PERFORMANCE OF THE 9 MeV RF LINAC FOR CARGO SCANNING

K.C.Mittal, V.Yadav, D.Bhattacharjee, Shiv Chandan, A.R.Tillu, R.B.Chavan, D.Jayaprakash, R.Tiwari, P.C.Saroj, S.R.Ghodke, N.Chaudhary, Mukesh Kumar, V.Sharma, R.L.Mishra, K.P.Dixit, D.P.Chakravarthy and L.M.Gantayet
Accelerator & Pulse Power Division, BARC, Mumbai

Abstract

A 9 MeV RF Electron linac for cargo-scanning has been successfully commissioned at ECIL, Hyderabad. The pulsed coupled-cavity on-axis linac operates at a frequency of 2856 MHz with pulse width of 6µs and 200 Hz repetition rate. This linac has been RF-conditioned up to a peak power of 2.6 MW. Peak beam current of ~100 mA has been measured at the output of the linac. X-ray dose of ~24 Gy/min/m has been measured on the tantalum target. Beam size of ~2mm has been obtained on the target. This paper highlights the features of the 9 MeV linac, its performance with RF power, behaviour of the linac under beam loading and measurements done to determine the x-ray dose rates.

INTRODUCTION

Cargo-scanning systems require a linac to produce high energy electrons, which bombard a high Z target to generate Bremmstrahlung radiation. These x-rays penetrate high density cargo and the resulting high quality images enable the detection of hidden, contraband goods, weapons, undeclared goods, etc.

A 9 MeV RF Electron linac for cargo scanning has been designed and developed by APPD/BARC at ECIL, Hyderabad [1]. The linac system has been designed to satisfy the specifications listed in Table 1.

Table 1: Specifications of the 9 MeV RF linac

Beam Energy	9 ± 0.1MeV
Average Beam Current	0.2 mA
Peak beam current	0.10 Amps
Average Beam power	1.0 kW
X-ray beam focal spot size	1 mm
X-ray symmetry	±5% at 7.5° off the central axis
Leakage of radiation	0.1 %
X-ray field size	Standard 30 °cone
Length of accelerator	~1 metre
Pulse Width	5 µs
Pulse repetition rate	200 Hz Max.
Injection voltage	50-70 kV
Microwave Frequency	2856 ± 2 MHz
Peak klystron power	2 – 3 MW (2.7MW nominal)
Average klystron Power	2 – 3 kW (2 kW nominal)

SYSTEM DESCRIPTION

An LaB_6-based electron gun serves as the injector of electrons into the on-axis coupled cavity linac, which is power by a klystron-based RF source [2]. The electrons are accelerated to an energy of 9 MeV in a length of ~1m. Fast current transformer at the end of the linac is used to measure the beam current. A solenoid is used to focus the accelerated beam to the required size on the water-cooled tantalum target placed at the end of the beam tube. The entire system from gun to target is maintained at a vacuum level of 10^{-7} torr with the help of sputter-ion pumps. Remote operation of the linac system, situated in the radiation shielded area, is performed through PC located in the control room [3].

X-rays produced from the target are then collimated to form a thin column of ~4mm and allowed to fall on the cargo. The x-rays penetrate through the thickness of the cargo and fall on the detectors placed on the other side of the cargo. At a given time, one column of the image is captured by the detectors. The horizontal dimension of the image is produced by moving the cargo at a given speed. The complete image is then reconstructed by using proper imaging techniques. The linac system is in the horizontal position and a view of the linac is shown in Fig.1.

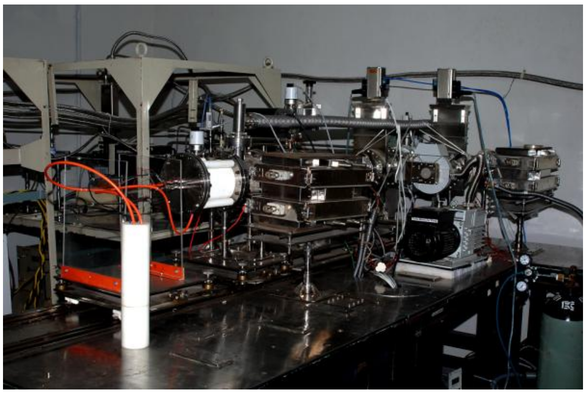

Fig.1 View of the linac system used for cargo-scanning

SYSTEM OPERATION

The entire linac system was assembled at the Linac Test Facility (LTF). Evacuation of the system was carried out till a vacuum level of 10^{-7} torr was obtained. RF power of 2.7 MW and Beam current of 100mA is required for generation of x-rays. To operate the Linac at high microwave power of 2.7 MW, RF Conditioning was carried out. For this purpose, the peak power of klystron was increased up to 500 kW at 10 Hz and then PRF was raised till 200 Hz. As PRF is increased, detuning of cavity resonant frequency occurs, due to which the RF reflected power increases. To reduce the reflected power, the RF frequency of the signal generator is varied to match the resonant frequency. The peak power is increased in steps of 100kW & PRF was increased from 10 to 200 Hz at each peak power level. When arcing was observed (as seen in reflected power pulse) or vacuum deterioration in linac, peak power was reduced by changing the gain of the driver amplifier and conditioning was done at higher PRF for longer duration. During RF conditioning, a vacuum of 3.0 x 10^{-7} mbar was maintained throughout the complete linac system. Vacuum and reflected power was continuously monitored and controlled during RF conditioning of the linac.

After ~200 hours of RF conditioning, forward power of 2.8MW and 200Hz PRF could be sustained. Beam trials were then carried out. The Maximum current of 140mA at 50Hz and 2.7 MW RF forward power with positive grid was measured. The photograph of Fig.2 shows the beam spot as seen on the tantalum target. The spot size is ~2.5 mm.

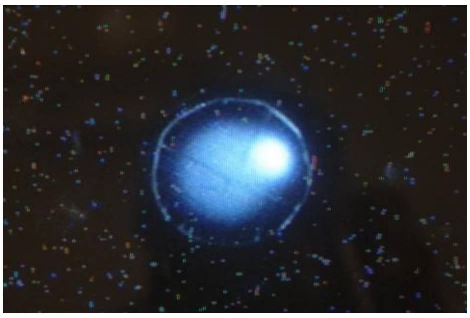

Fig.2 Beam spot seen on target

X-ray measurements

X-ray dose was measured using ionisation chamber at linac operating parameters of 2.7MW, 200Hz, 5μsec, 65mA peak beam current of 9MeV energy. Dose rate of 24Gy/min at 1m from the target was measured.

CONCLUSION

The design and development 9 MeV RF electron linac for cargo-scanning has been completed successfully. X-ray measurements have confirmed required dose rates of 24 Gy/min/m. Beam diameter of ~2 mm has been achieved. Experiments with collimator and imaging system with dummy cargo are in progress. A compact linac for 6 MeV has also being planned along the same lines.

REFERENCES

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[3] R.B.Chavan, et al, "Linac Parameter Acquisition System (LiPAS) for 9 MeV RF Linac", these proceedings