VIDEO PROFILE MONITORS DEVELOPMENT FOR THE CTF3 PROBE BEAM LINAC

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Abstract

The innovative CLIC concept is currently under study in the CLIC Test Facility (CTF3) at CERN where the acceleration of a probe beam will be demonstrated at an accelerating gradient of 100 MV/m. This probe beam, to be delivered by a linac called CALIFES, is composed of short electron bunches (0.75 ps, 0.6 nC) at 177 MeV with normalized emittance lower than 20 mm.mrad.

Measurements of longitudinal charges distribution, transverse emittance and energy spectrum rely on video profile monitors (VPM) after appropriate manipulations of the beam (deflecting cavity, quad scan and analysis dipole).

We report the design, development and test of these new VPM based on selectable YAG/OTR screens, optical line and CCD camera. Two selectable magnifications (1.75 and 0.33) are available via motorized lens mounts to comply both with resolution (20 µm) and field of view (10x10 mm^2). Study of optical line characteristics have been realised with Apilux code and Modulation Transfer Function (MTF) were measured. A grid pattern can be inserted at the screens position to check optical characteristics during operations. Tilt of the CCD plan in order to compensate the screen tilt of 15° has not proven to improve the depth of field and was not implemented on this device. However, this disposition is used on the third profiler used for energy spectrum measurement where the screen is larger and tilted by 45°.

SCOPE OF CTF3

CTF3 (CLIC Test Facility 3rd phase) is a collaboration driven by the CERN aimed to demonstrate before 2010 the feasibility of the future multi-TeV linear collider CLIC (Compact Linear Collider). Its scope is to check the two main innovative concepts of this future very large collider: the two beams acceleration scheme using 12 GHz RF power and copper structures offering a very high gradient of acceleration (100 MV/m) [1].

The RF power at 12 GHz is generated by decelerating an electron beam from a drive beam linac after appropriate bunch interlacing in a delay loop and a combiner ring. This RF power feeds accelerating structures that provide a high accelerating gradient to the main beam.

For CTF3, an accelerator called CALIFES injects this beam, acting here as a probe beam, into the 12 GHz accelerating structures. This installation is now due to start its operation very soon (Aug. 08).

PROBE BEAM SPECIFICATIONS

The accelerator CALIFES is built with 3 former LEP injector linac (LIL) sections. A laser driven photo-injector delivers trains of short bunches (6 ps) that are velocity compressed in the first section down to 0.75 ps and accelerated up to 177 MeV in the 2 following ones [2].

The stringent beam characteristics detailed in table 1 with their reasons, are checked by a set of diagnostics that allow the tuning of the accelerator (power and phase of the RF, laser pulse power…).

Table 1: CALIFES beam parameters

Parameters		Motivation
Energy	~ 200 MeV	Avoid beam disruption in high RF fields
norm. rms emittance	<20πmm.mrad	Fit in 12 GHz structure acceptance
Energy spread	< ± 2%	Measurement resolution
Bunch charge	0.6 nC	~ CLIC parameters
Bunch spacing	0.667 ns	
Number of bunches	1 - 32 - 226	Measure 12 GHz structure transients
rms bunchlength	< 0.75 ps	Acceleration with 12 GHz

Most of these diagnostics are grouped in the diagnostic section (Fig. 1) just before the beam delivery to the test stand.

Apart from 6 BPMs and a beam current transformer, all diagnostics (emittance, energy spectrum, charge distribution) rely on the acquisition of the transverse profile of the beam by 3 VPMs.

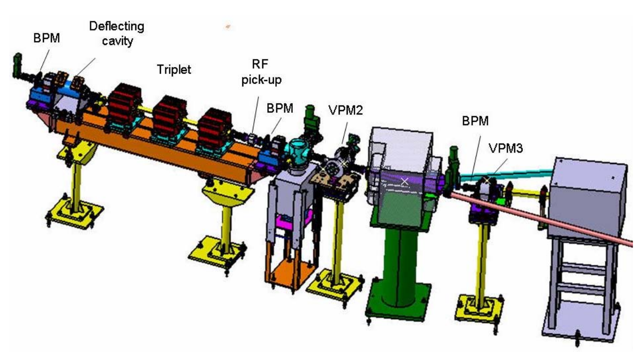

Figure 1: Diagnostics section.

VPM SPECIFICATIONS AND DESIGN

VPM specifications are related to the beam characteristics along the line.

The first VPM, downstream the photo-injector, measures the beam whose size is around one millimeter with energy around 5 MeV. A large YAG screen [3] (40x40mm^2) mounted on an air jack intercepts the beam at 45°. The optical magnification of 0.2 provides a resolution of 173 µm, sufficient to qualitatively assess the correct injector work.

The second VPM, downstream the triplet, is dedicated to transverse profiles measurement via quad scan and longitudinal profile with a deflecting cavity. Size of beam can vary from 50µm to few mm. The density of charge span imposes the use of two types of screen as well as two selectable magnifications (Figs. 2 and 3). A 200 µm thick YAG screen is used for low charge density associated with a magnification of 0.35, providing a resolution of 100 µm. A silicon OTR screen is used for high charge density in association with a 1.78 magnification for a resolution of 20 µm. To cope with the small depth of field the screen intercepts the beam at only 15° and the optical line looks at the screen at 30° from the beam. In addition, a back lighted calibration grid can be inserted on place of screens for in line checking of the optical performances and software correction of the images.

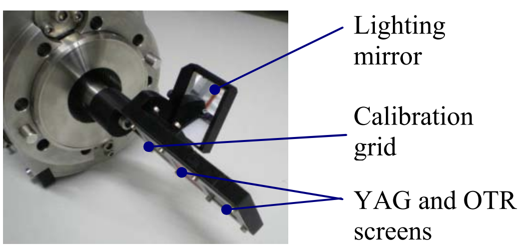

Figure 2: VPM2 screens holder.

The third VPM, downstream the analysis dipole, measures the dispersed beam whose horizontal size could reach 20 mm. A YAG screen, intercepting the beam at 45°, associated with a magnification of 0.25 provides a resolution of 140 µm. To mitigate the short depth of field the CCD camera is tilted by 10.5°.

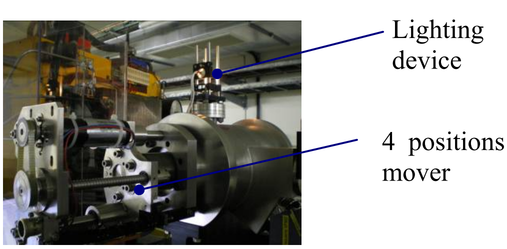

Figure 3: VPM2 tank.

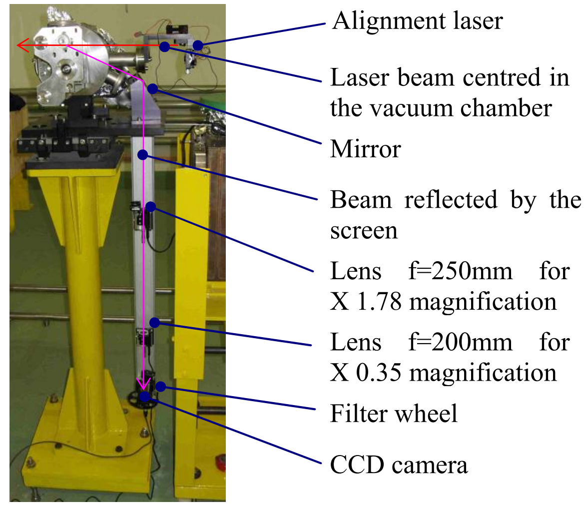

Figure 4: VPM2 system.

The video profile monitors have been design to fulfill the following requirements:

- compact and robust design : the complete system is mounted on a platform supported by a single column (Fig. 4). All equipments are enclosed in a casing offering protection against light, dust and shocks. Around this casing a lead shielding is mounted to protect the CCD camera against radiations.
- Use of standard manufactured optical equipments like motorized diaphragm OWIS IBM65, filter wheels OWIS FRM40, motorized lens holder New Focus 8892…
- Accurate optical alignment with a laser to simulate the electron beam before mounting on the line,
- On-line calibration with an optical grid in place of screen and focused external lightning,
- High flexibility of use (type of screen, magnification, light control)
- Easiness of interfacing with the CERN command/control.

VPM PERFORMANCE ASSESSMENT

Resolution performances have been measured on a test bench using Ronchi rulings, scaling from 2.5 lp/mm to 100 lp/mm, whose contrast was computed (Fig. 5).

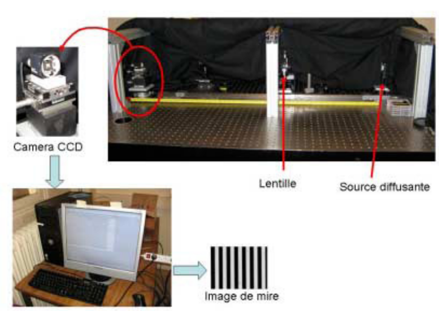

Figure 5: test bench measurement.

The modulation transfer function (Fig. 6) shows a 44 % contrast for a resolution of 100µm with the X 0.35 magnification and a 55% contrast for a resolution of 20 µm with the X 1.78 magnification.

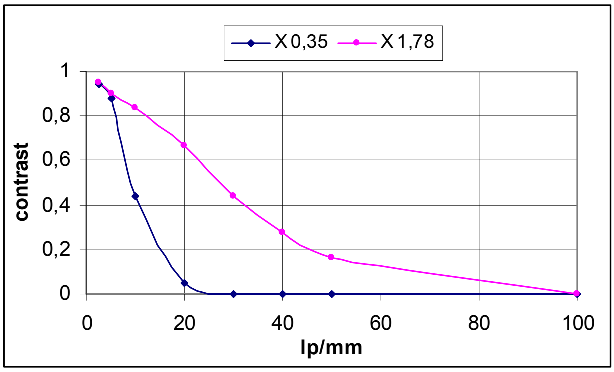

Figure 6: Modulation transfer function.

Mean magnifications have been computed making the FFT of the Ronchi rulings image and considering the CCD pixel size (6.5 µm).

On the VPM3, we can observe the effect of the screen interception angle (α=45°) on the contrast evolution along the transverse axis due to the limited depth of field (Fig. 7):

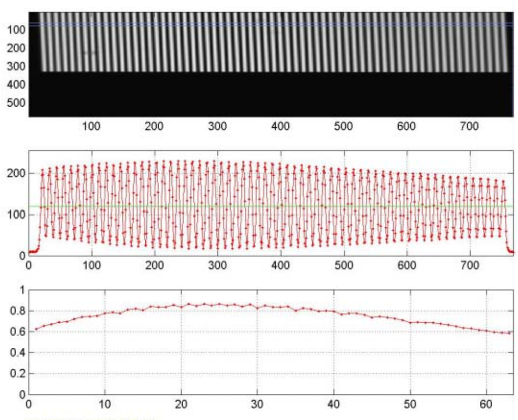

Figure 7: Contrast evolution along the line pattern.

A general improvement of contrast along the screen can be obtained tilting the CCD by an angle β (Fig. 8).

$\beta = \arctan(\gamma \tan(\alpha))$, with γ = magnification.

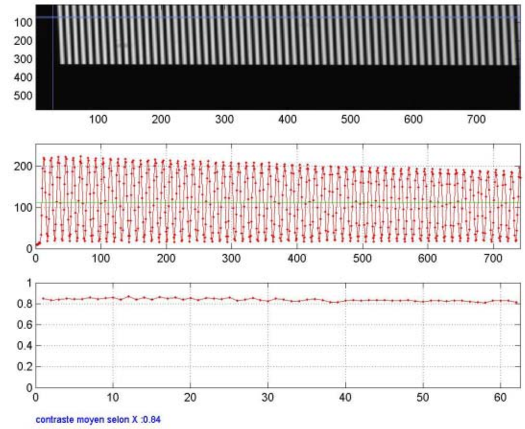

Figure 8: Contrast after CCD tilting.

However, the magnification is still affected by the variation of the object distance Δx versus the nominal distance between the lens and the center of the screen for which the magnification is γ_0. The result is a trapezoidal deformation of the calibration grid (Fig. 9).

$$\gamma(\Delta x) = \frac{\gamma_0}{1 - \frac{\gamma_0}{f}\Delta x}$$, with f: the focal length.

This problem will be treated by software.

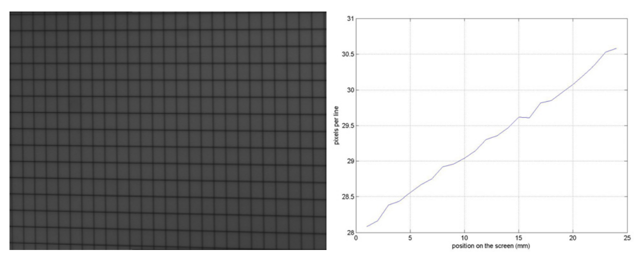

Figure 9: Image deformation and variation of magnification.

CONCLUSION

New profilers have been developed to fulfill the performance requirement of the CTF3 probe beam. Compactness and flexibility have driven their design. They will be soon tested at CERN during the commissioning of the Linac probe beam.

REFERENCES

[1] H.H. Braun, "Towards a Multi TeV Linear Collider; Drive Beam Generation with CTF3", APAC07
[2] A. Mosnier *et al.*, "The Probe Beam Linac in CTF3", EPAC 2006, Edinburgh, Scotland
[3] www.crytur.cz