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500 MW X-BAND RF SYSTEM OF A 0.25 GEV ELECTRON LINAC FOR ADVANCED COMPTON SCATTERING SOURCE APPLICATION

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Abstract

A Mono-Energetic Gamma-Ray (MEGa-Ray) Compton scattering light source is being developed at LLNL in collaboration with the SLAC National Accelerator Laboratory. The electron beam for the Compton scattering interaction will be generated by a X-band RF gun and a X-band LINAC at the frequency of 11.424 GHz. High power RF in excess of 500 MW is needed to accelerate the electrons to energy of 250 MeV or greater for the interaction. Two high power klystron amplifiers, each capable of generating 50 MW, 1.5 msec pulses, will be the main high power RF sources for the system. These klystrons will be powered by state of the art solid-state high voltage modulators. A RF pulse compressor, similar to the SLED II pulse compressor, will compress the klystron output pulse with a power gain factor of five. For compactness consideration, we are looking at a folded waveguide setup. This will give us 500 MW at output of the compressor. The compressed pulse will then be distributed to the RF gun and to six traveling wave accelerator sections. Phase and amplitude control are located at the RF gun input and additional control points along the LINAC to allow for parameter control during operation. This high power RF system is being designed and constructed. In this paper, we will present the design, layout, and status of this RF system.

INTRODUCTION

For the MEGa-Ray Compton scattering light source, a X-band (11.424 GHz) RF electron linear accelerator is chosen for its high gradient and compactness characteristics. X-band LINAC research and development had gone on for many years at SLAC for the Next Linear Collider project (NLC 1991-2004). In fact, high gradient test of X-band accelerator structures is continuing today at SLAC. The collaboration of our SLAC colleagues enable us to effectively select, design, and proceed with our LINAC layout and setup in a timely manner. The electron energy we want to achieve in our application is in the range of 250 MeV, which will result in ~2 MeV photons via head-on Compton scattering with a green laser beam.

HIGH POWER RF

The high power RF system is to provide adequate RF power to the accelerator to achieve the end-point electron energy. The accelerator consists of a X-band photo-gun and six sections of traveling wave accelerating structure, the T53VG3. The X-band photo-gun is a modified version of the 5.49 cells RF gun tested at SLAC in 2002 [1]. The RF budget for the gun is 20 MW and the fill time of the structure is 65 ns. The T53VG3 type travelling wave structure was extensively tested for high gradient operation and has operated at high gradient with low breakdown rates [2]. This structure is suitable for our LINAC because our electron bunch separation is large enough (~10 ns) that wake-fields are not likely to degrade the electron beam quality from bunch to bunch. The T-series structures are essentially the low group velocity (downstream) portion of the original 1.8 m structures. This structure can be operated with acceptable trip rate at gradients up to 90 MV/m. The fill time of this structure is 74.3 ns and a RF power of 70 MW is budgeted for each section.

Klystron and High Voltage Modulator

The high power RF source is a X-band klystron (XL-4) which was developed by SLAC in the mid 90's for the high power testing of the X-band structures [3]. The XL-4 is a solenoid focused klystron which requires a 0.47 Tesla solenoid. The key characteristics of the klystron are summarized in Table-1. The high voltage pulse required by the klystron is provided by a state of the art, solid-state high voltage modulator. We have chosen the solid-state modulator (K2-3X) built by ScandiNova for its pulse to pulse stability and solid-state modular design. The specifications of the high voltage modulator are summarized in Table-2. Two klystrons and two high voltage modulators are planned for the LLNL MEGa-Ray project.

Table-1: Klystron Specifications

Parameter	**Value for XL4**	**Units**
Frequency	11.424	GHz
Peak Power	50	MW
Pulse Width	1.5	msec
PRF	60	Hz
Gain	50	dB
Beam Voltage	430-450	kV
Perveance	1.2	$10^{-6}A/V^{1.5}$

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Efficiency	40	%
Bandwidth	50	MHz
Output VSWR	1.15:1	

Table-2: High Voltage Modulator Specifications

Parameter	Value for K2-3X	Units
Peak Voltage	450	kV
Peak Current	350	A
Pulse Flattop	1.5	msec
PRF	0-120	Hz
Inverse Voltage	10 (MAX)	kV
Voltage Rippl2	+/-0.25	%
P-P Stability	+/-0.1	%
Rise Time	0.8	msec
Pulse Width (FWHM)	2.5 (MAX	msec
Pulse to Pulse Jitter	<6	nsec

RF Compression

The high power pulsed RF output of two klystrons is 100 MW, 1.5 msec. The high power RF needs of the RF gun and accelerator sections are 440 MW for 210 ns (~ 3x fill time). The logical way to achieve this is to pulse compress the output of the klystrons to 500 MW, 210 ns and to distribute the compressed pulse to the RF gun and accelerating sections. SLAC has developed and demonstrated SLED II with multi-mode delayed lines with similar power gain factor [4]. The dual-mode SLED-II delay lines will be approximately 15 meter long with inner diameter of 17 cm. For compactness consideration, we are looking at folding the delay line in half with low loss bends. We are also looking into a chain of over-moded cavities approach [5].

RF Distribution

500 MW, 210 ns pulses are the desired output of the pulse compression system. These compressed pulses will be fed into a 13 dB coupler. The 13 dB (25MW) output will go to the RF gun. To allow for tuning and control, a phase shifter and attenuator are put in this arm. A barrier window is also planned for the RF gun. This is to limit the number of times the RF gun is exposed to air and to possibly provide for a configuration in which the RF gun can be baked and sealed as a unit before installation. The rest of the compressed power (475 MW) is to be distributed to the linear accelerator sections. A 3 dB H-hybrid is used to divide the 475 MW in half. Then a combination and 4.8 dB and 3 dB H-hybrids are used to distribute the power in one third portion (~ 70 MW) to each T53 section. A schematic block diagram of the system is shown in Figure.1. Phase shifters and other control elements will be added as needed.

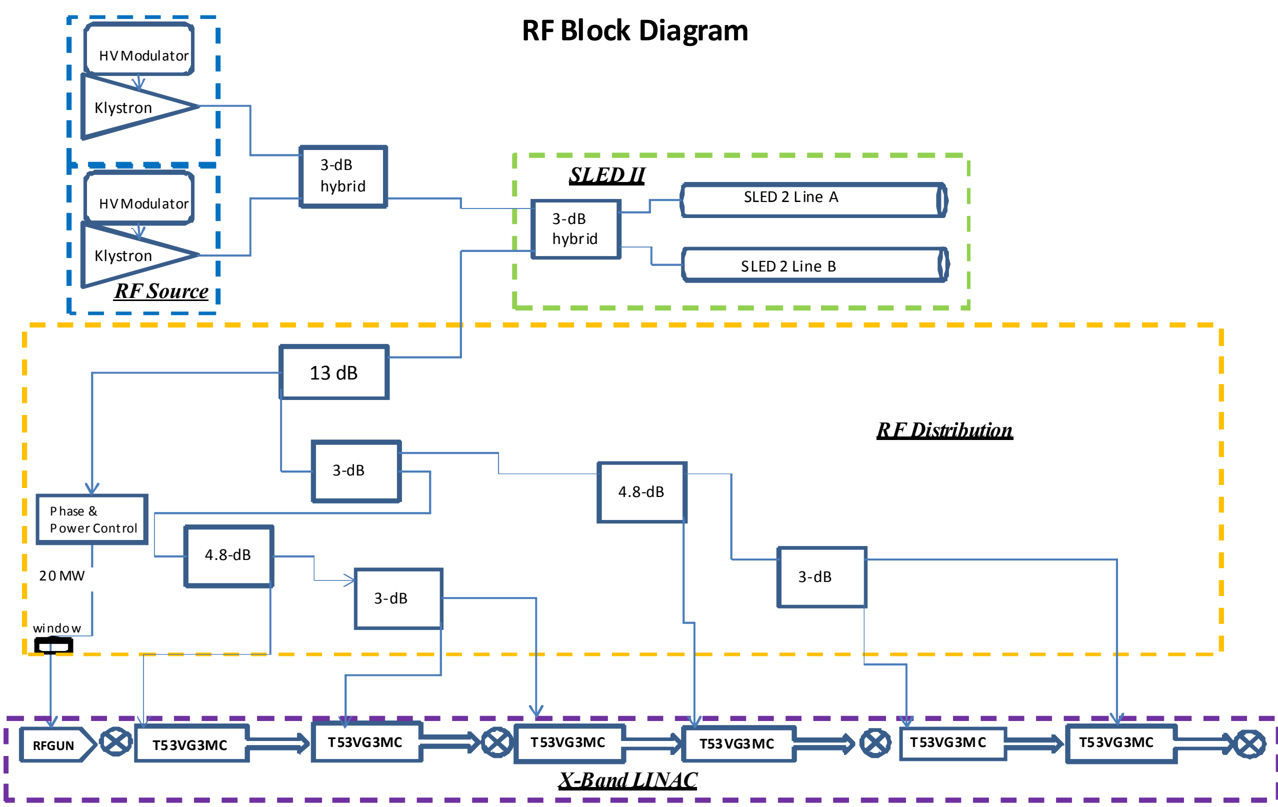

Figure 1: High power RF source, compression, and distribution block diagram

Summary

This system is being depolyed in stages. First will be the RF gun and one linac section which will be powered by one klystron and high voltage modulator. Subsequently, another klystron and high voltage modulator will be added. Then pulse compressor and the rest of the high power distribution will complete the system.

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