A NEW ELECTRON LINAC INJECTOR DESIGN UP TO 200 MeV

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Summary

A single mechanical structure can include the on-axis components necessary for best electron bunching and acceleration up to 200 MeV in S-band. Two accelerating sections are put in serie to be seen from the RF source as one load. The sections see a backward traveling wave (BTW) at the $3\pi/4$ mode. The electrical end of the first section includes the buncher. A slight frequency change induces beam radial control keeping at the same time the energy spectrum narrow. The input/output parts near the mechanical center insure good conductance, easy focusing and dilatation. Energy figures are given at 3 GHz and at 11.4 GHz without or with mechanical integration.

Introduction

The development of light sources asks for electron injectors from about 50 MeV to more than one GeV. Already the ELETTRA 1.5 GeV linac design takes advantage of the high shunt impedance of the backward traveling wave (BTW) to reduce the acceleration length to 30m per GeV for an expected peak RF power at 3 GHz of 225 MW at the klystron exit, before compression from 4.5μs to 0.8μs by a SLED-like system [1].

This paper presents a new design which extends the BTW use to preinjection. Feeding two BTW sections in serie, one achieves mechanical simplification, bunching integration and a simple control of the beam to RF dephasing to improve the beam radial control at low energy spread. The number of independent RF elements (sources, brazed sections, couplers) is decreased.

Backward Traveling Wave properties

The BTW had never been used until recently to accelerate [3]. It combines the advantages of traveling wave and standing wave. The forward TW electrically coupled on-axis (the classical "iris waveguide") is remarkable for its good adaptation and short filling time. The SW magnetically coupled off-axis is remarkable for its high shunt impedance. The BTW peculiarities are: (i) with reference to forward TW, the presence of noses (which insures a good shunt impedance) and the opposite directions of the beam and of the RF wave (required to accelerate), (ii) with reference to SW, the absence of the complicated coupling cells . One note that the RF input being near the beam exit and the buncher (if any) being near the RF exit, its field level depends on the line attenuation and for long pulses on the beam loading.

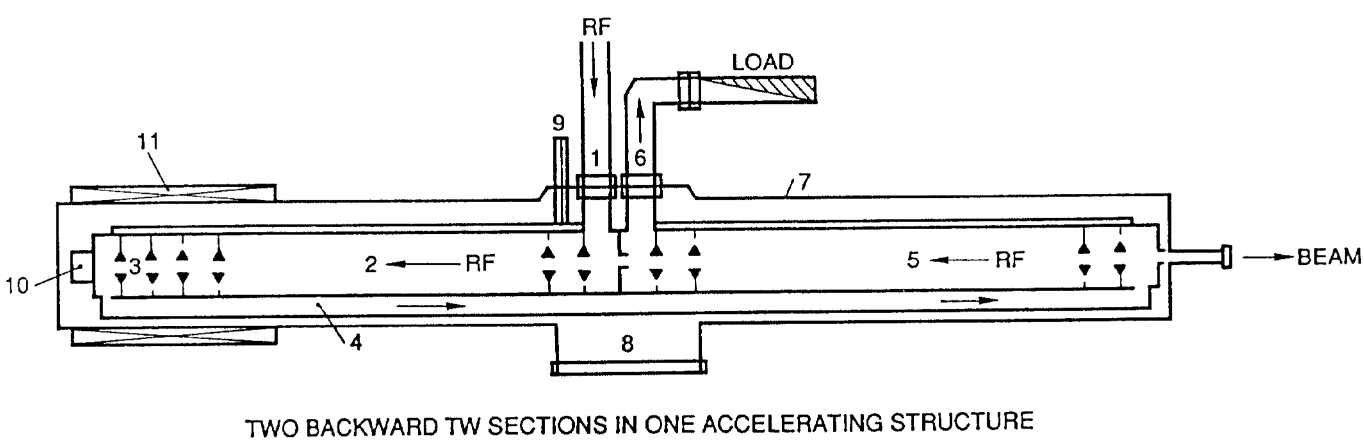

Figure 1: New design for a linac on-line structure up to 200 MeV

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Description of the new design [2]

To bunch properly one cuts the accelerator unit in two sections and inverts them with reference to the beam. Then the bunching occurs at mid-attenuation and mid-filling time so that line attenuation, beam loading, SLED-type RF pulse length are no more critical.

Figure 1 presents the unit when the (not required) mechanical integration of the two electrical sections is achieved. The RF power enters by the coupler (1) inside a BTW periodic structure or section (2) which integrates a bunching part (3), then flows along a rectangular waveguide (4) to the next section (5) and finally leaves the section by the coupler (6) to an RF load. The electron beam created by the gun (10), crosses the buncher made of shorter cells (3), then crosses the two sections (2) and (5) before leaving the unit. Other elements includes vacuum flange (8), cooling pipes (9), eventually solenoidal focusing (11).

Electrical properties

Even without mechanical integration, the phase control capability and the recombination option are achieved:

(1) The phase is controlled in a very effective way by an RF slight frequency change. Figure 2 shows the "phase law" along the acceleration axis (in fact it is the dephasing between beam and field at the cell mid-planes, modulo $2k\pi$). It lie on-axis when there is no asynchronism. The continuous or dotted lines are obtained by a slight frequency change df. With N being the number of wavelengths at the group velocity vg (constant), the cumulative phase (linear) increase or decrease is:

$$d\phi/2\pi = (c/vg)\ N\ df/f$$

This means that one can switch the accelerated bucket from one side to the other of the accelerating wave sinusoid to control at the same time the radial dynamics and the energy spread as analyzed in ref. [4]. Note that strong correction occurs right at the beginning of the second section.

(2) The recombination option uses a 3db coupler to feed one downstream independantly brazed section by two upstream ones. Then identical c/vg sections can be used at similar accelerating field levels.

Mechanical properties

(1) When mechanical integration is achieved as in fig.1, the input/output components for RF, vacuum, cooling are all nearby and near the middle of the structure. This eases the gun or the solenoidal focusing set-up and gives a better pumping and cooling.

(2) The waveguide linking the two sections do not need a phasor as precise check of RF phase on the axis of the two most far away cells is part of the standard RF cold tests. No phasor is used all along the high peak power flow from klystron to load.

(3) For lengthy structures, RF and vacuum seals are separated and the waveguide is easily put inside the vacuum envelope, along the periodic structure.

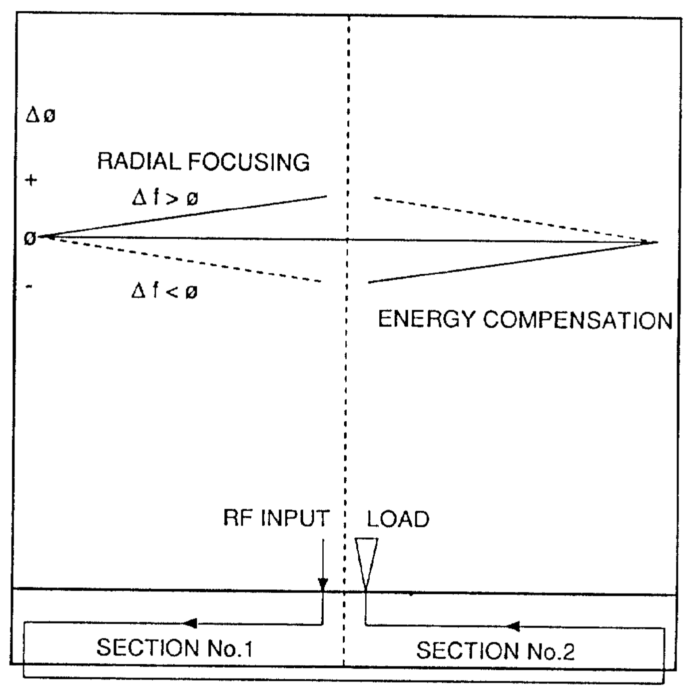

Figure 2: Dephasing control between beam and field. ΔΦ (RF/bunch) insures best dynamics for Δf slightly positive.

Integration in linac designs

One can either use the electrical properties only, connecting in serie independant sections, or add to it the mechanical integration illustrated on fig.1. The frequency choice is not limited to S-band.

(1) The first S-band example uses two standard 6m BTW units of the ELETTRA type, put in serie, without mechanical integration [5]. The first unit will includes a buncher simply made by decreasing several $3\pi/4$ end-cell lengths. One RF source of 45 MW - 4.5 μs at the klystron, compressed by the CIDR system, feed 12.3 m at c/vg = 18.5 for 0.76 μs filling time. With the BTW geometry, such low c/vg value can be obtained without too much shunt impedance loss [3]. 280 MeV are obtained at low current. The RF circuit does not include couplers other than SLED ones nor phasor. The peak field level is moderate.

(2) Mechanical integration is of interest when shorter total length and lower energy spread for large accelerated charge are required. The peak field level characteristic of ELETTRA is reached by integration of two 3 m sections in a 6.15 m enveloppe as in fig.1, giving 200 MeV at low current.

(3) A compact injector for FEL, in the long pulse steady state mode, can use the same unit. The sections have now variable c/vg. Fed by a 30 MW - 10 μs RF source (without pulse compression), it delivers 100 MeV at low current, 70 MeV at high peak current.

(4) In X-band, at 11.4 GHz, with same lengths of 2 x 3 m and a 100 MW - 1 μs klystron pulse compressed to 400 MW - 0.2 μs [6], one obtain 470 MeV energy gain at c/vg = 10 and the type IV scaled down geometry of [7] (note that feeding with the same RF source two units of 2 x 1.5 m each, at higher c/vg, gives 514 MeV. This slight energy gain does not compensate for the complexity).

The beam clearance is then 3 mm dia. (but can be increased up to 4 mm dia. with moderate energy loss). The great number N of cells used supposes low dispersion or c/vg value. The sensitivity to frequency misadjustments depends on the N c/vg product. It remains reasonable and comparable to the S-band ELETTRA design.

Conclusion

The design presented in this paper uses backward traveling wave geometry to bunch and accelerate electrons (or positrons). This is made in the best conditions (i) as the backward propagation relieves from the very high peak field constraint at the RF input when cells are reduced in length for bunching and (ii) as the cell geometry allows precise field shaping near the particle trajectories. This is very precious to optimize the radial behaviour.

References

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