ACCELERATING STRUCTURES TECHNOLOGY FOR AN S-BAND LINEAR COLLIDER

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Abstract

Easy fabrication and production of S-band linear accelerator structures is one of the main requirements for a future linear collider based on 3 GHz technology. At DESY the series production of spare sections for the injector linac (LINAC II) and the S-Band Test Facility has been started. Overall fourteen 5.2 meter long sections with a 20 cm long integrated load have to be replaced and four 6 m long sections for the test facility are required. The status of the tests and the results achieved so far will be presented.

Introduction

Reducing the fabrication costs for the accelerating sections of a Linear Collider (LC) has to be one of the figure of merits of a LC study. Apart from four 6 meter long accelerating sections for the S-Band Test Facility at DESY overall fourteen 5.2 meter long sections for DESY´s electron/positron linac (LINAC II) are going to be build. These sections are quite similar to the ones proposed for the S-Band LC [1] apart from the fact that the survey and alignment tolerances are larger by approximately an order of magnitude (300 μm).

	Linac II	LC	
attenuation	0.5-0.6	0.55	neper
length of the section	5.2	6	m
group velocity	3.3-1.2	4.1-1.3	% c
filling time	750	790	nsec
iris size	1.4-1.25	1.6-1.3	a/λ
average power dissip.	0.7	1.4	kW/m

Table 1: General parameters of the LINAC II and the 6 m Linear Collider section.

One other differences is the integrated ("collinear") load. The last 6 cells of the 5.2 meter section is coated with Kanthal to absorb the rf wave completely while still accelerating the beam. This might be an interesting alternative for a LC as well because the output coupler and the windows are not required anymore.

Production and Brazing

The sections are made from single cell cavities which are machined on lathes. The typical precision which is achieved is 4 micrometer rms on the diameter of the cavity and the iris which results in single cell frequency errors of approximately 200 kHz. So far the cavities are oversize in order to tune the section by indenting the outside walls. In figure 1 the cell to cell errors are shown for four 5.2 meter sections being produced recently.

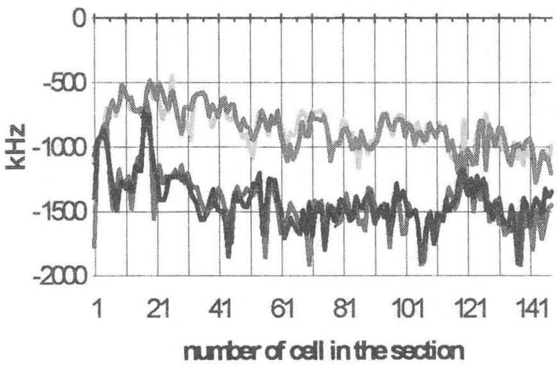

Figure 1: Frequency errors measured with single cells produced for four 5.2 meter LINAC II sections.

The average frequency is by design 1 (1.5) MHz below the operating frequency. The frequency errors can be tuned after brazing to achieve an rms phase error of less than 0.5° which in this case corresponds to an energy loss of approximately 0.01% per section. The brazing of different test pieces has been done up to a total length of 3.5 meter connected to a symmetric high power input coupler. This specific section has been brazed via inductive heating by a current-carrying loop using pieces of 6 to 12 cells.

Before tuning, the frequency of the cells in the brazed structure has been measured by two moving plungers which were used to detune the neighbouring cells. Later on the section has been tuned using the standard SLAC-method [2] and in a second step using a new method, which avoids the plunger in the section and only requires a perturbing bead [3].

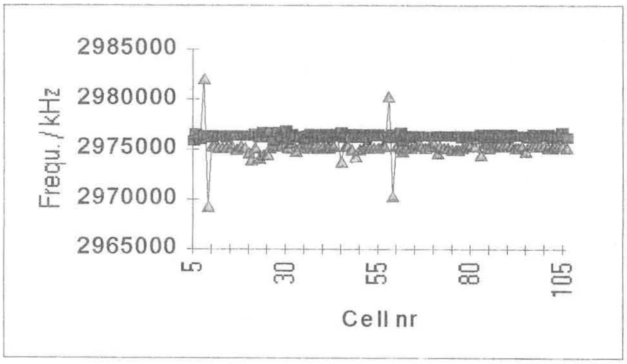

Fig. 2: Single cell frequencies of the brazed section before and after tuning.

Each Linac II section is equipped with a geometrical symmetric high power coupler and two antennas (in cell nr.2 and cell nr.147) two measure the incoming and outgoing rf-power. One port of the coupler is used to feed the power into the section, while the other one is used to pump the section. The couplers are quality controlled before connecting them to the accelerating waveguide and have a VSWR of less than 1.05 without any tuning. The phase- and amplitude asymmetry is compensated by shifting the cut-off position in the pumping waveguide, which is connected to the coupler. The dimensions have been calculated with MAFIA For the LC section a symmetric high power coupler symmetrically fed with rf-power will be used and has been build already[5].

Straightness and Alignment

Allthough no attention has been given to the straightness of the section during the production process so far, it is another main topic for the LC R & D. Methods have to be developped to measure the bendings of a section and to cure them. The result of a first measurement is shown in the next figure. The section had 4 supports at the final positions (in the picture marked by arrows) and was aligned at these support points to about 30 micrometer. The remaining sag was measured from cup to cup. While in principle the cup to cup maximum deviation could be +/- 10 micrometer given by the production tolerance, it turns out that the straightness is better and only a long wavelength distortions (≈1 m) is left. To keep the section straight during a high temperature brazing process (≈780 C°) seems to be very difficult. Therefore these distortions would have to be removed down to 30 µm rms [4] after brazing while in the structure shown in fig. 2 it is 90 µm vertically and more than 200µm horizontally. The force which is necessary to provide such a correction over 1 m (between two support points) is approx. 150 kg which has been tested with the strcuture as well.

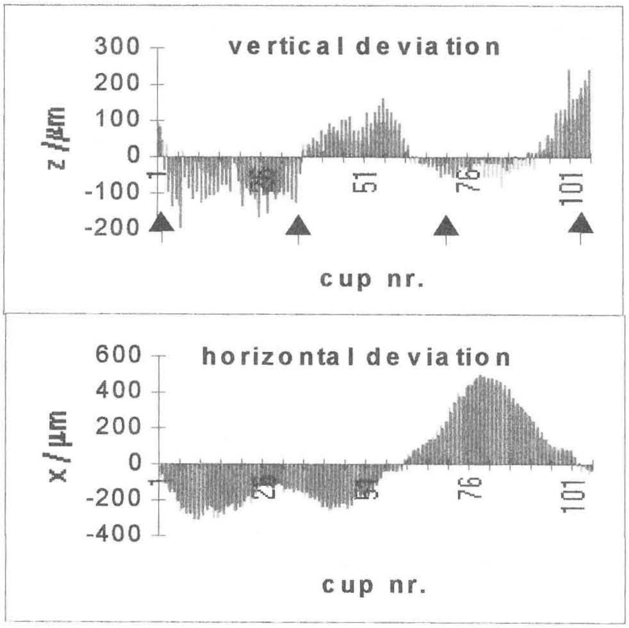

Figure 3: Horizontal and vertical displacement of the cup to cup alignment of the 3 m section after brazing.

Distributed Cooling in a Linear Collider

Distibuted cooling systems in a linear collider have many advantages as compared to standard cooling concepts being used so far (e.g. [6]). For future normal conducting Linear Colliders using long bunch trains, where typically 40 % of the rf-power is transferred to the beam, the heat load on the sections varies at least by the same amount and even by orders of magnitudes more for realistic conditions in case the bunch train length, the rep. rate or the energy is changed. Changing the average temperature of the section on the other hand changes the electrical length and therefore the energy transferred to the beam as well as the energy spectrum.

For machine physics requirements the pulse to pulse energy jitter, contributed by temperature effects, should be limited to less than 0.1 % at the end of the linac. If all the sections would be fed in parallel with cooling water having the same temperature control, the maximum tolerable temperature deviation is +/- 0.2 C° per section. Distributed cooling in that sense means, that each klystron station has its own temperature control which is coupled to a secondary circuit to remove the hot water via a heat exchanger. Every station can have its own working temperature and which will be mixed by fast valves from a hot and a cold line. Following this principle a feedforward for large average power changes can react within seconds by monitoring the average rf-power distributed in the section keeping the average temperature and therefore the elctrical length constant [7] . In the distributed cooling system not even large transients are a problem, because they are rms distributed along the linac which, for example has 1250 stations in case of the S-Band Linear Collider. In the simulation, it was assumed, that the temperature on the section changes by +/- 1.5 C°. This leads to a phase error of 23° per section and for a constant gradient structure to an energy error [2] of approximately 2.7 % which is of course not rms distributed any more because both, positive and negative phase differences result in a reduced accelerating voltage.

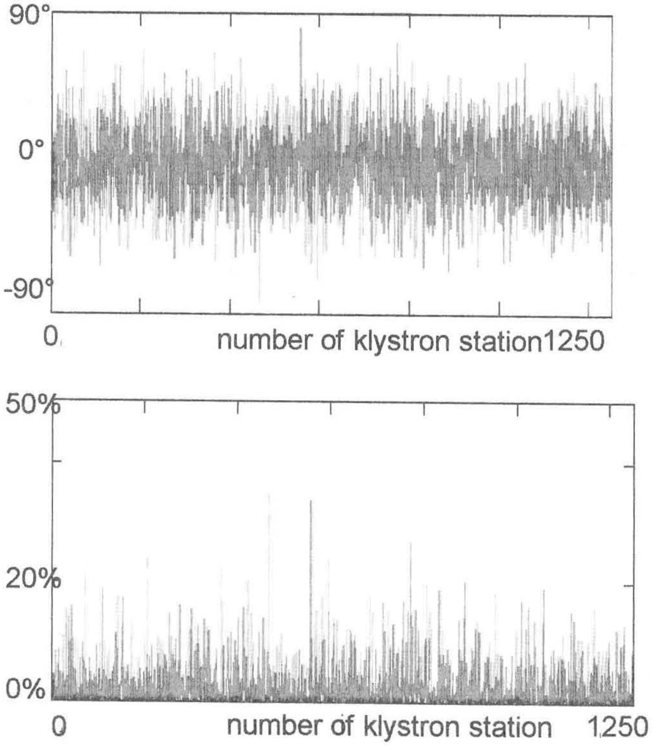

Figure 3: Phase and energy error per station along the linac (1250 stations) for an rms temperature deviation of 1.5 C°.

In figure 3 two random seeds are shown. In the first picture the phase differences from station to station relative to the optimum phase are shown for every station along the linac. In the second picture the corresponding energy loss per station is displayed. One can see that for some stations the energy error is of the order of 40 %. Averaging over many seeds it turns out, that the seed to seed jitter is still less than 0.1 %, which means that the temperature fluctuations being assumed are still tolerable. Because the average energy is reduced by 2.6 % at the same time, the active length would have to be increased by the same amount.

One further adavantage of the distributed cooling is, that every station can operate at a different temperature within feasible limits (45 +/- 5 C°). Going back to figure 1, the single cell rms-frequency error is 200 kHz while the offset is 1-1.5 MHz. The **energy loss due to this rms-error** after brazing of a complete section would be 2 %, which is acceptable if one would not have to tune section and could save on the machining of the cells (For example: no tuning holes in the cells) . The **systematic offset in frequency** for any section could be tuned by choosing the optimum operating temperature. With a frequency change of approximately 50 kHz per degree C°, assuming 3 GHz and pure copper for the structure, the tuning range would be +/- 250 kHz for the control limit given above.

In spite of the more complex cooling system proposed here, the necessity for a fast temperature control and the advantages to avoid the whole tuning procedure of the sections clearly votes for such setup.

Acknowledgement

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