A New Picosecond Bunch Length Monitor on the SRS

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Abstract

A dedicated experimental station is available on the SRS for optical diagnostics purposes, including monitoring of beam profiles and bunch lengths. The latter are typically in the range 20 - 100 ps and have been measured so far using a stroboscopic image dissector. A new monitor has now been commissioned and is able to resolve changes in bunch length of less than 5 ps, based on an ultra-fast photodiode imaging the visible synchrotron radiation. A complete description is given and typical results for the SRS are presented.

1. INTRODUCTION

The electron bunch length on the SRS has been measured using a stroboscopic image dissector for several years [1]. Recently a new bunch length monitor has been developed at Daresbury, based upon an ultra-fast photodiode, that also images the visible synchrotron radiation. This monitor has now been commissioned and does not yield the same values as the dissector. This paper describes the system in full and presents data comparing the dissector with the photodiode.

2. THE BUNCH LENGTH MONITOR

At the heart of the new monitor is an ultra-fast GaAs photodiode [2] which operates in the visible part of the spectrum. The specifications of the device are given in Table 1. The photodiode has an impulse response width of ≈10 ps which compares favourably with typical bunch lengths of 20 - 100 ps (sigma).

Model Number	Y-35-5252-22	
Bandwidth	18	GHz
Impulse Response Width (sigma)	10	ps
Rise Time	<18	ps
Fall Time	<18	ps
Operating Voltage	-5	V
Active Area	5×10^{-6}	cm^2
Wavelength Range	600 - 840	nm
Maximum Photocurrent pulse	10	μA

Table 1. Specification of the photodiode.

The main problem with the photodiode is the very small active area. The diagnostic beamline on the SRS is shared with a user station so there is a limited amount of light available. This makes it very difficult to focus enough light onto the diode to get a reasonable signal, even though the lens system has been carefully designed to minimise the focussed image size. This problem has been solved by using amplification of the output signal. However it is still crucial to maximise the signal from the photodiode by accurate alignment of the optics. For this reason the photodiode is mounted in a three-dimensional micropositioner which has micron resolution.

A schematic of the bunch length monitor system is given in figure 1. A reverse bias of 4.5 V is applied to the photodiode. The mean integrated current developed by the photodiode is monitored across the 1 kΩ resistor, for checking that the maximum allowable photocurrent is not exceeded. It is also useful for optimising the alignment of the photodiode. For convenience a splitter is used to separate the DC and RF signals. The RF signal which contains the bunch length information is amplified. To avoid degradation of the signal an ultra-wide bandwidth amplifier is employed [3]. The specification of the amplifier is given in Table 2.

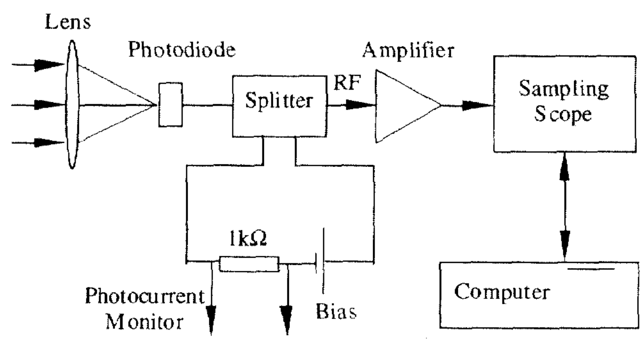

Figure 1. A sketch of the bunch length monitor system.

Bandwidth	0.1 to 18.0	GHz
Gain	34.0	dB (min)
Noise Figure	6.5	dB (max)
Operating Voltage	+15	V
Operating Current	360	mA

Table 2. Typical specifications of the amplifier.

The amplified signal is monitored using a Tektronix 7854 sampling scope. The trigger is either taken from the main storage ring RF system or from a capacitive beam pick-up. The scope is controlled remotely by a computer running the LabVIEW® software [4, 5]. The scope trace is captured and a Gaussian profile fitted to find the bunch length. Some signal averaging is usually employed to improve the repeatability though this is not strictly necessary. It is estimated that the complete system has an impulse response width of <20 ps.

A typical scope trace for a single bunch beam is shown in figure 2. Note that the output has some overshoot on the trailing edge which lasts for about 500 ps. This is of little consequence since the electron bunches are separated by 2 ns. The Gaussian fit is virtually unaffected by the overshoot.

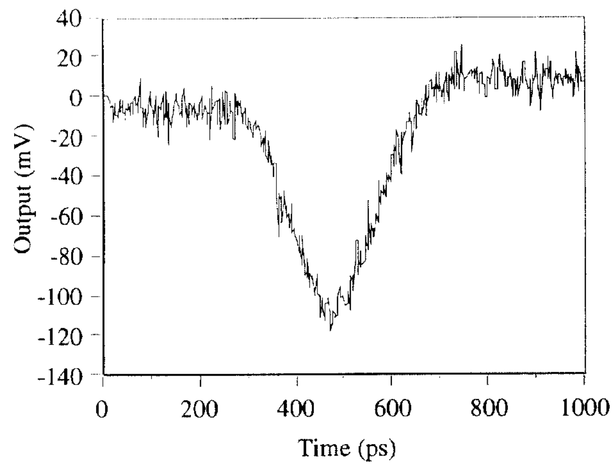

Figure 2. Output signal for a 24 mA single bunch beam at 2.0GeV.

With the present set-up it is possible to measure the bunch length down to bunch currents of around 0.1 mA. This could be improved by further amplification or a more favourable optical set-up. It has been confirmed by means of neutral density filters that the monitor has no intensity dependence that could distort bunch length measurement as a function of beam current.

3. Comparison with the Image Dissector

The bunch length is already measured on the SRS using an image dissector. The dissector measures the bunch length indirectly using a stroboscopic technique and is described in detail in reference [1].

During the early commissioning of the photodiode system it quickly became apparent that the two devices did not agree. Typically the dissector measured a bunch length about 30% longer than the photodiode. Both systems were examined in detail and two minor problems were found with the dissector but these could only account for a few percent in the bunch length.

In order to resolve these differences an experiment was carried out that compared the bunch lengths measured by these two systems with a third, independent, method. On an adjacent beamline a photon counting system was set-up. This well established technique has been used elsewhere for bunch length measurements [6]. The system used at Daresbury has an impulse response width of less than 25 ps.

The bunch length of a single bunch beam at 600 MeV was measured at 30 mA and below as the beam decayed naturally. The results are given in figure 3. It is clear that the dissector measures a significantly longer bunch length than the other two systems. The photodiode and the photon counting system agree well with each other. The reason for the over estimation in bunch length by the dissector is as yet unknown. The dissector system has been checked meticulously for intensity and wavelength dependence, diffraction effects, pulse broadening and calibration error.

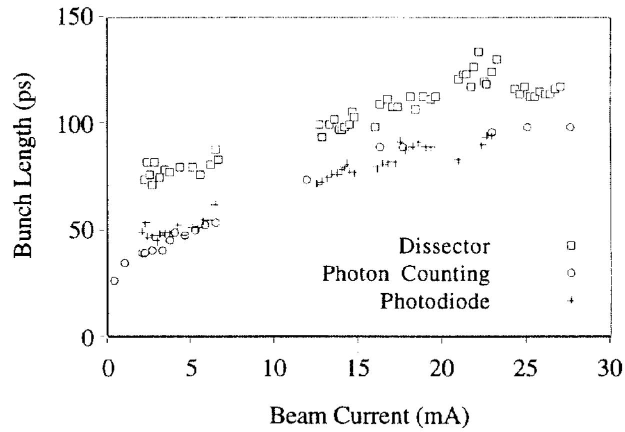

Figure 3. A comparison between the photodiode, image dissector and photon counting system.

4. Conclusions

A new bunch length monitor has been developed at Daresbury which is able to resolve changes in bunch length of less than 5 ps. This diagnostic is based upon an ultra-fast photodiode imaging the visible synchrotron radiation. All previous bunch lengths measured on the SRS were carried out using an image dissector. An experiment comparing the photodiode with the dissector and an independent photon counting system indicate that the dissector over-estimates the bunch length by about 30%. The reasons for this are unclear. The realisation that bunch lengths in the SRS have been over-estimated in the past has led to a revised broadband impedance measurement for the storage ring [7].

5. Acknowledgement

The photon counting system measurements were carried out by Dave Shaw.

6. References

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[7] M.W. Poole et al, "Revised SRS Impedance Estimates", these proceedings.