INTRAOPERATIVE X-BAND ACCELERATOR MICROWAVE STRUCTURE DESIGN

A.V. Mishin, R. G. Schonberg, H. DeRuyter, T. Roumbanis
Schonberg Research Corporation

Abstract

The microwave structure of a X-Band linear accelerator for use in intraoperative radiology is designed. Beam parameters 13 MeV and 10 mA which are expected for this accelerator [1] are analyzed.

1. Introduction

The proposed electron linear accelerator is to be a prototype linac for intraoperative electron beam therapy (IOEVBT). A Small Business Innovative Research grant was sought and awarded to study the feasibility of modifying a miniature X-Band (resonance frequency about 9.3 Ghz) linear accelerator (MINAC), developed for industrial radiography. The desirable linac maximum energy was determined to be 13 MeV for one meter long accelerator structure using the same magnetron microwave source as for MINAC [1]. It is required to regulate energy value down to 9 and 6 MeV. The value of 13 MeV is the maximum achievable energy using the available magnetron power source for this type of design, even when the accelerator cavity is optimized and a reduced aperture is used.

Initially, it was planned to use a separate prebuncher and a solenoid with 1.2 Kgs on axis magnetic field, placed over approximately 2/3 of accelerator section length [1]. Finally, we decided to make two of sections the same length as the 6 MeV MINAC industrial accelerator. This would make the technology procedure easier and similar to the MINAC manufacturing process. It also was quite clear that it would be to our advantage to get rid of the focusing coil. The accelerator structure was designed to avoid external focusing fields, although later, due to some difference in theoretical and experimentally obtained field distribution in a prototype guide we had to use a 5 inch long focusing coil, placed over a buncher region in the beginning of the first section. Power from the magnetron is divided into two arms using a power divider. The regulation of the output beam energy is provided by means of a broad range microwave power regulation (0..50% of magnetron power) injected into the second section.

2. Accelerator Structure Design

The accelerator beam centerline is shown on Fig. 1. The first section has a bunching cell [2,3] to increase a buncher efficiency to capture and accelerate low energy electrons.

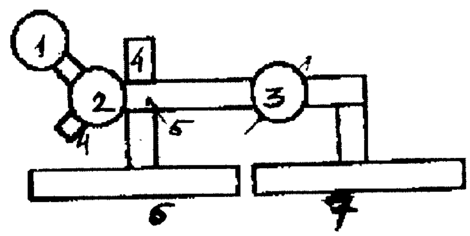

Figure 1: Accelerator RF components: 1-magnetron; 2-circulator; 3-power divider; 4-"dummy" load; 5-power/phase regulator; 6-1st section with bunching region; 7- b=1 section.

We are able to regulate power level injected into a second section as well as phase shift between fields in both guides. Circulator and power divider protect magnetron from the power, reflected from sections of accelerator and phase/power regulator. Reflected power is dissipated in two water cooled dummy" loads, placed in the microwave circuit.

The rest of the accelerator is a Los Alamos type side coupler structure with a cell profile shown on Fig. 2.

Superfish:TM010 Beta 1.0, 2a=0.1872"
GAP=0.4242" r=0.03 R=0.101/standard/Freq = 9406

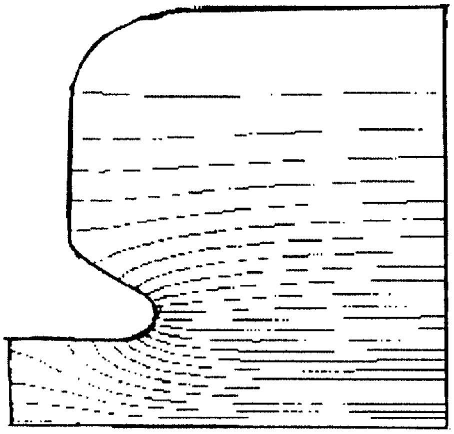

Figure 2: Standard Minac 6 accelerating cavity

Figure 3 presents beam dynamic results [4] for the prototype. The regular MINAC type on-axis cavity provides average energy of accelerated electrons equal to 9.5 MeV in a prototype accelerator.

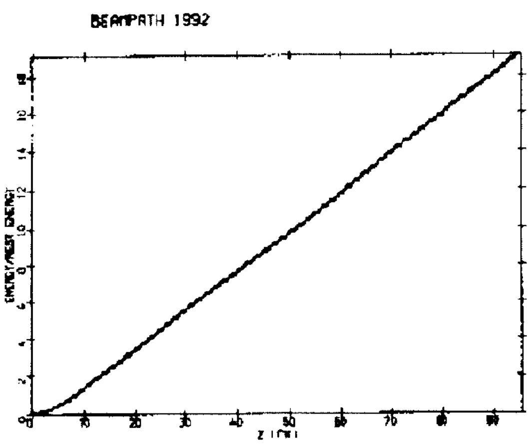

Figure 3: Energy gain along the accelerator prototype.

The first section is designed so that output energy should not be sensitive to the input microwave power and injection voltage fluctuations.

To increase the maximum energy in the next generation system, the cavity shape was optimized and the on-axis hole aperture reduced, as shown on Fig. 4. Assuming that we are not required to increase beam current but energy, this is suggested to be an appropriate action. Maximum shunt impedance of this structure should be equal to about 170 Mohm/m, which is about the highest value one could achieve at this frequency.

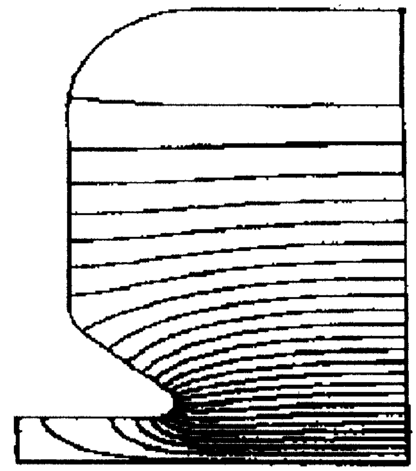

Figure 4: SUPERFISH:OPTIMIZED BETA 1.0 CELL 0.09" GAP 0.3842 Freq = 9394.607

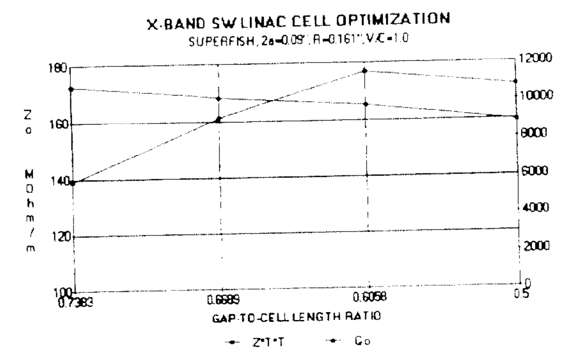

Figure 4: Profile of the optimized cavity and it's characteristics versus gap-to-cell ratio.

3. Experimental Verification

The first section of the accelerator was under high power test. The achieved energy value matches the theoretical value of 4 MeV at approximately 50% of the magnetron power. Electron gun with LaB_6 3mm cathode designed for 200 mA maximum current at 25 kV [5] was used during this test.

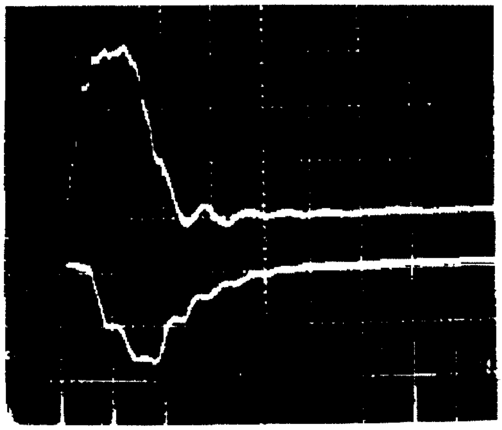

Figure 5: 60 A magnetron current pulse to Intraop guide at the operational frequency 9309.6 Mhz (top) and accelerated beam current, 20 mA (bottom).

Five inch long focusing coil with 2 kGs maximum on-axis magnetic field strength was placed over the buncher region. Magnetron current pulse together with accelerated beam current, detected after the output window foil in atmosphere, is shown on Fig. 5 beam spot diameter detected at 1 cm from the foil was about 2mm.

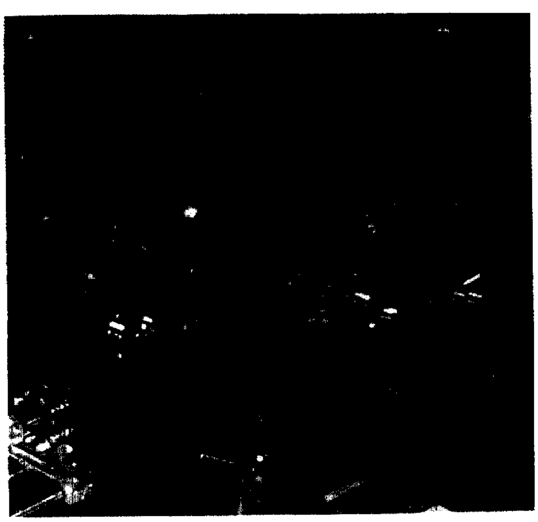

Figure 6: The complete assembled prototype.

4. Conclusions

The designed and experimental values match each other with an acceptable tolerance. This prototype represents a project to create a new generation of portable X-Band linacs with energy over 10 MeV and smooth energy regulation.

Authors' assessment is that the first round of work has been successful. The next step will be to reach the desired 13 MeV maximum energy value and improve packaging characteristics of the accelerator, try to make weight and size of the accelerator head meet the specification parameters [1].

5. References

[1] M.L. Meurk, R.G. Schonberg , G. Haynes, and J.M. Vaeth, The Development of a Smal, Economic Mobile Unit for Intraoperative Electron Beam Surgery, Am. J. Clin. Oncol. (CCT), p.p. 459-464, 1993.

[2] A.V. Mishin, Accelerator Structure for Low-Energy Electron Beam, Proceedings of the 1993 Particle Accelerator Conference, Washington, D.C., p.p. 971-973, 1993.

[3] Jerome L. Altman, Microwave Circuits, D. Van Nostrand Company, 1964.

[4] Y. Batygin "Beampath: A program Library for Beam Dynamics Simulation in Linear Accelerators", Proceedings of EPAC92, Berlin 1992, p.p. 822-824, 1992.

[5] A.V. Mishin, Ph.D. Thesis, Moscow, 1992.