ABSOLUTE MEASUREMENT OF UNDULATOR RADIATION SPECTRA (K-VALUE DEPENDENCE OF BRIGHTNESS)

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1. Introduction

An operational test of an undulator with 19 pole permanent magnets was successfully carried out in December, 1981, with SOR-RING at Tanashi, Tokyo. Experiments for confirmation of some predicted properties of the undulator radiation (UR) were also performed during the test operation. Measurement of spatial and spectral distribution of the UR, for example, demonstrated that the validity of the following formula for the wavelength to be observed in the limit of infinitesimal emittance was confirmed experimentally, i.e.,

$$\lambda_n = \frac{\lambda_u}{2n\gamma^2}\left(1 + \frac{K^2}{2} + \gamma^2\theta^2\right) \quad , \tag{1}$$

where, λ_n is the wavelength of the n-th order harmonic of the UR spectrum, λ_u is the period of undulation, γ is the ratio of the electron energy to its rest energy, and θ is the angle of observation relative to the undulator axis.

In this report, we describe new results of our measurement of absolute spectral intensity of the UR mainly concerning with its dependence on the field parameter K, which is expressed as

$$K = \frac{eB\lambda_u}{2\pi mc} = 0.934 \cdot B(\text{tesla}) \cdot \lambda_u(\text{cm}) \quad , \tag{2}$$

where, B is the maximum value of the magnetic flux density in the undulator. The brightness I_{nB} expressed in unit of photons/sec·mA·mrad^2·1% bandwidth is given on the undulator axis for infinitesimal emittance as

$$I_{nB} = 8.7 \times 10^{11} E^2 \frac{N}{\Delta_n} F_n(K) \quad , \tag{3}$$

where, N is the number of periods, Δ_n is the fractional width of the n-th order band of the spectrum, and E is the electron energy in GeV. $F_n(K)$ is a function of K expressed as

$$F_n(K) = \frac{n^2K^2}{(1+K^2/2)^2}\left[J_{\frac{n+1}{2}}\left(\frac{nK^2}{4+2K^2}\right) - J_{\frac{n-1}{2}}\left(\frac{nK^2}{4+2K^2}\right)\right]^2 \quad , \tag{4}$$

where, J_m is the m-th order Bessel function.

2. Experiments

The undulator has the period λ_u of 4 cm, and the K-value can be varied from 0.24 to 0.47 (B = 0.06 to 0.13 tesla). The SOR-RING was operated at 380 MeV of the beam energy (γ = 743.6).

A cylindrical mirror type photo-electron analyzer with 2π-acceptance at magic angle was set on the undulator axis through a pinhole of 0.5 mmϕ, which is 1840 mm distant from the center of the undulator and limits the full angular acceptance to 0.27 mrad. The spectra were measured in a range from 21.6 to

72.9 eV of photon energy, i.e., from the ionization threshold of neon used as a target gas to the L-absorption edge of the aluminum foil used as a filter.

3. Results and Discussion

Figure 1 shows the brightness spectra of the 1st and 2nd order harmonics of the UR obtained for several K-values. It can apparently be seen that, as K increases, the ratio of the brightness of the 2nd order harmonic to the 1st order increases.

Figure 2 shows a plot of the peak values of the 1st order harmonic against the K-values. In the figure, the dashed line indicates the calculated brightness normalized at K = 0.47. It can be seen that the K-dependence of the brightness is in good agreement between the experiment and the calculation.

However, the absolute values of the brightness actually obtained were smaller than that of the calculation by factor of 4, the difference being due in part to the effect of finite emittance, because an error in the absolute calibration is within a factor of 2.

Thus, we can conclude that the followings were confirmed experimentally: a) the brightness of the higher order harmonics of the UR spectrum increases relative to the lowers with increasing of K, and b) the K-dependence of the brightness can be expressed exactly by the function (4), provided the absolute value of the brightness to be observed actually is smaller by a factor than that of calculation for infinitesimal emittance due to the finite emittance of the beam.

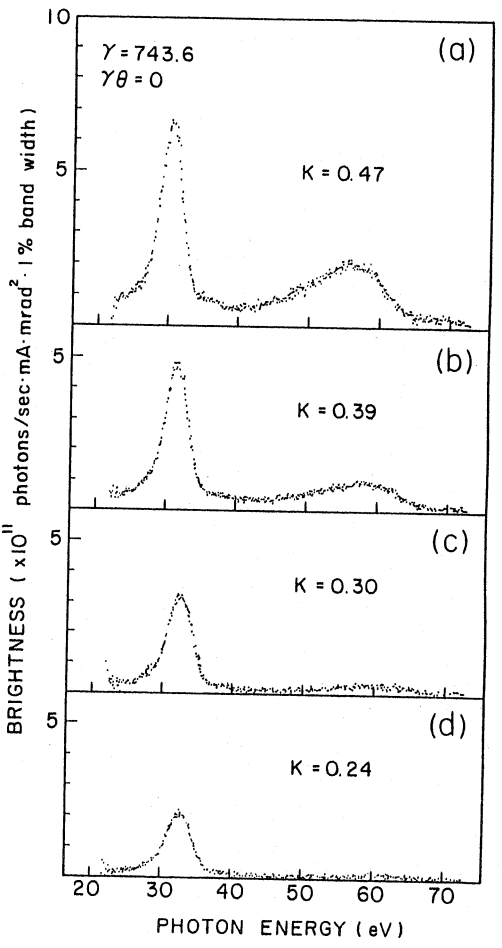

Fig.1 Brightness spectra obtained in changing K-value.

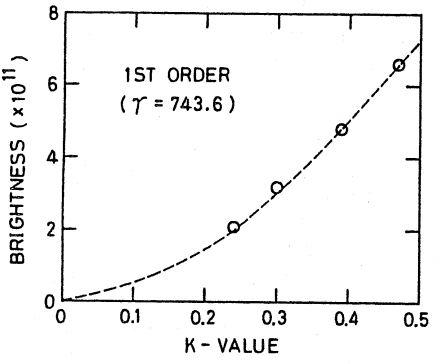

Fig.2 Plot of the peak values of the 1st order harmonic against K.

References

1) H. Kitamura et al., KEK Preprint 82-12 (1982), to be published in Jpn. J. Appl. Phys. 21 (1982).
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