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MEASUREMENTS OF MICROBUNCH ENERGY SPECTRA ON A S-BAND ELECTRON LINAC

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Summary

A method was developed to measure with high resolution the energy spectrum of electron microbunches, produced by a S-band Linac. The electron beam is deflected by an analysing magnet and collected on the inner conductor of a fast coaxial target. The signal is analysed by a fast sampling scope which is triggered by a pulse composed of the electron current signal and a residual fundamental which is used as the fine time reference. For a given value of the magnetic field H, those of the bunches having electrons of the corresponding energy contribute to the signal which is displayed bunch by bunch on the scope. Using the manual sweep of the scope and varying H, the intensity variation of each bunch with H is registered. Series of energy spectra of the bunches are shown for electron bursts of 5 and 14 ns. These measurements were performed as part of a feasibility study for the installation of a post-acceleration pulse compression magnet.

Introduction

The S-band Linac of the Central Bureau for Nuclear Measurements provides electron bursts with a maximum energy of 150 MeV and burst widths adjustable to values between 4 ns and 2 μs.[1] Two typical and much used sets of parameters are: 4 ns, 10 A, 120 MeV and 14 ns, 8 A, 100 MeV.

The accelerator is mainly used as a pulsed neutron source for high resolution neutron time-of-flight measurements. Neutron bursts are produced via bremsstrahlung by (γ,n) and (γ,f) processes following the impact of the electron bursts on the target which consists of uranium and which is cooled by mercury.[2]

As the energy resolution of the neutron data strongly depends on the electron burst width (the shorter, the better) and the peak current (the higher, the better) considerable effort is continuously going into the improvement of these parameters. The highest peak current obtained so far on target for the at present shortest burst widths of 4 ns is 12 A which corresponds to about 50 nC of accelerated charge. At burst widths of 14 ns one obtains accelerated charges of about 120 nC.

To improve the peak current at 4 ns burst width and to possibly decrease the burst width to lower values, a post-acceleration pulse compression system will be installed. This will consist of a special magnet in which the train of bunches of a burst of say 14 ns undergoes a 360° deflection before it leaves the system. Since the energy of the electron bunches decreases steadily from the beginning to the end of the train due to the fact that the acceleration in the Linac consumes energy stored in the cavities of the accelerator, the trajectories of these bunches have different lengths. This effect can be used for a time compression of the bursts.[3]

The size of the compression effect depends critically on the energy spectra of the bunches and on the slope of the decrease of their mean energy along the train. This paper describes a method for the measurement of the energy spectra of the bunches.

The measurement system

The accelerated electron beam which has a diameter of about 10 mm is deflected by a 30° analysing magnet placed at the exit of the accelerator. It then crosses a 1% slit and impinges on a fast coaxial target.[4] (Fig. 1). To determine the shape and

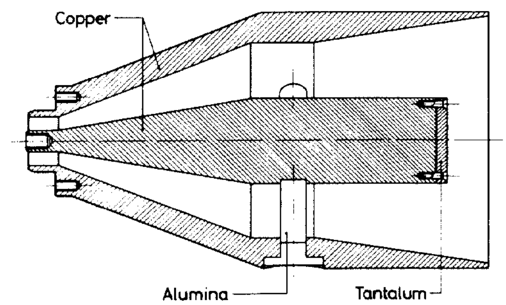

Fig. 1: Fast coaxial target.

the matching of this target, the part "Time-Domain Reflectometry" (TDR) of a sampling scope has been used. A pulse of 40 ps rise time is applied to the target. The reflections are plotted in function of time on a X-Y recorder. Positions of discontinuities may be measured and the shape of the target modified to improve the matching. Reflected pulses are shown in Fig. 2 for the target alone directly

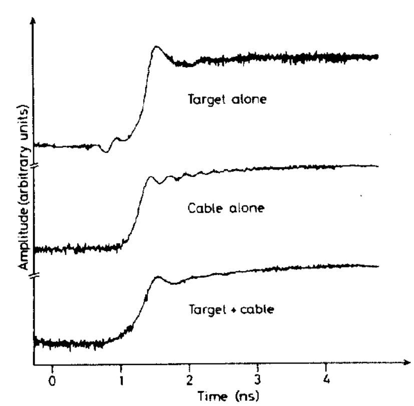

Fig. 2: Reflected pulses used for obtaining the matching of the target by "Time-Domain Reflectometry" method.

connected to the generator, for the air dielectric coaxial cable of 37 m length alone and for both the target and the cable. The rise time of the whole system is in fact about two times shorter than the measured value obtained with the reflected pulses. The bandwidth is then about 2 GHz. The beam is absorbed in a 5 mm thick tantalum plate (1,3 radiation length) and a 120 mm long copper rod which forms the inner conductor of the coaxial arrangement.

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The time structure of the electron beam is a sequence of microbunches which are about 60 ps long and have a period of 333 ps. Between the magnet and the targets, they have a shape as indicated in Fig. 3.

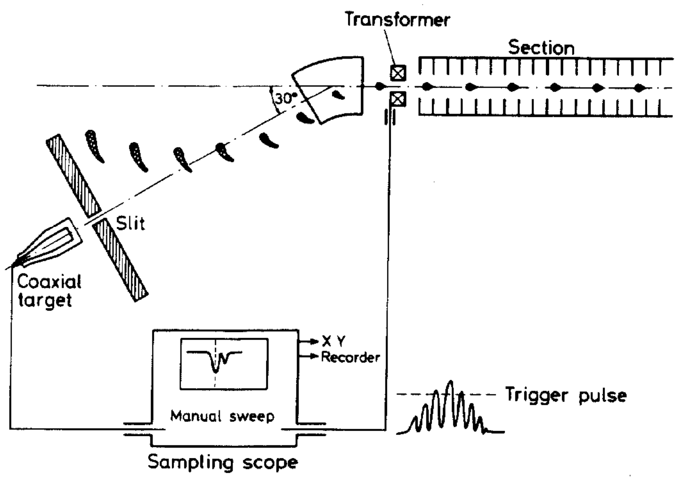

Fig. 3: Principle of microbunch energy spectra measurements.

Only electrons of an energy corresponding to the deflecting field and to the 30° angle will cross the slit and hit the target in phase with their relative position in the pulse. The overlap of the energy spectra of subsequent bunches implies that for a given value of the magnetic field, several bunches will participate in the signal. They are resolved (Fig. 4)

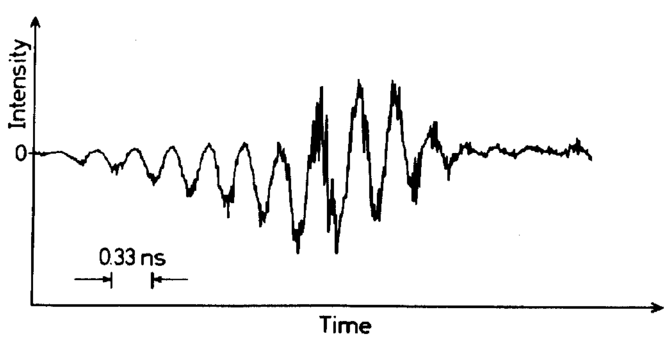

Fig. 4: Intensity of 106 ± 0.5 MeV electrons of a sequence of bunches. Beam parameters: 4.5 ns, 10 A, 50 Hz.

with the help of a fast sampling scope connected to the cable of the target. We have used for these measurements the Hewlett-Packard TDR/sampler group 1815/1817 with a rise-time of 28 ps. The pulse shown in Fig. 4 represents a sequence of well separated electron bunches collected on the target, all of the electrons having energies of 106 ± 0.5 MeV. We consider now only one of these bunches and, using the manual sweep of the scope, we adjust the spot on the maximum intensity of this bunch.[5] Then we record this quantity in function of the magnetic field, on a X-Y recorder. The intensity of the bunch considered is registered in function of the electron energy. This operation is repeated for all the bunches.

The scope is triggered by a signal very coherently synchronised with the beam structure. To achieve that in an easy way the signal was used which is produced by a current transformer normally placed at the output of the accelerator and before the magnet (Fig. 5).

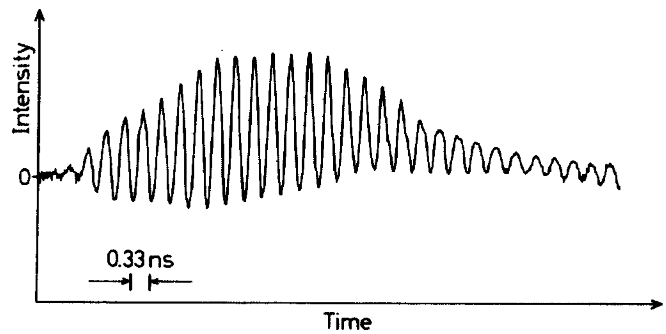

Fig. 5: Core signal used as trigger pulse.

The pulse collected on this device represents the beam profile. When such a ferrite is mounted without special care and connected to a high frequency cable, a large rf pulse is also observed, induced directly on the wire of the coil. The composite pulse shows a stepwise rise, where the steps show the period of the bunches.
The pulse is applied to the "trigger count-down" of the sampling scope which is then synchronized to the fine structure of the beam. With our accelerator, the electron beam is not synchronized with the rf. If measurements should be performed on pulses shorter than 4 ns, it could be necessary to do that in view of improving stability.

Results of measurements

Many groups of microbunch spectra have been registered in different working conditions of the linac. The two presented here correspond to pulses of 14 ns, 7 A (Fig. 6) and to 4,5 ns, 10 A (Fig. 7). With these parameters and at a repetition rate of 800 Hz, which is generally used, the electron beam power is equivalent to 8 resp. 4 kW.

The described fast coaxial target is not designed to handle such a power. However, to operate the accelerator in realistic conditions, the repetition frequency of the modulators is kept at 800 Hz while the beam is injected at 50 Hz. The power dissipated in the target is then a small fraction of 0.5 kW, the major part being stopped in the slit defining material. For practical reasons the spectra were registered only every fourth bunch at 14 ns and every second bunch at 4.5 ns. We observe in both cases the evolution of the bunching along the pulse as the stored energy and the electric field are decreasing with time.

During the measurements at 14 ns, some position jitter occured in the operation of a modulator thyratron. This led to a doubling of the spectra visible on the spectra of the last bunches.

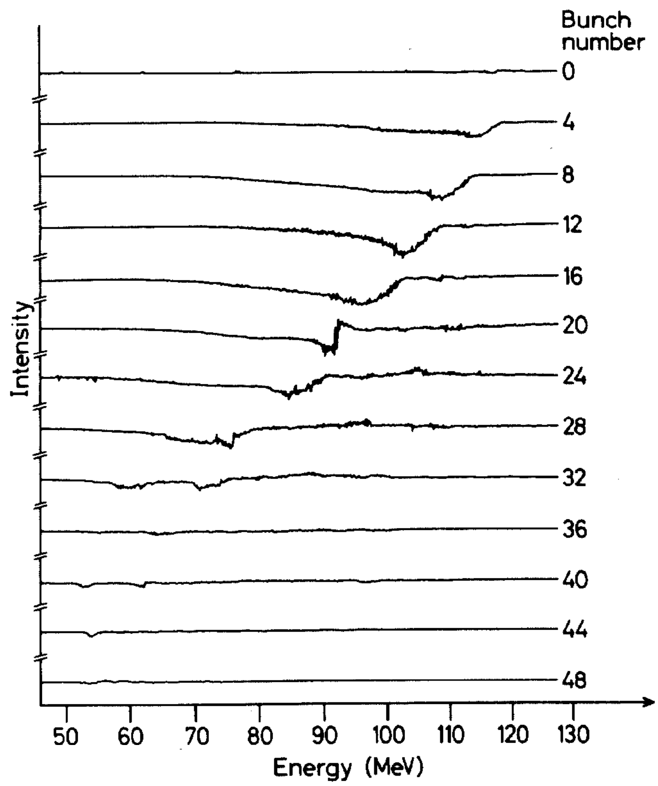

Fig. 6: Energy spectra of the electron bunches (14 ns pulse length).

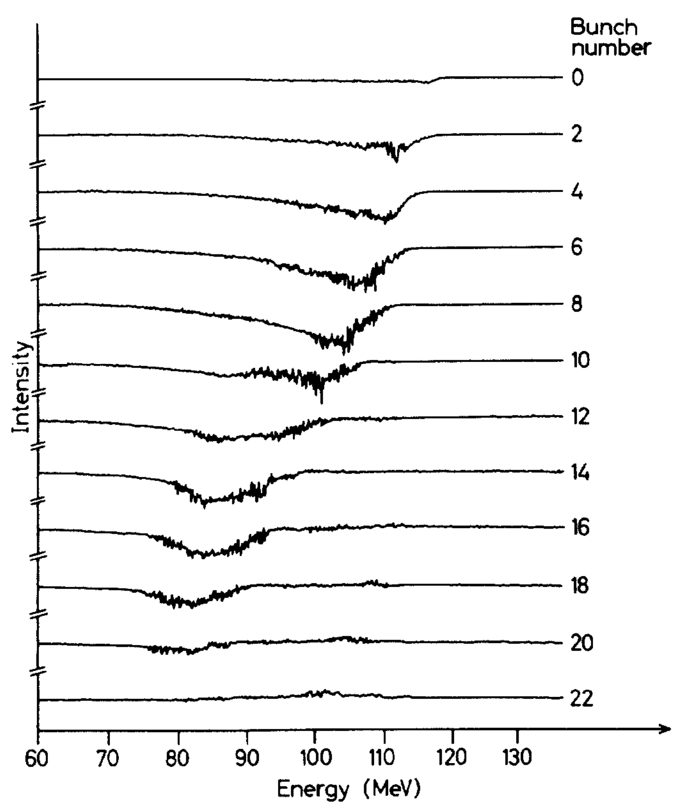

Fig. 7: Energy spectra of the electron bunches (4.5 ns pulse length).

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