MICROWAVE SOURCE DEVELOPMENT FOR 9 MeV RF ELECTRON LINAC FOR CARGO SCANNING

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Abstract

For cargo scanning, high energy X-rays are required. These X-rays can be generated from accelerated electrons. A 9 MeV Cargo scanning RF LINAC [1] has been developed at ECIL, Hyderabad. The Microwave power source required for RF Linac is a klystron-based system generating 5.5 MW peak, 10 kW average, at 2.856 GHz. Various components required for microwave source were identified, procured, tested and integrated into the source. Microwave source was tested on water load, then it was connected to LINAC and RF conditioning and e-beam trials were successfully done.

For operating the microwave source, a PC based remote handling system was also designed and developed for operating various power supplies and instruments of the microwave source, including the Klystron modulator, Signal generator and other devices. The accelerator operates in pulse mode, requiring synchronous operation of the Klystron modulator, RF driver amplifier and E-gun modulator. For this purpose, a synchronous trigger generator was designed and developed.

This paper describes the development & testing of microwave source and its remote operating system. The results of beam trials are also discussed in this paper.

MICROWAVE SOURCE DEVELOPMENT

A Klystron (THALES, TH2163) based Microwave power source of 5.5MW peak, 10kW avg., at 2.856 GHz frequency has been developed. The Klystron requires RF drive power of 70W, given from a 150W driver amplifier. The pulse cathode voltage of 150kV & current of 110A is given from a Klystron Modulator, procured from M/s Scandinova, Sweden. For microwave power transmission, components like circulator, directional coupler, water load and RF window are used, rated for 8MW (pk), 15kW (avg) power. All components were tested on VNA for VSWR<1.1 and insertion loss<0.05dB. Total insertion loss for the complete waveguide line is 0.25dB (i.e. 5.5% power loss). These components were assembled and installed with the Klystron system. Microwave plumbline is pressurized with 1.5 bar SF_6 gas for handling high microwave power. For this, an SF_6 filling waveguide is connected in waveguide line and an SF_6 gas-handling unit has been installed. A gas inlet valve opens if the pressure falls below 14psi and closes when the pressure increases up to 21psi.

An LCW plant is installed for cooling Klystron, Klystron modulator, Electromagnet, Circulator, water-load, RF-window and other LINAC components.

Testing on Water Load

The Klystron was tested on water load at 5.5MW peak, 10kW average power. Its VI characteristics are shown in Fig.1. Beam perveance of 1.9 µPerveance was measured. Variation of forward Klystron power with input RF drive power at Modulator voltage & current of 132kV & 92A is given in Fig.2.

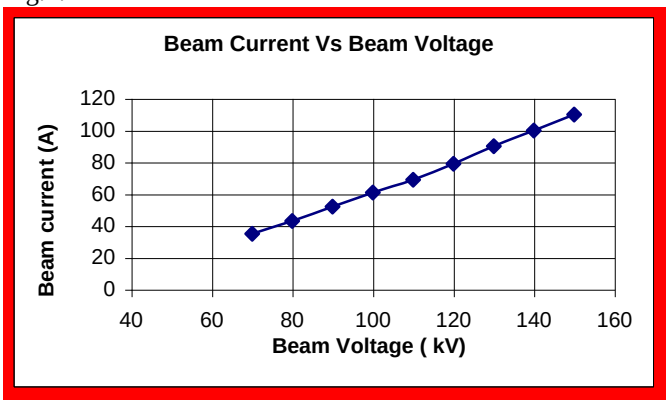

Fig. 1: V-I Characteristics of Klystron

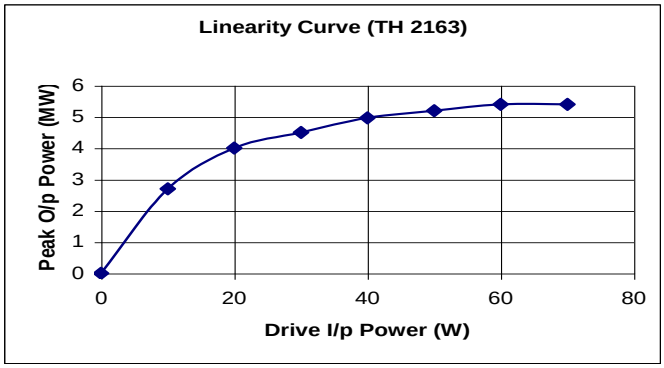

Fig. 2: Klystron Output power variation with input drive power

RF Conditioning of LINAC Cavity

Whenever the cavity is feed with microwave power for the first time, the microwave power is very gradually increased from very low power (<100kW peak power). RF conditioning of Cavity is very gradually done to avoid any surface damage due to arcing. The peak power handling capacity of the cavity is gradually increased. Whenever there is arcing, the pressure inside cavity also increases. So, while RF conditioning, both Vacuum and ARC fault are monitored. Pfeiffer make controller has been used to monitor Vacuum in LINAC. The controller has relay contact, which has been programmed for fault generation if the pressure falls below 5x 10^{-6} mbar. When the pressure improves above 5x10^{-7}, the fault clears and system is ready to operate. For the required operation, the RF conditioning has been done up to 2.8 MW, 200 Hz. For 9 MeV energy at beam current of 75 mA, RF power of 2.75 MW is required.

SAFETY INTERLOCKS

Various safety interlock has been implemented for safe operation of the Microwave source. The klystron modulator has been interlocked with Water flow, ARC detector, Klystron Electromagnet current, Klystron modulator door and SF_6 gas pressure. In case of any interlock getting activated, the input trigger pulse to klystron modulator is blocked, thus no output RF power is generated. The klystron electromagnet supply is interlocked with water flow, as there is high current, which can damage the electromagnet in absence of water.

A relay based hardwired interlock unit has been used for implementing the above-mentioned interlocks.

For the safe operation of the system, the Sync trigger generator is interlocked with Vacuum and ARC. In case of pressure falling or Arcing, the trigger pulse to the system is stopped which also saves the linac cavity from damage.

REMOTE OPERATION AND DATA ACQUISITION

There are various power supplies and instruments of Microwave source like Signal generator, RF Driver amplifier, ARC detector, Klystron modulator, focussing coil supply, Microwave power-meter, oscilloscope, synchronous trigger generator, SF_6 Gas handling unit and vacuum controller. Klystron modulator has RS-485 port, so it was connected to PC using RS-232 to RS485 converter. RF Driver amplifier, Signal generator, Microwave power-meter and oscilloscope have RS-232 port so a serial device server Model No. Nport 5650I-8-DT, Make: MOXA [2], was used to convert Ethernet port to 8 RS-232 ports.

The synchronous trigger generator, focussing coil supply and Vacuum controller also have RS-232 port but they are kept at different location. So a Ethernet switch was used to connect two serial device server N port 5650I-8-DT* (eight RS-232 ports) and N port 5410I* [3] (four RS-232 ports), generating total twelve RS-232 ports.

Software driver supplied with these serial device server generate virtual COM ports on PC. A PC based software was developed using VB to monitor and control these devices. Graphical user interface has been designed for convenient operation of the system.

Synchronous Trigger Generator

A Synchronous trigger generator has been designed and developed for giving trigger pulses to Klystron modulator, e-gun modulator and RF driver amplifier. The generator produces variable delay (1-10 µsec), variable width (1-10µsec) and variable PRF (1Hz to 450Hz) pulses. IC74123, multi-vibrator, is used for generating variable width and variable delay pulses. The pulse rate is varied using micro-controller. Push buttons and a display is provided for varying the output PRF from the front panel.

The Synchronous trigger generator unit has two channels for monitoring high to low signal (5V to 0V) coming from "ARC Detectors" and Vacuum controller. So, in case of arcing, the microcontroller stops the pulses to the system. This helps in quenching of Arc and also the vacuum improves. The unit also has been designed to operate locally as well as remotely. RS-232 interface has been provided for remotely controlling and monitoring it through PC.

LINAC OPERATION

After integrating various sub-systems & RF conditioning, the e-beam trials were done. The maximum electron current of 105 mA was measured at 9 MeV. X-ray dose of 24Gy/m/min was measured using ionisation chamber, which is as per the requirement for cargo-scanning.

CONCLUSION

The RF source was successfully tested up to 2.8 MW peak & 4 kW average power with LINAC as load, without any beam loading. Electron beam output power of 650 W has been achieved. The LINAC is ready for X-ray imaging. After assembly of Collimator and detector assembly, the X-ray imaging experiments will begin.

REFERENCES

[1] K.C.Mittal, et al, "Performance of the 9 MeV RF linac for cargo scanning", these proceedings

[2] http://www.moxa.com/product/NPort_5600-8-DT.htm

[3] http://www.moxa.com/product/NPort_5410.htm