ADVANCED LIGHT SOURCE LINAC SUBHARMONIC BUNCHER CAVITIES

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ABSTRACT

The Linear Accelerator (Linac) in the Advanced Light Source (ALS) is designed to provide either single or multiple bunches of 50 MeV electrons for the booster synchrotron. Three bunchers are used in the Linac. The 3 GHz S band buncher has been described elsewhere(1). This report deals with the two lower subharmonic bunchers. One operates at 124.914 MHz while the other operates at 499.654 MHz.

INTRODUCTION

The Linear Accelerator of the ALS is used to provide single or multiple bunches of 50 MeV electrons for the booster synchrotron. The electron gun(1) serves as the source of the electrons. A series of up to 19 micro electron bunches or a single macro electron bunch is initiated by pulsing the cathode and gating the grid of the electron gun. Figure 1 shows a simplified diagram of the ALS linac. The cathode of the gun is being pulsed by 124.914 MHz pulses which are derived from the 499.654 MHz Master Oscillator(2) of ALS. Each electron bunch exiting the electron gun and entering the 124.914 MHz subharmonic buncher has a pulse width of 2.5 ns. This first buncher compresses the 2.5 ns bunch to a width of 800 ps. The 499.654 MHz subharmonic buncher further compresses the electron bunch to a width of approximately 200 ps. After going through the 7th gap of the 3 GHz buncher the electron bunch attains a width of 20 ps.

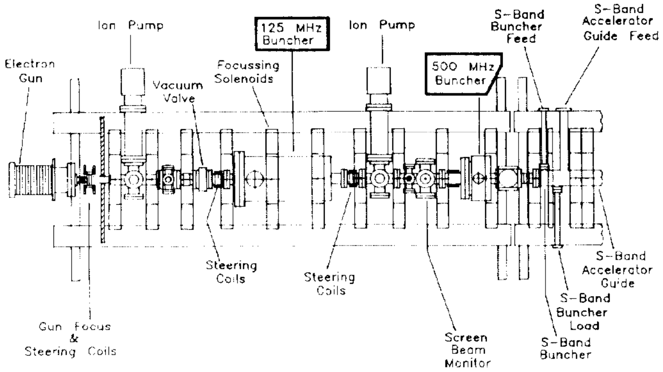

Fig. 1 Diagram showing partial front end of the ALS Linac

DESIGN CONSIDERATIONS

Since the buncher cavities only interact with the electron beam for a maximum period of 150 ns at ten pulses per second, it is logical to operate the RF system in the pulse mode. Keeping the duty cycle of the pulse system to a minimum will reduce cavity heating effects with the attendant problems of expansion and resonance frequency shifting.

The low duty cycle also allows a very economical power amplifier using low power dissipation tubes. The duty cycle of 15 μs gate time and a pulse rate of 10 Hz is 0.015%. Such an amplifier will produce 24 kW of RF peak power when the mean power is only 3.6 W. The power amplifier specified for the buncher system is capable of producing 250 W mean power. This power level allows the cavity to be outgassed and conditioned against multipacting. The sensitivity of temperature on the resonant frequency of the buncher is reduced by using a low Q cavity. A lower Q factor also allows a shorter gate time which in turns reduce the filling time. Another advantage of the lower Q factor is to reduce the cavity to beam interactions should it become necessary to operate the linac without one or both of the buncher RF systems operating. To obtain the low Q factors, stainless steel was used to make both buncher cavities. A decision was made to construct the cavities in two sections thus allowing access to the nose cones. This feature will enable future repolishing of the cones or the addition of anti-multipacting coating if needed. Both buncher cavities are of the capacitive end loaded quarter wave coaxial transmission line type. This configuration provides reasonable cavity physical sizes at both 124.914 MHz and 499.654 MHz with the lengths of the cavities being sections of the drift space. The resonant wavelength is related to the capacitive reactance (Xc) by the following expression:

$$Xc = Zo \tan (2\pi/l)\, L$$

where l = resonant wavelength
L = coaxial line length

and $Zo = 138 \log (D_2/D_1)$ in vacuum

where D_1 = outside diameter of the center conductor
D_2 = inside diameter of the outer conductor

The shunt impedance and the Q factor of a coaxial cavity has been described in detail in(3,7). More discussions on the subject can be found in(4,5,6).

The power (P) required with a fixed gap voltage (Vp) is given by:

$$P = V_p{}^2/(2R_L)$$

where V_p = Peak voltage required across the gap
R_L = Loaded shunt impedance

Equations for calculating various parameters of the foreshortened quarter wave coaxial cavity have been complied into a Basic program(7) which was used to make design studies of the buncher cavities. The 10 - 90% rise time of the envelope of a RF burst can be estimated by the following expression:

$$Tr \simeq 0.7/BW$$

where BW = 3 dB bandwidth

The expression is a semiempirical relation between bandwidth and rise time of a tuned circuit(8). The bandwidth of a tuned circuit must be twice that of a video circuit in order to achieve the same rise time due to the fact the two sidebands of a modulated signal occupy a frequency band that is twice the

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modulating frequency. Hence the familiar expression of the rise time of a video circuit, Tr ≈ 0.35/BW becomes 0.7/BW.

The electron micro bunches as well as the macro bunch would not be sent to the cavities until the RF burst is well in the plateau area. A RF gate time of 15 μsec has been specified to make sure that the RF is in full swing before the electron bunches arrive. A maximum gate time of 30 μsec however is allowable. It is evident from the previous discussion that the Q of the cavities should not be made too high to avoid long RF gate time. On the other hand if the Q is made too low the peak power required of the power tubes may become impractical.

The gap spacing of both cavities have been specified to be 2 cm. With this small gap spacing the transit time factor(9) at the particle speed concerned is close to unity. The calculated shunt impedance hence are approximately the same as the transit time corrected shunt impedance for both cavities.

The operating gap voltage specified is 60 KV. Using Kilpatrick's criteria(10), the maximum field such a gap capable of withstanding is around 150- 200 KV/cm at the frequencies of interest in high vacuum. The nose cones are constructed with stainless steel which has a much higher electrical strength than copper(11). The diameter and hence the capacitance of the nose cone was chosen to provide practical cavity body lengths.

Both the electric and magnetic field distribution of the fundamental mode of the cavities were obtained by using Urmel-t(12) to determine the coupling loop locations.

THE 125 MHz BUNCHER CAVITY

Figure 2 shows the mechanical structure of the 125 MHz buncher cavity. A summary of its characteristics is given below:

Operating Frequency	124.914 MHz
Q (loaded)	775
Gap spacing	2 cm
Loaded shunt impedance	92 KΩ
Power required	20 KW (Vg=60 KVpk)
RF burst rise time	4.5 μsec
Tuner range	0.5 MHz
Bandwidth (3dB)	160 KHz
Drive loop dimensions	3 cm x 2.5 cm x .8 cm

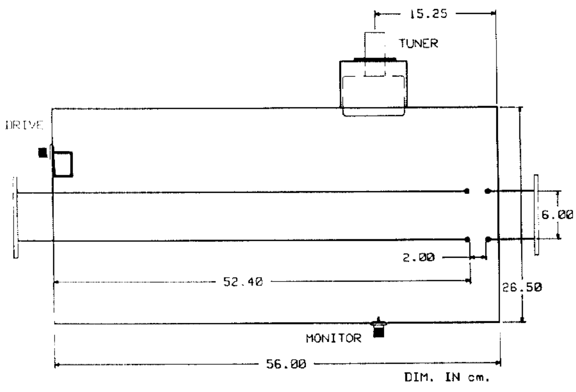

Fig. 2 125 MHz buncher cavity

Figure 3 shows the frequency response of the 124.914 MHz cavity. Figure 4 is the monitor output of the cavity with a 30 μsec RF burst drive. The 10-90% rise time of the envelope waveshape is 4.5 μsec. The 100% peaking time is close to 8 μsec.

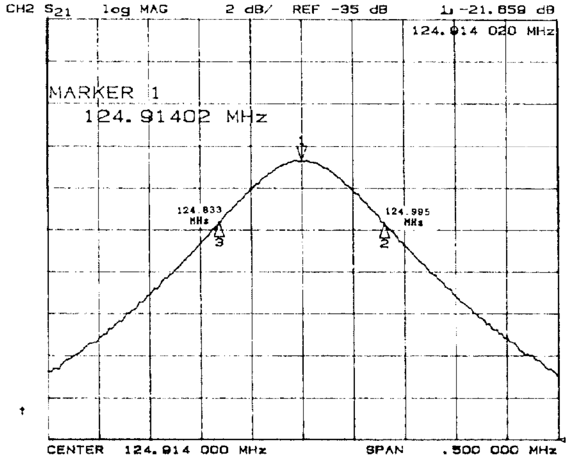

Fig. 3 Frequency response of the 125 MHz cavity

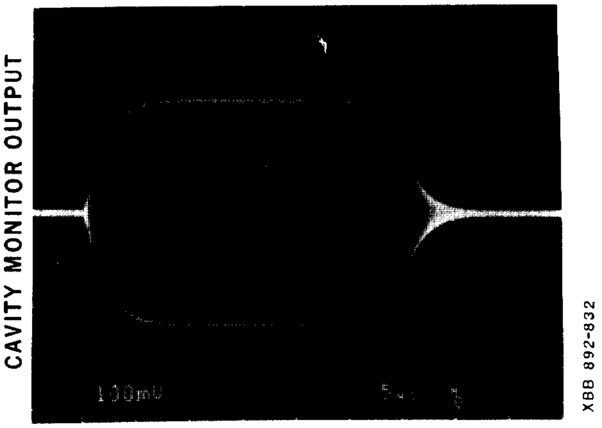

Fig. 4 Monitor output of the 125 MHz cavity with a 30 μsec RF burst drive

THE 500 MHz BUNCHER CAVITY

Figure 5 shows the 500 MHz buncher cavity. A summary of its characteristics is given below:

Operating frequency	499.654 MHz
Q (loaded)	637
Gap spacing	2 cm
Loaded shunt impedance	124 KΩ
Power required	14.5 KW (Vg=60 KVpk)
RF burst rise time	0.9 μsec
Tuner range	1.8 MHz
Bandwidth	785 KHz
Drive loop dimensions	1.5 cm x 1.5 cm x .8 cm

Figure 6 shows the frequency response of the 499.654 MHz cavity. Figure 7 is the monitor output of the cavity with a 30 μsec RF burst drive. The 10 - 90% rise time is 0.9 μsec. The 100% peaking time is close to 1.8 μsec.

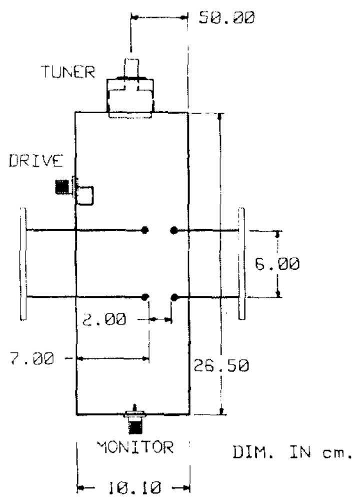

Fig. 5 500 MHz buncher cavity

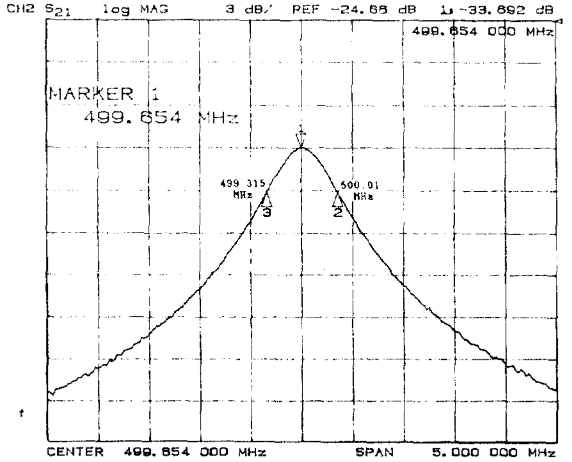

Fig. 6 Frequency response of the 500 MHz cavity

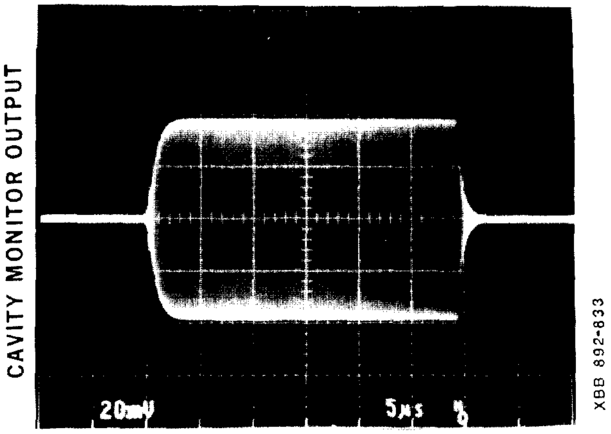

Fig. 7 Monitor output of the 500 MHz cavity with a 30 μsec RF burst drive

FINAL ASSEMBLY

The gap-spacings of the nose cones are very sensitive in determining the final resonant frequency of these cavities. Should the nose cones be misaligned or set too wide apart or too close together the final resonant frequency could be off by an amount which would be outside of the tuning range of the tuner and render the cavity useless.

The final assembly of the cavity will involve setting the tuner at mid-range and the nose cones will then be set to obtain the desired resonant frequency. At this point the nose cones positions will be fixed either by setscrews or clamps before they are welded in place.

CONCLUSIONS

The two buncher cavities in the ALS have been designed and are being fabricated. Prototypes were constructed and various measurements have been made to confirm the calculated parameters. However tests under high vacuum have not been made because the models were not made to operate under high vacuum conditions. With the tests performed so far the design parameters and the actual performance are in good agreement. Approximately 35 KV spark down voltage has been achieved in air across the 2 cm gap spacing in both buncher cavities.

ACKNOWLEDGMENTS

This work was funded by the Director, Office of Energy Research, Office of Basic Energy Science, Material Science Division of the U.S. Department of Energy under Contract DE-AC03-76SF00098 with Lawrence Berkeley Laboratory. Reference to a company or a product name dose not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

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