STATUS OF THE CTF3 PROBE BEAM LINAC CALIFES

F. Peauger, D. Bogard, G. Cheymol, P. Contrepois, A. Curtoni, G. Dispau, M. Dorlot, W. Farabolini, M. Fontaine, P. Girardot, R. Granelli, F. Harrault, JL. Jannin, C. Lahonde-Hamdoun, T. Lerch, PA. Leroy, M. Luong, A. Mosnier, F. Orsini, C. Simon, DSM/Irfu, CEA Saclay, France, S. Curt, K. Elsener, V. Fedosseev, G. Mcmonagle, J. Mourier, M. Petrarca, L. Rinolfi, G. Rossat, E. Rugo, L. Timeo, CERN, Geneva, Switzerland, R. Roux, LAL, Orsay, France

Abstract

The CLIC project based on the innovative Two Beams Acceleration concept is currently under study at CTF3 where the acceleration of a probe beam will be demonstrated. This paper will describe in details the status of the probe beam linac called CALIFES. This linac (170 MeV, 0.9 A) is developed by CEA Saclay, LAL Orsay and CERN. It has been installed in the new experimental area of CTF3 to deliver short bunches (1.8 ps) with a charge of 0.6 nC to the CLIC 12 GHz accelerating structures. We report new results of beam dynamic and RF simulations considering the new CLIC parameters. The construction of CALIFES in the CLEX building is presented. Recent measurements from the laser system are discussed. Details about the HV modulator tests and the power phase shifter fabrication will be described and the start of commissioning will be also reported.

INTRODUCTION

The electron linac CALIFES [1] (Figure 1) will produce both single bunch and bunch train spaced by 0.66 ns to X-band structures in order to perform various tests such as beam kick due to RF breakdown or dipole mode excitation, in addition with the Two Beam Acceleration demonstration. The main linac parameters have been updated and are shown in Table 1.

Table 1: CALIFES main parameters.

Parameters	Value
Final linac e^- energy	170 MeV
Emittance rms	< 20 π mm.mrad
Energy spread (single bunch)	< ± 2%
Energy / Phase deviation (multi-bunch)	< ± 1% / < 10 ° at 12 GHz
Number of bunches Nb	1 – 32 - 226
Bunch charge (single/ multi bunch)	0.6 nC / 6 nC/Nb
Initial/final bunch length	5.3 / 1.8 ps, 1.6 / 0.5 mm
Transverse beam size	0.6 mm x 0.6 mm
Bunch spacing	0.66 ns / 1.5 GHz
Train length	21 – 150 ns
Train spacing (rep. rate)	5 Hz

BEAM DYNAMIC AND TRANSIENT RF SIMULATIONS

Due to fact that the flat top duration of the compressed RF pulse (1.3 µs) is close to the structure filling time (1.23 µs), the accelerating field profile must be precisely computed (Figure 2). With a drive frequency slightly above the centre frequency (+ 150 MHz), the filling of the structure is nearly complete after a pulse propagation of 5.5 µs. A quasi steady state is reached and no major changes of the beam quality are expected.

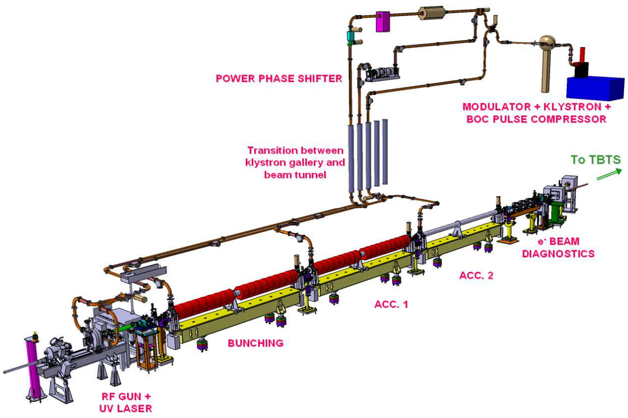

Figure 1: 3D layout of CALIFES.

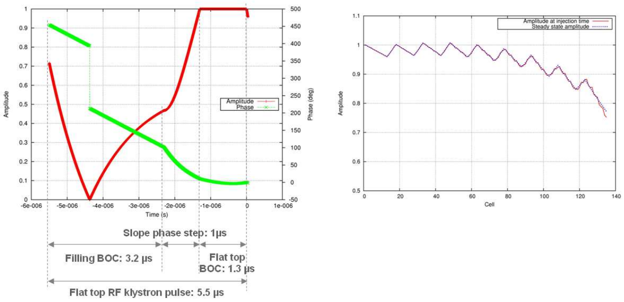

Figure 2: RF pulse shape after compression (left) and amplitude field profile after 5.5 µs (right).

In single bunch operation, simulations showed that the transverse profile at the end of the linac are $x_{rms} \sim y_{rms} \sim$ 0.6 mm. The bunch length at the end of the linac is z_{rms} = 0.176 mm and the emittance is 13.04 mm.mrad. The final linac energy is 169.6 MeV/c with an energy spread of $\Delta P/P =$ 1.006 %.

In multi bunch operation, we calculated a total energy deviation between the first and last bunch of 5.4 % at 170 MeV and a phase deviation of 15.5° at 12 GHz. The bunch charge will be reduced with the number Nb of bunches, Qb < 6 nC / Nb, such a way that both energy and phase deviations are smaller than respectively 1% and 10° at 12 GHz.

INSTALLATION IN THE CLEX BUILDING

While the CLEX building was still under construction, a pre-installation of the linac began in Nov. 2006 in building 182 at CERN for two S-band structures re-used from the former LEP injector linac. These elements were transferred in CLEX in June 2007 and the beam stopper, the spectrometer dipole magnet and some supports were quickly installed. All the elements were pre-aligned in less than 1 mm. The BPMs and the dipole steerers are supported by a common girder and alignment support. There were connected to the accelerating sections in Oct. 2007 to allow first alignment procedure and vacuum tests (Figure 3).

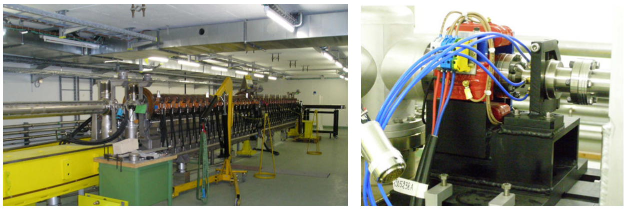

Figure 3: Accelerator sections (left), dipole steerer and BPM (right) installed in November 2007.

After being fine tuned in laboratory, the Video Profile Monitors (VPM) and laser beam line components were progressively installed between Dec. 2007 and May 2008. The high voltage modulator including the oil tank, the PFN rack and the auxiliary power supplies were installed in Dec. 2007 and tested with its dedicated klystron in April 2008. The RF gun was delivered in May 2008 from LAL and a final frequency tuning was completed directly on the linac in June 2008 (Figure 4).

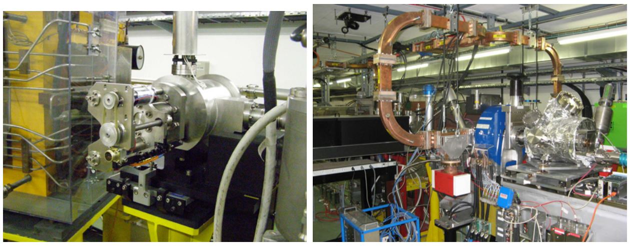

Figure 4: VPM n°2 and RF Gun installed between Dec. 2007 and June 2008.

Some alignment problems for the structures and the beam diagnostic elements were identified, mainly through visual inspection and metrological measurements. The misalignment issues were caused by errors in alignment input data and accidental manipulation of the elements. The final alignment (~ 0.1 mm) has been completed in May 2008.

Finally, the RF network including splitters, windows, couplers and loads were progressively installed during summer 2008 (Figure 5).

Figure 5: RF network in the klystron gallery (left) and the beam tunnel (right) installed during summer 2008.

LASER SYSTEM

Since both drive and probe beams must be synchronous, the 10 ps width pulses created in IR at 1.5 GHz for the drive beam are derived after a double amplification. The diode pumped Nd:YLF based amplifiers enhance the laser energy up to 10 µJ per pulses before being gated to create from 0.4 to 150 ns pulse train (pulse pickers). The laser beam is then converted from IR to green by a KTP crystal (10 mm) and from green to UV (261 nm) by a BBO crystal (12 mm) with a specified conversion efficiency of around 35% each.

A transport path of 80 m long under vacuum has been built to deliver the UV pulses to the photocathode. 25% losses are expected in the pulse picker and transport line each. A final UV nominal energy of 370 nJ would give a bunch charge of 0.6 nC considering a quantum efficiency of 1%.

Experiments done in March 2008 showed that the amplified IR pulses energy was limited to 4.3µJ, and that the crystal efficiencies were respectively 13% and 4.3%. This leads to a UV pulse energy of 15 nJ on the photocathode, giving 0.03 nC and 45 mA instead of 900 mA.

The main hypothesis to explain the low conversion efficiency is a presence of a significant DC component around the 10 ps pulses. Remarkably improvements have been achieved very recently, in Sept. 2008 by the CERN team. The UV energy per pulse reached 133 nJ, giving 0.26 nC and 390 mA.

The UV beam transport down to the photocathode has been demonstrated (Figure 6). The oval profile of the beam is mainly due to the high walk-off (85 mrad) combined with the low diameter (130 µm) of the green beam focused on the BBO.

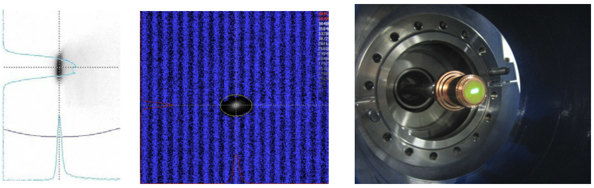

Figure 6: UV beam after the second crystal (left), on the virtual photocathode (middle) and on the photocathode itself (right).

The Pulse Picker has been installed and tested in July 2008. Rise and fall times are fast enough to select the desired number of bunches (Figure 7). The transmission is

81% and no discontinuity has been observed during the flat top.

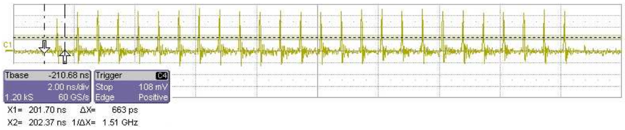

Figure 7: Train of 26 pulses spaced by 0.66 ns gated by the Pulse Picker system.

BEAM DIAGNOSTICS

The video profile monitors and the five BPM are widely described in [2] and [3]. They have been calibrated and installed in the linac.

For these two diagnostic systems, the control command interface is in progress in order to be able to check the beam profile as well as its position in the control room.

RF SYSTEM

Modulator

The modulator has been fabricated by PPT (Germany). It delivers quasi-rectangular pulses of 300 kV - 300 A - 7.6 µs at 5Hz to a 45 MW S-band klystron. It has been commissioned first at factory on a dry load at low repetition rate and tested at nominal values on two different klystrons at CERN. A pulse quality problem was discovered during the first high power tests. A ripple of ±4% was measured on the cathode voltage flat top. The problem was identified to be a superposition of a long wave on the flat top and a high frequency noise at the beginning of the voltage pulse. The long wave oscillation has been efficiently removed by a fine tuning of the PFN. The HF noise is believed to be due to fast oscillations in the voltage divider used to measure the pulse in the oil tank. This hypothesis has been confirmed by pulse quality measurements with the RF pulse. The klystron has been driven at saturation up to 42 MW and a remarkably good voltage ripple of ±0.3 % has been deduced from the RF pulse ripple measurement. No signs of HV breakdown were observed.

Power Phase Shifter

The power phase shifter aims at tuning the off crest RF phase of the first section for velocity bunching. This new component is made of three sliding circular waveguides working on the TE_{01} mode. The mode conversion is done by two "wrap around" mode launchers. During its fabrication, the first brazing operation of the two main parts failed. A leakage has been detected and some drips of the brazing alloy appeared. Experiments on samples at different temperatures showed that the chosen alloy was very sensitive to temperature variation during brazing melting period. The converter has been re-used to a scale one prototype to validate a new brazing alloy and check the thermal behaviour of the assembly during the temperature ramping. In particular, the temperature probes inserted in two of the four posts (74 mm height) confirmed that a strong temperature gradient occurs in this region. The cleaning procedure and alignment mechanism have also been improved. The prototype shown in Figure 8 has been successfully brazed in March 2008. The assembly is tight and the join did not produce any drips neither lacks. Two new converters are now under construction and will be available for high power test in March 2009.

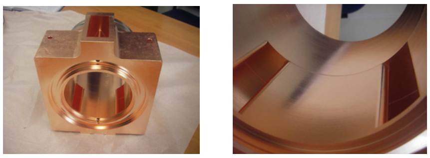

Figure 8: Mode converter prototype for a qualification test of the brazing process.

RF Conditioning

The RF conditioning has started in Sept. 2008. An RF pulsed power of 43 MW – 1µs – 5 Hz has been reached in less than 2 hours. The waveguide pressure stayed below $0.5.10^{-8}$ mbar and only few RF breakdowns were observed on the scope, identified by a fast increase of the reflected power. The filling time of the structures was measured by the time delay between the input and the output incident RF pulse (Figure 9). It is 1.2 µs and in a good agreement with our predictions.

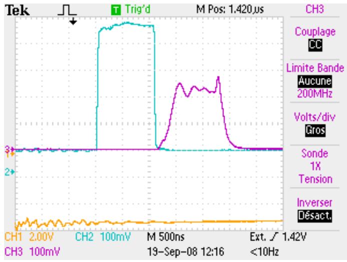

Figure 9: Incident RF pulse at the input (blue) and output (pink) of the 1st travelling wave accelerating structure.

CONCLUSION

The electron beam line, the laser transport line and most of the RF network are now under vacuum. The RF conditioning will continue during October and the start of operation with beam is planned in Nov. 2008.

ACKNOWLEGMENTS

We would like to thank our colleagues from CERN for their large contribution on the CALIFES project.

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