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NEW APPROACH TO THE DESIGN OF A SC LINEAR COLLIDER (II)
RF Power Input and Filling

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Abstract

We continue exploration for the possibility of increase of the repetition rate for the Next Linear Collider with SC structures operating at ~3*GHz*, simultaneously while decreasing the bunch train length. Here we propose a new input for RF power into the accelerating structure. Two-klystron scheme for RF feeding is also introduced.

INTRODUCTION

In our previous publication [1] we analyzed the possibility to move the Next Linear Collider SC accelerator structure into regime with increased repetition rate with shortening the bunch train length at the same time. This was forced by desire to make the perimeter of the cooler shorter. We also suggested ~3 *GHz* as a basic operational frequency band. Operation with 3 *GHz* allows to have bunches running closer, so the power carried out by the beam increased by the same proportion. This allows stronger coupling between structure and the RF power feeding line so that filling time can be cut. Efficiency of using RF power that is defined as

$$Eff \cong \frac{Beam\ time}{Beam\ time + Filling\ time},$$

can be kept at least the same while the beam duty is cut in the same proportion. If repetition rate is increased, then the same luminosity can be achieved here. As a result, the bunch train length can be made shorter and, hence, a more compact damping ring can be used here.

The main desire of this consideration is to make the SC linac more reliable, cheap and well defined from an engineering point of view. Keeping in mind that lots of modeling is required for elements, so shorter wavelengths allows much cheaper fabrication and handling of RF hardware. Due to this, more variants can be tested. Practically all Laboratories have equipment for operations with 10-*cm* wavelengths.

Analyzing materials published in literature, we came to conclusion that shorter wavelengths allow higher accelerating gradients. An important parameter here is the ratio between the frequency of RF, rate of electron-electron collisions and the length of coherence. All this is in favor of shorter wavelengths. Here we continue our considerations, concentrating our attention toward technical details.

FREQUENCY

The operational frequency of choice is the main topic of LC considerations since the earlier days of linear collider activity. Although the reasons for the choice of 1.3 *GHz* are well described by TESLA team, we have revisited this topic for better understanding of the situation.

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[1] Electronic version is available at http://www.lns.cornell.edu/public/CBN/2004/CBN04-8/CBN 04-8.pdf .Work supported by NSF.

It is clear that for the fixed electric field value along the gap $h\sim\lambda/2$, energy stored in each cavity is proportional to the volume of cavity. This is

$$W = \tfrac{1}{2}\mu_0 \int_V \left|\vec{H}\right|^2 dV \propto \lambda^2 h \propto \lambda^3 \cdot M \propto \lambda^2 L\,, \tag{1}$$

μ_0 –is magnetic permeability of vacuum, $\lambda = c/f$ –wavelength, f–frequency, c –speed of light, M –is number of cavities per structure, L –is total length of structure. This moves anyone to have RF frequency as high as possible; VLEPP, next CLIC. This tendency must be convoluted, however, with the difficulty to obtain RF power required and tolerances, which are typically increasing with the frequency.

As far as operation of SC cavities, the surface impedance of superconductors are growing with frequency as a square, $R_s \propto f^2/T \exp(-1.76T_c/T) \propto 1/\lambda^2$, where T_c stands for critical temperature; BCS theory[2]. This fact is now treated as a strong argument in a favor of 1.3 *GHz*.

However, as the surface area S itself is decreasing in reversed proportions, absolute losses in *single* cavity P_{cell} do not depend on frequency at all. Really,

$$P_{cell} = \tfrac{1}{2} R_s \int_S \left|\vec{n}\times\vec{H}\right|^2 d\sigma \propto \frac{Const}{\lambda^2}\lambda^2 = Const\,, \tag{2}$$

where $\vec{n}$ is unit vector normal to the surface, *Const* –is a constant, integration is going over the surface of cell. So the total losses per structure are going to be $P = M \times P_{cell} \propto M$. Thus, the drop of quality factor in one cell $Q_0 = 2\pi W f / P_{cell} \propto \lambda^2$ is not a matter of greater losses, but caused by a reduction of stored energy. *This is a very important nuance here.* So by comparison, Q_0 is not the appropriate procedure here. We made comparisons of losses for fixed numbers of cavities. If the length of accelerator is fixed, then dissipating the power is growing $\sim M \propto L/\lambda$ –simply more cavities having higher frequency can be positioned inside the same longitudinal space. We expect, however, that for higher frequency, the accelerating gradient achieved is also higher, see below. Also, as the frequency is higher, HOM are evacuating faster in the same proportion allowing more dense filling by bunches. All this allows stronger structure coupling with the input line as $1/Q_{ext} \cong 1/Q_0 + 1/Q_{beam}$, where Q_{ext} –is a quality factor associated with loading by input system, $Q_{beam} = 2\pi f W / P_{beam}$ –associated with beam loading and P_{beam} –is a power, carried out by the beam. The power of the klystron available at $\lambda \sim 10cm$ is far beyond required for the beam loading compensation (acceleration).

The quality factor itself is important for keeping absolute losses low. Really, energy dissipated in the walls of a single SC cavity goes to be

$$P_s = \frac{2\pi f W}{Q_0} \cong \frac{\pi f \varepsilon_0 \int_V \left|\vec{E}\right|^2 dV}{Q_0} \approx \pi f \frac{\varepsilon_0 E_0^2 \lambda^2}{2Q_0} \propto Const\,, \tag{3}$$

as it is the same as defined in (2), but now we can take Q_0 known from experiment. If the length of accelerator is fixed, then $P_{tot} = P_s \times M \cong P_s \cdot L/\lambda$, i.e. total power dissipated in all structures is inversely proportional to the wavelength. For estimations, let us take E_0=30 *MV/m*, $\lambda = 0.1m$, h=0.05m, $Q_0 \cong 5\cdot 10^9$, then energy stored in one cell, M=1 becomes $W \cong 5J$, and peak power dissipated is $P_s \cong 20W$. If duty time is $\tau \cong 0.3ms$ for f_{rep}=30 *Hz*, then the average power dissipated

[2] For Niobium resistance at 1.3 GHz goes to be ~800nΩ at 4.2°K and goes ~15nΩ for 2°K.

by that cell becomes $\overline{P} \cong 0.2W$. For 1.3 *GHz*, $Q_0 \cong 1\cdot 10^{10}$, $P_s \cong 80W$, and taking into account that $\tau \cong 1ms$, f_{rep}=5 *Hz* the last number goes to ~0.4*W*. Even structures having the same length, the losses for 3 *GHz* will be ~ same.

So again, our desire is to make filling time shorter. In absence of the beam this is possible only if coupling is made stronger or just by extensive feeding by boosted power. As the structure with shorter wavelengths has lower stored energy $\sim \lambda^2$, then it becomes possible to fill it faster, with lower energy spend. In case of a sparking event, less energy will be deposited in material of the structure. As an effective quality factor of the structure, it is defined by the energy carried out by the beam[3] and the value of quality factor Q_0 itself becomes less important, when duty time is decreased. Remember, NLC –a room temperature machine has ~ same overall power dissipation as TESLA.

So, RF heat load *per structure* is not a function of wavelengths. Indeed, the heat losses might become smaller as a result of lowering the surface area of cold mass $\sim 1/\lambda^2$, despite the area of surface cells is higher for shorter wavelength, when the total length is fixed. This is due to an engineering realization of cold mass surface as a cylinder with a radius $\sim \lambda$. This outer tank cylinder covers all SC wiggling surface. Also, heat load can be lowered a by reduction in the cross section of the suspension/support system as the weight of cold mass is decreased and, of course, by decreasing the dimensions of power transferring lines, such as waveguide or coaxial line. Cryostat for a 3 *GHz* structure can be made more compact, with significant reductions of heat losses. Thus cryogenic equipment will be more compact as well. Altogether, with availability of RF equipment, this makes shorter wavelengths preferable because it makes this project much cheaper in cost.

One other peculiarity associated with SC RF is that the limiting factor here is not the electric field strength, but *magnetic* field value at the surface. This is due to the fact that magnetic field penetrates the material and induces oscillations of electrons, which are not bound as Cooper pairs. However, one can see that peak magnetic field value is not a function of frequency, if the accelerating gradient is fixed. The easiest way to illustrate this is a pillbox cavity operating with *E*-mode(s). Really, electric field dependence

$$E_z = E_0 J_0\left(\frac{\lambda_i r}{R}\right) e^{-i\omega t}, \tag{4}$$

where J_0–is Bessel function, $\lambda_i = 2.405,...$ are it's roots, *R* stands for the radius of cavity, together with Maxwell's equation $rot\vec{E} = -\partial\vec{B}/\partial t$, yields $\frac{\partial E_z}{\partial r} = E_0 \frac{\lambda_i}{R} J_0'\left(\frac{\lambda_i r}{R}\right) = i\omega B_\varphi$ and taking into account, that $\omega = \lambda_i c / R$, one can obtain

$$H_\varphi = i\sqrt{\frac{\varepsilon_0}{\mu_0}} E_0 J_1\left(\frac{\lambda_i r}{R}\right) e^{-i\omega t}, \tag{5}$$

not dependant on ω. Here, ε_0–is a dielectric permittivity of a vacuum, $J_1(x) = -J_0'(x)$. One can see that from here, by changing the radius, it changes the resonant frequency of cavity $\omega = 2.405c/R$. If, however, the accelerating electric field along the cavity is fixed, then for the same ratio *r/R,* the value of the magnetic field is the same, not dependant on the frequency. For example, on cylindrical walls, the magnetic field value becomes

$$|H_\varphi| = \frac{1}{120\pi[\Omega]} E_0 J_1(2.405). \tag{6}$$

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[3] Keeping in mind that the duty time is much less than the time associated with quality factor; $\tau = Q\lambda/c$ which is $\tau = 10^9 \cdot 10/3\cdot 10^{10}$~0.3 seconds for wavelength $\lambda = 10cm$ and Q_0=10^9, meanwhile loaded Q_{ext}=3 10^6 for TESLA.

For the pillbox cavity, the maximum magnetic field value is reached at slightly smaller radii at the top and bottom sides.

It is interesting that in reference [2] on pages 284-285, a comparison between achieved and expected values of RF fields for two frequencies 3*GHz* and 1.3*GHz* is represented. It is clearly seen from there that high voltage expectations for 3 *GHz* RF is much higher than that for 1.3 *GHz*. For 3 *GHz* single cell cavity graph shows that ~40% cavities will reach ~55 *MV/m*, while for 1.5 *GHz* 5-cell cavity the same 40% of cavities will reach ~20.5 *MV/m* only. This comparison is made by simulations and by experiments. This important item remained without undergoing further discussion, however. One brief reference given stays that with lowering wavelength, the area of cavity is lowering; hence the number of possible emitters on it is lowering too. So this is another item in a favor of short wavelength.

In Ph.D. thesis [3] published at Cornell in 1993, a RF cavity operating at 2856 MHz was investigated. Besides promising the results announced, E_{peak} =113 *MV/m* (H_{peak}=1600Oe[4]), author spent only 9 days total (!) to carry out all set of experiments as shown in [3]. It is clear that technology of preparing the cavity has greatly improved since that time. The testing scheme could also be improved.

I concluded that a structure operating with ~3 *GHz* has indubitable advantages compared to 1.3*GHz*. Thus there is strict indication for the revision of a frequency band suitable for SC LC towards 3 *GHz*.

RF INPUT

A structure of our interest is shown schematically in Fig. 1 below. The number of cavities in this structure and its shape is not fixed at the moment. We can now say that the shape is optimized to reduce the magnetic field value at the surface, making the cavity look closer to Ω, than the TESLA profile. What is important here is that at the left side in Fig.1, the diameter of the tube is chosen so that the transverse mode can propagate inside, i.e. its diameter $D \geq D_{cr} = \lambda_{tr}/1.81$, where $\lambda_{tr} = cf_{tr}$ and f_{tr} stands for the frequency of the transverse mode in the structure. Our intentions are to make the power input from this side *together* with the extraction of HOM. One peculiarity that might be important here is that transverse mode E_{11} typically has a group velocity directed oppositely to E_{10}, which can be tuned to the necessary one. In any case, for a standing wave structure this is less important.

Once again, we would like to have stronger coupling between structure and power lines. We could see the structure with higher frequency has lowered quality factor Q_0, so this is in favor of this desire. Stronger coupling allows shorter filling time and more effective evacuation of high order modes. We suggest a waveguide-type coupling for these purposes.

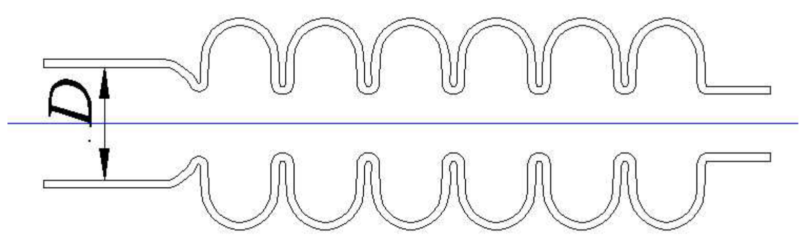

Figure 1: RF structure. Left tube diameter is greatly increased, so it is open for a transverse mode. At the left side, diameter is lowed slowly at some distance.

[4] While limiting superheating field for Niobium ~2000Oe.

First, let us say that coupling with a coaxial coupler looking to the beam and further transferring to a waveguide, Fig. 2, *is unacceptable* from our point of view. The reason for this is the following: Looking to the beam, a coaxial coupler acquires fields with spectrums starting from a frequency of zero. This coaxial line transfers to a waveguide at some distance outside of cryostat, see Fig.2. The waveguide has limited spectral transparency, however, starting from the cut-off frequency $\omega_c \cong \pi c / a$, where a stands for the width of waveguide.

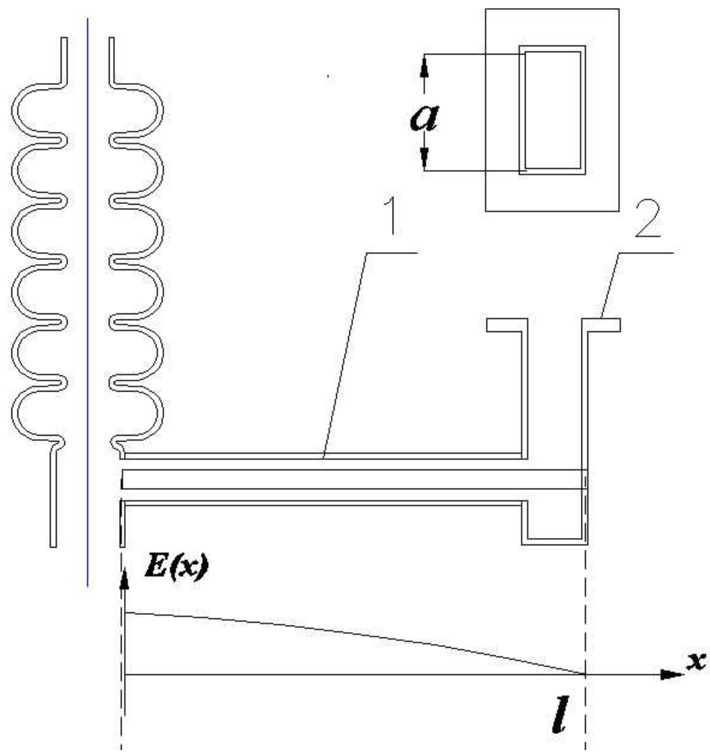

Figure 2: Field distribution along coaxial input line 1 coupled to a waveguide 2 for the lowest resonant wavelength. Waves with theirs wavelengths between ~4l and 2a are trapped.

This means that part of the transmission line between the orifice looking to the beam and the coax-waveguide transition can trap RF waves with a spectrum within the bandwidth $\{0 - \pi c / a\}$. So the standing waves have a lower harmonic with the wavelength $\lambda_s \cong 4l$, where l – is the distance from the tip of the coaxial coupler to the transition. The previous reflects the fact that the lowest wavelength of a standing wave has a ~zero electric field value at the transition and ~maximum at the end of the line, looking to the beam. As a result, the lowest frequency comes in mostly practical cases to λ_s=4l~5 *m,* which corresponds to $f \cong c / \lambda_s$~60 *MHz* or even lower (end capacitor-type lips, ceramics, diameter variations, etc., make this threshold wavelength lower). In this situation, we will be lucky if the beam spectrum will be not within the forest of resonance peaks standing with 60*MHz* within one another. Although 60 *MHz* is a big number compared to the bandwidth of the SC structure, this can cause additional problems, especially for machine is operating in DC mode. At least this will introduce an additional variable and it will be necessary to take it into account while changing the coupling. In one scenario, two symmetrical couplers make a situation even more complicated as this, their resonant lines are inter-coupled, what causes the spectrum to be split in half. One can see now why this type of coupling could not be recommended. Again this might be unacceptable for a SC accelerator operating in a continuous mode, such as a recuperation linac, storage ring and so on.

Now let's switch to a brief analysis of more preferable couplers. We begin to consider a coupling between waveguide and the structure starting from the one arranged in a typical way, as it is shown in Fig.3.

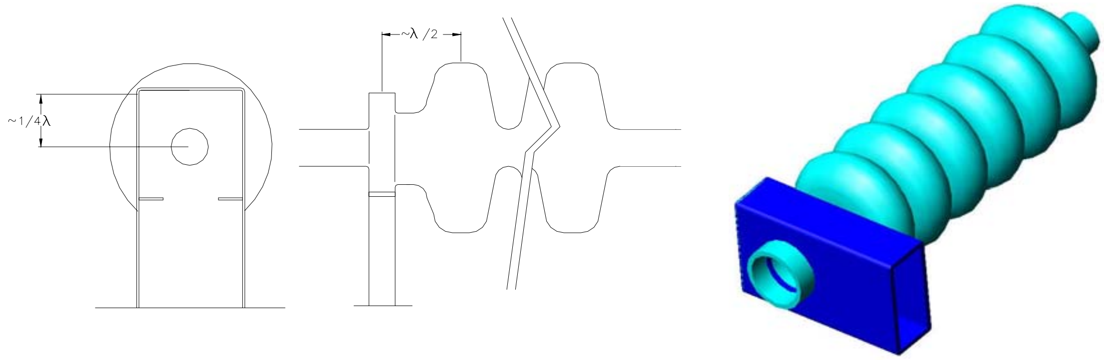

Figure 3: Simplest wave guide-type coupler.

This type looks good, however it introduces asymmetric action to the beam from the input side as the mode with fundamental frequency has significant distortion in the region of input[5]. Usually at room temperature cavities operating in storage rings, the input coupler is located far from the beam, so higher spatial harmonics with the main frequency degrading exponentially to the center of the cavity. This is not so for the SC cavity, where the coupler is located much closer to the beam than to the main structure. One other modification of this approach might be a coupler with an intermediate cavity, Fig. 4. The idea here is to screen the input hole from the beam by a reduction in the height of the cavity.

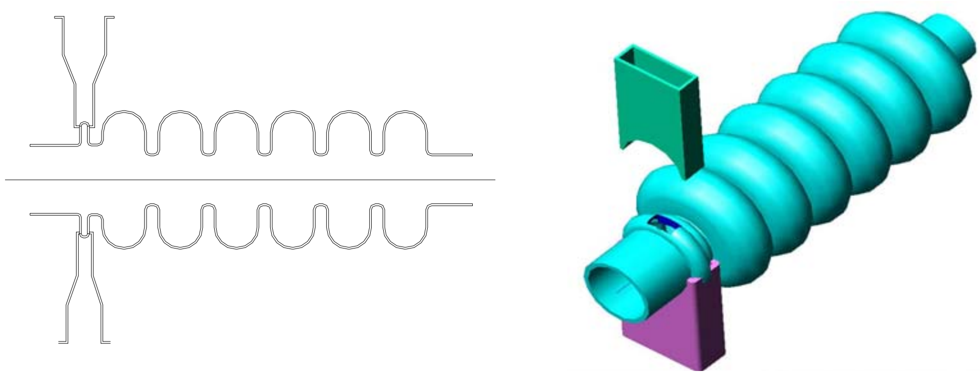

Figure 4: Coupling with the help of slot-cavity, which looks like local diameter's extension. This cavity has a fundamental frequency much higher than the main structure has.

As the frequency is much higher, than the main one, the RF phase in it is shifted 180° with respect to input one.

Action to the beam can be estimated by the following: if the cavity is coupled optimally, then there is no reflection from the input coupler and the effective current I running in transmission line is defined by $I = \sqrt{P/Z}$, where P stands for transmitting power and Z for effective impedance. As there is no reflection in the matched case, we can take this current as a reference for the one running through the loop at the end of the coupler (real current or displacement current). The magnetic field could be estimated as $H \cong I/d$, where d—is a characteristic size, typically the size of tube, d~D in Fig. 1. The field integral could be estimated as

[5] We mentioned this in the internal note distributed around Cornell Laboratory on June 20, 2000.

$$\int Hdl \approx \int \sqrt{\frac{P}{Z}} \times \frac{1}{D} dl \cong \sqrt{\frac{P}{Z}}\,. \tag{7}$$

For the kick difference across the bunch we have the estimation

$$y' \cong \frac{\sqrt{\varepsilon\beta}}{D} \frac{\int Hdl}{(HR)} = \frac{\sqrt{\varepsilon\beta}}{D} \frac{\sqrt{P/Z}}{(HR)}, \tag{8}$$

where factor $\sqrt{\varepsilon\beta}/D$ is the ratio of the beam size at the place where the coupler is located to the tube diameter, ε –stands for emittance, β –for envelope function, (HR)–is magnetic rigidity of the particles. This factor represents the gradient of the field at the beam size distance. So perturbation of emittance $\Delta\varepsilon \cong \beta \cdot y'^2$ goes to be

$$\frac{\Delta\varepsilon}{\varepsilon} \cong \frac{\beta^2}{D^2} \cdot \frac{P}{Z} \cdot \frac{1}{(HR)^2} \quad \left[= (0.4\pi)^2 \frac{\beta^2}{D^2} \cdot \frac{P[W]}{Z[Ohm]} \cdot \frac{(300)^2 \cdot 10^{-18}}{(pc[GeV])^2} \right], \tag{9}$$

where we have represented this formula in practical units at the right, and we used definition of magnetic rigidity $pc[eV] = 300(HR)[G \cdot cm]$. Substitute here for estimation P=100kW=$10^5 W$, Z=100 Ohm, $\beta = 20m$ D=0.05m, pc=10 GeV, one can obtain from (9) $\Delta\varepsilon/\varepsilon \cong 2.5 \cdot 10^{-7}/pass$. Although this number is not big, the coherent kick to the bunch itself goes to be $D/\sqrt{\varepsilon\beta}$ times bigger, than the kick across the bunch. So (8) yields $y' \cong \sqrt{P/Z}/(HR)$, $y' \cong 1.2 \cdot 10^{-6}$ *rad/pass*. This angle requires attention.

The importance of this kick for a room temperature linear collider, where the input power is much higher, was recognized a long time ago. Moscow team investigated excitation with help from two input holes, see Ref. in [4]. This input type increases symmetry from a dipole to a quadrupole type. S-band linear collider, developed at DESY, has had this type of coupler. *We fulfilled this coupler to a magic T-bridge*. A sketch of this type of coupler is shown in Fig.4. It has the advantage in the evacuation of dipole mode right in this region. This type of coupling has the dimension in direction along the structure defined by a narrow wall. A coupler of this type couples the magnetic field inside the waveguide and the magnetic field from a fundamental mode. So in the region where the hole is located, the magnetic field increase might be problematic as it moves the superconductor closer to the limit.

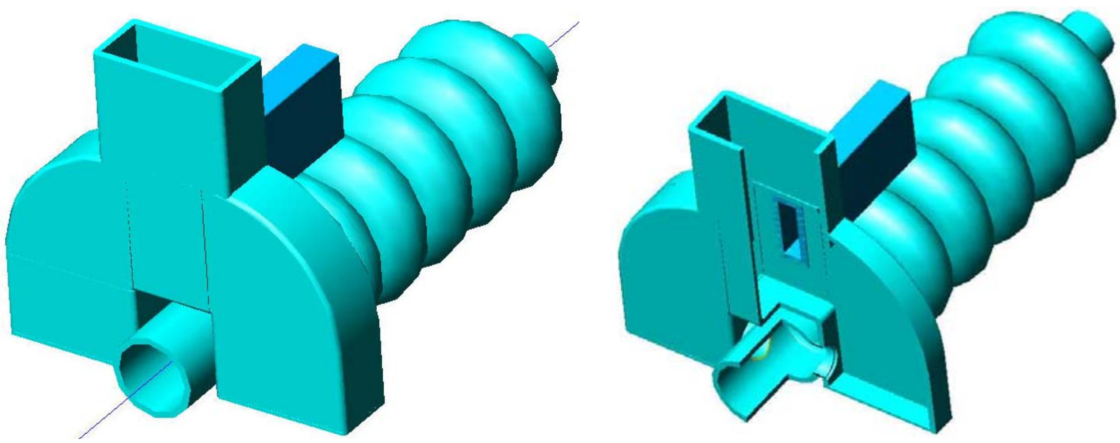

Figure 5: Inductive coupling with magic-T. Smaller waveguide evacuates dipole-type HOMs.

Waveguide for evacuation of HOM made with reduced width, so this helps to prevent leakage of RF power there. High order modes, having higher frequency, escape through this waveguide without reflection. These types of couplings are magnetic ones, which have an increased magnetic field value at the orifice. Electrical field $\vec{E}$ is necessary to support energy flow $\vec{S} \cong \vec{E} \times \vec{H}$ could be considered as a secondary agent as it is defined by magnetic field, or more exactly by an interruption of currents, supported by a magnetic field in a wall. So *it could not be recommended* for high power input, as SC is restricted by magnetic field strength. A coupler with coaxial line looking to the beam is a capacitive coupler as it is coupled to electric field. So we have the desire to couple our structure with a waveguide coupler, but through the electrical field. One solution is represented in Fig.6 below.

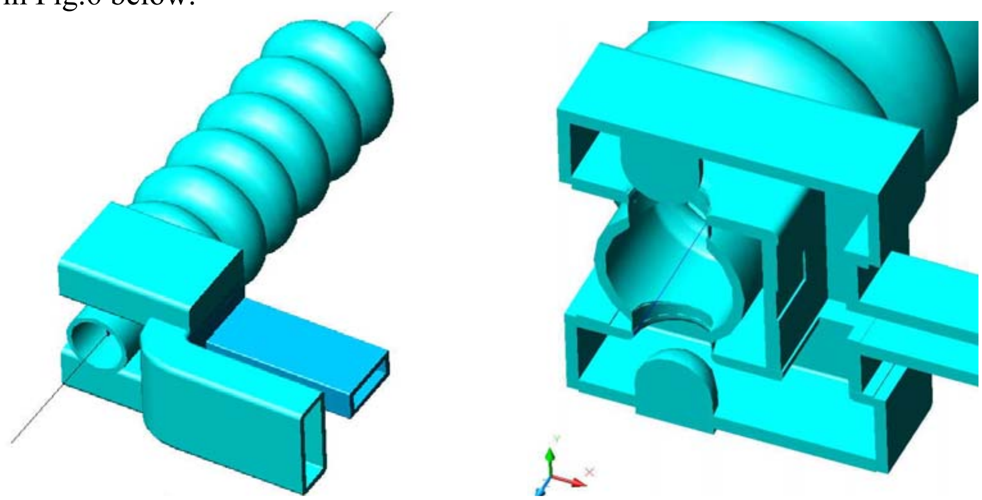

Figure 6: Capacitive coupling with magic-T. Smaller waveguide evacuates dipole-type HOMs. At the right –scaled cut across the input region is represented.

A waveguide can be transferred into a coaxial line at some distance. Now this can be done as attenuation will be enough to block resonant modes of the coaxial line from orifices looking to the beam. This coaxial line can be recommended only for heat flow reduction. For 10-cm wavelength rectangular waveguide gives comparable heat losses however. Also, a coaxial type can be used for

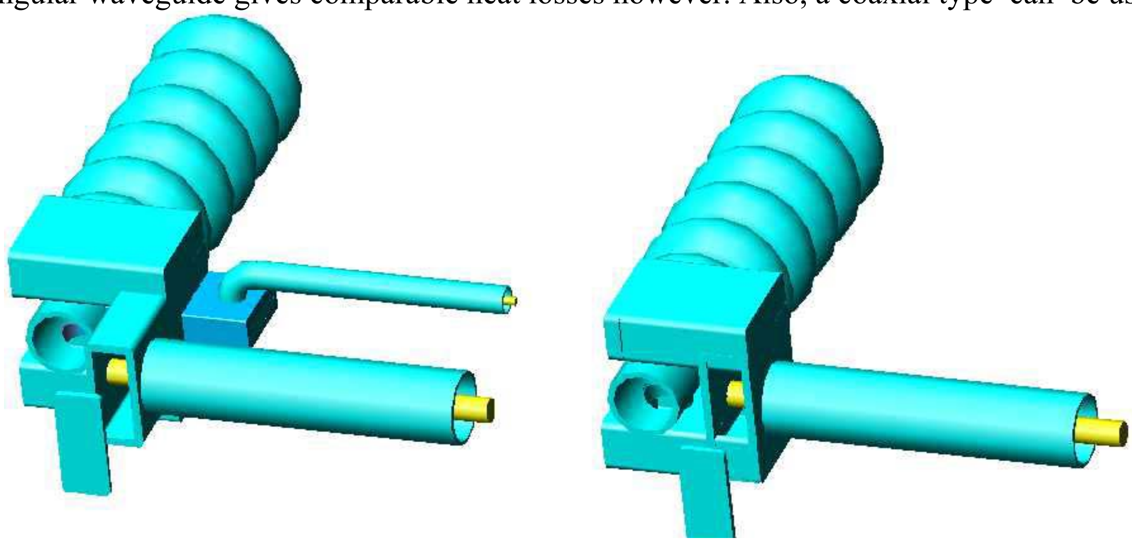

Figure 7: Transferring to a coaxial line. At the right –coaxial shifted so that it coupled to the transverse mode. Shown with cover removed.

evacuation of higher order modes and rectangular waveguide –for main input in the same structure. This type of coupling allows high input power and symmetrical input together with good coupling with higher order modes. Spatial orientation shown in Figs. 6, 7 allows efficient extraction dipole mode with vertical polarization. Namely this polarization is responsible for the dilution of vertical emittance. Mode with rectangular polarization can be extracted by breaking symmetry. These types of devices are well known in RF engineering.

A coupling is defined by the diameter of holes and by the height of the cylinders, together with the overall configuration of the coupling unit. The coupling can be trimmed by changing the height and configuration of the cylinders, Fig.8. As we suggest to over couple waveguide and structure, this will make this problem less important. In other words, we are not planning to tune the coupling much. This will be done once. For these purposes height can be changed or if these cylinders are made as bellows, so there will be no sliding contacts.

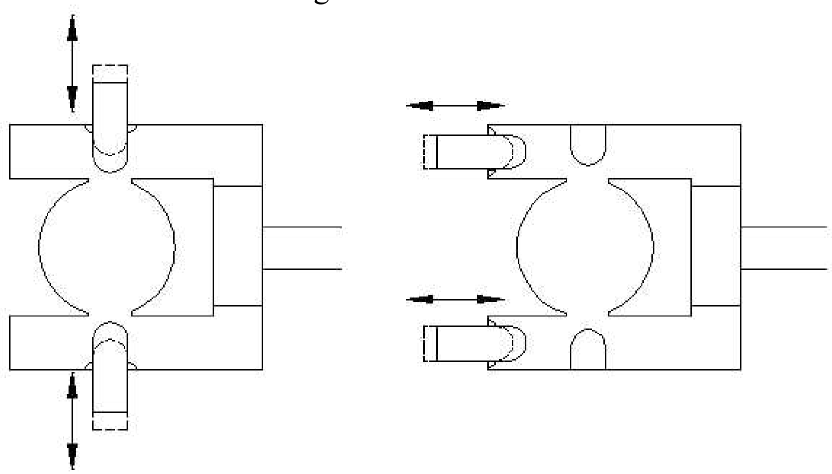

Figure 8: Changing of the coupling by variation of height of coupling cylinders, left. At right, such trimming is done by changing the back wall position.

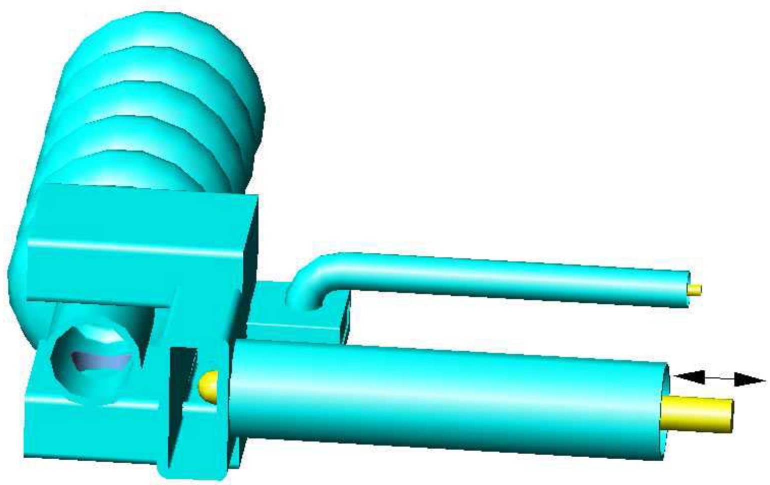

Figure 9: Tunable device with intermediate resonant circuit, which includes magic T and coaxial RF input with movable central conductor.

The device represented in Figure 9 is basically the same as in Fig.7, however, here the central electrode does not touch the wall. So the magic T and the fraction of a waveguide serve as intermediate resonator. As the coaxial is now separated by the waveguide, there is no direct coupling between the beam lower order modes and the modes which are trapped in the coaxial line. The same idea can be applied to the coupling represented if Fig. 7 at right.

In small limits coupling can be tuned by deformation of a wall. More powerful tuning is to change the resonant frequency of the structure.

It will be not a problem to optimize this input with RF codes available on market now in broad variety. This will be done in separate publication.

We conclude this paragraph with suggestions for the coupler shown in Fig.6 serve as a base model.

FILLING RF POWER PATTERN

In the TESLA scheme the coupling is adjusted so that in presence of the beam the electrical field strength kept flat. To do this $Q_{ext} \cong 3 \cdot 10^6$ has been chosen. This is about 2000 times lower than unloaded Q_0. The period of RF for 1.3 *GHz* is $T_0 = 1/f \cong 0.769ns$, so $Q_{ext}T_0 \cong 2.3ms$. The filling time chosen T_{fill}=530 μs, beam acceleration time T_{beam}=800 μs, RF pulse duration $T_{RF} = T_{fill} + T_{beam}$=1330 μs yields efficiency of usage RF as

$$Eff = \frac{T_{beam}}{T_{RF}} = \frac{800}{1330} \cong 60\%.$$

Our strategy announced in [1] was associated with shortening T_{fill} and T_{beam} in the same or better proportion, to make the bunch train shorter while efficiency is kept the same. Shorter accelerator wavelengths help in this. Luminosity was kept the same by increasing the repetition rate in the same proportion. This procedure allows having more compact damping ring in first place, and, more important, makes the accelerator cheaper. In addition, this strategy does not require a fast kicker as a key element. It could be considered as a complementary element. A more compact damping ring allows having damping time required by radiation in magnets only without any wiggler [5]. Namely this will pave the road to a low emittance injection system.

Coming back to the TESLA design, with Q_{ext} chosen, the structure has no RF reflections with the beam. Namely this makes filling time longer, as during filling there is no beam and, hence, the reflections persist. Power from the klystron is constant during the time starting from the filling to the end of the beam.

With the increasing frequency of a main structure from 1.3 to ~3*GHz*, the quality factor drops naturally to ~1/8 of its value at 1.3 *GHz*, just as the fact that stored energy dropped.

So in principle one can consider the time sequence for bunches in the train few times more condensed[6]. Also as the beam defines the main loading here, so $1/Q_{ext} \cong 1/Q_0 + 1/Q_{beam}$, then increasing current is the desirable action. It is not necessary to increase the charge in each individual bunch; the way to do this in making more bunches in the train with reduced distance between them. This will allow the coupling to increase. In turn this will help in the wake field evacuation.

One can see, while stronger coupling helps in shortening the rise time is structure, and reflections will disappear, when beam appears in structure. If the coupling chosen is even stronger, then reflections will persist while the beam is in the cavity and the field level will have no flat top. To avoid this one needs to manipulate the RF input power.

There is a way for shortening filling time even more radically. Let us consider the power pattern as it is shown in Fig. 9. Here the first power burst serves for fast filling.

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[6] Remember, in S-band DESY project the bunch spacing was 6ns only with total number of bunches per pulse -333.

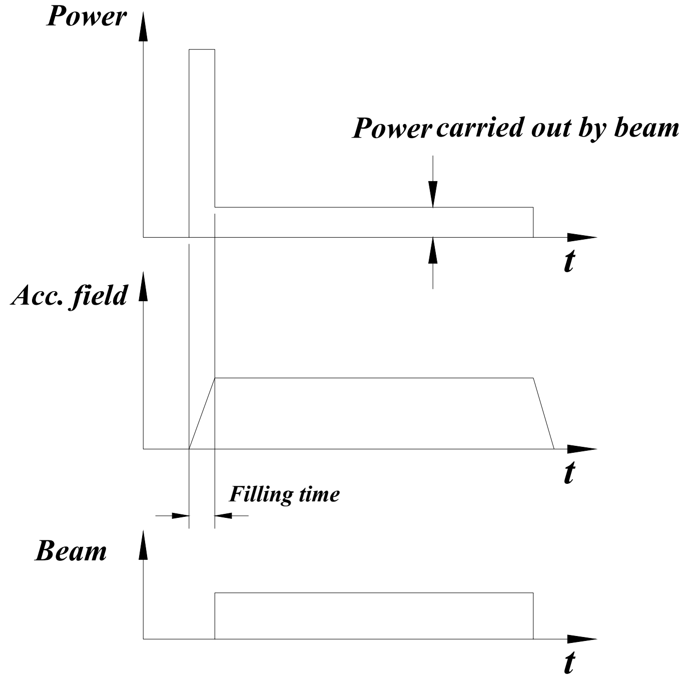

Figure 9: Pattern of power, accelerating field in structure and beam current.

Efficiency of power generation with such a time pattern cannot be high with only one klystron used: the klystron beam is still running with full current and voltage. As manipulation with voltage and current simultaneously is not an easy task, we suggest usage of *two klystrons*, Fig. 10. The first one is a short-pulsed powerful one and the second one is a longer duty with power, just required to feed the accelerated beam. So the first klystron pumps the accelerating structure at reduced time, defined by geometrical coupling. In this scheme, in contrast with the only one used at TESLA.

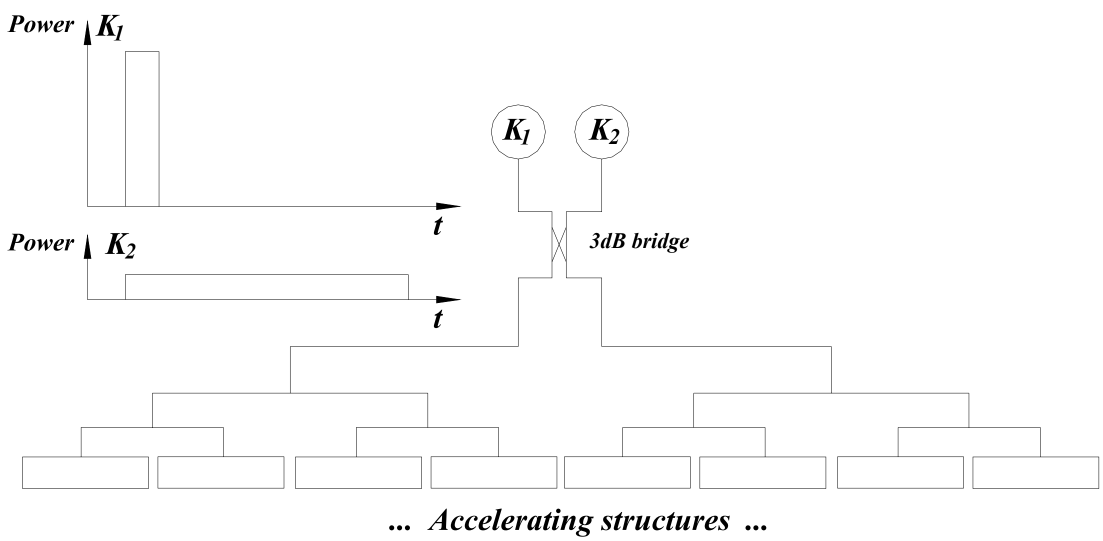

Figure 10: Two-klystron scheme for RF power feeding.

As the 3dB bridge supports opposite phases in its two outputs, the RF phases of these two klystrons made opposite for proper RG output phasing.

CONCLUSIONS

The goal of our consideration announced in [1] –the beam train length reduction obtains more fundamental support while analyzing detailed input schemes. Again, a 3 *GHz* band looks much more preferable for a SC linear collider, than a 1.3 *GHz* one, especially in view of higher gradient achievable. So the train length is decreasing, allowing the damping ring with a moderate perimeter. And this is due not to the shortening of kicker rise time, but by shortening the train length.

The RF feeding scheme proposed allows effective operation of the SC structure with increased repetition rate at 3 *GHz*. It makes possible adjust independently the power feeding the beam and the power used to fill the structure to the level required. A two-klystron scheme makes RF efficiency high. An additional klystron and a 3*dB* bridge make the operation of an accelerator with different currents more flexible. This might be true even for feedback purposes. Other solutions include a multi-ray grided-cathode klystron, so the grid locks independently few mini-cathodes[7]. Until the time when, such a Klystron is engineered, a scheme with two Klystrons might be the perfect solution.

A possible disadvantage of this scheme such as requirement to withstand for higher power can be tolerated as, first, the power itself is much less, that in the planning room temperature structures at the same frequency and, second, at a higher frequency the coupler proposed has a much advanced properties. These schemes can be recommended for the SC linear collider and other SC RF system operating at 3 *GHz* as well as for anyone operating at 1.3*GHz*.

More detailed descriptions will be done in separate publications.

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[7] Klystron with controllable perveance.