A PULSED LINAC FRONT-END FOR ADS APPLICATIONS

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Abstract

Quite a number of projects worldwide develop proton driver linacs for neutron sources and for other Accelerator Driven Systems. One trend is to use a high duty factor and superconducting cavities as much as possible. Alternatively, one can aim on short duty factor and count on a continuing rapid development of pulsed rf amplifiers based on power transistor technology. A 500 mA, 5% duty factor layout of a proton injector is presented, consisting of a filament driven volume ion source, of a 150 keV transport section and of a 4.5 m long 162.5 MHz RFQ up to 2 MeV beam energy. Results of beam dynamics and technical designs will be presented.

INTRODUCTION

Worldwide there is an increasing interest in high power ADS (Accelerator Driven System) applications in the multi-MW range. Most of the planned facilities are using low to moderate beam currents (2-50 mA) with cw operation like MYRRHA [1] or the Chinese ADS [2]. The concept described in this paper is based on a pulsed linac with a duty factor of about 5% with very high beam currents of up to 500 mA of protons. The average beam current on the target should be larger than 20 mA. The advantage of lower duty factors is the economic use of room temperature RF structures alternatively to superconducting cavities.

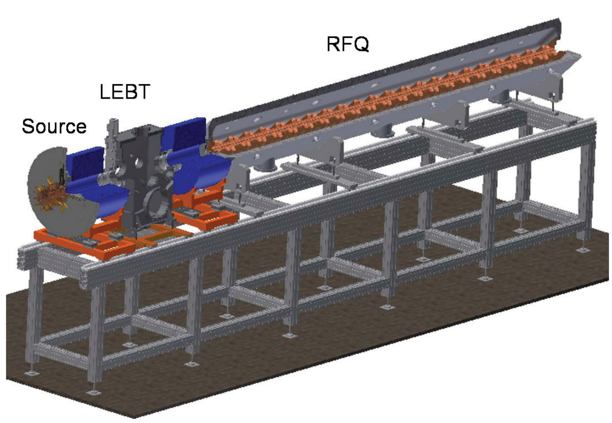

Figure 1: Schematic view of the high current 2 MeV front-end.

Of course, the required RF peak power is significantly larger because of the high beam load. But ongoing developments in pulsed solid state amplifiers will lead to a further reduction of the costs for RF power sources. Alternatively it may be possible to use Solid State Direct Drive^{TM} technology [3] in the future.

The 500 mA front-end consists of a high current proton volume source, a short LEBT-section and a 2 MeV 162.5 MHz 4-Rod-RFQ. Figure 1 shows schematically the layout and table 1 summarizes the main parameters.

Table 1: Main parameters of the 500 mA front-end

Parameter	Value	Unit
Particles	protons	NA
Current	500	mA
Platform voltage	150	kV
Source	volume type	NA
LEBT	magnetic	NA
RFQ	4-Rod	NA
Frequency	162.5	MHz
Energy	2	MeV
Duty factor	5	%

PROTON SOURCE

The proton source is a filament driven volume source which is based on the 220 mA proton source for the FRANZ project [4]. The extraction voltage has been set to 150 kV to keep emittance growth due to space charge small and to limit the technical effort as much as possible. A single hole extraction will be used to minimize the emittance. Numerical simulations have been performed to optimize the triode-extraction system. The other two beam species H_2^+ or H_3^+ can be reduced by source tuning and the proton content will be around 90% of the total beam current. Figure 2 shows schematically the 500 mA proton source.

LEBT

To optimize the beam parameters for injection into the RFQ a very compact LEBT-section consisting of two solenoids and a diagnostic chamber has been chosen. This enables the space charge compensated beam transport of high proton currents with only modest emittance growth. The space charge compensation in the simulations was 90%. Beam transport simulations have been performed with a simplified solenoid model. The solenoid aberrations can be kept small by designing for low aperture filling factor below 0.5. The transmission for the different ion species along the LEBT has been simulated to 100% for protons, 40% for H_2^+ and 24% for H_3^+. Figure 3 shows the loss profile for the two last mentioned species. The unwanted

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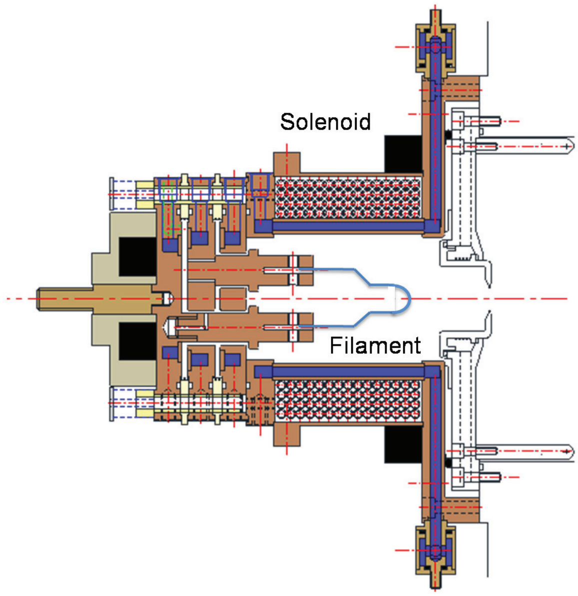

Figure 2: Schematic view of the 500 mA proton source (without extraction system).

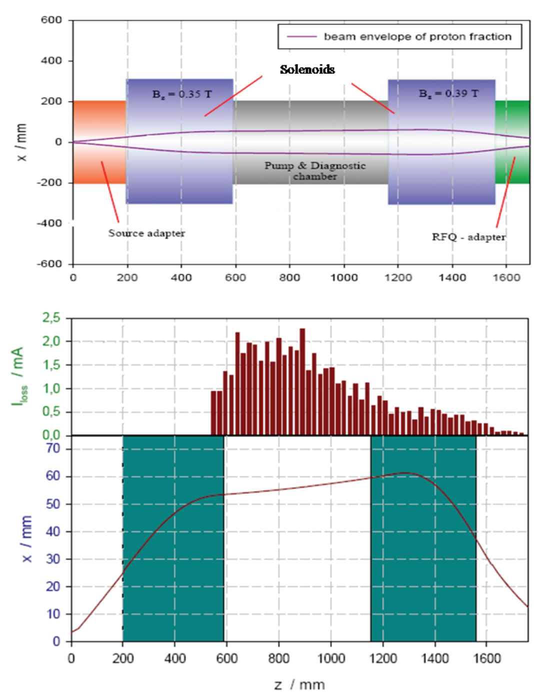

Figure 3: LEBT layout and proton beam envelopes as well as loss profile for other beam species.

species are not matched into the acceptance of the RFQ. Most of these particles will be lost in the RFQ.

RFQ

A 4-Rod RFQ has been chosen as first RF structure. This cavity type is the most common RFQ-structure for proton and ion beams below 200 MHz. The 4-Rod RFQ has several advantages:

- Excellent possibilities for tuning (field, frequency)
- Easy handling and access
- Reliability
- Cost efficient when compared to other structures

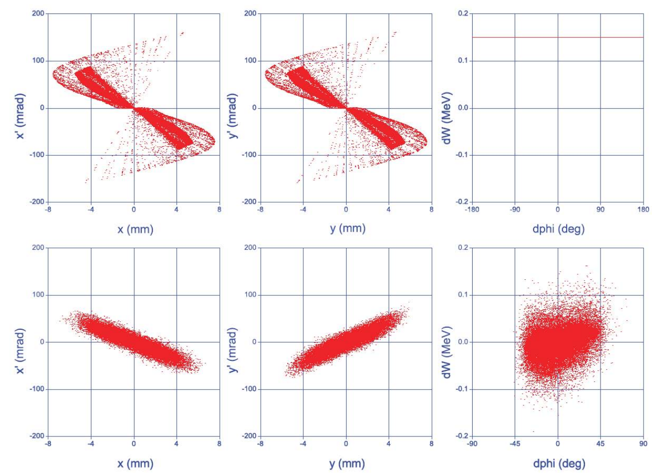

Figure 4: Input and output particle distribution of the RFQ with realistic input distribution.

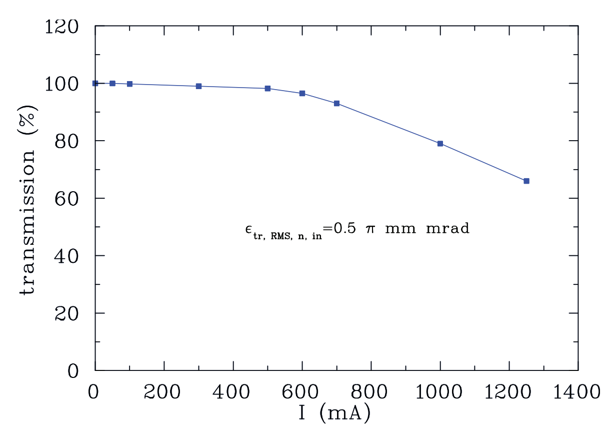

Figure 5: Simulated transmission as function of the input current.

As RF frequency 162.5 MHz has been chosen which gives the possibility to switch to the commercially available frequency of 325 MHz at higher energies. Beam dynamics simulations have been performed to optimize the transmission through the RFQ. Figure 4 shows the input and output phase space. As input the realistic particle distribution given by LEBT simulations has been used. The normalized transverse input RMS emittance is 0.6 π mm·mrad. A high electrode voltage of 150 kV is required to guarantee enough focusing strength for the high current proton beam.

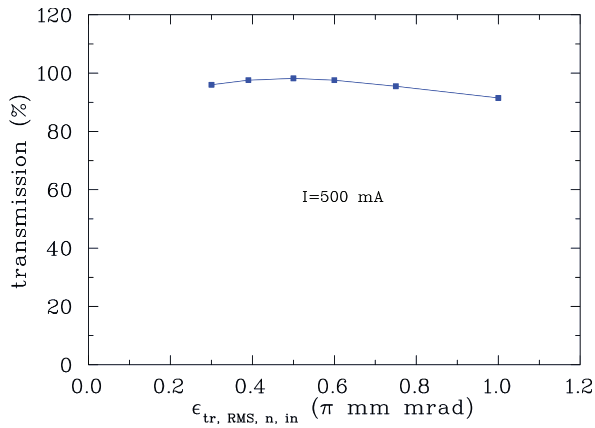

Figure 6: Transmission as function of the transverse input emittance.

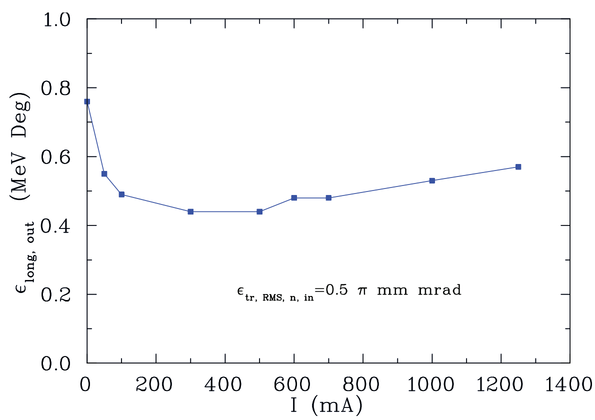

Figure 7: Longitudinal output emittance as function of the beam current.

The length of the RFQ is about 4.5 m, the calculated transmission is > 90 %.

Several simulations have been performed to study the influence of different input parameters like current or emittance on the transmission and output beam quality. Figure 5 shows the transmission as function of the beam current. The transmission stays constant for beam currents of up to about 600 mA, while for higher values there is a significant decrease of the transmission. Figure 6 shows that the transmission is relatively insensitive for the transverse input emittance between 0.3 and 1.0 π mm·mrad. For the simulations in figures 5-8 an ideal input phase space distribution has been used.

The longitudinal output emittance is influenced by the beam current with a minimum close to the design current (Fig. 7). The transverse output emittance increases linearly with the transverse input emittance (Fig. 8).

RF simulations have been performed to estimate the required RF power. Figure 9 shows the RF structure, the surface current density and the magnetic field distribution. The expected shunt impedance is 75 kΩm. This leads to a specific peak power of 300 kW/m without beam loading. The thermal load is expected to be 15 kW/m.

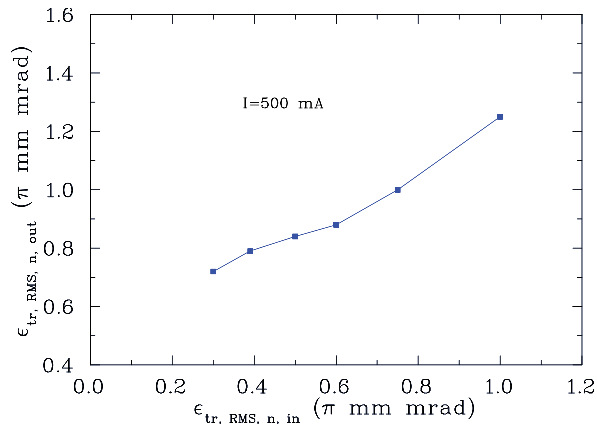

Figure 8: Transverse output emittance as function of the transverse input emittance (bottom).

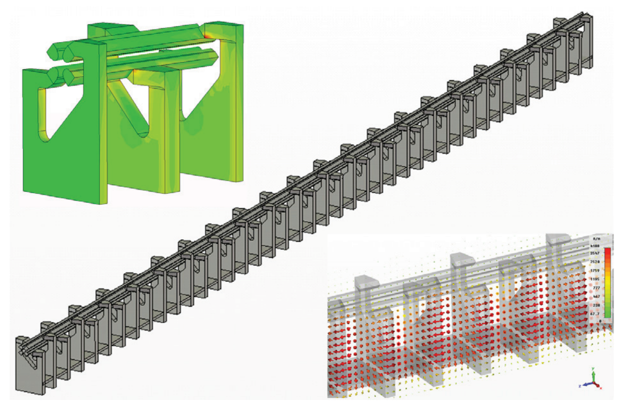

Figure 9: RF simulations of the 4-Rod RFQ.

CONCLUSION

A 500 mA proton front-end consisting of a high current volume source, a compact LEBT and and a 4-Rod RFQ has been investigated. Despite of the challenges due to the high beam current it seems to be feasible to build and to operate such a machine.

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