MEASUREMENT OF BUNCH LENGTH WITH AN IMAGE DISSECTOR TUBE

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Abstract

The length of the electron bunches in the SRS storage ring has been measured by focusing the synchrotron light onto an image dissector tube. The technique is described, which is applicable both to the single bunch mode and to the multibunch mode. Bunch lengths of approximately 0.2 ns are measured with a resolution of 0.05 ns.

1. Introduction

For electron storage rings a knowledge of the length of the electron bunches is important for understanding the role of instabilities, whilst a measure of the relationships between bunch length and other parameters, such as beam energy, bunch current, etc., can enable the coupling impedance between the beam and the vacuum chamber to be calculated.

Storage rings with low frequency r.f. systems have long electron bunches whose length may be measured from the signal induced in a short pick-up probe responding to the passage of the electric field of the bunch. This technique is limited to a resolution of approximately 0.2 ns, and cannot be applied to storage rings with high frequency r.f. systems. Instead signals may be derived from the synchrotron light image of the beam, either from a fast photomultiplier or from a fast photo-diode. The fast photomultiplier builds up data slowly by statistical analysis of single photon counts. The fast photo-diode is relatively insensitive, but has a resolution of 0.1 ns or better. Streak camera techniques are also applicable but only give single shot measurements.

An alternative technique, which is described here, uses a device known as an Image Dissector Tube. This may be thought of as a combination of streak camera and electron multiplier and has the advantages of being sensitive, so that it may be used with low bunch currents, and having a fast response which permits bunch length measurements to be made to a resolution of at least 0.05 ns. The technique has been previously described in the Soviet literature, but this work is the first description of its application to multi-bunch electron beams, using the 2.0 GeV Synchrotron Radiation Source (SRS) at Daresbury.

2. The Image Dissector Tube

The Image Dissector Tube, whose normal application is as a fast TV camera tube, is shown schematically in fig. 1. It consists of two stages, an image section and a multiplier section, which are separated by a narrow slit.

In the first stage, the image section, a photon image falling onto a photo-cathode is transferred as an electron image focused onto a narrow slit. The electron image may be scanned rapidly across the slit by a pair of electrostatic deflection plates situated between the photocathode and the slit. The potential difference between the photocathode and the slit is approximately 7.5 kv so that the transit time spread of electrons between them is of the order of 10^-11 seconds and hence the fast time structure of the original photon pulse is preserved.

Electrons passing through the slit enter a multiplication section consisting of a dynode chain such as is found in a standard photomultiplier tube. Here the electron intensity is multiplied by several orders of magnitude but the fast time structure of the initial electrons is smeared out by the action of the dynodes.

For measuring bunch lengths in an electron storage ring a synchrotron light image of the beam is brought to as small a focus as possible on the photocathode. The smallest dimension of the beam, usually the vertical, is arranged to be parallel to the dissector slit. A high voltage, high frequency, sinusoidal scan is applied to the deflector plates. This scan is a submultiple of the storage ring main r.f. and is therefore phase locked to the bunches arriving at the photocathode.

The action of this r.f. scan is stroboscopic and produces a stationary pattern of bunch images across the slit plane, as shown in fig.2.
from the final stage of the dissector is thus a measure of the stationary bunch pattern at the slit plane, and from this the bunch length can be measured directly.

3. Equipment used at the SRS

At the SRS we have used an image dissector tube type LI-602 obtained from the Institute of Nuclear Physics, Novosibirsk, under an exchange agreement between Daresbury Laboratory and the USSR Academy of Science. A similar tube is available from the Hamamatsu Corporation, but we have not yet had the opportunity to try it.

The visible portion of the synchrotron radiation is reflected from within the storage ring through a lead glass window by a water cooled beryllium mirror mounted at 45°. The light is passed through the shield wall to a diagnostic station which is approximately 5 metres from the radiation source point. A pellicle is used to reflect 1% of the light towards the dissector, where it is brought to a focus by a 100 mm focal length TV lens.

The high frequency scan applied to the deflector plates is 31.25 MHz, which is derived from the 500 MHz main storage ring r.f. system by dividing by 16. The peak voltage is about 1 kilovolt. The slow linear scan also applied to these plates is at 20 ms and is locked to the mains supply. Approximately 1.5 kV peak to peak deflection is applied.

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The image converter section operates with about 7.5 kV between the photocathode and the slit, which is at ground potential. The multiplier section operates with about 2.0 kV between the first dynode and the final anode, which is also at ground potential. A times eight amplifier is used to drive the dissector output into a cable to a monitoring station.

4. Results

The bottom trace of Fig.3 shows a typical output from the dissector over the period of the slow linear scan. The top trace is the linear sweep voltage. The output signal shows the stationary pattern of bunches produced by the stroboscopic r.f. deflection. Since the deflection frequency is one sixteenth of the storage ring r.f. one would expect 16 bunches to be seen, but for clarity the deflection phase has been carefully adjusted to overlap the bunches on both directions of deflection. Hence, 8 apparent bunches are seen.

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Typical results for the SRS at 2 GeV with multibunch beams of about 1 mA per bunch are as follows:

- Measured bunch length FWHM: 0.250 ± 0.02 ns
- Contribution from finite vertical beam size FWHM: 0.05 ns
- Contribution from orbit length of 15 mm FWHM: 0.05 ns
- Contribution from transit time spread: 0.05 ns

The final result for the FWHM bunch length is thus 0.220 ± 0.025 ns, which is to be compared with the theoretical prediction of 0.195 ns at 2.0 GeV in the case.

5. Conclusion

The image dissector is a useful device for measuring electron bunch lengths in storage rings. It is sensitive, so that useful signals can be obtained from single bunch currents of 0.01 mA, and fast, with a resolution of 0.05 ns. When used with multibunch beams it is easily calibrated from the known inter-bunch spacing. However, because of the fairly slow rate of the sampling sweep it cannot respond to fast changes in the bunch structure and simply measures the average length of the bunches.

References


