

## S-band RF System Possibilities for NLC

A. D. Yeremian  
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### 1. Introduction:

There are several possibilities for arranging the klystrons and SLEDs for the NLC S-band accelerator to achieve the required energy and energy spread for a train of electron bunches. The energy spread needs to be minimized such that the centroid energy variation of the bunches in a train is less than 0.2% rms and the single bunch energy spread variation is also less than 0.2% rms at the entrance to the damping ring, as well as along the S-band linacs. The single bunch edge energy spread is about  $\pm 0.6\%$  in the booster linac due to the bunch length. Any additional single bunch energy spread introduced while compensating for the train energy spread needs to be taken out within 2 accelerator sections. The preferred scheme would be where there is no single bunch energy spread growth at all, even in a single section.

Seven different possible klystron/SLED configurations to power the S-band accelerators are described here using 66 MW-5  $\mu\text{sec}$  or 135 MW-5  $\mu\text{sec}$  S-band klystrons and SLED I systems with either 66 MW or 135 MW input. Some schemes use phase modulation of the klystron while others use amplitude modulation to achieve the appropriate input power profile out of the SLED for beam loading compensation. In some cases, even though the klystrons are being phase modulated, the SLED sees an effective amplitude modulation as an input such as in cases # 1 and # 2.

Phase modulation of the RF into the SLED during the latter part of the pulse translates to phase variation of the electric field in the structure. Using this technique one can compensate for the bunch centroid energy variation within the train due to beam loading, but at the same time a correlated variation in single bunch energy spread is introduced. This variation can be taken out in the next section by modulating the phase of the klystron by equal but opposite amount from the previous section.

Amplitude modulation of RF into the SLED during the latter part of the pulse allows for the appropriate ramping of the electric field amplitude in the accelerator structure. Since the beam is riding at the crest, the bunch centroid energy variation in a train due to beam loading is compensated without introducing variation in the single bunch energy spread.

Phase modulation of the klystron is achieved by running the klystron in saturation and using I&Q phase modulation of the drive signal phase. Since the klystron is running in saturation it is practically unaffected by the amplitude stability of the low level RF. Amplitude variation of less than 2% within the pulse and less than 0.2% from pulse to pulse can be expected from the klystron.

Amplitude modulation of the klystron is achieved by running the klystron unsaturated and using I&Q amplitude modulation of the drive signal. The question is "Can the pulse to pulse amplitude stability of the low level RF be small enough that the klystron amplitude stability is less than 0.2% while the klystron is not running saturated.

Another important question to answer is: Can we build a SLED system which accepts 135 MW input power?

It should also be noted that the cost and risks associated with constructing a modulator for one 135 MW or two 66 MW klystrons is similar. One modulator can accommodate one 135 MW klystron or two 66 MW klystrons.

The final configuration we choose should depend on klystron and high power component feasibility, manufacturability, reliability and cost.

The electron beam pulse train requirements in the S-band structures are worked out backwards from the beam requirement at the IF' [1,2]. The relevant parameters for the beam, the rf, and the structures in the S-band accelerators, are listed in table 1 [3].

Table 1. Electron beam and structure parameters in the ILC S-band structures

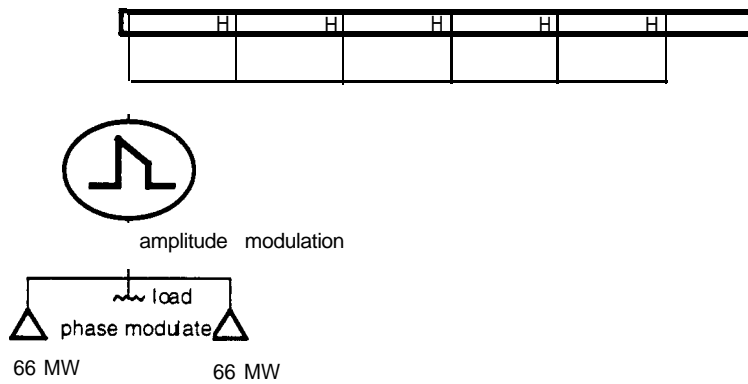
	e- Booster	e+ Driver	e- Prelinac	e+ Prelinac
<b>Beam train width (ns)</b>	250	250	250	250
<b>I ave (Amp)</b>	0.9	0.9	0.7	0.7
<b><math>\Delta E/E</math> train, rms (%)</b>	<0.2	<0.2	<0.2	<0.2
<b><math>\Delta E/E</math> single bunch, edge (%)</b>	< $\pm 0.6$	< $\pm 0.6$	< $\pm 0.6$	< $\pm 0.6$
<b><math>\Delta(\Delta E/E)</math> single bunch, rms (%)</b>	<0.2	<0.2	<0.2	<0.2
<b>Loaded gradient (MV/m)</b>	15	15	17	17
<b>Ave unloaded gradient (MV/m)</b>	21	21	21	21
<b>P<sub>ave</sub> in each structure (MW)</b>	72	72	72	72
<b>RF PW into structure (ns)</b>	$\geq 600$	$\geq 600$	$\geq 600$	$\geq 600$
<b>Structure fill time (ns)</b>	600	600	600	600
<b>Structure length (m)</b>	4	4	4	4
<b>Structures/girder</b>	6	6	6	6
<b>Number of girders</b>	6	19	22	22
<b>Spare girders</b>	0	2	2	2
<b>Klystron Pulse Width (<math>\mu</math>s)</b>	$\geq 5$	$\geq 5$	$\geq 5$	$\geq 5$
<b>Intrapulse ampl. stability (%)</b>	< 2	< 2	< 2	< 2
<b>Pulse to pulse ampl. Stab. (%)</b>	< 0.2	< 0.2	< 0.2	< 0.2
<b><math>\Phi</math> stab. inter &amp; intra pulse (°)</b>	< 2	< 2	< 2	< 2

**2. Various possible klystron/SLED configurations for the S-band linacs:**

**Configuration 1.**

- Combining two 66 MW klystrons into one 135 MW SLED
- 138 Klystrons 66 MW-5 $\mu$ sec
- 69 SLEDs 135 MW in
- 69 High power combiner/splitter 135 MW
- 69 Additional High power loads
- $\Phi$  modulation of klystron
- A modulation into SLED
- 0 single bunch energy spread growth in structure

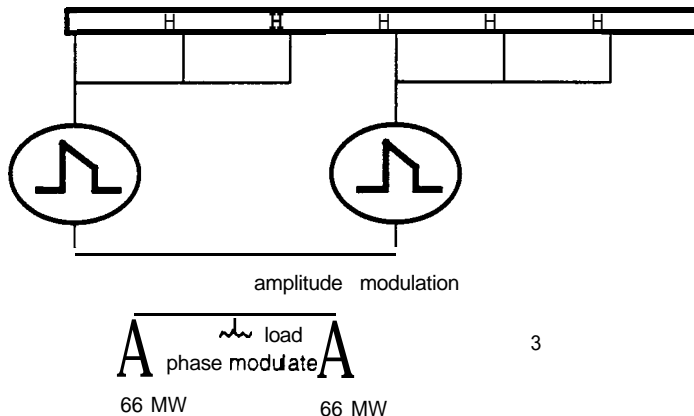
S-band girder configuration # 1



**Configuration 2.**

- Combining two 66 MW klystrons then splitting into two 66 MW SLEDs
- 138 Klystrons 66 MW-5 $\mu$ sec
- 138 SLEDs 66 MW in
- 138 High power combiner/splitter 135 MW
- 69 Additional High power loads
- $\Phi$  modulation of klystron
- A modulation into SLED
- 0 single bunch energy spread growth in structure

S-band girder configuration # 2



**Configuration 3.**

2 Klystrons 66 MW powering 2 separate SLEDs

138 Klystrons 66 MW-5 $\mu$ sec

138 SLEDs 66 MW in

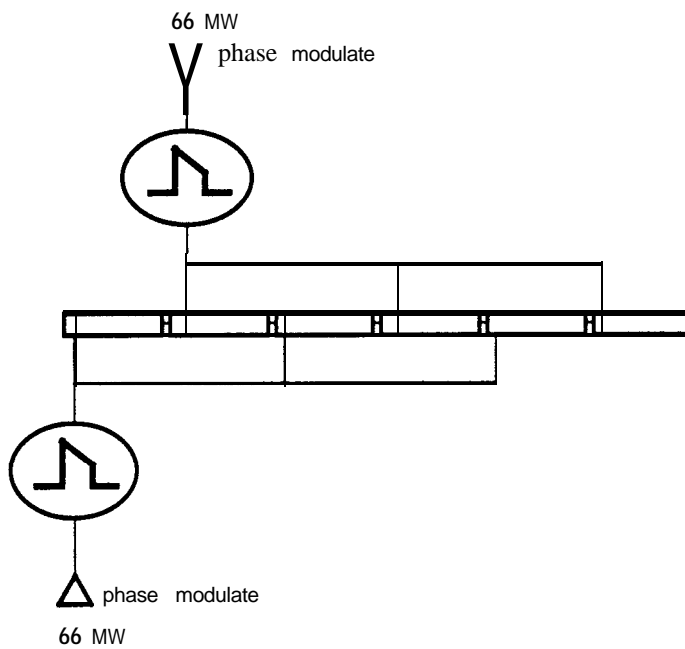
0 High power combiner/splitter

$\Phi$  modulation of klystron

$\Phi$  modulation into SLED

single bunch AE growth in one structure is taken out in the next 'structure.

S-band girder configuration # 3



**Configuration 4.**

2 Klystrons 135 MW powering 2 separate SLEDs

70 Klystrons 135 MW-5 $\mu$ sec

70 SLEDs 135 MW in

70 High power combiner/splitter

$\Phi$  modulation of klystron

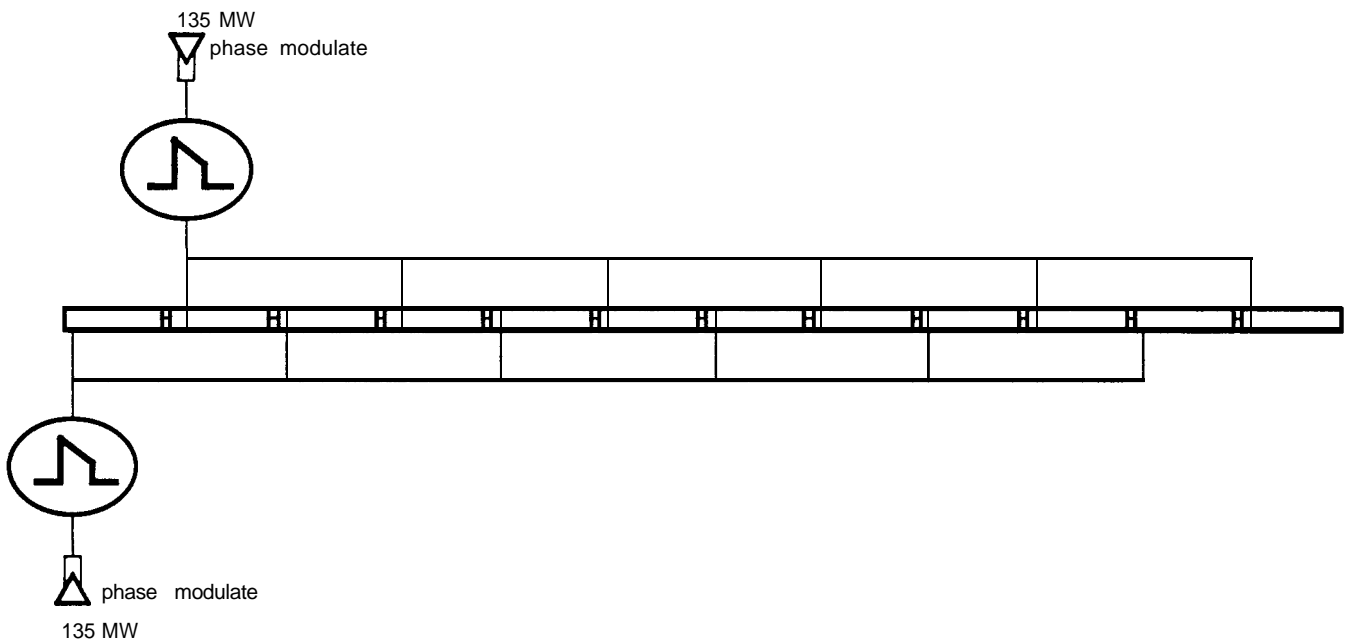
$\Phi$  modulation into SLED

single bunch AE growth in one structure is taken out in the next structure.

Need an even number of girders of 6 structures.

Add one more girder of 6 structures to positron drive linac to make it 20.

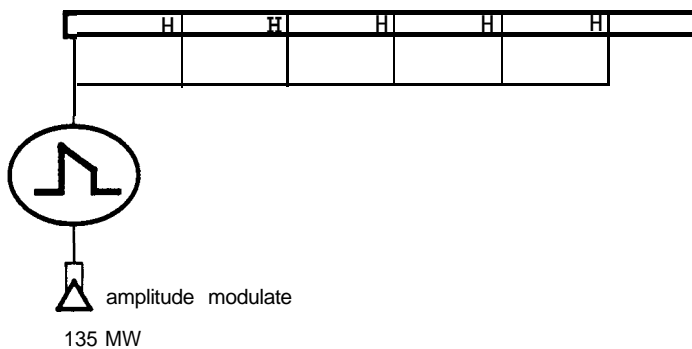
S-band girder configuration # 4 (2 girders)



**Configuration 5.**

- 1 Klystron 135 MW 1 SLED
- 69 Klystrons 135 MW-5 $\mu$ sec
- 69 SLEDs 135 MW in
- 69 High power combiner/splitter 135 MW
- A modulation of klystron
- A modulation into SLED
- 0 single bunch energy spread growth in structure
- klystron not in saturation, low level RF stability coupled to klystron stability

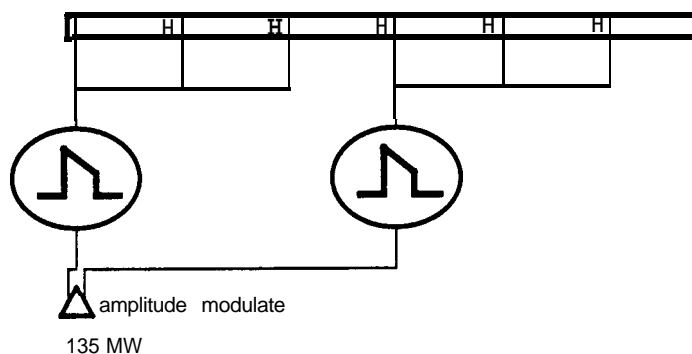
S-band girder configuration # 5



**Configuration 6.**

- 1 Klystron 135 MW powering 2 separate SLEDs
- 69 Klystrons 135 MW-5 $\mu$ sec
- 138 SLEDs 135 MW in
- 0 High power combiner/splitter
- A modulation of klystron
- A modulation into SLED
- 0 single bunch energy spread growth in structure
- klystron not in saturation, low level RF stability coupled to klystron stability

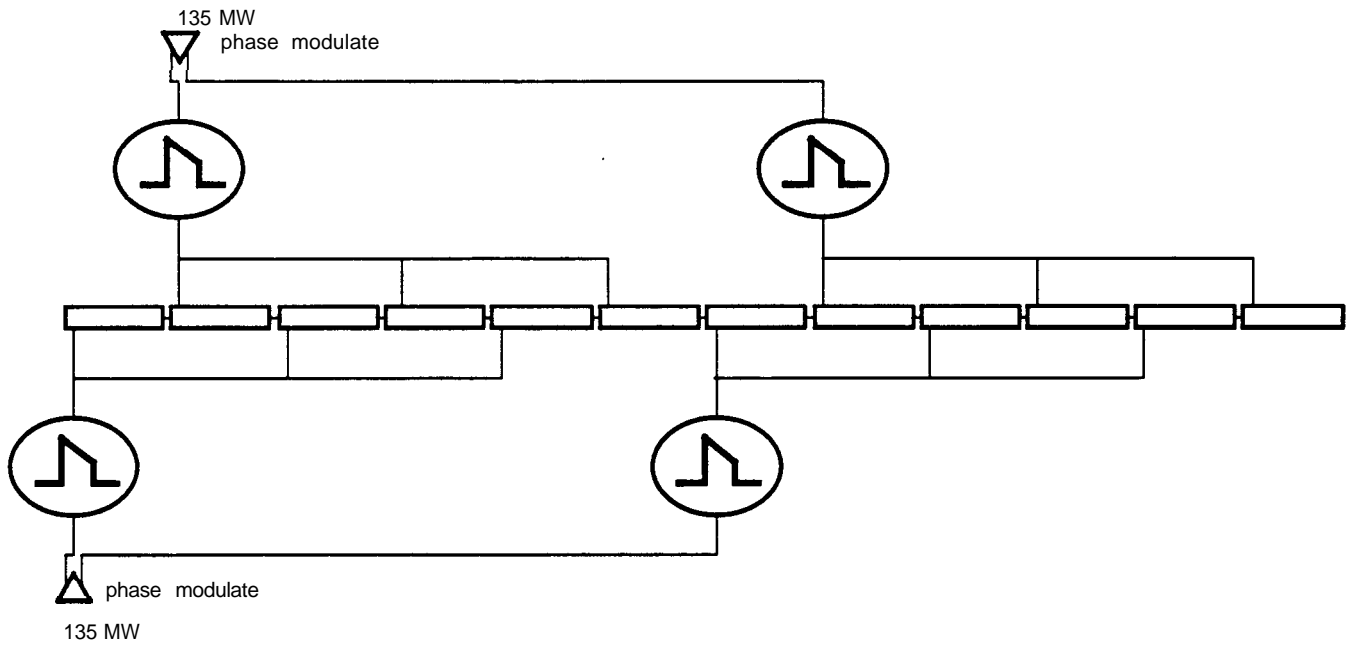
S-band girder configuration # 6



**Configuration 7.**

- 1 Klystron 135 MW powering 2 separate SLEDs
- 70 Klystrons 135 MW-5 $\mu$ sec
- 140 SLEDs 135 MW in
- 0 High power combiner/splitter
- $\Phi$  modulation of klystron
- $\Phi$  modulation into SLED
- single bunch AE growth in one structure is taken out in the next structure.
- Need an even number of girders of 6 structures.
- Add one more girder of 6 structures to positron drive linac to make it 20.

S-band girder configuration # 7



The attributes of each configuration are summarized in Table 2. An easy way to look for trends in the table is to think that the "NO" entry is a desirable attribute, and fewer components are desirable attributes. Since there are no columns with only "NO" entries and the minimum number of components, one has to make a decision about the trade-offs.

Table 2. A summary of key attributes for each of the seven configurations for distributing the RF in the S-band linacs.

Configuration Attributes $\Rightarrow$ $\Downarrow$	<b>1</b> 66MW	<b>2</b> 66MW	<b>3</b> 66MW	<b>4</b> 135MW	<b>5</b> 135 MW	<b>6</b> <b>135 MW</b>	<b>7</b> 135 MW
<b>Single bunch <math>\Delta E/E</math> growth in 1structure</b>	<b>NO</b>	<b>NO</b>	<b>YES</b>	<b>YES</b>	<b>NO</b>	<b>NO</b>	<b>YES</b>
<b>135 MW SLEDs</b>	<b>YES</b>	<b>NO</b>	<b>NO</b>	<b>YES</b>	<b>YES</b>	<b>NO</b>	<b>YES</b>
<b>135 MW power combiner</b>	<b>YES</b>	<b>YES</b>	<b>NO</b>	<b>YES</b>	<b>YES</b>	<b>NO</b>	<b>NO</b>
<b>Additional High power Loads</b>	<b>YES</b>	<b>YES</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>
<b>Klystron amplitude modulation</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>NO</b>	<b>YES</b>	<b>YES</b>	<b>NO</b>
<b>Number of klystrons</b>	<b>138</b>	<b>138</b>	<b>138</b>	<b>70</b>	<b>69</b>	<b>69</b>	<b>70</b>
<b>Number of SLEDs</b>	<b>69</b>	<b>138</b>	<b>138</b>	<b>70</b>	<b>69</b>	<b>138</b>	<b>70</b>
<b>Number of 135 MW combiners</b>	<b>69</b>	<b>138</b>	<b>0</b>	<b>70</b>	<b>69</b>	<b>0</b>	<b>0</b>
<b>Number of added high power loads</b>	<b>69</b>	<b>69</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>

### **3. References:**

[1] Proposed **ILC** Parameters ----DRAFT', T.O. Raubenheimer, K. Yokoya, March 29, 1998

[2] NLC Injector Parameter Comparison, A. D. Yermian, January 8, 1998

[3] Based on coversation with T. O. Raubenheimer, Zenghai Li