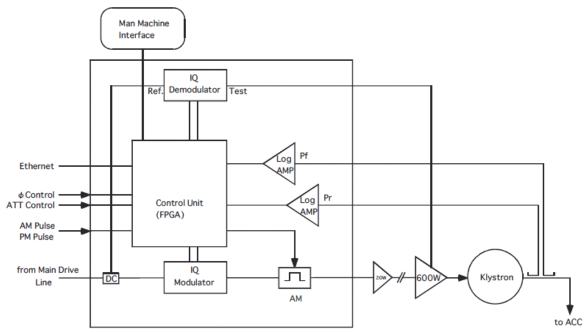

Figure 2: Diagram of a proposed compact LLRF unit for KEKB Injector L-band RF

Vacuum

Design work on the vacuum system is ongoing. The volume, the sureface area and the vacuum conductance are the primary parameters for the design. Those numbers of WR650 waveguide and the accelerator structure are shown in Table 4. From these numbers, we can sketch the L-band vacuum system. For example, the coupler of the accelerating structure is known as the most vulnerable to RF breakdowns therefore it is critical for stable operations to lower the pressure around the coupler as much as possible. If we assume the gas emission rate from the accelerator structure or the waveguides is lower to be some 2×10^{-8} $Pa\ m^3/s/m^2$, we need more than 50 litters/s evacuation at the coupler area in order to maintain the pressure below 2×10^{-6} Pa.

Table 4: Area, Volume and Conductance

WR650 Waveguide (unit length)	Surface Area	$0.50m^2$
	Volume	$0.014m^3$
	Conductance	270 L/s
Accelerator Structure (2m long)	Surface Area	$1.9m^2$
	Volume	$0.05\ m^3$
	Conductance	3 L/s

The gas emission rates from the surfaces are the fundamental data for the vacuum design. Since the surface area per unit length of L-band components is about twice of that of S-band, it is preferable to lower the gas emission from the surface. The rate from Aluminum alloy surface will be available soon and we can actually start to design the detail configuration of the pumps to meet the vacuum requirements.

TEST PLAN

The whole devices and components will be tested before they are assembled to be the L-band capture section of Linac. In this JFY2010, we will have the delivery of the 40MW klystron, the 12MV/m – 2m accelerating structure and whole components necessary to construct a half unit (includes one accelrator structure) of the accelerator. The test of the klystron will be done in this autumn at Klystron Test Hall. We will check its performance and if it is sucessful, we are going to do the high power testing of RF components such as a dry RF load using the power provided by this klystron.

The accelerating structure will be delivered in January next year 2011. One accelrator unit will be constructed with this structure. The L-band klystron will be moved to the sector 1-4 connected to the modulator and a new transmission line will be constructed to the acclerator structure which will be set in KEKB Linac tunnel. Its high power test will be done in two stages: in the first stage, the test will be done for the structure alone and in the second it is with the focussing magnetic field (the structure will be immersed in the focussing field) to check whether the application of the field induces additional breakdown events in the structure.

CONCLUSION

Most of the specifications of the e+ beam in Linac are considered to be already fixed and work for a new L-band accelerator system for the positron capture section in Linac has started. The key devices such as klystron and accelerating structure are now under their fabrication stage. Other components needed to form a power transmission line and various RF components are already ordered. Those devises and components will be assembled for the klystron power test. The test will be done in this autumn.

The construction of the first half RF unit of the accelerator will be done within this JFY2010 and high power testing of the accelerating structure will be done in next year 2011.

REFERENCES

[1] M. Masuzawa, "Next Generation B-factories", these proceedings.
[2] T. Sugimura, "The Linac Upgrade Plan for SuperKEKB", these proceedings.
[3] http://mo-ohtsuka.co.jp/moflange/index.html