Real Time Spectrum Analyzer

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Abstract

A Real Time Spectrum Analyzer (RTSA) has been designed for the 50 MeV RF linac of the free electron laser named CLIO°. It displays in real time the beam distribution in 2 dimensions : energy and time with a resolution of 0.3 % and 64 sampled times respectively during the macropulse. RTSA is based on an optical transition radiation converter and linear diode array. It allows to measure the beam energy distribution along the macropulse with and without laser oscillation. RTSA includes in the same frame a 32 channels transient recorder and a digital oscilloscope with 8 bit amplitude resolution. It offers multiple presentation : 1 to 128 curves can be displayed simultaneously in montain view (3 D). Preliminary tests on a 20 MeV linac facility are reported. The results show the unique capabilities of our device to identify so as to correct the various instabilities that may appear on the operation of an RF linac. This is particulary useful for a FEL dedicated linac where the beam stability is crucial.

I. INTRODUCTION

In a RF linac dedicated to free electron laser (FEL), the laser oscillation gain depends on some electron beam parameters quality, as energy spread by the particles in the bunch. The optimum can be obtained if the operator, in control room, has opportunity to observe in a real-time display the consequences of the different parameter adjustement. The Real Time Spectrum Analyzer (RTSA) has been designed for this with good time efficiency. The RTSA has full time response, for both storage data and full graphical representations, in less than human reflex i.e. < 0.1 second.

II. DESCRIPTION

The first element of the RTSA [1] is the bending magnet which extracts the electron beam of the FEL optical cavity. It gives the horizontal spacial dispersion for the different energies particles in the beam.

The beam goes through an Optical Transition Radiator converter (OTR) made of a thin aluminum foil. This foil is stretched in a circular support, perpendicular horizontally to the nominal beam direction, vertically inclined at 45°.

The backward OTR at the specular angle is extracted through a sapphire window. The light is transmitted through a large aperture achromatic lens. The image of the dispersed beam is focused vertically by a cylindrical lens in a linear 32 photodiode array.

With a horizontal magnification of one, the energy resolution is 0.32 % and the total limit scale, 10 %.

Every photodiode has an adaptative amplifier with gain adjustment (that gives possibility to control the sensitivity of the 32 photodiodes) and a 50 Ω feed through coaxial cable bringing the signal to the control room.

All of the elements located in the radiative room are protected by appropriate shielding. 8 coaxials of successive photodiode signals are put together in 15 meters double shielded cable so as to suppress parasitic noise due to the E.M. induction synchronized with useful signal like klystron modulator pulse. 4 identical cables go through the shielded wall to the control room in a double Europe G64 crate which contains the hardware cards. The latters are managed by a 68000 microprocessor card supporting 0S9 operating system. The software application has been developped in C language and based on default procedures as well as specialized keys. Overall view of the general architecture is shown on fig. 1.

A. Specific cards

A.1. Acquisition cards : Each card include 8 identical channels, they are designed in order to digitalise and memorise the analogic photodiode signals. A channel is made of :

- An adaptative amplifier which provides separation between the input and A/D converter.
- A sampling stage with a 8 bits flash A/D converter which operates at 6.4 MHz rate in a burst of 64 samples during the macropulse of the linac gun current.
- Then a storage memory is given with a depth of 8 K 8 bit RAM for 128 linac macropulses capability.
- Common adjustable flash A/D reference voltages are given by an annex card.

. In acquisition mode, data are loading in parrallel for the 32 channels.

. In reading and acquisition modes, data are controled via specific fast bus by synchro address card and transfered to the xzy card.

A.2. Synchro/addressing card : this double access card is programmable by the microprocessor on the G64 Bus. Synchronization, address and control signals are supplied to steer acquisition and display states by the specific fast bus.

A.3. XYZ card : Visualisation on a xyz general purpose monitor and transfer via a Fifo in RAM disc of the data are the two functions of this card. Data flow coming from the acquisition cards are treated to generate 1 to 128 curves made of 32-64 or 128 points each, according to the type of analysis wished (spectrum or temporal). Z axe is the video brightness. X and Y features axes are entirely programmable through the G64 Bus and we can act on the amplitude, the depth (for 3D presentation), the space and width of the curves. The software ensures a default configuration for each picture of

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° CLIO : Collaboration pour la réalisation d'un Laser Infrarouge à Orsay.

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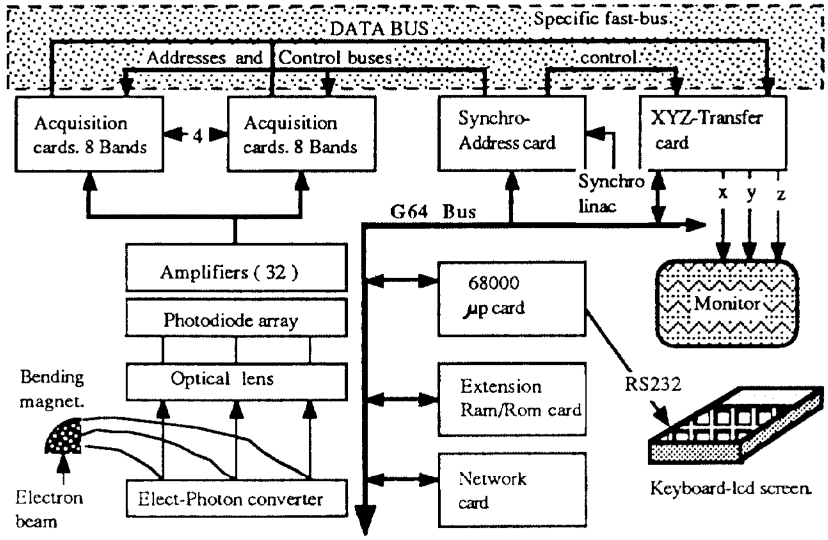


Figure 1 : Real Time Spectrum Analyzer architecture.

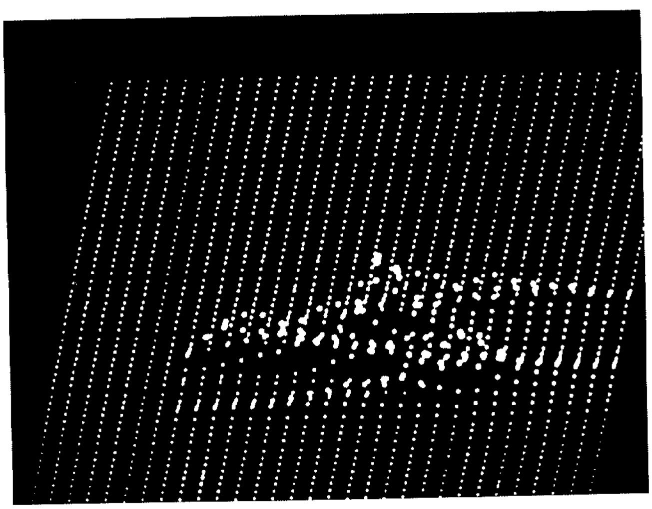
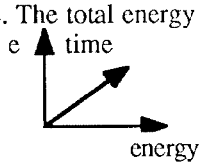


Figure 2 :
Expected energy profile during the macropulse every 156 ns sample time. The total energy scale is 3 %. .



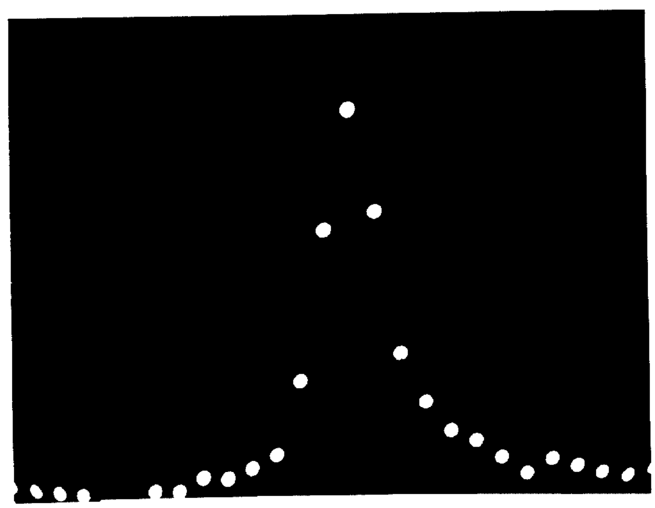


Figure 3 :
Energy spreading for particular sample time. Every dot corresponding at one photodiode signal and 0.1 % of energy dispersion.

points. X, and Z output amplitudes are settled to supply a 5 MHz bandwidth oscilloscope. Total view refreshed by recurrent read memory suppress unpleasant flicker and gives a good brightness.

B. Standard Cards

Standard microprocessor and extension Ram or Prom are needed to operate the system. Software application is in the extension Prom and Ram and are used for the safekeeping data. Exploitation of the whole may be done either through a terminal (VT100-200...) or a little keyboard with 8 rows of 40 characters.

C. Hardware and software design

Hardware and software are designed to support varied acquisition and display modes as well as transfer and optional functions. Users, choosing different "menus" realize the desired orders independantly of the running acquisition or display state. Three types of acquisition are allowed and all of them are released by a synchro pulse coming from the Linac machine.

a) Recurrent Mode
Each macropulse (10 µs lenght) is numerised and unfold the previous one. Spectrum or oscilloscopic display is offered in real time until the operator decide an another mode.
b) Single mode
Only one macropulse is acquired and displayed in a permanent way.
c) Multipulse mode
We numerise 128 macro-pulses (10 µs lenght -50 Hz repetition) while displaying each one then wire automatic stop and cyclic display (on the 128 macro-pulses) occurs.

Remembering that each macro-pulse is numerised in 64 samples on 32 energy bandwidths and this for 128 macropulses, 6 modes of visualisation are possible, offering 2 spectra or 4 temporal analysis ways. By default, spectrum display takes place. Some options make exploitation easier such as overbrightness x and/or y axes, to select curve for zooming or to access other viewes, curves number and extension, 3 dimension presentation, delayed acquisition and so on.

Remarks :
1) Analysis time can be extended by masking 2 to 127 synchro pulses of linac.
2) By a single 32 input relays commutator we can observe 32 different scaled signals given by pick-up along the linac like : intensity, xy positions, transverse sizes, direct and reflected RF power in the different accelerating structures, and so on.

We have tested [2] the RTSA on LAL 20 MeV linac facility(*). The sensitivity according to the prediction [3], [4] is less than a factor 2. (Results are affected by the lack of the definitive mechanical device).

(*) NEPAL : Nouvelles expériences pour les Accélérateurs Linéaires.

The total noise is equivalent to 0,1 mA (CLIO nominal macropulse current is 200 mA RMS).

With the RTSA we have detected in the discret delay line of the modulator klystron, a bad adjustment of the sefs wich gives an oscillation in the beam energy particles during the macropulse (See fig. 2).

The best resolution obtained at one precise time during the macropulse is 0.2 % (See fig. 3).

III. CONCLUSION

The RTSA helps to obtain the optimum Linac adjustments and to observe different types of instability, i.e. temperature variations, magnitude and phase fluctuation of the RF power klystron, and so on. Its use on the CLIO machine will not miss to be effective as far as adjustment optimisation and pre-recorded treatment of the energy spread are concerned .

IV. REFERENCES

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