LOW LEVEL RF SYSTEM FOR THE ENERGY RECOVERY LINAC PROTOTYPE

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Abstract

The Low Level RF system is described for the Energy Recovery Linac Prototype (ERLP) being constructed at Daresbury Laboratory. An analogue based feedback system, built around low cost proprietary components, has been designed to control the 1.3 GHz RF system for this project. The system is scaleable, has digital control and can be easily upgraded as greater understanding of the accelerator becomes known. The design of the system is based around the central core of a very low phase noise master oscillator, which can provide, multiple outputs and timing pulses at all the required frequencies for the RF, laser and accelerator sub-systems.

INTRODUCTION

Daresbury Laboratory is constructing an Energy Recovery Linac Prototype (ERLP), to develop the skills required for building a larger 4th Generation Light Source (4GLS). This paper deals with the low level RF system that will be critical to the operation of the ERLP. The accelerator RF system is based on TESLA technology, and is being built by ACCEL gmbh. The cryo-modules were designed at HEPL Stanford University in conjunction with FZ Rossendorf and are being successfully used at Rossendorf on the ELBE facility. As the ERLP is being constructed on a tight budget and timescale; cost is an issue in all equipment areas. Collaboration with the ELBE engineers is proving extremely useful, and components are be purchased from ELBE to speed up the build and commissioning of the RF system.

Requirements of the LLRF

The LLRF must provide stable, low noise signals to the booster SCRF module and main LINAC SCRF module at 1.3 GHz. In addition a phase locked signal at 81.25 MHz must be provided to synchronise the laser cathode gun. Control of phase and amplitude for each cavity will be achieved using an analog based system linked into the EPICS control system of the machine. The output from the control loops will drive e2v Inductive Output Tubes (IOT's) rated at 16 kW.

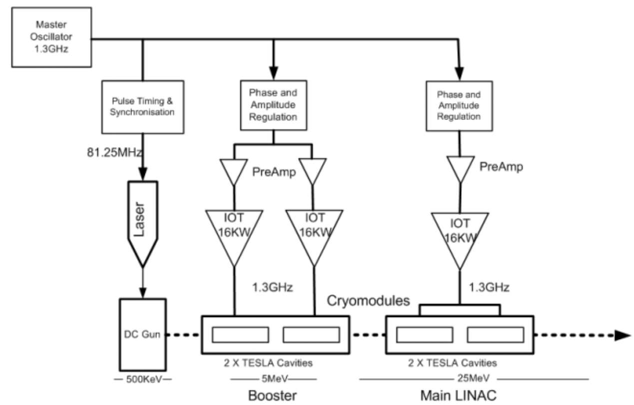

Figure 1: Basic RF system architecture.

SYSTEM OSCILLATOR

The source for the RF system is taken from a Vectron rubidium class OCXO double oven oscillator. This provides a 10MHz output with a very high stability of +/- 5*10^{-11}(0 to +50 C). In addition the phase noise of this OCXO Vectron oscillator is excellent (see Table 1). This source will be used as the basis for all RF and timing signals for the accelerator.

1.3GHz Generation

Two methods are being investigated to provide the 1.3 GHz. Using the 10MHz ultra stable source as a reference, an Analog Devices AD4112 phase locked loop will drive a 1.3GHz VCXO from Vectron (CO-286VP-0) (see Figure 2). The electronic design for this system has been done at Daresbury. This approach has been used at the ELBE facility and proved satisfactory.

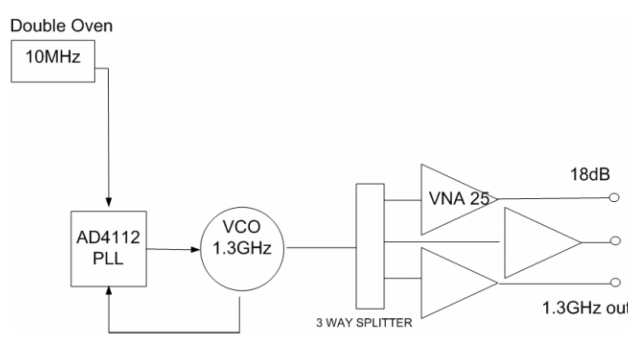

Figure 2: PLL and VCXO 1.3GHz Oscillator.

It is expected that the VCXO characteristics will be acceptable for use in the ERLP, this will provide us with an extremely cost effective, high stability oscillator when phase locked to the ultra stable 10 MHz source. Harmonic

0-7803-8859-3/05/$20.00

and sub harmonic content is tested at –35 dBc for this oscillator.

Distribution of the 1.3 GHz to the various RF stations will be achieved using low loss ATM Inc. CF400 phase stable cable. RF signal interconnection cables around the cryostat and into the control electronics will be performed by CF135 phase stable cable. These cables have excellent performance figures in terms of temperature stability, loss per foot and mechanical phase stability.

Table 1: Phase noise of system oscillators.

Frequency from main carrier Hz	10MHz dBc/Hz	1.3GHz VCXO dBc/Hz	81.25MHz M'plier dBc/Hz	1.3Ghz M'plier dBc/Hz
10	-126	-60	-93	-69
100	-141	-90	-123	-99
1 K	-143	-118	-154	-130
10 K	-143	-130	-168	-144

The multiplier/divider option offered by Wenzel Associates (See Figure 3) offers even lower phase noise (see Table 1) and gives the possibility to distribute the 10 MHz around the machine and use a multiplier local to each RF source to produce a local 1.3 GHz for each RF station. Tests to validate this approach in terms of phase stability and investigations into the cost of oscillators verses cable will be made on the ERLP ready for the 4GLS design.

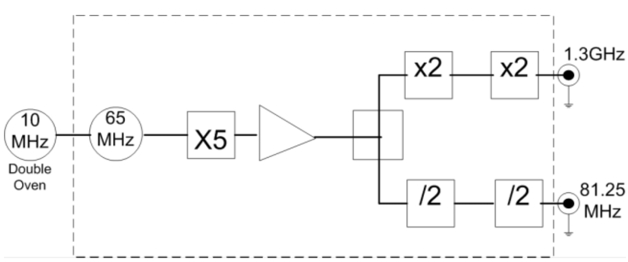

Figure 3: Multiplier based oscillator.

LASER RF

The laser for the photocathode free runs at a frequency around 81 MHz. The photocathode gun needs to be synchronised to the RF system so the laser electronics will be forced to lock to the main RF frequency. Depending on which oscillator design is used, the laser 81.25 MHz can be generated directly from the 10 MHz source, or divided down from an RF pickup located in one of the cavities. The dividers are from Inphi Corporation and feature 50 ps rise time and data rates of up to 25 GB/s. The 1.3 GHz signal will be taken from a cavity probe, divided by two and then by a further eight to produce the required 81.25 MHz.

RF FEEDBACK SYSTEMS

RF Amplitude Detection

For detection of RF signal levels, the AD8361 chip will be used. This provides a 30 dB range and is usable from DC to 2.5 GHz providing a output of 700 mV for 10 dBm input

Phase and Gain Control Loops

An analog control system will be used to for the phase and gain loop. This will be bought from FZ Rossendorf as a working system (see Figure 4). It can achieve phase control over 100 degrees and gain range of 25 dB for amplitude control. The system has proved itself in operation on the ELBE facility holding the phase to 0.02 degrees and amplitude to $2 * 10^{-4}$.

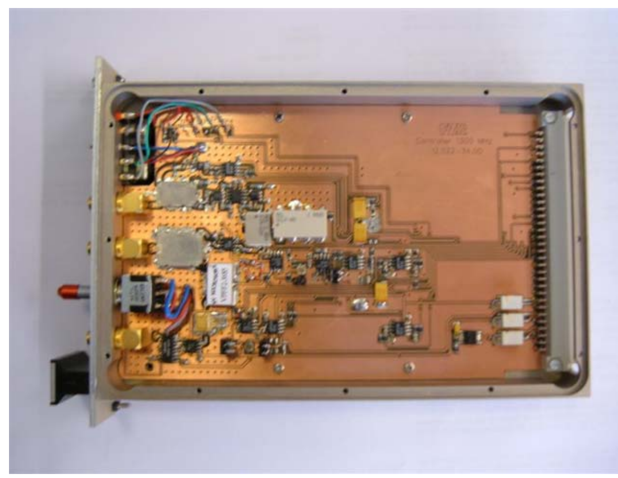

Figure 4: ELBE 1.3 GHz controller.

The controller uses cost effective low noise components to great effect. The detection of phase is done at 1.3 GHz using a minicircuits SYM-22H mixer. Low noise figure minicircuits VNA25 are used throughout as RF amplifiers, while low noise Linear Technology op amps are used for DC amplification and buffering at various points in the circuit. The controller provides DC outputs of the phase and gain signals for diagnostic use and loop setpoints can be adjusted using the accompanying service unit (see Figure 5). This also allows selection of manual/auto for the loops and provides adjustment of the gradient and phase angle required.

Fast RF switch off is controlled by a minicircuits M3SWA-2-50D GaAs switch which produces 50 dB of isolation. This in turn is switched by a fibre optic receiver driven by the machine protection system.

This controller will provide a known starting point for control of the cavity loops and allow development of a digital signal processor based system that will be needed for the 4GLS project.

Figure 5: ELBE 1.3 GHz controller crate.

IOT RF Drive Amplifiers

To access various solid state drive amplifiers for the 4GLS project, it was decided to purchase from multiple manufactures. To this end a 300 Watt unit from SSB gmbh, two 250 Watt units from Microwave Amplifiers Ltd (see Figure 6) and one 250 Watt unit from Wessex Electronics have been purchased. The amplifiers are due to be tested driving the first e2v 16 kW 1.3GHz IOT in June 2005. All the units are expected to run at full power for extended periods be unconditionally stable and self protecting.

Figure 6: Microwave Amplifiers 1.3 GHz 250 W Amp.

SUMMARY

A low cost and high performance low level RF system is being constructed for the ERLP. Buying in technology and equipment already proven is essential for the ERLP project as the fastest and most cost effective way to achieve known results.

It will allow rapid commissioning by using relatively simple control electronics that have been thoroughly tested and are well understood on the ELBE facility.

The oscillator system will provide the low noise and very stable reference that is needed for a Linac based light sources.

It remains to be seen which is the best way to synchronise the photocathode gun laser to the RF system. However both oscillator systems will be available when the machine is running, these will be driven from the same reference oscillator so comparisons can be made for the divided down and multiplied up methods of generation.

Developments into digital signal processing techniques for the control of amplitude and phase will be undertaken once the machine is functioning. This will allow direct comparison with an established operating control system on a functioning machine. A DSP system is essential for 4GLS.

REFERENCES

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