A 750 KEV RFQ LINAC FOR THE AGS POLARIZED PROTON PROGRAM*

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Summary

A radio-frequency quadrupole (RFQ) linac has been chosen for use as the preaccelerator for the polarized H^- beam at the BNL AGS.[1] The low injection energy of 20 keV eliminates the need for installing the bulky and complex polarized ion source within a large high-voltage dome. A preliminary design, BNL 4, has been completed which accelerates 1 mA of polarized H^- from 20 keV to 750 keV with 98% transmission efficiency. It uses the four vane structure with modulated vane tips developed at LANL as the linac cavity. It has an average aperture radius, r_0, of 0.47 cm and nominal normalized acceptance of 0.27 π cm-mr. The structure has a vane length of 1.248 m and requires only 45 kW of rf excitation power. It has been conservatively designed to operate with a maximum surface electric field strength of 22.4 MV/m (1.52 times the Kilpatrick limit).

Introduction

The four-vane RFQ linac[2,3] is a structure which has four-pole symmetry and produces focusing, bunching, and acceleration of charged particle beams by the use of radio frequency electric fields only. No internal static magnetic or electric quadrupoles are required in the structure proper, as is the case with a conventional rf linac. The four-pole symmetry of the device produces a strong electric quadrupole field in the vicinity of the beam aperture which can be used to focus and confine low beta charged particle beams. Because the beam focusing is performed by the rf electric field, it is possible to produce strong focusing forces in the low beta region where conventional quadrupole magnets are not feasible. In fact, it is the strongest known low beta focusing structure.[4] By modulating the pole pieces, a longitudinal component of the electric field is produced which is used to bunch and accelerate the beam. Proper design of the radial matching, shaping, bunching, and accelerating sections results in a linac capable of accelerating particles of low injection energy to moderately high output energy levels with greater than 90% capture efficiency.[4]

An RFQ has been selected as the preaccelerator for the BNL polarized beam facility because it enormously eases the development, operation, and maintenance of the polarized ion source. The complex and bulky equipment associated with the ion source can be placed at beam line floor level and therefore is easily accessible for adjustment and maintenance. The controls and diagnostics can be hard-wired to the control station without the need for a 750 kV transducer to ground, thereby enormously easing the installation, operation, and maintenance of the system.

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* Work supported by U. S. Department of Energy.

Design Parameters

The preliminary parameters of the AGS RFQ design, BNL 4, are listed in Tables I and II. A package of auxiliary programs and PARMTEQ developed at LANL were used to design the linac and study its beam dynamics. The RFQ has an average r_0 of 0.47 cm and a nominal acceptance of 0.27 π cm-mr (normalized). There is only a modest emittance growth for 100% of the particles of 0.06 π to 0.10 π cm-mr normalized for 1 mA beam current input. The transmission efficiency is 98%. The modulated vanes are 1.248 m long. The RFQ was designed with a inter-vane voltage of 65 kV which produces a peak surface electric field strength of 22.4 MV/m (a conservative level of only 1.52 times the Kilpatrick limit). Only 45 kW of rf power are required to excite the structure.

TABLE I - AGS RFQ Design

Frequency	201.25 MHz
Ion	H^-
Number of Cells	137
Length	124.8 cm
Vane Voltage	65 kV
Peak Surface Field	22.4 MV/m
Inital Radius, r_0	0.47 cm
Final Radius a_f	0.29 cm
Initial Mod., m_i	1.00
Final Mod., m_f	2.06
Initial ϕ_s	-90^0
Final ϕ_s	-30^0
Estimated Peak rf Power	45 kW
Nominal Acceptance	0.27 π cm-mr
Initial Energy	20 keV
Final Energy	750 keV

TABLE II - PARMTEQ SIMULATIONS RESULTS

Input	I_i	1 mA
	W_i	20 keV
	ε_n (100%)	0.060 π cm-mr
	ε_n (90%)	0.042 π cm-mr
	ε_n (rms)	0.010 π cm-mr
Output	I_0	0.98 mA
	W_0	750 keV
	ε_n (100%)	0.10 π cm-mr
	ε_n (90%)	0.044 π cm-mr
	ε_n (rms)	0.011 π cm-mr
	Transmission	98%

Mechanical Design

The preliminary mechanical design for the AGS RFQ is shown in Fig. 1. It consists of an outer manifold and the symmetrical four-vane RFQ assembly. The outer manifold is a resonant half-wavelength rf cavity and is tuned using the movable end shorting plates. It also serves as the vacuum manifold for high-speed uniform vacuum pumping. The eight slots cut into the inner cylinder wall function both as vacuum pumping holes and rf coupling slots to the RFQ. There are five large access ports on the outer cylinder of the manifold. Two of the central ports are used for vacuum pumping while the off-center port is used for the rf power input feed loop.

The vanes are to be made of solid copper reinforced with a bolted and pinned steel support plate in the vane base. The base also contains a water cooling channel for temperature control. The vanes are easily removed for repair or replacement. Their electrical contact is provided by thin copper membranes which are electron-beam welded to the vanes. The other side of the membrane is brazed to a steel frame. A crushed gold wire is used to provide the electrical contact between the frame and the RFQ cylinder. The membrance also electrically hides the steel support plate and positioning mechanism of the vane from the rf field. The vanes are aligned by means of a set of support bolts around a pivot point at each end. The vane tip modulations will be machined on a three-axis numerically-controlled mill.

The other major parts of the RFQ will be made of mild steel and electroplated with 254 μm of copper. We have developed, during this past year, an electroplating procedure with an industrial vendor using brightening and leveling agents which produces a bright, high-conductivity copper deposit on large internal or external surfaces with apertures. It displays good adhesion under heat and vacuum. An initial strike of cyanide copper is followed by a 254 μm deposit of acid copper. The resulting deposit is very uniform. Typically, the procedure levels the surface finish from 1.27 μm to 0.25 μm. The copper deposit has an electrical conductivity greater than 90% of pure copper.

RF Design

The RFQ structure will be excited in the modified TE_{210} mode by the use of a manifold cavity (developed at LANL).[6] The manifold cavity is formed by placing a larger metallic cylinder around the RFQ linac cavity. This forms a rigid coaxial line with the outside cylinder of the RFQ, and can be made to resonate at the RFQ frequency by placing shorts $n\lambda/2$ apart. In our case, the shorts will be $\lambda/2$ apart. Energy is coupled into the RFQ from the manifold by cutting eight slots in the outside cylinder of the RFQ.

Three steps are planned to tune the structure to frequency and set the proper field level. First, small, adjustable protruding cylinders are placed at the ends forming a capacitor between pole tip and end wall. Adjusting the gaps of these "buttons" allows frequency tuning, field leveling, and also provides the proper terminating impedance for the vanes. Second, adjustable slug end tuners, either placed on the end plates near the vane base or on the vane base itself, will allow further adjustment of cavity frequency and field level. They will be adjusted until the end buttons are in their nominal range. Third, small adjustable tuners in the cylindrical wall of the RFQ will provide fine tuning adjustment. The fine tuners will allow some decoupling of the mechanical alignment requirements from the requirement to balance the vane voltages.

Vacuum

The vacuum pumping will be provided by a 1000 ℓ/sec cryopump and a 250 ℓ/sec ion pump. With the impedances of the eight rf coupling slots and pumping between the vanes, the effective speed at the beam position is 390 ℓ/sec. This will give a base pressure of 4×10^{-8} Torr under ideal conditions with only the gas load from the 10 m^2 of non-OFHC copper. Under normal operating conditions, it will probably be an order of magnitude worse. This will still be excellent for high voltage standoff, and will strip less than 0.1% of the beam.

Schedule

The RFQ preaccelerator is scheduled for installation at th AGS in early 1983. The low-energy transport line to provide matching into the 200 MeV linac has a preliminary design using existing elements. Two low-voltage fundamental frequency bunchers are required to maintain the bunch structure in the transport line.

It is expected that the AGS operation with polarized protons will start by mid-1983.

References

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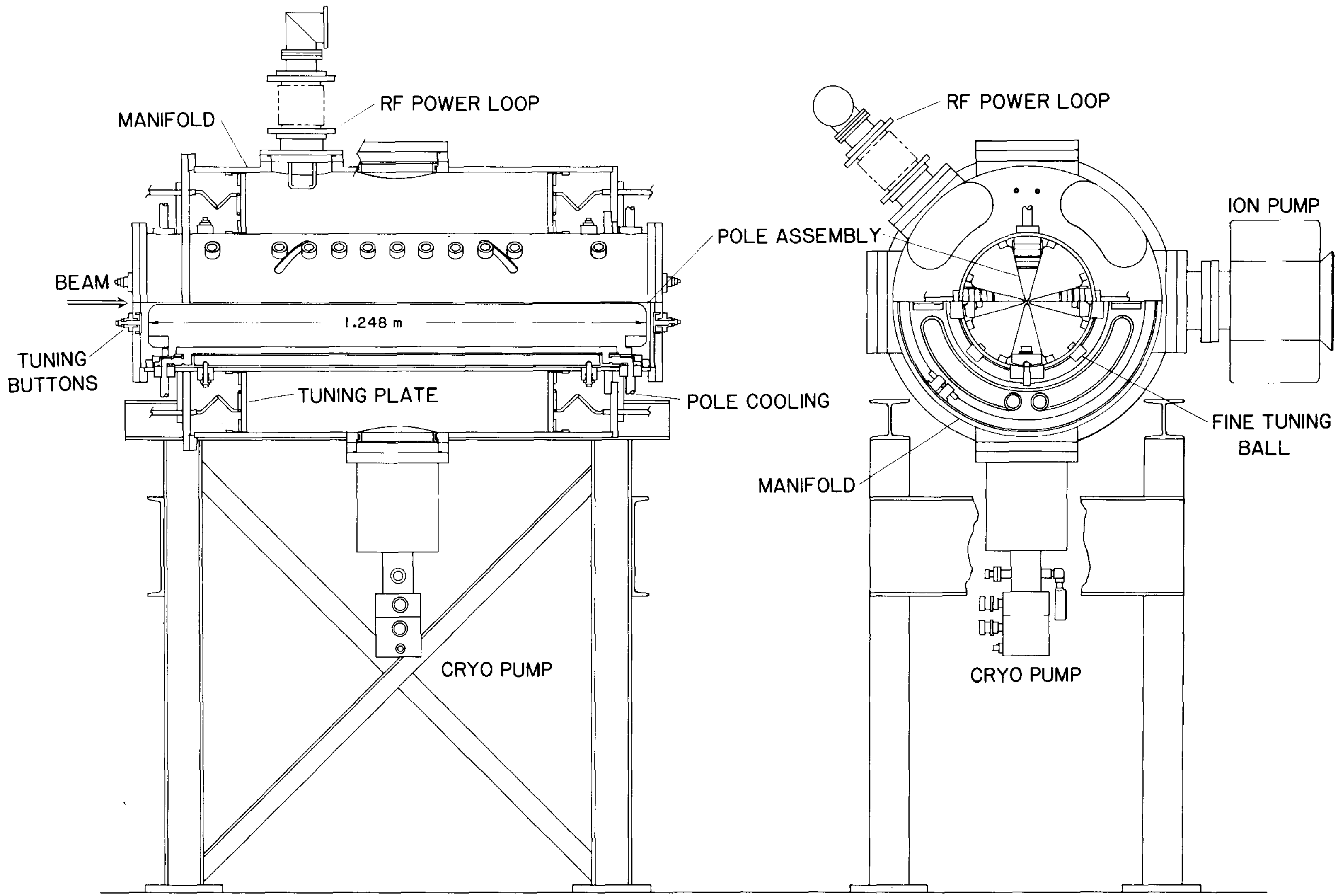

Fig. 1 A 20-750 keV RFQ Linac Preaccelerator for the Polarized H^- Beam at the AGS.