THE S-BAND LINEAR COLLIDER TEST FACILITY

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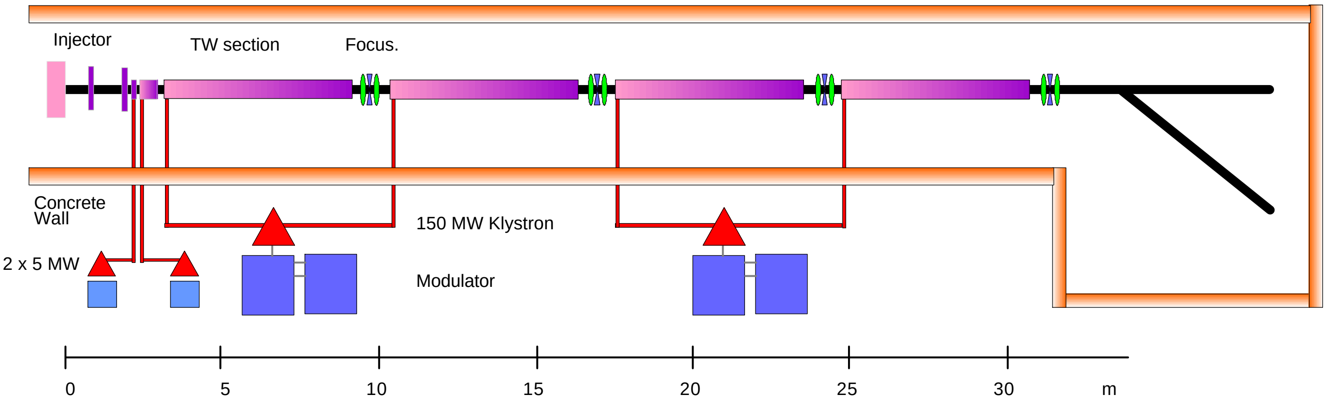

Figure 1: General Layout of the S-Band Test Facility at DESY

The S-Band Linear Collider Test Facility under construction at DESY will serve as a unique test bed for the necessary technical developments of a large scale 2×250 GeV e^+e^- linear accelerator. The test facility consists of two modular units similar to those to be installed in a Linear Collider tunnel (see also [1]). The questions of Higher Order Mode excitation, measurement, damping and feedback on the accelerating cavity and the quadrupole position are especially important and have to be addressed in order to understand the most crucial aspect of a 15 km linear accelerator namely the beam stability. Simultaneously the performance of the newly developed rf-systems will be investigated. The status of this set-up will be presented.

I. INTRODUCTION

Although S-Band linear accelerator technology is well accepted and used around the laboratories, the demands for an S-Band Linear Collider are not a simple extrapolation from any existing accelerator, e.g. the **SLC** [2] at SLAC. Two main reasons lead to the decision, to build and operate an S-Band test accelerator at DESY.

1) The parameters being proposed for the S-Band Linear Collider, even if they are based on well proven and existing linacs, have been pushed to what we think are the limits which can be achieved within the next few years of research and development. Especially for the klystrons and modulators the required peak power (compare **Table 2**) is more than twice as high as compared to the 5045 klystron (65 MW, 3.5 µsec) being in use at the **SLC** right now. Because the modulators and theklystrons are the most expensive single items of a Linear Collider, reliable operation must be proven and the costs for production have to be estimated.

2) A dedicated test accelerator will give the only possibility to prove the feasibility and to a certain extend the reliability of the proposed components and concepts. This is especially true for the HOM cures being proposed for all the future colliders and the feedback's designed to stabilise accelerator components down to rms amplitudes of 10th of nanometers. The whole test accelerator is planned be commissioned by the end of 1996 in order draw a conclusion on the future R & D programs going on at DESY towards a linear collider.

II. THE MODULE LAYOUT

The general layout of the test facility is shown in figure 1. For the S-Band Collider a "linear collider module" consists of one 150 MW klystron driven by one modulator producing a 3 µsec rf pulse which is fed into two 6 meter long accelerating sections. Quadrupoles, beam position monitors and beam diagnostics are part of such a module as well.

Energy at full current	400	MeV
overall length	≅ 40	m
injector energy	≈ 5	MeV
current pulse length	> 2	µsec
modulator & klystrons	2	
number of bunches	1-250	
particles per bunch	$1.5,3,5*10^{1}$	
norm. emittance γε	$\approx 50 \times 10^{-6}$	π m rad
bunch to bunch distance	8,16,24	nsec
average beam current	> 300	mA

Table 1 Main parameters of the S-Band test linac.

The test facility consists of two similar modules, with an injector in front in order to produce the full charge design bunch train and a beam diagnostics station down stream to analyse the beam energy, emittance and position. The parameter overview is given in table 1.

A. The Modulator and Klystron R & D

Klystrons and Modulators turned out to be the most expensive single components of a linear collider. Therefore as much peak power as possible has to be produced with a single device. In order to satisfy the RF peak power requirements for the S-band linear collider a separate R & D program together with SLAC has been started in 1993. Following an earlier development being done in 1985 when a 150 MW, 1 µsec-klystron with an efficiency of more than 50 % was build [3], the goal now was, to construct and operate a 150 MW klystron with a pulse length of 3 µsec and a repetition rate of 50 Hz. In 1994, only $1^{1}/_{2}$ years later, the klystron has been tested meeting the specifications. A second klystron with a slightly modified output circuit geometry and improved HOM damping in the drift tube will be tested during summer 1995. The operating parameters achieved with the first of at least two different klystrons being constructed so far are listed in the next table. This klystron has been shipped to DESY already. Both klystrons have been simulated with 2 D and 3 D codes extensively to optimise the overall layout[4].

	5045	SBLC	
Beam Voltage	350	528	kV
µ-Perveance	2.0	1.8	$A/V^{1.5}$
Output Power	67	>150	MW
pulse length	3.5	> 3.0	µsec
Electronic Efficiency	46	42	%
Drive Power	350	< 400	W
Solenoid Field	0.12	0.18	T

Table 2 Parameters of the 150 MW klystron being tested in 1994 at SLAC and the SLC standard klystron, the 5045.

The modulator considered to drive the 150 MW klystron is a PFN type modulator with pulse forming network connected to a pulse transformer. Such a modulator has been constructed already at SLAC to test the klystron at full power and at a maximum repetition rate of 60 Hz. Two further modulators are under construction at DESY for the S-Band test facility. The modulators are designed for a maximum voltage and current of 550 kV and 700 A. For the test facility, these klystrons will be installed during 1995.

B. The Accelerating Section and the HOM Suppression Techniques to be Applied

The section is a standard 2 π/3 mode constant gradient type section which is designed to have a continuous group velocity taper from the beginning to the end. Because the accelerating section is the main driving force for multi- and single bunch instabilities which deteriorate the beam emittance, not only possibilities to reduce the costs have to be investigated but also HOM damping and alignment is an issue. A first 5.2 meter long accelerating section has been assembled and brazed at DESY by the end of 1994. The high power test ended successfully after approximately 50 hours of rf processing with a maximum gradient of 25 MV/m within the structure. The vacuum pressure achieved so far was of the order of 10^{-8} Torr.

	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
alignment toleran.	≅0.200	<0.030	mm rms
aver. power dissip.	0.7	1.4	kW/m

Table 3 Parameters of the accelerating sections build (LINAC II) and proposed (LC).

Other major technical developments being made so far are a very compact symmetric high power input coupler [5] and the collinear load [6]. The collinear load absorbs over the last eight cells of the section the remaining rf-power while still accelerating the beam. Such a load avoids a second high power coupler (costs), is perfectly symmetric (no transverse kicks due to field asymmetries) and absorbs any higher order mode touching the section end as well.

The final required straightness of the section is determined by the tolerable HOM excitation. Assuming an average Q value of the HOM's of 2500 (natural Q≈13.000) with a bunch charge of $3 \cdot 10^{10}$, the tolerance calculated so far is 30µm rms over the full six meter length. The first section has been measured after brazing and maximum deviations from the axis of the order of one millimeter appeared. After correction, the rms. value was of the order of 100 micrometer but nevertheless is to large by almost a factor of 4.

To control the HOM excitation and consequently the beam break-up in a Linear Collider, each section will be equipped with two HOM dampers. One near the front end and one almost at 2/3 of the section length. Definitely two couplers are not sufficient for damping all the modes in the HEM_{11} passband because about 2/3 of the severe modes in this passband are trapped at different locations of the section. The HOM couplers, in combination with a set of micromoovers, will have to control the beam induced HOM power. While the HOM couplers are used to couple out as much HOM power as possible, the amplitude of the extracted power will be prepared as a control signal for the micro-movers below the section support. In addition an R & D program has been set up with the MPEI in Moscow to develop symmetric high power couplers which couple out the HEM_{11} modes being trapped close to the input end.

Another method for internal damping is under development [7]. Sputtering a thin (≈20 µm) stainless steel layer onto the top of the iris strongly damps trapped higher order modes but almost not affect the fundamental mode. First measurements indicate a Q-reduction of the HOM mode by a factor of 5 while the fundamental Q only changes by 5 %. High power tests still have to be done. The combination of both methods will provide the required overall damping and HOM control.

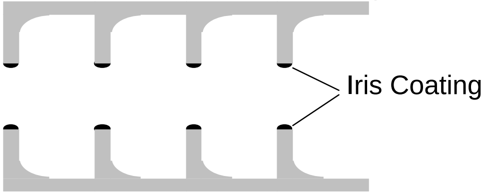

Figure 1 Sketch of the iris coating to introduce losses for the HEM_{11} mode with only little effect on the accelerating field.

C. Ground Motion, Vibration and Feedback

Any kind of quadrupole motion of the order of 20-200 nm within a frequency range of 2-15 Hz can hardly be damped either passive or with beam based feedback techniques. Therefore ground motion detectors (geophones and accelerometers) have been tested and further developed [8]. Each quadrupole in the test facility (and in the Linear Collider) can be equipped with such a detector and either feedback on the vertical quadrupole position via piezo-movers or on the vertical beam position via correction coils. Attenuation with an active feedback between 6 and 12 dB within this frequency range has been achieved so far and corrects the vertical rms quadrupole motion down to the 20 nm range.

In addition a simple and stiff concrete support for the quadrupole has been build and designed which shifts mechanical resonance’s well beyond 100 Hz to avoid any excitation driven externally. To decouple the vibration introduced by water flow within the coil windings of the quadrupole, the coils are mounted on a separate aluminium support within the quadrupole yoke. This support can be mounted separately to the floor.

III. THE INJECTOR

The injector under commissioning right now has to produce the full charge bunch train identical to the one planned for the Linear Collider. The small emittance, the single bunch energy spread and bunch length can of course not be achieved in a 3 meter long set-up. Recently the gun part of the injector went into operation and current pulses with the design bunch to bunch distances and burst length (3 μsec and 8,16 or 24 nsec distance; compare table 1) have been produced with a bunch charge of $3.7 \cdot 10^{10}$ per bunch. A complete description of the injector layout, the expected performance and the currents achieved is given in [9].

IV. THE EXPERIMENTAL PROGRAM

To address the beam dynamics questions, the bunch train will mainly be used to perform single- and multi-bunch instability experiments and investigate different beam loading compensation schemes. The questions of Higher Order Mode excitation, measurement, damping and feedback on the accelerating cavity and the quadrupole position are especially important and have to be addressed in order to understand the most crucial aspect of a 15 km linear accelerator namely the beam stability. Especially the concept of measuring the beam induced dipole mode power at the position of the HOM dampers and feedback via the micro-movers on the position of the section is crucial. Therefore a transverse mode cavity will be introduced into the front end of the beam line to modulate the bunch transversely and excite specific frequencies in the accelerating structures.

In order to handle the large number of bunches, various types of monitors for position and beam size are under construction and will be installed in the test facility. Wall current monitors and beam position monitors are going to be checked out, especially for the bunch to bunch resolution within one burst [10].

V. Acknowledgement

I would like to thank all the members of the collaboration from the different institutes and countries for their contributions. The significant progress which has been made during the last 3 years is based on the enthusiasm of the people involved and the willingness of the management to encourage this work.

VI. References

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