STATUS OF THE HERA-RFQ INJECTOR

A. Schempp, H. Klein, P. Schastok
Institut für Angewandte Physik,
Universität Frankfurt am Main,
Robert-Mayer-Str. 2-4
D-6000 Frankfurt am Main, FRG

K.H. Pape, S.H. Wang*
DESY, Notkestr. 85, D-2000 Hamburg 52, FRG

The HERA injector is a 18 keV to 750 keV RFQ for acceleration of a 20 mA H^- beam. The RFQ is under construction and will be ready for rf-tuning in June 1986. Specific properties of this RFQ will be discussed and first measurements will be presented.

INTRODUCTION

For the HERA project at DESY a RFQ is being built as injector for the 50 MeV Alvarez-linac[1,2]. Fig. 1 shows the RFQ preaccelerator layout using a FNAL H^- ion source and two CERN type solenoids for beam matching into the RFQ. The application of the H^- injection allows for a design current of only 20 mA. Beam dynamic calculations showed that a short RFQ with an injection energy of only 18 keV (final energy 750 keV) and a modest electrode voltage of 70 kV can be chosen. This has advantages for the mechanical design, the RF properties and the operation reliability.

RFQ-DESIGN

The beam dynamics design has been done using mostly the standard approach developed in Los Alamos[3] resulting in a high current transmission and a good beam emittance. Table 1 gives some parameters of the HERA-RFQ. The RF resonator has to provide the designed electrode potential and should have good mechanical stability, reasonable dimensions, and good efficiency. Because of the experience with operating RFQs a four-vane-structure has been chosen as RF resonator. It consists of a cylinder, in which four electrodes are mounted symmetrically. In order to provide a proper axial field distribution, the manufacturing of the electrodes and the adjustment has to be done with high precision. In addition the RF properties of this type of resonator require a highly symmetrical structure to avoid dipole components in the axial field, which lead to beam quality deterioration.

The mechanical design differs from other 4 vane RFQs. We tried to make a separated function structure. Mechanical adjustment, rf-contacts, rf-tuning, stabilization, and vacuum cooling can be done independently resp. changed indepently.

The mechanical adjustment is done with two 3D-positioners per vane, rf-contacting between vane and tank is done with a contact bar on each side of the vane, rf-tuning and stabilizing are done in the end cell. Only the outer cylinder is cooled and vacuum can be applied from the outside at the very last.

Fig. 2 shows a cross section of the RFQ, fig. 3 shows a vane positioner.

The vanes as the main part are made out of Cu-Cr alloy, which has favourable mechanical properties but still very good electrical and heat conductivity. The vanes have been machined out of a solid, forged block which has been annealed at high temperature, in order to avoid bending by residual internal stresses after milling. An inherent part of the design is the independent control of the critical parts and the mechanical alignment with help of a computarized 3D measuring machine with very good accuracy, ± 2 µm seem possible.

Careful machining has been done at Pfeiffer (Balzers) at Aßlar. The vane tip dimensions and the modulation proofed to have deviations below 10 µm from the theoretical values for two test vanes and two final vanes. This was measured independently from the production by Komeg (Zeiss). Measurement was done comparing 2,300 points along the vane with theoretical values and the straightness of the reference edges. Two vanes showed deviations up to 20µm. A "banana" like bending along the axis of highest momentum indicated residual stresses. After remachining these vanes had the same precision as the other ones.

Fig. 4 shows plots for the mechanical measurements along the vanes. The deviations are enlarged by a factor of 150. The maximum deviation occurs at the low energy end at the transition from the radial matching section to the shaper. There the theoretical set of values had not been smoothed out as had been done for the milling machine values. The wheel milling tool (ø min 12 mm) cuts with an angle of 15° giving a very clean cut and resembles 150° degree of a circular arc.

* present address: University of Beijing, Beijing, China

All parts of the RFQ have been produced and controlled. The only part giving a delay has been the outer tank, which seemed to be simple and was given to a subcontractor. Problems with the capacity of this branch resulted in a delay of 3 months for this part. After completing the tank will be copper plated at GSI and then the vanes will be installed and adjusted with help of the Zeiss-3D-machine. The promised date for delivery now is the end of June.

RF ASPECTS

A basic problem for four-vane-structures is the balancing of the four quadrants[4,5], which is one reason for the required precision of the manufacturing and tuning. The four quadrants are very weakly coupled with the result that the frequencies of two dipole modes, which have unwanted polarity of the electrode voltages, are approximately 0.5 MHz aside the quadrupole modes. This gives rise to mode mixing which makes the voltage distribution in the resonator "unflat". The next longitudinal mode will be approximately 15 MHz higher, because the length L of the structure is smaller than the free space wavelength λ_0 of the frequency and the perturbation of this mode is proportional to $(L/\lambda_0)^2$. In general, the flatness is proportional to the mode separation.

We will apply our resonant rings[4,5] to stabilize the HERA-RFQ. There will be one loop ring coupler (RLC) at each end plate of the RFQ. Fig. 5 shows a scheme of the coupling ring together with two vanes, the end cells of which are tied together. The dipole modes are symmetrically shifted away by the rings because the stored energy of the RLC is added resp. subtracted to that of the dipole modes. The RLC concept allows for the use of only one slow-tuner for thermal frequency shift and an adjustable single drive loop to match four different beam currents because the induced imbalance does not tilt the field distribution.

Fig. 6 shows the end tuner for frequency tuning together with the RLC in the vane cut back area. Fig. 7 shows a drawing of the rf part of the adjustable drive loop featuring a phase shifter near the fixed end, a movement of the total loop and vacuum window, and a tuning window, and a tuning insert for balancing the perturbation by the loop.

LITERATURE

1 A. Schempp et al., IEEE Trans. Nucl. Sci., NS 32, No. 5 (1985) p. 3252
2 HERA-report 84/12, DESY Hamburg (1984)
3 K.R. Crandall, R.H. Stokes, T.P. Wangler, BNL 51143 (1983) p. 205
4 A. Schempp, Linac 84, GSI-Report 84-11 (1984) p. 339
5 A. Schempp, Field Stabilization, this conf.

Table 1 RFQ parameters

Input energy W_{in}	18	keV
Output energy W_{out}	750	keV
Radio frequency f	202.56	MHz
Beam current I	20	mA
Total length L_{tot}	117.7	cm
Total cell number N_o	135	
Intervane voltage V^o	70.5	kV
Maximum electric field E_{max}	21.9	MV/m
Vane modulation m	1 to 1.88	
Minimum aperture radius	3.5	mm
Average radius r_o	5.0 - 5.2	mm

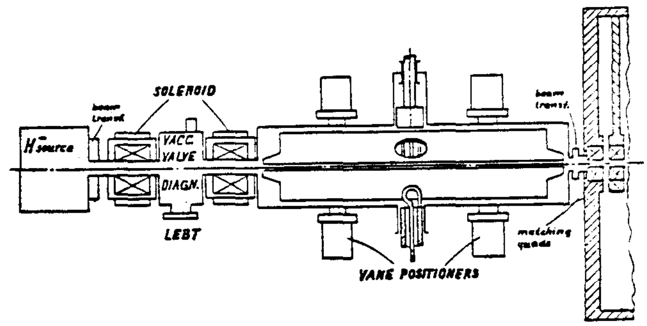

Fig. 1 Layout of RFQ preaccelerator

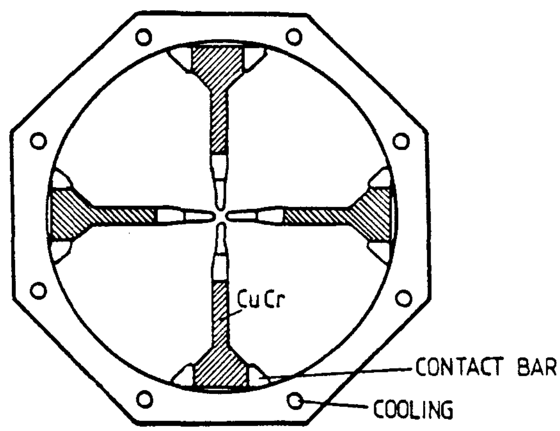

Fig. 2 Cross section of the RFQ

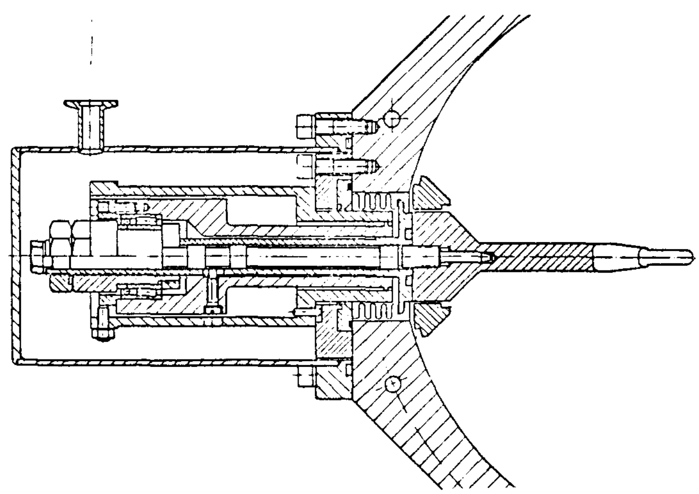

Fig. 3 Vane positioner

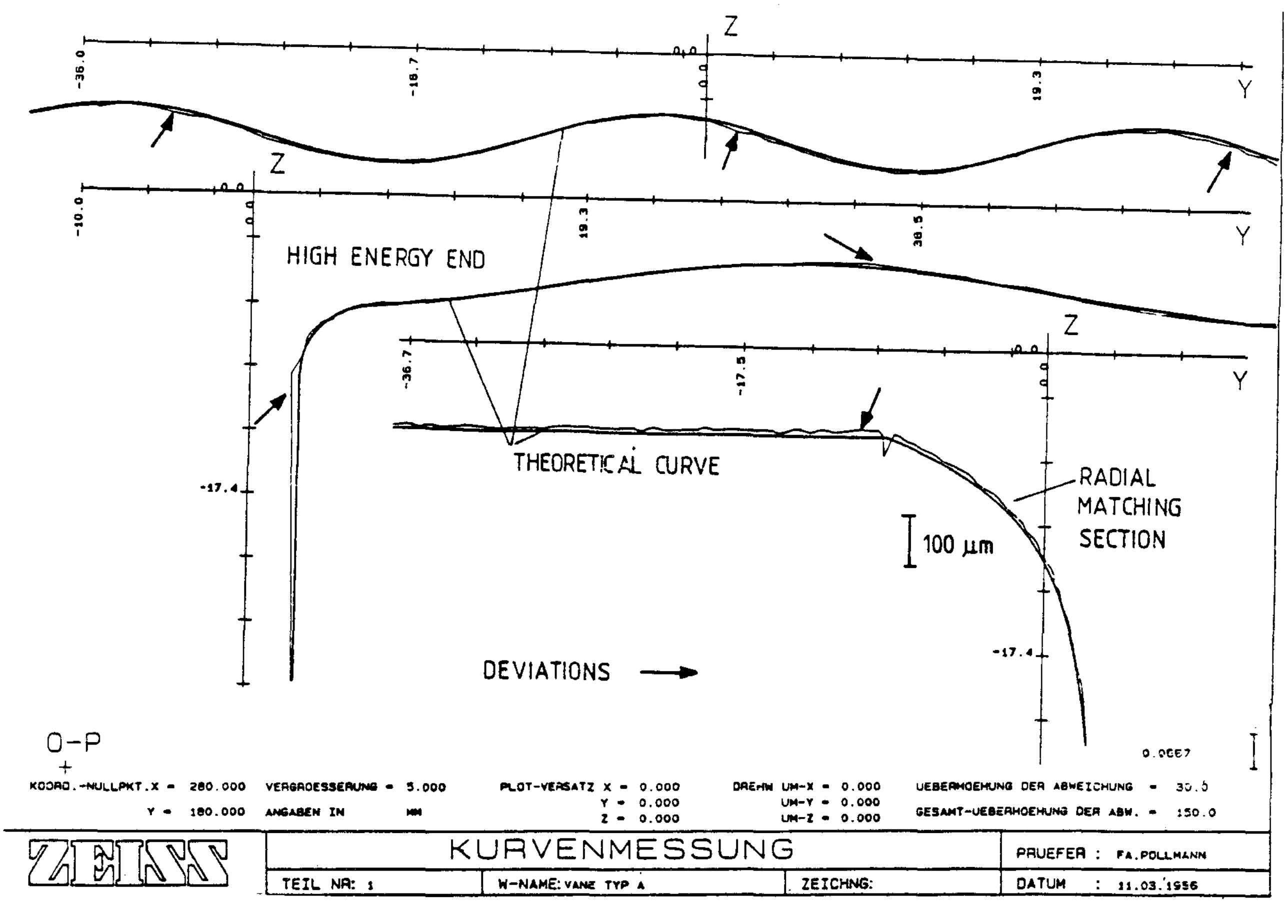

Fig. 4 Measurement of vane tip modulation

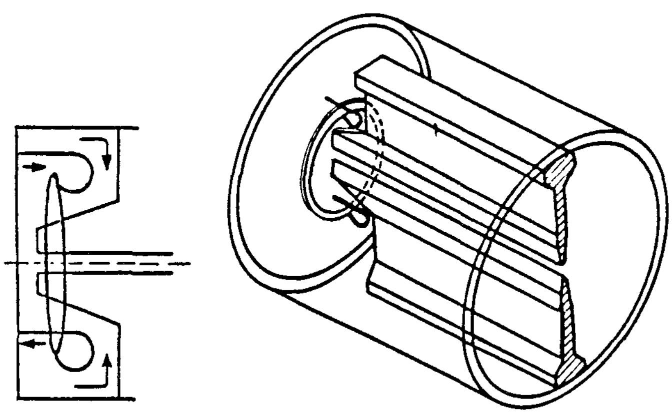

Fig. 5 Coupling ring scheme

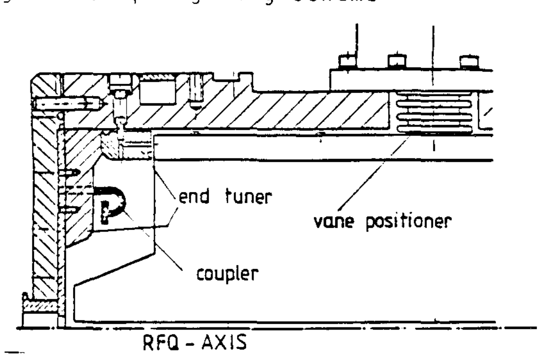

Fig. 6 End tuner and RLC in the vane cut-back

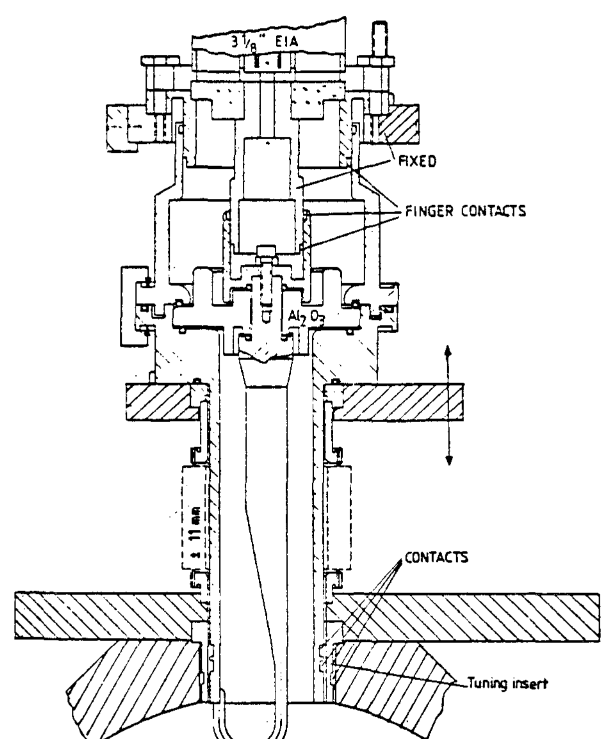

Fig. 7 Adjustable RF drive loop