EQUIPMENT FOR ELECTRON BEAM ENERGY CALIBRATION IN HLS *

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Abstract

The Set up for energy calibration of electron beam will be built by the method of resonant depolarization in HLS. Polarization time of electron beam of Hefei storage ring, distribution of depolarization field, the input power of exiting trip and depolarization time were calculated. With the Beam Loss Monitor system, the relative change of the beam lifetime is measured, due to increase the coupling degree and cavity voltage. The change of Touscheck lifetime expects to be measured due to depolarization.

INTRODUCTION

The middle or low energy electron storage ring also is used as a primary radiation source standard for radiation sources in the VUV and soft X-ray spectral range [1]. This means that the spectral photon flux of the synchrotron radiation originating in the bending magnets is calculated from the measured storage ring parameters and geometrical quantities by Schwinger's theory. Obviously, the relative uncertainty of the calculated spectral photon flux depends on the uncertainties of the input parameters. Therefore the relevant storage ring parameters have to be measured with very small relative uncertainties of typically some 10^{-4} in order to obtain a relative uncertainty below 0.1% for calculated photon flux. On storage ring parameter important for the calculation of the spectral photon flux is the energy W of stored electrons. The energy of an electron beam can be calculated fairly accurately from a model of the integrated dipole fields around the storage ring, and the measured uncertainty of energy with this method only obtain 10^{-3}. But the resonant depolarization can used as electron beam energy calibration with high precision [2, 3, 4], and the measured precision is below 10^{-4}, the measured method is sample. So the resonant depolarization method will be used as electrons energy calibration in HLS.

The precession frequency of the electron spin around the vertical dipole fields depends only on the beam energy, it is possible to accurately find the beam energy by measuring the spin precession frequency. This was done first in storage ring VEPP-2M, secondly, all of DORIS, CESR and LEP used the method for calibration electrons energy. The middle or low energy electron storage ring such as BESSYI[2] , BESSYII[3] and ALS[4] have used successfully the method for calibration electrons energy. The parameters necessary to dimension equipment for the measurement of the beam energy of Hefei electron storage ring via the resonance depolarisation are collected in this paper.

Table 1:Nominal HLS parameters

E	Beam energy	800MeV
C	Circumference	66.1308m
f_{rf}	RF frequency	204.016MHz
H	Harmonic number	45
α	Momentum compaction	0.044
I	Beam current	200-300mA

DEPOLARIZATION RESONANCE

The z-component of the spin vectors of individual electron s are oriented parallel(up) or anti-parallel(down) to the vertical guide field. Initially the population of the up and down states is equal, i.e. the beam is not polarized. A small fraction of the emission procession processes of synchrotron radiation is connected with the change of spin state (spin flip synchrotron radiation). This electron beam polarization process is also called as the Sokolov-Ternv [5] effect. For Hefei light source (HLS) the polarisation time τ_p is approx 4.346 h at 800MeV,. The polarisation time is given by: [1]

$$\tau_p(s) = 98.66\frac{\rho(m)^2 R(m)}{E(GeV)^5} \tag{1}$$

The calculated value 4.346h is only for reference. Error fields coming from, for example, magnet misalignments lead to depolarization at resonances between the beam orbit and spin motion. So really polarization time may be longer than 4.346.

The relation between the spin precession frequency ω_{spin} and the electron energy is given as:

$$\omega_{spin} = (1+\alpha\gamma)\omega_0 \tag{2}$$

$\gamma = \frac{E}{m_0 c^2}$, α is the electron magnetic moment anomaly $\alpha = \frac{g-2}{2} \approx 0.00115965219$.

After the polarization has built up, it may be destroyed, if the radial field $H_x(t)$ of the depolarizer is in resonance with ω_{spin}, the resonance condition for depolarization is:

$$w_{dep} = (\alpha\gamma \pm n)w_0 \tag{3}$$

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While the polarization is destroyed, the Touschek scattering rate increases. The depolarization process may be monitored by measuring beam loss rate. As the frequency of depolarization determined, the beam energy will be calculated accurately by formula (3).

DEPOLARIZATION FIELD

The radial field $H_x(t)$ will be applied to the beam by a pair of striplines mounted in the storage ring vacuum chamber. When input power is 12.5w, with OPRA program, integrated field is calculated on axial. Different input power V.S integral field is showed in fig 1.

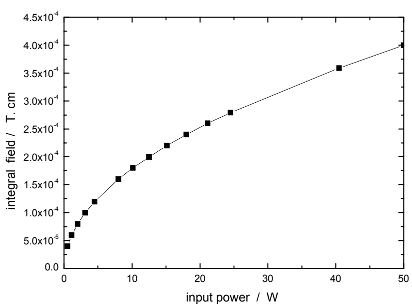

Figure 1: Different input power V.S. integral field

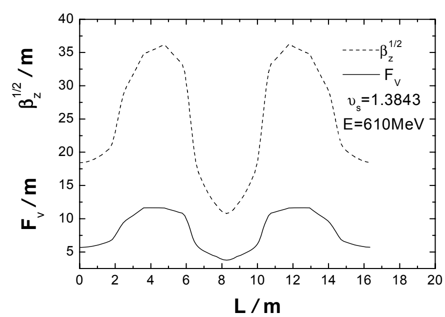

Figure 2: The spin response function and the envelope in one period of the ring.

SPIN RESPONSE FUNCTION

The characteristic or "spin response function" F(s) of the ring optic is relative to the lattice of ring . When the radial field is applied to the beam by striplines, the radial field will disturb the revolution electrons, and change direction of sipn of electron by spin response function. As the F(s) is bigger, the effect of depolarization is stronger. But the biggest F(s) is not necessary for depolarization, and the choice of value of F(s) is convenient for experiment.

The spin response function can be calculated with below formula [4]:

$$F(s) = \frac{Nutationfreqency\Omega_x withoscillation}{Nutationfreqency\Omega_x withoutoscillation}$$

The calculated result is show in fig.2. Because the position of striplines of Hefei storage ring can not be changed, the value of F(s) is 1.569 in this position.

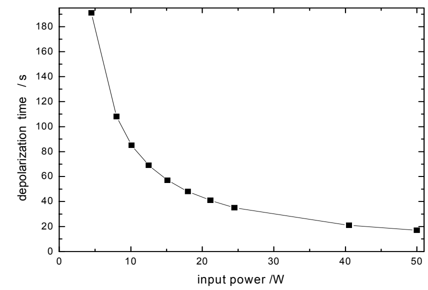

Figure 3: The depolarization time V.S input power.

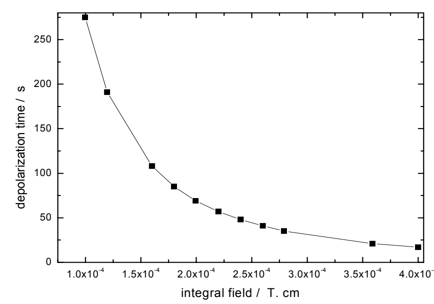

Figure 4: The depolarization time V.S. the integral field.

DEPOLARIZATION TIME

The depolarization time can calculated by the below formula [6]:

$$\tau_{dep} = \delta\omega_{dep}\frac{Z_s}{2P}\cdot\left(\frac{\langle H_z\rangle 2L\pi ra}{\Omega_z l_{dep}\,|F(s_{dep})|}\right)^2 \qquad (4)$$

The $<H_z>$ is average strength of radial field, $\langle H_z\rangle = \frac{1}{L}2\pi\rho\cdot H_z$, l integrated length, L is circumference length, r is length between beam and stripline. For HLS, $\mu_0 H_z$ =1.2T, l_{dep} =72cm, L =66m, ω_{spin} = 2π · 3.6969MHz, r =4cm, $F(s_{dep})$ = 1.569. The depolarization time V.S. input power, showed in fig.3, the depolarization time V.S. the integral field, showed in fig.4. In the same time, $\delta\omega_{dep} = \pm 2\pi\cdot 1$kHz.

TOUSCHECK LIFETIME MONITOR

The beam loss monitor system mounted in Hefei electron storage ring may be used to measure the relative variation of the Touscheck life time. When the couple factor was changed, beam loss rate was measured, showed in fig5. While the coupling factor increases, the cross section for the Touscheck scattering process decreases. So the beam loss decreases, and Touscheck lifetime increase. Also beam loss rate change was measured when the cavity voltage changed from 90 to 150 kV, showed in fig 6. From two experiments, the beam loss monitor system can measure the relative variation of Touscheck lifetime. And it expected that the beam loss monitor system can distinguish the variation of Touscheck lifetime of beam depolarization.

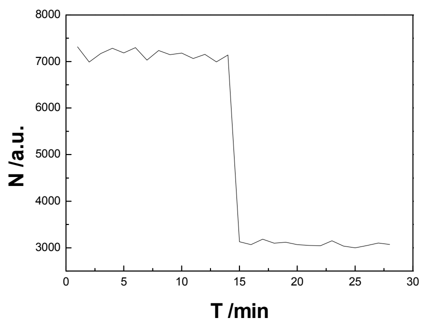

Figure 5: The change of beam loss rate due to the change of coupling factor.

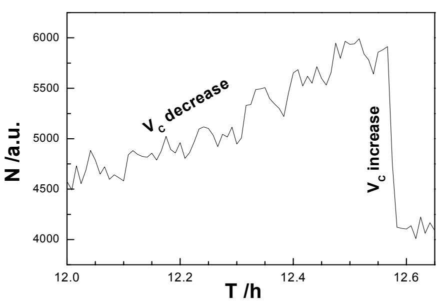

Figure 6: The beam loss rate V.S. cavity voltage.

The parameters of equipment were calculated, and the equipment of electron energy measurement of resonant depolarization has been built up. The experiment of electron beam energy calibration will be taken in the future.

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