THE ACTIVITY ON LINEAR ACCELERATORS AT THE ENEA FRASCATI CENTER

L. Picardi, G. Messina, C. Ronsivalle, A. Vignati
ENEA , INN-SVIL
P.O. BOX 65, 00044 Frascati (ROMA) ITALY

Introduction

Some ten years ago the activity of our laboratory, historically involved in the field of microtrons, started in the linac field, stimulated by the need of building a racetrack microtron.

Since then four small linear accelerators were built in our laboratory both for a 100 MeV racetrack microtron and for e- beam processing test of materials [1].

Linac building technology was shared with an italian industry, "IRVIN Elettronica", which, up to now, has built both S-band and L-band linacs for industrial purposes in the power range of 5 MeV, 5 KW and now is building a self-focusing small linac radiography dedicated designed by our Lab.

ENEA is also being involved in infrared FEL research and after the good results of a 2 mm wavelenght FEL driven by a 2.5 MeV microtron[2], we started the design of a linac for a FEL facility in the far i.r. devoted to an experiment of muonic hydrogen spectroscopy in cooperation with INFN[3].

Linac Development

Linear accelerators developed in our laboratory are 40 cm long standing wave, pi/2, side or on axis coupled structures working at 2.998 GHz and feeded by a klystron or a magnetron . We generally fully provided for machining, tuning and brazing by ourselves. Tuning usually has been achieved by means of tuning screws fixed to the structure after the final brazing. A fast tuning method has been developed consisting in the comparison of the pi/2 mode frequency of the whole linac to the frequency of the pi/2 mode of the portion of the linac composed by all but the end cells and excited in the coupling cavities. This comparison allows a quick closure of the stop band according to its physical meaning. After, only a more careful tuning of the end cells has to be done.

Typical values of the characteristics of a linac produced in our laboratory are those listed in the table below and that pertain to the racetrack microtron one[4].

TABLE 1

Frequency	2.998 GHz
Number of cells	1/2+7+1/2
Q factor	12000
Coupling coef. to waveg.	3.5
First nei. coupl.	.04
Second nei. coupl	-.002

5 MeV Linac applications

A 5 MeV on-axis coupled linac was built some years ago intended primarily for e-beam processing tests. It works at a typical current of .2 A in 4 µs pulses ad a p.r.r. of 50 Hz.

Many applications were performed in these last three years [5].

- Crosslinking of commercial resins, polymers and heat-shrinkable materials
- Production of color centers in Tl+ doped KCl crystals for 1.5 ÷ 1.6 µm wavelenght laser application: a long-term stability of these color centers has been achieved and a high production efficiency compared to the gamma rays irradiation.
- Destruction of polyclorobiphenyls (PCB) in dielectric oils: a degradation of 99.9% at 20 MRad has been obtained with opportune Cl- trap consisting of H2 insufflated in the sample emulsioned with water.

Self-focusing radiographic linac

The requests for a compact radiographic accelerator which has to be used as a portable tool for checking structures like bridges, are typically:

- 5 MeV as maximum energy
- 400 Rad/m as Dose rate which correspond to a linac peak current of 130 mA, 4 µs at a rep rate of 280 Hz
- a spot size of 2 mm or lower
- weight and size as small as possible.

In order to reduce the weight of the machine an auto-focusing particle dynamics was developed which avoids the requirement of the usual focusing bulky solenoids. This has been achieved by shaping the axial electric field in the first cell, making it growing slowly in order to smoothly bunch and shrinking and slightly accelerating the electrons in it. Indeed in the first millimeters of the first cavity, where bunching occurs, some electrons encounter an accelerating and focusing field and some others a decelerating and defocusing one, but the resulting radial dispersion is limited because of the reduced electric field stenght.

Afterwards, when the bunch is formed, which happens about in the center of the cell, the beam sees a lens which focuses it at the exit of the first cavity. Moreover the lenght of the first cavity and the injection energy are adjusted in order to let the beam pass in the center of the next cells after the RF peak so to have a futher RF focusing (fig.1).

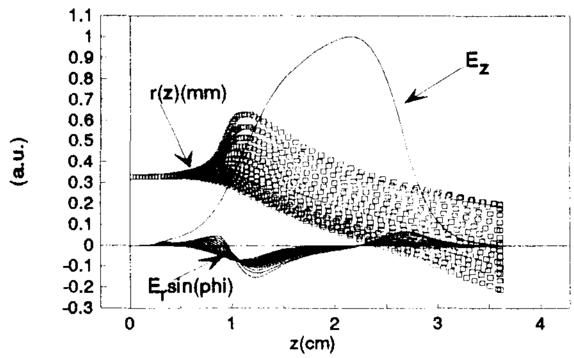

Fig.1 First cavity dynamics (phi=170°-310°)

The main parameters of the linear accelerator are reported in table 2 below:

TABLE 2

Injection Energy	13 KeV
Cathode Current	430 mA
Number of cells	8
Lenght of cells (mm)	25, 40, 45, 48, 50, 50, 50
Max Electric Field	28 MV/m
RF Power to the Struc	990 kW
Max Output Energy	5 MeV
Output Current	180 mA
Energy Spread	2.5 %
Output Beam Radius	1 mm

μ FEL Linac

For the experiment of muonic hydrogen spectroscopy [3] in course of design in cooperation with INFN a 180 μm, 100 ps long FEL pulses are required. These pulses must be synchronized to the trigger signal produced by the single μ with a delay not greater than 1.5 μs. This can be obtained using as FEL source a 9 MeV RF linac. The frequency of the RF, however, is linked both to the micropulse lenght and to the synchronized operation; indeed utilizing a low RF frequency (for example 200 MHz) leads easily to a 200 ps microbunch but the system is no longer triggerable due to the large filling time of the cavities (20 μs). On the contrary a 3 GHz linac can be triggerable (500 ns rise time), but its micropulse is typically 10 ps long.

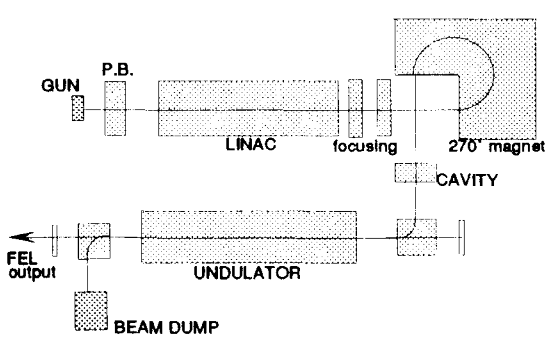

Fig.2 μ-FEL linac layout

For these reasons we are designing a 3 GHz linac followed by a magnetic system able to stretch the micropulse making use of the non isochronous properties of a suitable achromatic 270° magnet with respect to the energy spread (fig.2). In table 3 the characteristics of the linac and the magnetic system are reported.

The results of the preliminary PARMELA calculations show an increase of the FWHM bunch lenght from 15° to 116°. This spread-phase correlation can be also used to reduce the final energy spread introducing a cavity after the magnet which allows a final energy spread of .4 %.

TABLE 3

Injection Energy	100 keV
Prebuncher voltage	9 kV
Electron final energy	9 MeV
Linac capture efficiency	70 %
Bunch lenght (FWHM) at linac exit	14 ps (15°)
Energy spread (FWHM) at linac exit	3 %
270° magnet bending radius	20 cm
Bunch lenght at magnet exit	107 ps (116°)
Cavity voltage	200 kV
Energy spread (FWHM) at cavity exit	0.4 %

In fig. 3 the energy-phase diagram and phase and energy distributions at the exit of the correcting cavity.

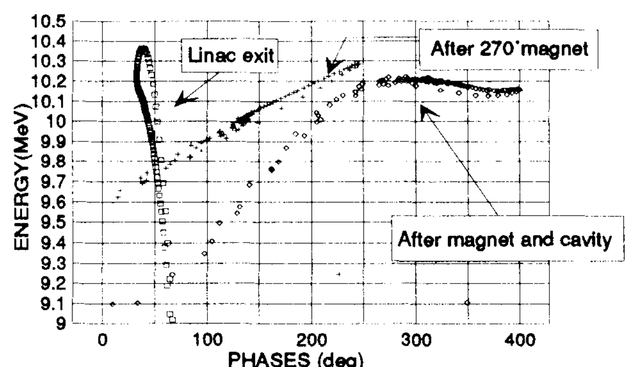

Fig.3 Energy-phase diagram in different points of the accelerator

Conclusions

The development in small linac design and construction performed in ten years of activity at the ENEA Frascati Center has been briefly described and some interesting future projects have been evidentiated. In addition some development in the field of small linear accelerators can be also stimulated by compact FEL design because a source of this kind in the wavelenght range below 1 mm is mature to be designed.

References

[1] U. Bizzarri et al. ,"Electron Accelerators at the ENEA Frascati Center: Development and Applications" NIM B50 (1990) 331-337.

[2] R. Bartolini et al. "Coherent emission and gain from a bunched electron beam", to be published.
[3] P.S.I. Proposal R-9206-1, "Spectroscopy of muonic hydrogen" (Dec. 1991).
[4] C. Ronsivalle et al. "Characterization of the performances of the ENEA Racetrack Microtron" presented at the 1992 EPAC, Berlin.
[5] G. Messina et al. "on the use of a 5 MeV Electron Linac for Electron Beam Tests Processing", presented at the 1992 EPAC, Berlin.