# THE ALPI LINAC PULSING SYSTEM

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*Abstract*

The existing 16 MV XTU tandem will serve as the first injector of the linac ALPI [1], which is under construction at Laboratori Nazionali di Legnaro. The dc beam produced by this machine has to be compressed into bunches about 100 picoseconds wide, with low longitudinal emittance and with the proper time-energy ratio. This will be achieved by a pulsing system [2], based on a 5 MHz double drift buncher, placed 3.5 m upstream the tandem, and two superconducting quarter wave resonators located 8 m and 16 m upstream the linac, working at 160 and 80 MHz, respectively. A couple of choppers will suppress tails and dark current transmitted by the low energy buncher, and a travelling wave chopper will scale down the 5 MHz frequency when needed. A resonant phase detector will be used for stabilizing the time of arrival of the ion bunches at the linac.

The system is designed in order to bunch all kinds of ions; it will be used both for injecting ALPI and for the pulsed beam experiments where the tandem alone is needed. The installation, now in an advanced stage, will be completed during 1992.

## 1 INTRODUCTION

The longitudinal characteristics of the heavy ion beams are critical for the injection of the beam in a linac, when a good beam quality has to be preserved during acceleration.

Two main parameters must be considered: the first is the linac phase acceptance, which is usually set to $5^o$ , corresponding to 174 ps for the 80 MHz cavities of ALPI; the second is the optimal energy-phase ratio [3], that keeps to minimum the longitudinal emittance growth during the acceleration process.

The main injector for ALPI is the Legnaro 16 MV Tandem; it is well known that this kind of accelerators produce beams with low emittance and good energy resolution. The intensity of the beam reaching the linac, however, will be typically one or two order of magnitude lower than the one produced by the source, due to the charge selection needed after every stripping process; an efficient pulsing system is therefore required in order to keep the beam current as high as possible.

A two-stage pulsing system based on a low energy double drift buncher [4,5] can meet these requirements.

## 2 STRUCTURE OF THE SYSTEM

The ALPI pulsing system consists of the following elements (starting from the low energy side, see fig. 1):

1. a pre-tandem travelling wave chopper, whose function is to scale down, when required by the experiment, the main frequency of the bunched beam from 5 MHz to $5/2^n$ MHz, where $n = 1, 2, 3, ..., 32$; the beam intensity is reduced by the same factor;
2. a pre-tandem double-drift buncher [6], working at 5 MHz; this device can produce a pulsed beam with a time width in the nanosecond range; its efficiency is higher than 70%;
3. a 5 MHz post-tandem chopper of the biased type [7] (nicknamed *buttafuori*) located before the analyzing magnets, capable to eliminate most of the dark current with a minimum increase in longitudinal emittance;
4. a 10 MHz post-tandem chopper (postchopper 1) located just after the U-bend leading to the linac;
5. a second 10 MHz chopper (postchopper 2), optimized for higher ion velocities, is located on the line leading to the experimental hall. The low energy chopper and the second postchopper, as well as a phase detection system based on the measurement of the current on the slits following the postchopper, existed in the previous pulsing system and were upgraded in order to meet the new requirements;
6. a phase detector based on a 5 MHz resonant cavity excited by the pulsed beam; it will be used to correct the fluctuations in the transit time, typically a few nanoseconds, observed in ions travelling through the tandem [8];
7. an 80 MHz superconducting cavity ($\beta_{opt} = 0.055$) that will be used as the main high energy buncher [9]; the time acceptance of this cavity, when used as a buncher, is about 2 ns;
8. a second (160 MHz) superconducting resonator [10]; in ALPI-phase 1, which foresees the acceleration of ions up to nickel, this cavity will be used as a superbuncher; in ALPI-phase 2 the 80 and the 160 MHz resonators will form a telescopic system in the longitudinal phase space that will be able to create a time waist with optimum energy-time ratio for ions of all masses.

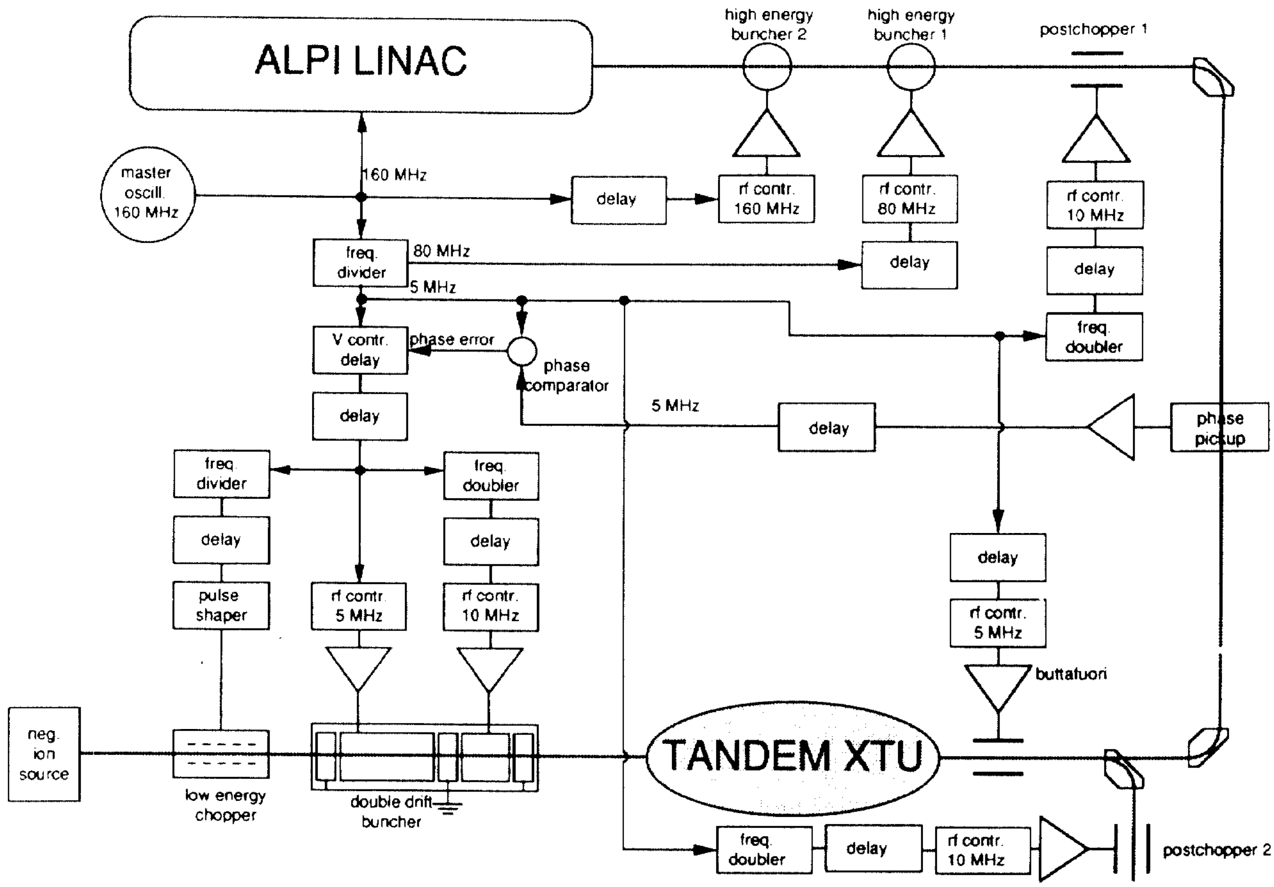


Figure 1: Pulsing system block diagram.

## 3 ELECTRONICS

The reference signal of the pulsing system is generated by dividing the 160 MHz master signal of the LINAC down to 5 MHz, from which all other rf signals are obtained: the phase shift of all higher frequencies, obtained by multiplying the 5 MHz reference, is then determined without ambiguity.

The reference signal for every resonator is provided with a 8 bit programmable delay generator (Analog Devices AD9500) which covers slightly more than 360° of one cycle, with 1 ns steps at 5 MHz and 500 ps steps at 10 MHz.

The reference signals of the 10 MHz harmonic of the double drift buncher, as well as the ones of the postchoppers, are equipped also with fine delays that can be set with an accuracy of 200 ps.

A voltage controlled delay controls the rf reference signal for the components upstream the tandem. This device is driven by the error signal produced by the phase pickup and allows to compensate for fluctuations in the phase of arrival of the ion bunches at the linac.

The delay cards are mounted on G96 crates together with cards performing other functions (power switches, choice of the reference signal source, mechanical actuators, etc.).

The phase and amplitude stabilization of the resonators is done by rf controllers developed at Legnaro [11]; controllers of the same type are used for the ALPI superconducting resonators.

## 4 COMPUTER CONTROL

The pulsing system is controlled via computer; this choice allows future developments and automation.

The computer control system is organized in three levels: at the first level we have the man-machine interface provided by a graphic program, based on a hierarchical window structure; at the second level a concentrator, linked through an ethernet network to the first level, receives commands from the console and distributes them to the third level by means of serial links. At the third level we have resonator controllers and G64 based controllers for stepping motor and digital I/O needed by the delay cards.

The two superconducting bunchers are included in the superconducting linac control program.

All the parameters that are needed for running the system in a configuration ( phases, amplitudes, frequency, etc.) can be saved in a file and recalled whenever the same beam is to be used. The pulsing system set-up, in routine operations, takes only a few minutes.

In the future many steps which still need the operator intervention (like resonators tuning) will be automated via software.

## 5 PRELIMINARY MEASUREMENTS

The pre-tandem section, consisting of low energy chopper and double drift buncher, as well as the the postchopper 2 and the phase detection system of the beam line leading to the experimental room, is already in operation, together with the computer control system; the *buttafuori*, postchopper 1 and 5 MHz phase detector are still under construction.

Some tests were performed in order to verify the reliability of the system. The beam time at our disposal was limited and the following results, obtained with a $^{16}O$ beam, should be considered as preliminary ones.

The time measurements were done by means of a microchannel plate detecting the electrons emitted by a tungsten wire hit by the beam; the time resolution of this detector was about 200 ps. The efficiency was measured with the following procedure: by means of a Faraday cup we verified that the dc beam current didn't change by switching on the double drift buncher; then we measured the fraction of counts inside the peak (the limits were set at 10 % of the maximum number of counts) over one cycle.

The bunching efficiency of the double drift buncher is above 75 % in a 3 ns FWHM peak (without phase stabilization). Switching the postchopper 2 and the phase stabilization system on, the beam resulted in a 1 ns FWHM peak containing 50% of the DC beam (measured with the Faraday cup).

Although these results are within the design requirements, we think that the performances could be significantly improved by reducing the size and the energy spread of the beam delivered by our old 140 KV injection platform.

## 6 CONCLUSIONS

The installation of the ALPI pulsing system is near completion.

The 80 and the 160 MHz niobium superconducting bunchers were constructed and tested; the latter one is now being mounted on the beam line, as well as the 5 MHz chopper. The construction of the 10 MHz postchopper 1 and the 5 MHz phase detector will be completed during the coming few months.

Double drift buncher, low energy chopper, postchopper 2, phase stabilization system and their electronics, as well as the control software, are now in operation; according to the preliminary results obtained with oxygen ions the system is reliable, user-friendly and satisfies a wide range of experimental requirements.

The automation via software of some procedures, like resonator tuning, will make the pulsing system setup even faster.

The time resolution, which fulfills the design requirements for low mass ions, could be significantly improved by a better quality of the beam delivered by the existing 140 KV injection platform; in order to allow the injection of high mass ions in ALPI, the construction of a new, high stability 300 KV platform is foreseen.

## 7 ACKNOWLEDGEMENTS

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