Design of a Quasi-periodic Undulator

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Synchrotron radiation generated with conventional undulators has several harmonic peaks in photon spectrum. A new type of undulator has been devised not to generate the higher harmonics passing through crystal monochromators, because the harmonics are, in general, harmful in monochromatic energy experiments. The new undulator has a quasi-periodic array of magnetic poles and generates photon flux with intensity maxima at irrationally factored energies in spectrum, which can be absolutely cut out with crystal monochromators.

The present idea originates in the formal equivalence between the mathematical expressions of the X-ray scattering intensity with crystals and the spectral-angular intensity of synchrotron radiation, that is,

1) for the scattering intensity;

$$I(q) = \left| \int_{-\infty}^{\infty} \rho(r) \exp(-2\pi i q r)\, dr \right|^2 , \qquad (1)$$

2) for the synchrotron radiation;

$$\frac{d^2 I}{df\, d\Omega} = \left| \int_{-\infty}^{\infty} F(r_n) \exp\{-2\pi i (f/c) r_n\}\, dr_n \right|^2 , \qquad (2)$$

where r_n represents the distance between an electron and the observer. We know that the diffraction pattern I(q) from a quasi-crystal ρ(*r*) has no translational symmetry in reciprocal space and we can infer that a quasi-periodic motion of electron in the undulator generates some harmonics with irrationally factored energies in spectrum.

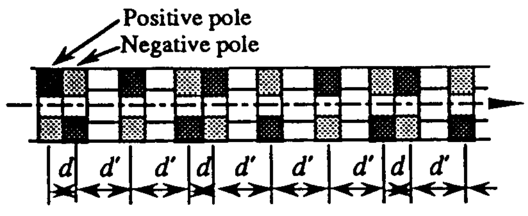

Fig. 1 Actual arrangement of magnetic poles in the quasi-periodic undulator of h=√5.

The ith lattice position in a quasi-periodic lattice can be expressed in a general form of

$$x_i = i + \left(\frac{1}{\eta} - 1\right)\left[\frac{i}{\eta+1} + 1\right], \qquad (3)$$

where η is an arbitrary irrational number and denotes the largest integer less than y. The lattice is characteristic of an quasi-periodic array of lattice points with two different inter-site distances d and $d'(d'/d=\eta)$. Positive and negative magnetic fields are alternately repeated on the undulator. If the magnetic poles are arranged in a quasi-periodic fashion as shown in Fig. 1 ($\eta=\sqrt{5}$), the spectrum is calculated as shown in Fig. 2. We can see sharp maxima without any periodicity. For the sake of comparison, we calculated a spectrum from a periodic undulator with the same number of magnetic poles as shown in Fig. 3. Under the conditions indicated in the figure caption, the first peak energy is the same as the lowest one in the quasi-periodic undulator spectrum.

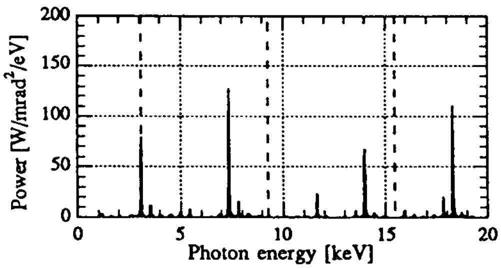

Fig. 2 Spectral angular power density of the quasi-periodic undulator. The number of poles=100. Undulator gap=30 mm. Electron beam=100 mA at 8 GeV.

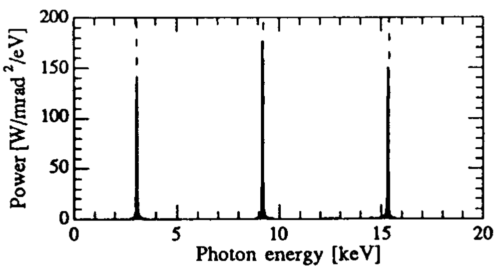

Fig. 3 Spectrum from a periodic undulator. The number of poles=100. K=1.8. Electron beam=100 mA at 8 GeV.