ACDIV-2014-05
June, 2014

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Two pulsed klystrons are used to feed the linac cavities. We present a modification of the distribution of the RF waveguide system that will allow us to power the ALBA linac with any of the two klystrons installed. The new system improves the time response after a klystron failure. Using the single klystron working mode a 60MeV electron beam is achieved at the linac exit. To match this beam to the booster, adjustments on the linac-to-booster transfer line and on the booster ramping parameters have to be performed. The commissioning of the whole injector for low linac energy is under way. Details of the waveguide upgrade and the results of the ALBA linac operated with only one klystron are reported.

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Abstract

ALBA is a third generation synchrotron light source whose injector consists of a 100 MeV linac and a Booster that accelerates the beam up to the full energy, 3 GeV. Two pulsed klystrons are used to feed the linac cavities. We present a modification of the distribution of the RF waveguide system that will allow us to power the ALBA linac with any of the two klystrons installed. The new system improves the time response after a klystron failure. Using the single klystron working mode a 60 MeV electron beam is achieved at the linac exit. To match this beam to the booster, adjustments on the linac-to-booster transfer line and on the booster ramping parameters have to be performed. The commissioning of the whole injector for low linac energy is under way. Details of the waveguide upgrade and the results of the ALBA linac operated with only one klystron are reported.

INTRODUCTION

The ALBA Synchrotron is in operation for users since May 2012. During this time, the injection to the Storage Ring has been performed with two injections per day, typically at 120 mA, but the injector has been designed to be able to operate in top-up mode, where frequent injections keep the average storage ring current within few percent variation. Top-up operation at ALBA has been implemented and tested and will be offered to users by summer 2014 [1].

The ALBA linac is driven by two Thales TH2100 klystrons that deliver 5μs pulses at a frequency of 3GHz. They generate a maximum output of 35MW at a repetition rate of 3 Hz. Klystron 1 feeds the bunching section and also the first accelerating structure. Klystron 2 feeds exclusively the second accelerating structure. Although in ALBA no klystron tube failure has occurred yet, the replacement of a klystron tube or modulator interrupts the linac operation for at least 24 hours.

In addition, when operating in top-up mode, the injector reliability will be more demanding because it requires the injector to run almost continuously. This fact will have an impact on the service lifetime of several subsystems of the injector, like on the klystron tubes. Consequently, when operating in top-up mode we expect that they will have to be replaced more often.

In order to keep the ALBA injector operative after a klystron failure the RF distribution of the ALBA linac has been slightly modified by connecting the two separated waveguide systems, as shown in Fig. 1 (golden colored components).

A S-band switching system has been installed in the waveguide system and allows us to use Klystron 2 to power the low-energy section in case that Klystron 1 fails. With only one klystron the linac delivers around 60 MeV. So that injection into the Booster is still possible while, in the meantime, the damaged klystron can be connected to a dummy load for reparation.

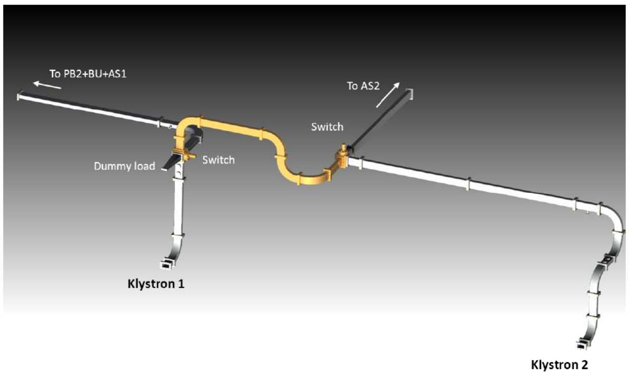

Figure 1: Modification of the RF distribution.

THE ALBA LINAC

The ALBA pre-injector is a 100 MeV linac delivered by Thales and commissioned in 2008 [2].

Figure 2: The ALBA Linac

A 90 keV pulsed beam generated by a thermionic gun (in multi or single bunch) is first sent to the three stage bunching system consisting of a sub-harmonic pre-buncher at 500 MHz (PB1), a 3GHz pre-buncher (PB2) and a 22-cells standing wave buncher (BU). The bunching system is designed to reduce the energy spread and to minimize the transmission losses. Two identical travelling wave constant gradient accelerating sections (AS1 and AS2) increase the energy up to a maximum of 125 MeV. See Figures 2 and 3 and Table 1. The linac is routinely operated at 110 MeV.

Table 1: Main parameters of the ALBA Linac

Parameter	Specification
Linac exit energy	110 MeV
Repetition rate	3 Hz
Relative energy spread (rms)	0.30 %
Norm. Emittance, both planes	15 mm.mrad
Energy variation pulse to pulse	0.20%
Jitter	30 ps

Typically, klystron 1 delivers 25MW to the bunching system and to one accelerating section whereas klystron 2 delivers 15 MW to the second accelerating section. The sub-harmonic pre-buncher has an independent RF amplifier.

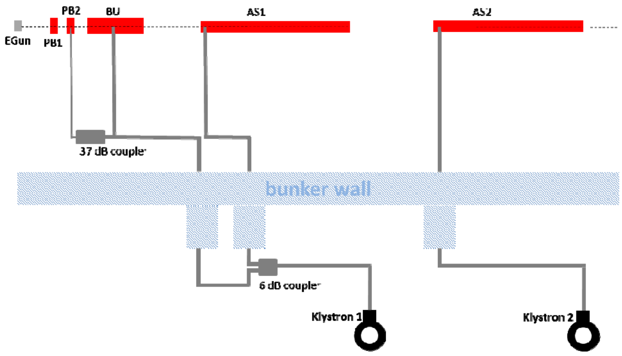

Figure 3: Scheme of the ALBA linac with the original RF distribution.

WAVEGUIDE MODIFICATION

The original RF distribution of the ALBA linac was composed of two independent circuits of WR284 waveguides. Each circuit was fed by one klystron and brought the RF power from the service area to the linac cavities placed in the bunker. In order to prevent arcing inside the waveguides they are filled with SF6 gas at a pressure of 3 bar. Ceramic windows separate the gas from the cavity vacuum.

As another improvement, we have installed a set of accelerometers on top of the waveguides as arc detectors since they detect the vibrations produced by internal arcs.

Recently, the waveguide distribution has been modified in the service area in order to connect the waveguide circuits of both klystrons, see Figure 1.

As it is shown in Figure 4 the connection is achieved by means of two S-band waveguide switches manufactured by Sector Microwave. Each switch has four ports and is set manually.

The two switches are connected via additional WR284 waveguide pieces. An AFT S-band CPR284 water cooled load is installed in one of the four ports to be used as test stand for new or repaired klystrons.

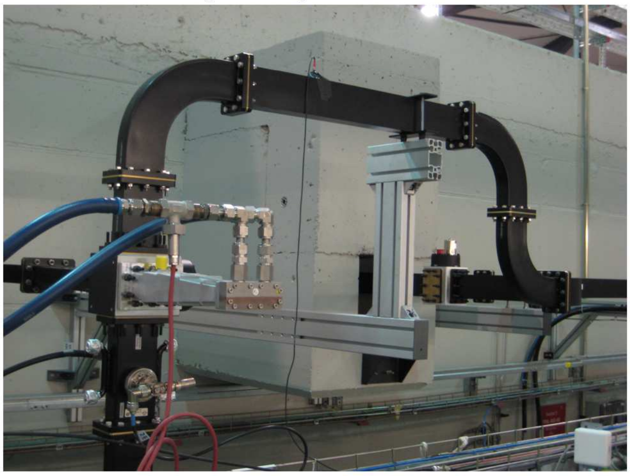

Figure 4: Detail of the waveguide connection with the switches.

The switches have two positions and allow to operate in three different configurations, see Table 2:

Table 2: Modes of klystron operation after the switches upgrade

Switches Configuration	KA1 feeds	KA2 feeds
Mode 1	PB2+BU+AS1	AS2
Mode 2	Dummy load	PB2+BU+AS1
Mode 3	PB2+BU+AS1	Dummy load

In normal conditions both klystrons are used to operate the linac, i.e., the switches work in Mode 1. But in case of failure of klystron 1 the switches system allows us to run the linac at low energy by setting the switches to Mode 2. Then klystron 2 powers the bunching system and the first accelerating section.

In addition, in Mode 2, klystron 1 can be repaired and/or exchanged in parallel, without stopping the linac operation since we will be able to operate it on the load. In the same way, if klystron 2 is failing the system allows to run the linac at low energy with klystron 1 while klystron 2 is being repaired. This is achieved by using the switches configuration Mode 3.

SINGLE KLYSTRON MODE

The new waveguide components were installed in January 2014. During the first attempts of powering the linac with only klystron 2 arcing problems aroused in the new installed waveguide pieces. The arcing persisted after several hours of conditioning. As a consequence, the maximum power delivered by klystron 2 was limited to 15 MW.

The system was opened and revised in two occasions. The first intervention was used to solve additional SF6 leak problems due to the use of new waveguide gaskets which could be as well responsible of some of the arcing. In the second intervention a section of the waveguide with high curvature was slightly modified to smooth its path.

Afterwards, new high power conditioning allowed us to power the new waveguide with klystron 2 up to 20 MW, not yet the 25MW needed for having a good bunched beam at low energy, due to some mismatch on the system which causes high reflected power. Further work is needed to determine the cause of the high reflected power production.

Nevertheless, at this level of power with klystron 2, the beam generated had already an energy of 57 MeV at the linac exit.

When switching off klystron 2 a beam energy of 67 MeV is achieved at the linac exit. Properties of this beam are compared to the nominal 110 MeV beam in Table 3.

Table 3: Parameters of the linac beam achieved using either one or two klystrons.

Parameter	**Both klystrons**	**One klystron**
Energy	110 MeV	67 MeV
Energy spread	0.30%	0.80%
Norm. Emittance y	8 mm.mrad	16 mm.mrad
Norm. Emittance x	8 mm.mrad	14 mm.mrad

The beam energy spread is more than doubled for the beam obtained in single klystron mode. Since the energy acceptance of the booster is roughly 1.5 MeV this beam is good enough to be injected to the booster and ramped to 3 GeV. The energy and energy spread of both measurements taken in a dispersive region are shown in Fig. 5.

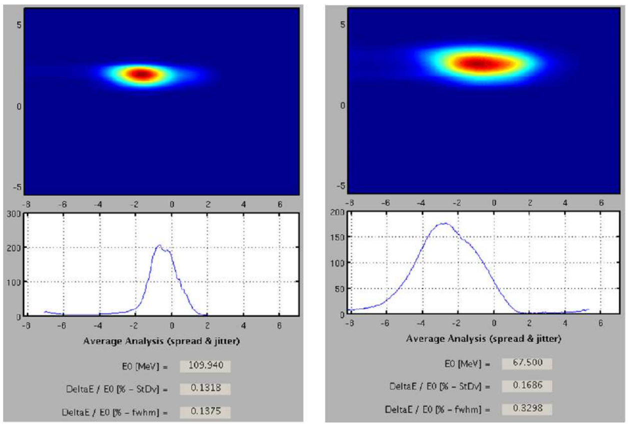

Figure 5: Energy measurements of the beam at the linac exit for a 110 MeV (left) and a 67 MeV beam (right). The measurements are an average of 20 shots at 1nC.

The commissioning of the single klystron mode injector is still under way. The main goal achieved so far has been to inject the 67 MeV beam from the linac exit to the ALBA booster and perform one complete round. To manage the adaption of the magnet settings from linac-to-booster transfer line, pulsed elements and booster, they have been scaled accordingly with the new energy. Since the scaling is not linear, some empirical optimization has been necessary. The current transmission from linac to ltb has been kept almost unchanged.

CONCLUSIONS

A S-band switching system has been implemented to the RF waveguide distribution, allowing the ALBA linac to operate in single klystron mode. Once will be fully implemented, this mode will keep the operation of the ALBA facility almost interrupted in case of failure of one of the two linac klystrons. This issue is of crucial importance when switching operation to top-up mode, expected in the following weeks.

AKNOWLEDGEMENTS

The contribution of F.Mares and the rest of operator group are gratefully acknowledged.

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[2] A.S.Setty et al. **"**Commissioning of the 100 MeV Preinjector for the ALBA Synchrotron", PAC'09, Vancouver (Canada), 2009