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Two-photon correlation of synchrotron radiation by a novel delay-time modulation technique

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Introduction

The two-photon correlation of the synchrotron radiation has been paid much attention, since it gives the photon statistics of the synchrotron radiation and, if the synchrotron radiation is known to be chaotic, the electron-beam emittance of the storage ring is estimated from the two-photon correlation without being affected by some instabilities of the electron beam. However, the precise measurement of the two-photon correlation has been a difficult work due to the short temporal coherence as compared with the response time of the detector [1]. In order to overcome the difficulty, we have developed a new instrument based on the time-modulation technique and succeeded in observing an apparent bunching effect originating from the chaotic nature of the synchrotron radiation by using a dragon-type monochromator.

Result and Discussions

The experiment was performed at an undulator beamline, BL-16B. The detail of the instruments is explained in the references [1,2]. The monochromatic light with photon energy of 55 eV, whose energy resolution was expected to be about 10000, was diffracted by a Fraunhofer slit. The width of the slit D was changed between 8 μm and 96 μm and the spatial coherence was controlled by the slit. The diffracted beam was divided into two beams by a mirror and each beam was measured by a photomultiplier tube (PMT) as shown in Fig. 1.

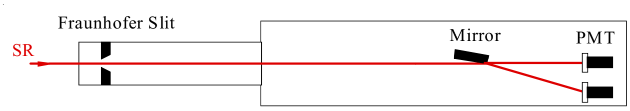

Fig. 1 The optical system for the measurement of the two-photon correlation (top view).

The signals from the PMTs were analyzed by a delay-time modulation circuit. The correlation of two photons emitted from a bunch or those emitted from different bunches were measured by changing the delay in the circuit with two solid-state switches. We modulated the delay-time with a frequency of 0.795 Hz and measured the correlation S by a digital lock-in amplifier in order to eliminate a trivial correlation originating from the bunch structure of the electron beam. For the normalization of the correlation, the averaged currents from the PMTs I_1 and I_2 were measured by digital electrometers. For each width of the Fraunhofer slit, we accumulated the signal for about four hours and the normalized correlation $V(D) = S/(I_1 I_2)$ was obtained. This value is given by the integral of the second order coherence on the Fraunhofer slit. The theory predicts that $V(D)$ should be a monotonically decreasing function of D for the chaotic light and constant for the coherent light, respectively. Fig. 2 shows the measured correlation $V(D)$. As D becomes larger, $V(D)$ tends to decrease, and this clearly indicates that the synchrotron radiation (undulator radiation) emitted from the PF ring has a chaotic component. By fitting $V(D)$ with a theoretical curve calculated with a Gaussian-beam approximation, the electron-beam emittance is estimated with a knowledge of the beamsize of the photon beam on the Fraunhofer slit. The beamsize measured with a tungsten wire scanner was 60.9 μm, and the electron-beam emittance in the horizontal direction was estimated as 39 nmrad. This value was very consistent with the designed value of 36 nmrad. Therefore, we concluded that the two-photon correlation was successfully measured in a high accuracy with the new technique [2].

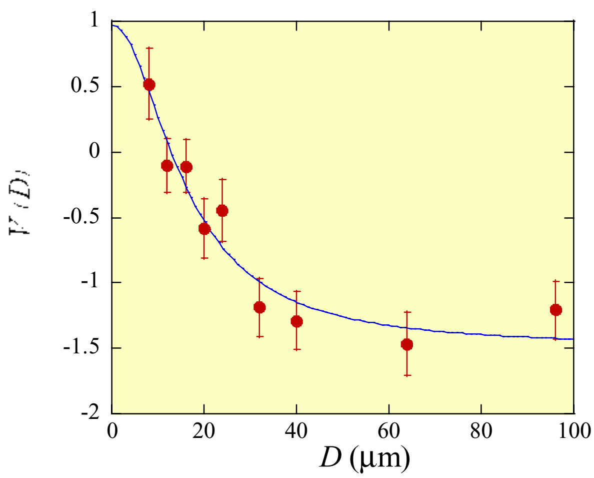

Fig. 2 Observed two photon correlation V_x as a function of the width of the Fraunhofer slit D.

References

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