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Preliminary design of high-power wave-guide/transmission system for multimegawatt CW requirements of 100 MeV proton LINAC

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Abstract. Development of a 100 MeV CW proton LINAC has been planned at CAT. This LINAC will be needing CW rf power in the frequency ranges of 350 MHz and 700 MHz for its RFQ and DTL/CCDTL/SFDTL structures respectively. The power to the accelerating structures will be produced by either 1 MW CW or 250 kW CW klystrons/inductive output tubes (HOM IOTs). The power needed by respective feed points in the structure is max. 250 kW which will be powered by splitting the power from 1 MW klystron/klystrode into four channels by using a wave-guide system. In case of using 250 kW tubes the power to the structures will be provided directly from each tube. Two types of wave-guide transmission system have been considered, viz, WR 2300 for 350 MHz rf needs and WR 1500 for 700 MHz rf needs. The typical wave-guide system has been designed using the 1 MW CW klystron followed by wave-guide filter, dual directional coupler, high-power circulator, three 3 dB magic TEE power dividers to split the main channel into four equal channels of 250 kW each. Each individual channel has dual directional couplers, flexible wave-guide sections and high power ceramic vacuum window. The circulator and each power divider is terminated into the isolated ports by high power CW loads. Out of the four channels three channels have phase shifters. Present paper describes the technological aspects and design specifications-considerations for these stringent requirements.

Keywords. Proton LINAC; RFQ; klystron.

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1. Introduction

1 GeV proton linear accelerator operating in CW mode has been planned as injector for accelerator driven system for future nuclear power generation project. A 1 GeV proton synchrotron to be used as a spallation neutron source (SNS) has also been planned. The 100 MeV LINAC consists of 70 keV ion source, 3.5 MeV RFQ, 20 MeV drift tube LINAC followed by CCDTL/SFDTL to reach 100 MeV. This 100 MeV LINAC will be powered by several 1 MW CW or 250 kW CW vacuum tubes (klystrons/klystrodes/HOM IOTs). The rf system has been designed to have a provision of providing a 500 microsecond pulsed rf for the 100 MeV LINAC when used as an injector for SNS. The overall rf system has been designed/configured to feed this high power to various stages of the LINAC with various parts. First part will be supplying power to RFQ. Second part will be supplying power to

the main accelerating tanks of DTL/CCDTL/SFDTL. In the preliminary design the overall requirement of rf power is about 9 MW CW for proton beam of 100 MeV, 20 mA.

2. High power rf part

2.1 *rf Source*

The rf power required by the accelerating structures will be provided by 1 MW/250 kW CW klystrons/klystrodes operating at 350/700 MHz respectively for RFQ and DTL/SFDTL [1,3]. Based on the available klystron tubes (Thomson, Marconi) as reference the specifications are listed in table 1.

2.2 *rf Power distribution*

For 350 MHz and 700 MHz systems the main components of high-power wave-guide transmission are shown in figure 1 and overall distribution in figure 2.

2.3 *Wave guides*

The rf power for acceleration of protons inside the accelerating structure, supplied from high-power klystrons, is taken up to the desired ports by means of wave-guide line. The factors of primary importance for a wave-guide system are: power handling capacity, insertion loss, impedance uniformity, band width, physical dimensions/tolerances, economic considerations and self strength.

For 1 MW CW rf transmission WR 2300 is used at 350 MHz and WR 1500 wave guide is used at 700 MHz. The high-power wave-guide components are designed using these wave guides. The wave-guides are made from aluminium alloy 6061 plates which are heliarc welded at four corners (table 2).

Table 1. Specifications of klystrons for RFQ and DTL/SFDTL.

Specifications	Units	RFQ	DTL/SFDTL
Operating frequency	MHz	350	700
Output power CW min.	MW	1	1
-1 dB Elect. BW	MHz	$+/-0.8$	1
Gain	dB	40	40
Drive power max.	W	200	100
Efficiency	%	70	65
Beam voltage	kV	90	95
Beam current	A	20	17
Length	m max	4.8	4.2
Height	m	1.85	1.75
Width	m	1.0	1.0
Weight with magnet.	kg	2250	2724
Output wave guide	WR	2300	1500

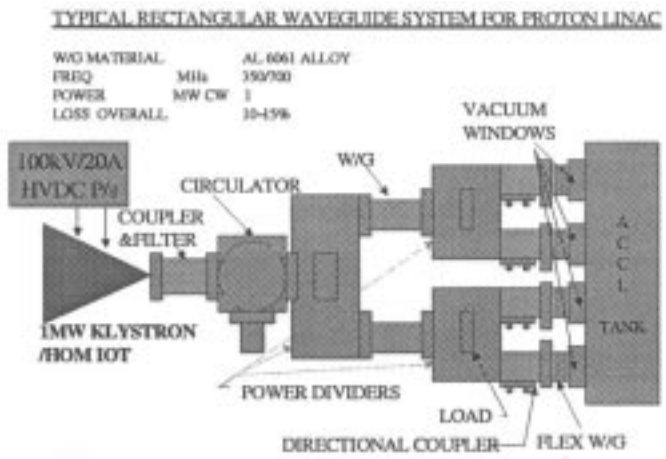

Figure 1. High-power wave-guide system.

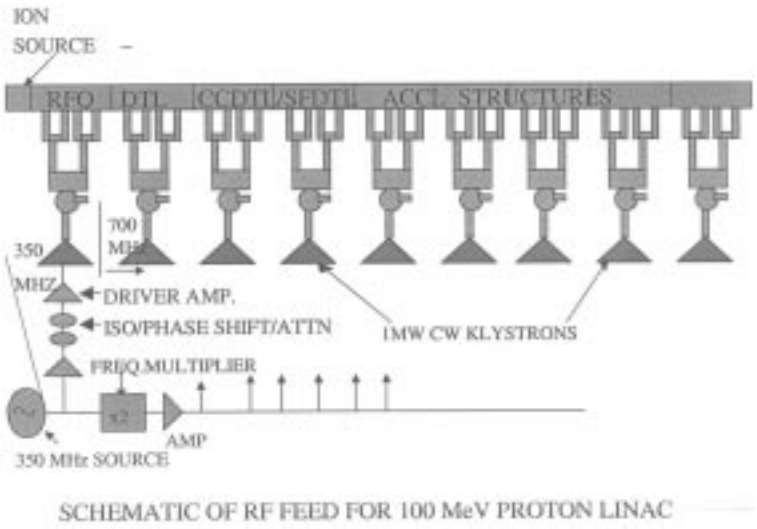

Figure 2. rf System schematic showing a 350 MHz klystron and eight 700 MHz klystron feeding to various parts of 100 MeV proton LINAC.

2.4 *Circulator*

Circulators are essentially required to protect klystron in case of excessive rf power reflections from the accelerator end. Readily available three-port wave-guide junction circulators will be used. The isolated port is terminated with dummy load of full power rating (table 3).

2.5 *Magic TEE power dividers*

It is intended to divide 1 MW power channel to four equal power channels of 250 kW max. Folded magic TEE with compensation and tuning provide this division. The isolated port is terminated with rf loads of corresponding rating. All magic TEE is intended to be made for the maximum rating to have standardization, as it does not lead to major variations in their dimensions (table 4).

Table 2. Rectangular wave-guide specifications.

Type	WR	2300	1500
Freq.	MHz	320–490	490–750
Material Al alloy		6061	6061
Attenuation	dB/m	0.002	0.0026
	%/100m	4.6	6.4
Dimensions broad mm	± 0.25	584.2	381.0
Narrow mm	± 0.25	292.1	190.5
Peak power capacity	MW	700	350
Average power	MW	1.5	1.5

Table 3. Specifications of circulators.

Construction		Three port	
Frequency	MHz	350	700
Power handling	MW CW	1.3	1.3
BW	%	2.5	2.5
Isolation	dB	>26	>26
Insertion loss	dB	<0.05	<0.05
Wave-guide flange	WR	2300	1500
VSWR		1:1.05	1:1.04

Table 4. Specifications of power dividers.

Frequency	MHz	350/700
Power handling	MWCW	1
BW	%	2.5
Insertion loss	dB	<0.05
Power division	dB	3
Isolation	dB	35
Imbalance	dB	0.1
W/G Flange	WR	2300/1500
Material		Al 6061 alloy
VSWR matched loads		1:1.05

2.6 *High-power microwave loads*

Microwave dummy loads are required in large number for terminating the circulators as well as magic TEE power dividers isolated ports. We have considered load construction in wave guide with dielectric tubes filled with water. For compact construction four channels

of the dielectric tubes are considered. We have option for glass as well as for teflon tubes. The maximum power ratings with 1 MW CW as well as 250 kW CW power level at both the frequencies are considered. The size of the 250 kW loads turns out to be much smaller. The VSWR in these components constrained to 1.08 max.

2.7 *Dual directional couplers*

Dual directional couplers with coupling loops attached on the respective wave guides are provided for measurement of power going into the accelerator as well as that reflected. Fast protection removes the drive from the klystron in case of high reflections sensed by these couplers (table 5).

2.8 *Filters*

Wave-guide harmonic filters will be placed at the output of the klystron to dissipate out the power at harmonic frequencies. Antennas are inserted into the narrow wall of the wave guide through a coaxial feed containing a matched load. Care is taken to reduce the coupling of the fundamental mode to the filter. The harmonic power will be coupled out in the TE11 and TM11 modes [2].

2.9 *Vacuum windows*

We have considered two types of vacuum windows for the proton accelerator. In the first case the half height wave guide is converted into a coaxial geometry and the alumina ceramic barrier is placed in the coaxial part. The coaxial part is then converted back into the half height wave guide. The second option is to have a pill box/circular resonant construction, which is in line with the half height wave-guide sections (table 6) [4].

Table 5. Specifications of couplers.

Type	WR	2300	1500
Power	MW CW	1.3	1.3
Frequency	MHz	350	700
Material	Al alloy	6061	6061
Insertion loss	dB	0.06	0.06
Coupling forward	dB	60	60
Reflected	dB	45	45
Directivity	dB	30	30
VSWR		1:1.03	1:1.03

Table 6. Specifications of vacuum windows.

Power handling	MW	0.7
Frequency	MHz	350/700
Vacuum	torr	1×10^{-7}
BW	%	2.5
Insertion loss	dB	0.05
W/G	WR	2300/1500
VSWR		1:1.04

3. Conclusion

Design of the high power rf transmission system with 1 MW CW klystrons and wave-guide components made from WR 2300/WR 1500 wave-guide structures has been described. The main specifications of the components have been worked out for further development of rf system.

References

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