FIRST PERFORMANCE OF THE RFD LINAC STRUCTURE*

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Abstract

Our "Proof-of-Principle" prototype of the RFD linac structure is fully assembled, tuned, and under vacuum, awaiting the delivery of the rf power system, which is now 15 months late and scheduled for delivery at the end of this conference (September 1998). Hence, we have no linac beam or full power performance to report. Nevertheless, we have some ion source beam, prototype assembly, and low-power linac performance to report.

1 THE RFD LINAC PROTOTYPE

A "Proof-of-Principle" prototype of the new RFD linac structure has been installed in the Linac System's laboratory in Waxahachie, TX. The purpose of this prototype is to demonstrate the validity of this new format of rf electric focusing and the practicality of using this new linac structure for a variety of scientific, medical, and industrial applications. The prototype is fully assembled, tuned, and under vacuum, awaiting the delivery of the rf power system, scheduled for delivery in the near future.

This prototype, comprising a 25-keV duoplasmatron ion source, a short two-element einzel lens LEBT, a 0.65-m-long, 0.8-MeV RFQ linac section, and a 0.35-m-long, 2.5-MeV RFD linac section, is shown in Fig. 1. The left-most section of the prototype, as shown in the figure, contains the ion source and LEBT, the middle section contains the RFQ linac, and the right-most section contains the RFD linac. The linac structures were designed to operate at 600 MHz; they both are currently tuned to 596.48 MHz.. The entire length of the prototype is 1.5 meters; the total length of the two linac structures is 1 meter.

The ion source, on loan from Los Alamos, is a scaled down version of the LAMPF ion source, designed and built for the PIGMI program in the late 1970s. It still produces more than 15 mA of proton current, which is more than adequate for this application. The ion source/LEBT vacuum enclosure is pumped by a single 400 l/s turbo pump and operates, under normal hydrogen gas flow, at a vacuum pressure of about $2x10^{-4}$ Torr.

The LEBT incorporates a small amount of electrostatic steering, a two-element einzel lens, and a small amount of beam diagnostics near the entrance to the RFQ linac. An excitation of 24.5 kV on each einzel lens element produces a small, well-centered beam spot at the entrance to the RFQ linac, without the use of any beam steering. A four-quadrant beam collection plate followed by a beam current transformer completes the Ion Source/LEBT portion of the system.

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The RFQ linac structure was fabricated as four separate pieces of OFE copper; two major pieces (the top and bottom vanes) and two minor pieces (the side vanes). The vane tips were contoured with a special, fixed-radius cutter, with a very small (3.5 mm) throat radius. The intent was to bolt the four pieces together for low power testing and to furnace braze them together for operation. However, for expedience, we chose to eliminate the final furnace brazing step.

For want of a proper machining fixture, the precision of the four RFQ pieces was not as high as expected. In spite of its short length, the RFQ tuning process was quite difficult. In the end, we found considerable help from the dipole-mode tuning rods developed by Los Alamos. Figure 2 shows the resulting mode spectrum and the field distribution at three places in each of the four quadrants. The quadrant fields appear to have an rms deviation of about 2.2%.

The RFQ vacuum enclosure is pumped by a single 400 l/s turbo pump. It typically operates at a vacuum pressure of $1x10^{-6}$ Torr. The RFQ assembly incorporates an ultra-thin (6.35 mm) beam line vacuum valve to provide vacuum isolation between the ion source/LEBT region and the RFQ region for maintenance purposes.

Fig. 1. 2.5-MeV RFD Linac Prototype.

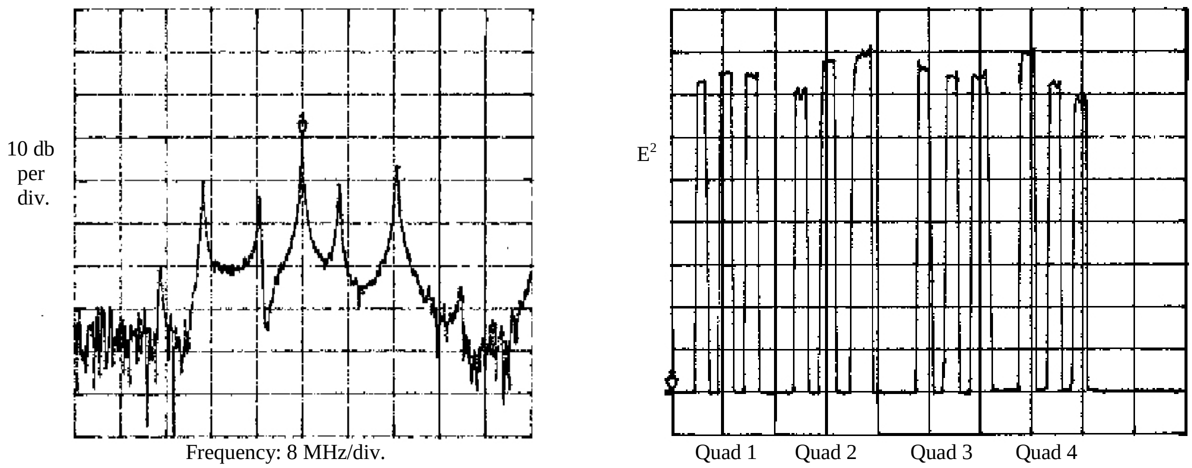

Fig. 2. Mode Spectra and Field Distribution in the RFQ Linac Structure.

The RFD linac structure is essentially a simple water-cooled cylindrical tank, loaded with RFD drift tubes. The RFD drift tube body and stem design comprises two half-body electrodes, with a total of four fingers to create the rf quadrupole field along the axis, supported on two water-cooled support blades that emanate from a single stem that mounts in a single hole through the linac tank wall. Both the drift tube and the hole are precision machined and no provision for additional alignment is planned.

The stem/blade assembly is a 4-layer stainless steel sandwich requiring two hydrogen-furnace braze cycles for completion. A portion of this assembly was machined to a circular cross section and precision ground to a cylindrical surface for installation into a reamed hole in the tank wall. The stem and hole is keyed to control the angular orientation of the drift tube. Fig. 3 shows two views of the RFD drift stem prior to adding the two half drift tube bodies. Several views of an RFD half drift tube body are shown in Fig. 4.

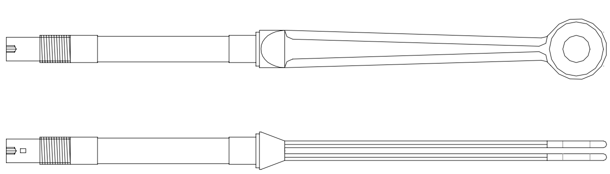

Fig. 3. RFD Drift Tube Stem.

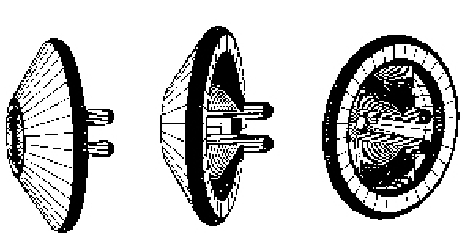

Fig. 4. Several Views of an RFD Half Drift Tube Body.

Soon after receiving the RFD drift tubes, we installed them in the RFD tank and checked the resonant frequency. It turns out to be about 595 MHz. As the RFQ frequency is about the same, we accepted 596.48 MHz for the Proof-of-Principle (POP) prototype.

We developed a way to measure the RFD lens excitation. By pulling a small "copper sponge" (diameter ~ 2.4 mm) along the axis of the linac, stopping inside each RFD drift tube, we shorted each RFD lens in succession, resulting in a frequency perturbation to the structure in proportion to the electrical stored energy in each lens. Initially, we employed the usual phase shift technique used for bead pull measurements. However, as the perturbation was larger than the Q-width of the structure, it was better to simply measure and record the resulting resonant frequency. The results are presented on the upper half of Fig 5. Next, we proceeded to measure the drift tube body gap, which has a direct effect on the expected lens excitation. The results are presented on the lower half of Fig. 5. Note the correlation! After inspection and adjustment of the RFD Drift Tube geometry, the uniformity of excitation was very good.

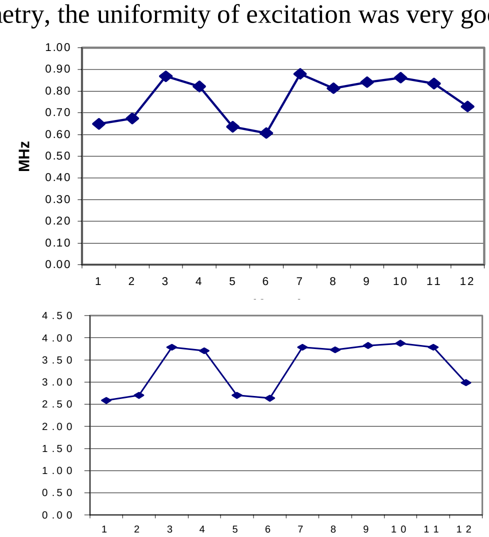

Fig. 5. RFD Lens excitation (upper) and Physical Misalignment (lower).

A resonant coupler, designed to couple the excitation of the two linac structures by locking their fields in phase and amplitude, is being employed. The resonant coupler extracts precisely the right amount of rf power from the RFD structure to excite the RFQ structure. It has the form of a quarter-wave stub in a cylindrical can as shown in Fig. 6. Slots near the base of the quarter-wave stub provide coupling to the fields of both the RFQ and RFD structures.

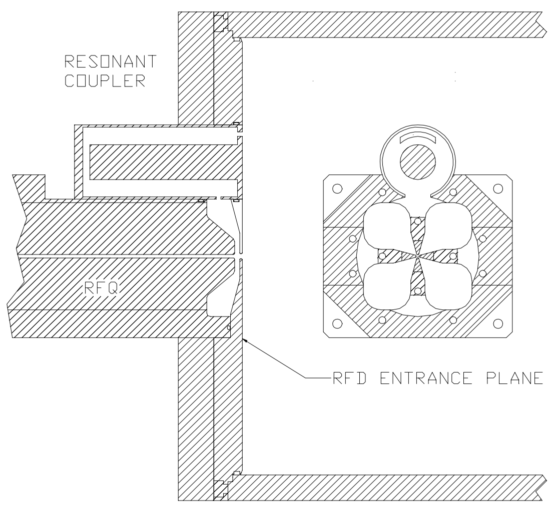

Fig. 6. The Geometry of the Resonant Coupler.

The two linac structures together with the resonant coupler form a chain of three coupled resonators that, when properly tuned, can be excited in three different modes corresponding to 0, $\pi/2$ and π phase shift between adjacent resonators. These three modes can be seen in the mode spectra of our coupled linacs shown in Fig. 7.

Our system is tuned to use the $\pi/2$ mode, which is well known for its ability to lock the phase and amplitude of the fields in adjacent cavities with great accuracy.

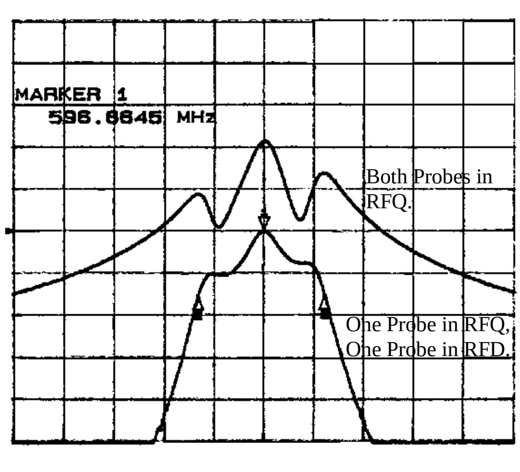

Fig. 7. Mode Spectra of the Coupled Linacs.

The rf power system is based on a multiplicity of high power YU-141 planar triodes. It is designed to produce a peak power of 240 kW at a pulse duty factor of 0.5%. It will consist of a chain of two intermediate power amplifiers (IPAs) and one final power amplifier (FPA). The IPAs will be rack mounted, while the FPA will be mounted directly above the RFD linac section, as shown in Fig. 1. The IPAs will use a total of 3 of the planar triodes. The FPA will utilize an all new single cavity configuration of 12 planar triodes in parallel.

This rf power system is nearing completion at JP Accelerator Works, Inc. It features easy tube replacement (individual cathode assemblies), a broadband cathode circuit (no tuning required), a light weight cavity assembly, built-in phase and amplitude control, a PC based control system with fiber-optically isolated control modules and professional controls software. The system is scheduled for delivery next month (September 1998).

We hope to demonstrate successful performance of this new linac structure in the very near future. The status of this effort will be reported promptly on our web pages at: **www.linac.com**

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