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OPERATION AND IMPROVEMENTS OF THE ALBA LINAC

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THE ALBA LINAC

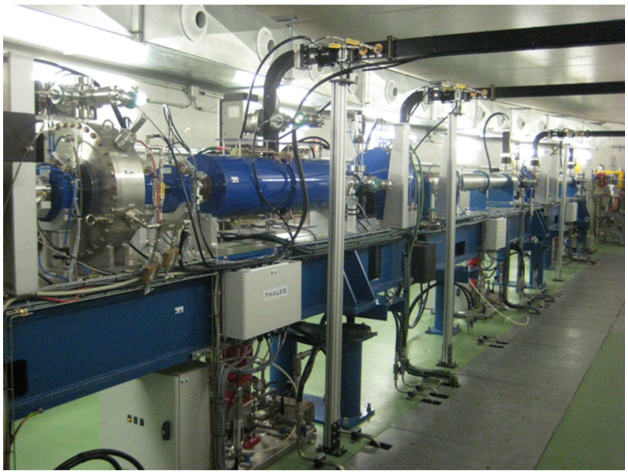

Figure 1: The ALBA Linac

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. The ALBA storage ring has a circumference of 268.8 m and provides a photon beam to 7 beamlines [1]. The ALBA pre-injector is a Thales linac installed and commissioned in 2008 [2].

The beam at the linac is generated at 90 keV by a thermionic gun in multi or single bunch. The beam is then sent to a three stage bunching system consisting of a sub-harmonic pre-buncher cavity resonant at 500 MHz (PB1), a 3GHz pre-buncher (PB2) and a 22-cells standing wave buncher (BU). The energy of the beam at the buncher exit is of 16 MeV. Two identical travelling wave constant gradient accelerating sections (AS1 and AS2) increase further the energy up to a maximum of 125 MeV. However, the linac is routinely operated at 110 MeV. The beam emittance in both planes is of 15 mm.mrad.

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.

TOP-UP OPERATION

Until recently, ALBA has been operating for users performing two injections to the Storage Ring (SR) per day to the present nominal current level of 120 mA. In June 2014 ALBA offered to users its first operation in top-up mode, where frequent injections keep the average storage ring current within few per cent variation [3].

Currently a two-third storage ring filling pattern is used, in which 320 out of the 448 buckets of the SR are filled with electrons. For this fill the linac is operated in multi-bunch mode, delivering trains of 32 bunches per injection. At present, top-up mode injections are performed every 20 minutes. At each injection the linac delivers 10 shots to refill de SR with 1mA of current. In this way, the current is distributed between all the full buckets of the SR.

Linac single bunch injection in top-up mode is being implemented and expected to be offered to users in 2015. This injection mode will allow us to select and to inject on the less populated bunches, thus keeping a more uniform distribution of electrons among the buckets [4].

LINAC STABILITY

The ALBA Linac is running reliably since started its operation in 2010. At the early stages of the linac operation we experienced that the thermionic gun filament heating process and the thermalization of the klystron components (gun components and low level RF) need a stabilization period of 36 hours to have good energy and charge stability at the linac beam.

The linac beam is also sensitive to fluctuations of the air and cooling water temperatures of the linac bunker and of the service area, where the klystrons and the racks with instrumentation are located. Air temperature fluctuations of 0.7ºC p-p on the linac bunker produce beam charge oscillations of 0.15 nC. After that the temperature of the linac bunker is kept at 23±0.2 ºC. On the service area the temperature is also of 23ºC, but with a day-night temperature variation of about 1ºC.

Instabilities of the linac beam position are observed from time to time at the exit of the bunching stage, where the first YAG screen is located. The instabilities follow the pattern shown in Figure 2. The beam position drifts for several minutes (in x and/or y-direction) until it suddenly shifts. These instabilities are typically small, with shifts of less than 1mm, and do not disturb operation. However, sporadically, the instabilities are amplified and affect as well to the linac charge, which also oscillates following the same pattern. The source of the instabilities is still under investigation.

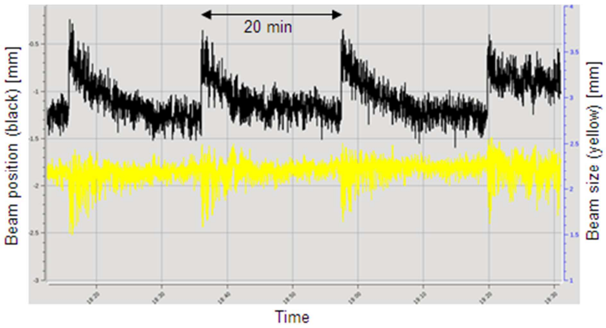

Figure 2: Beam position instabilities observed at the first YAG screen of Booster. The instabilities come from the linac beam but the source is still under investigation.

BEAM ENERGY

Linac beam energy and energy spread measurements are performed at the Diagnostics line by using the calibration of a bending magnet (see Figure 3). The beam is deflected 30 degrees and its size is measured either by using a YAG/OTR screen or by measuring the charge transmission through a slit [5].

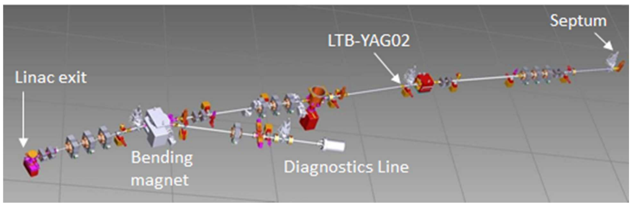

Figure 3: Schema of the Linac To Booster transfer line (LTB) and the Linac Diagnostics line (LiDia).

The beam at the linac exit has typically an energy of 110 MeV and an energy spread below 0.3% rms (see Figure 4). The energy and energy spread are determined from analyzing several linac shots to take into account the energy jitter, which is of about 0.1% rms. The source of this jitter has been investigated and found out to be produced in part by the HV power supplies that feed the klystron modulators. However, this is not a problem for the ALBA injector since the energy acceptance to the booster is bigger than 1% peak to peak.

Over a year the linac beam energy varies ±1MeV due to thermal effects. The variations can be corrected by optimizing the linac parameters at the start of each run. Along the runs (with a typical duration of 3 or 4 weeks) the beam energy varies less than 0.3%. A plot with daily energy measurements taken in Run 4 of 2014 is shown in next section, in Figure 6.

On the other hand, a new linac beam energy measurement point has been studied and is being implemented at the Linac To Booster transfer line (LTB), at the fluorescence screen LTB-YAG02 (see location in Figure 3). Because of the smaller bending deflection angle (only 5 degrees) and of the complexity of its optics, energy measurements at LTB are less accurate. However, an energy measurement at LTB is faster because there is no need to send the beam to LiDia, and therefore it is most suitable to be used in top-up operation.

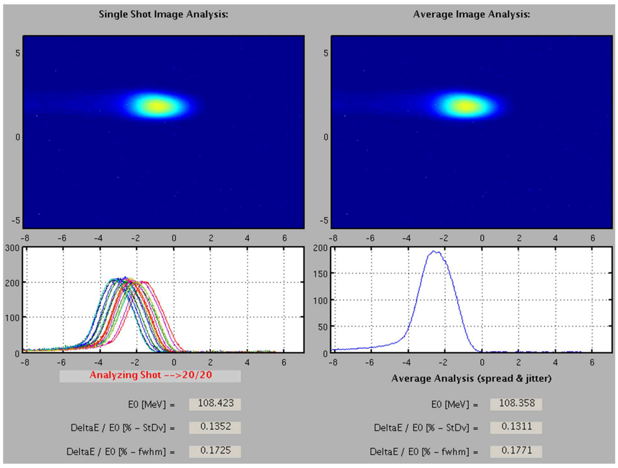

Figure 4: Energy and energy spread measurement of the linac beam taken at the Diagnostics line (LiDia) evaluating a set of 20 shots on a YAG screen.

MADx simulations [6] have been performed to meet a LTB lattice that minimizes the betatron function and maximizes the dispersion function at the measurement point, LTB-YAG02. With the new LTB lattice we are capable to measure linac beam displacements at LTB due to energy shifts with a resolution of 0.45 mm/MeV (see Figure 5). Taking into account that the precision of the beam position measurement is 0.1mm this resolution is good enough to detect energy shifts of 0.25 MeV, well below the energy acceptance to booster.

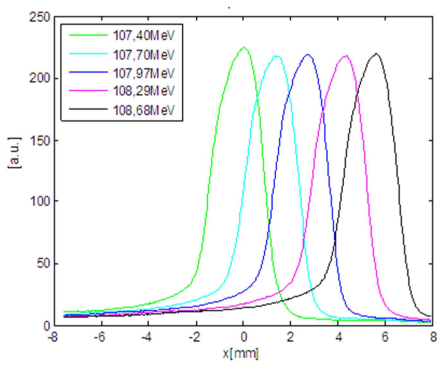

Figure 5: Beam position measurements taken at LTB-YAG02. Energy shifts produce a displacement of the beam in x-direction. The resolution is 0.45mm/MeV. At the Diagnostics Line the resolution is 20mm/MeV.

Since the new lattice does not provide a beam injection to the booster it is only used for energy measurements. A python routine is being implemented to automatically perform energy measurements at LTB between top-up injections.

A comparison of the energy measurements taken at LiDia and at LTB during several weeks are shown in Figure 6. Both measurements are in very good agreement.

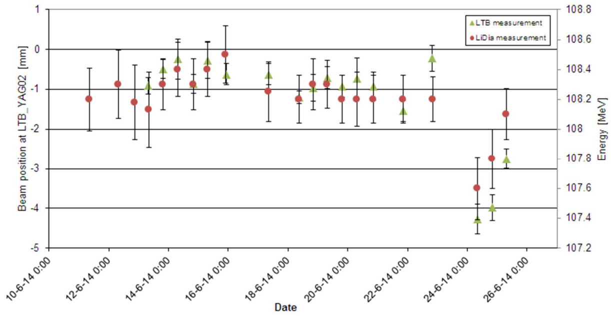

Figure 6: Linac beam measurements taken at LiDia and at LTB-YAG02 during ALBA Run 4 are in good agreement.

WAVEGUIDE UPGRADE

Two pulsed Klystrons are used to feed the 3GHz cavities of the linac. In the original RF distribution, Klystron 1 fed the bunching section and the first accelerating structure, whereas Klystron 2 fed exclusively the second accelerating structure.

A S-band switching system installed recently in the waveguide system connect both circuits and allows us to use Klystron 2 to power the low-energy section in case that Klystron 1 fails [7]. The new RF distribution will keep the ALBA injector operative after a klystron failure, preventing operation interruptions of several hours.

Each switch has two positions and allow us to operate the klystrons in three different configurations, as shown in Figure 7. In case that one klystron fails it can be repaired and/or exchanged and commissioned while the other klystron keeps the linac being operative.

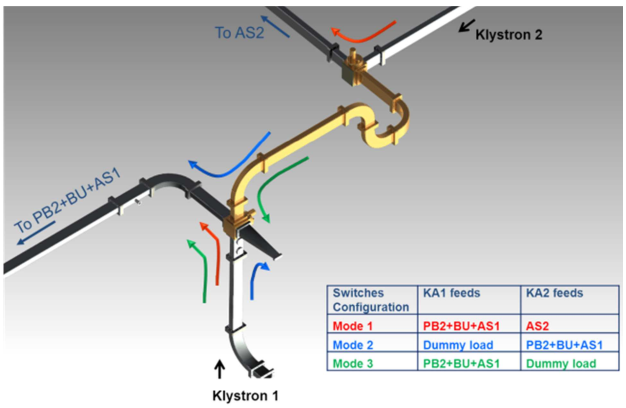

Figure 7: The two WR284 waveguide circuits are now connected by means of two switches manufactured by Sector-Microwave. They offer three modes of operation.

With only one klystron the linac delivers around 67 MeV which can be injected to the booster. The commissioning of the single klystron mode injector (Linac+Booster) is still under way. Injection into the Booster has been achieved, multiturn storage and ramping is under way.

We expect to have the low energy injector ready for operation by the end of 2014.

SUMMARY

We have reported our experience operating the ALBA Linac in decay mode as well as in the recently implemented top-up mode. Furthermore, the development and implementation of a new energy measurement point at LTB has been presented and demonstrated to be a reliable and faster method to detect energy shifts of the linac beam during top-up operation. Another improvement is the upgrade of the waveguide system that allows us to operate the ALBA linac with either one of the two klystrons. The commissioning of the low energy injector is still under way.

ACKNOWLEDGMENTS

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