HESYRL 200 MEV LINAC SINGLE BUNCH ENERGY SPECTRUM MEASUREMENT

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Summary

HESYRL 200 Mev electron Linac was finished in Dec. 1987, and has been running well since then. A careful study on single bunch energy spectrum for the Linac was done. The measurement shows the energy spread of the Linac is ±0.4%. The measurement is described in this paper.

Introduction

HESYRL is a dedicated light source producing VUV light and soft x-rays. It consists of a 200 Mev electron Linac as an injector, a 30 meter long drift section, a 53 meter long transport line and an 800 Mev storage ring.

The LINAC is one of travelling wave type, operating at frequency of 2856 MHz, has constant impedance, 2/3 π mode. The total length of it is about 35 meters, consisting of 9 three-meter 30 Mev accelerating sections. Among them the first one is a preinjector. A 30 meter drift section following the Linac leaves a space for putting more accelerating sections in the future either to raise the injection energy or for other nuclear physics experiment. A switching magnet and a DC bending magnet are at the end of the drift section to controll beam direction. There are 3 lines after the switching magnet (see Fig.1). One goes to the storage ring, one goes to a Nuclear Physics Experimental Hall. The third one is used for a magnetic analyzer for measuring beam energy spectrum. HESYRL 200 Mev Linac could produce 150 mA electron beam, which has surpassed the designed current value, at 50 p.p.s, with bunch length of 0.5 micron second. The beam energy can be up to 225 Mev. The switching magnet bends beam to the storage ring, the nuclear physics Hall or the energy spectrum analyzer according to a time sequence given by Linac timing system. Since the switching magnet is switched at a certain frequency such as one pulse per second toward the magnetic sepctrum analyzer, therefore during the injection or Linac running, the energy spectrum can be monitored without interrupting the machine operation.

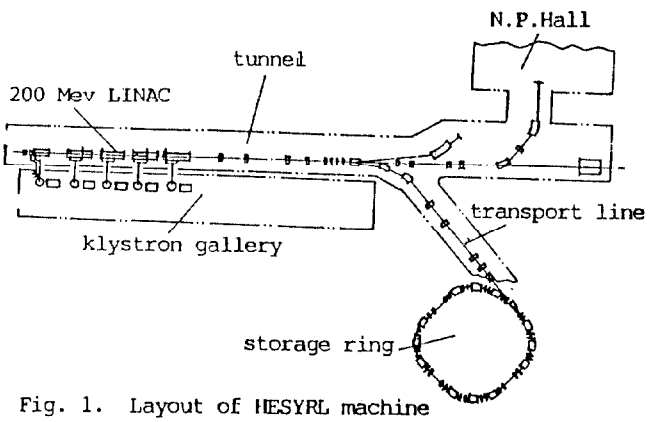

Fig. 1. Layout of HESYRL machine

Main Parameters of the 200 Mev LINAC

electron energy	224 Mev
current	50 mA(p-p)
pulse width	0.2-1 s
	3-4 ns
energy spread	±.5%
klystron power	15 MW
number of klystron	5
operating frequency	2856 MHz
type of mode	2/3 π
accelerating structure	constant impedance
electric field strength	122KV/cm
group velocity	V_g = 0.012 c
attenuation of field	α =0.178/m

Energy Spectrum Analyzing Set-up

A 50 mm high, 100 mm wide AF995R fluorenscent screen is placed right after the vacuum chamber window of the magnetic analyzer. AF995R fluorenscent screen is made of a chromium stabilized alumina rouge produced by Desmarquest of France. AF995R will emit red light by electron bombarding. It is very sensitive and without discoloration. The light intensity distribution due to electron bombarding on the screen represents the energy spectrum. A mirror reflects the light through an F=50 mm lens to focus the light spot on a Reticon linear photodiode array which has 256 elements with space resolution of 25 micron and sensitive area of 26 micron high. The total length of the Reticon is 6.4 mm. The image size is reduced by a factor of 20 to fit the Reticon length. Although before measurement a small light bulb, which simulated the light spot on the screen, was used to set the mirror, lens and Reticon at right positions, but because the beam position could be changed by Linac steering magnets operating at different current setting, in order to focus the image easier on the Reticon, the mirror has to be rotated by a remotely controlled very slow motor to change the reflecting angle. The 1.6 turns per minute motor speed is reduced again by a facor of 35. One sitting in the control room by rotating the mirror could easily locate the image of the light spot of the AF995R on the Reticon and could vertically scan the light spot to find out the vertical center line of the light spot to get the spectrum of it. Since Reticon line scanners operate in the charge storage mode, the charge output of each diode (below saturation) is proportional to exposure, i.e., the irradiance or light intensity multiplied by the integration time or the time interval between successive starrt pulses. Reticon linear diode array is a self scanning device. In order to observe a stable signal from the Reticon photodiode array, the start and clock pulses of the Reticon are taken from the Linac timing system. A storage oscilloscope can catch the spectrum signal of one shot. So the measured spectrum is of one electron bunch.

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The magnetic analyzer has a bending radius of 1.2 meter, 60 degree bending angle with 18 degree edge focusing angles. The switching magnet also has a bending radius of 1.2 meter, the bending angle of it is 6 degree. Since the 200 Mev electron beam can be considered as a parallel beam, a calculation of beam optics showes that a light spot of 10 cm on the fluorenscent screen represents 4% energy spread. There is a 1 cm wide untransparent adhesive tape on the screen. Because the tape prevents light from going through, there is a step on the spectrum signal which gives an indication of the energy spread scale. This was not shown in the picture presented here.

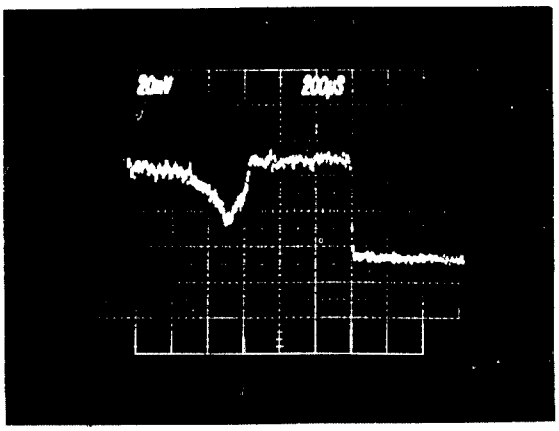
When bombarded by electrons AF995R screen emits red light which is within the sensitive wavelength range of the Reticon photodiode array. The emission of the screen is almost not influenced by electron energy at the measurement accuracy. The observation showed that the residual emitting time of AF995R screem is less than 5 ms. Reticon scanning frequency is 250 KHz, one scan for 256 points is about 1 ms. For one pulse per second measurement, a storage oscilloscope can easily catch the energy spectrum display.

Result

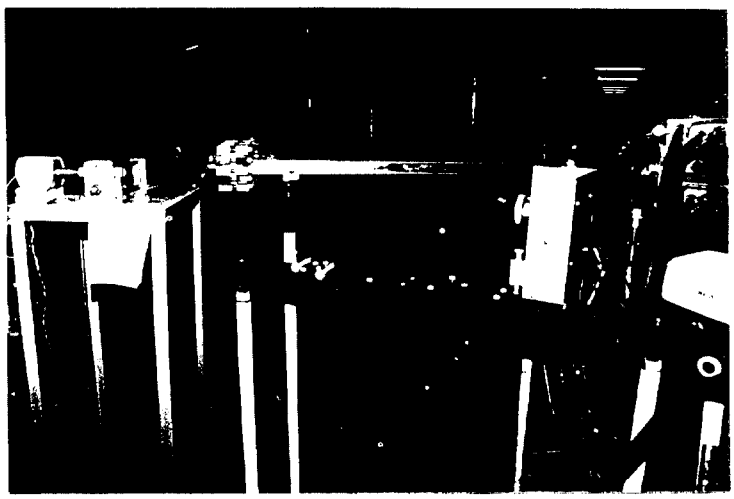
The picture in this paper shows the single bunch energy spectrum measured by the method described in this paper. The x axis correspondets the photodiode element location along the Reticon linear diode array, which also represents the energy changing of the electrons, the Y axis represents the electron density. The scanning line at down right side shows an unscanning period of the linear diode array. Electron's energy is increasing along the x axis direction. The peak is at 224 Mev. The electrons with lower energy have long "tail". Every x division is .8% energy spread. The picture was taken at beam current of 50 mA. A collective voltage was added between the window and the screen to restrain the secondary emission, but the test proved that the secondary emission effect can be negligible here.

The measured energy spread is consistant with the theoretical calculation which is ±.5%. The energe spectrum is quite stable and repeatable. The method has been proved very easily made, and reliable. The resolution and accuracy are very satisfied.

Energy Spectrum Measurement Set-up, view 1



An Energy Spectrum of
200 Mev Linac Single Bunch



Energy Spectrum Measurement Set-up, view 2