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MAGNETIC MEASUREMENT OF TAPERED GAP U50 UNDULATOR

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Abstract

In this paper, we report the field integral and phase error measurements of the tapered U50 prototype PPM undulator by Hall probe and stretched wire methods.

INTRODUCTION

There are interests in Tapered Undulator technology to compensate the beam energy loss and compensation of energy chirp in the relativistic beam in free electron lasers and inverse free electron lasers. The tapered undulators are used for high photon energy synchrotron radiation production [1]. The tapered undulator improves the conversion efficiency of the relativistic electron beam power into coherent short wavelength radiation in free electron lasers [2, 3] improves the accelerating gradient of the inverse free electron lasers.

The tapered undulator at Laser & Insertion Device Application Laboratory (LIDA) is a 50 mm period undulator. It has twenty number of periods.

LIDA HALL PROBE AND STRETCHED WIRE MAGNETIC MEASUREMENT SYSTEMS

The LIDA-DAVV Laboratory is equipped with Hall probe magnetic measurement bench [4]. It uses Wollaston prism interferometer and position sensitive detectors for probe alignment. The Michelson interferometer measures the longitudinal motion accuracy of the measurement. In the Hall probe measurement method, a specially designed carriage on the bench carries the probe through the undulator at a given speed and delay while the measurements are being performed. We use F.W. Bell make Hall probes and Tesla meters. The field integrals are calculated from the field mapping by a homemade MATLAB based code. The LIDA Laboratory has developed a stretched wire system to measure the field integrals and the field harmonics as well. In the method the first field integral and second field integral are measured from the induced voltage at appropriate wire translation inside the undulator [5, 6].

MEASUREMENT

The tapered gap U50 undulator is measured in the Hall probe. For the measurement one end is fixed and the other end gap is changed and readout is checked in the DRO attached to the girder. Figure 1 presents the measurement of magnetic field for three different gaps 18 mm, 17.70 mm and 18.30 mm.

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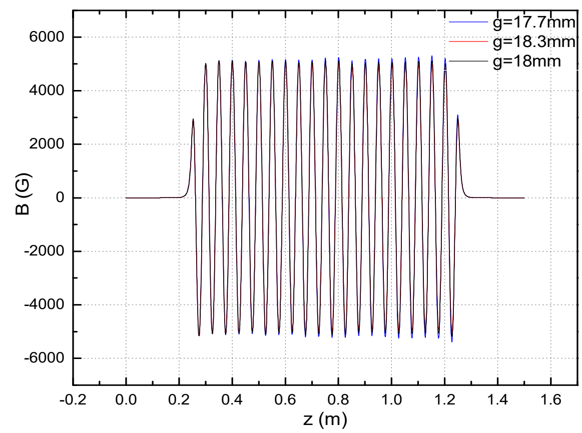

Figure 1: Hall probe mapping of the undulator.

The undulator parameter is given,

$$K = 93.308\lambda_u(\mathrm{m})B(\mathrm{T}) \tag{1}$$

The peak value of K from Eq. (1) and Fig. 1 is plotted in Fig. 2. To find the tapered profile we use the K-variation as [7],

$$K(z) = K_0\left(1 - \alpha_K \frac{z}{L}\right) \tag{2}$$

Where K_0 represents the untaper K-parameter, z is position along the length of the undulator; L is the length of undulator and the parameter α_K specifies the tapered profile.

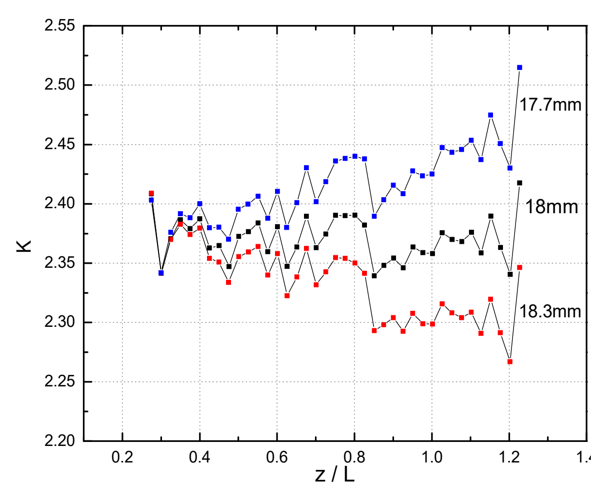

Figure 2: Variation of K at poles of undulator.

Figure 2 is fitted with a curve, the data in Fig. 2 is linearly fitted and the tapered profile is read from Eq. (2).

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This allows us to relate the tapered profile versus end gap shown in Fig. 3.

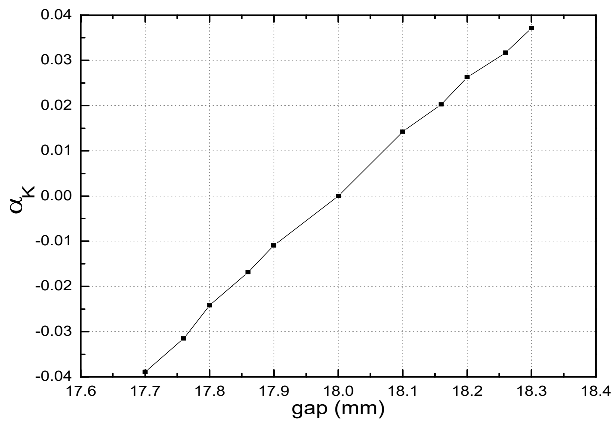

Figure 3: Taper parameter as a function of end gap.

The field integrals from the Hall probe data is shown in Figs. 4 and 5, respectively. To compare the field integrals obtained from the Hall probe data, we take the stretched wire measurement. The measurement by stretched wire is taken by a copper litz wire of 100 strands which is stretched for 2140 mm along the axis of undulator. The first integral of magnetic field with stretched wire is measured by moving 1mm both the end of stretched wire parallel to the axis of undulator with 5000 steps/s providing 1.5625 mm/s speed to the translational motion of wire. The second integral of magnetic field is measured by providing translational motion to only one end of stretched wire in the undulator 1 mm with same speed while another end is fixed at the axis of undulator and calculated by [5]

$$I1 = \frac{1}{N\Delta x}\int_0^{\Delta t} V dt \tag{3}$$

$$I2 = \frac{L}{N\Delta x}\int_0^{\Delta t} V dt \tag{4}$$

Where $I1$and $I2$ are first and second field integrals respectively, N is number of turns in wire, Δx is translational distance and $\int_0^{\Delta t} V dt$ is integrated induced voltage. The wire is moved a number of times and average is being taken. The results of both the measurement matches closely with each other, first integral measured by stretched wire differ only by ~2G cm and the second integral differ by ~100G cm^2. The comparison of first integral and the second integral of magnetic field at different taper values measured by the Hall probe point to point measurement and stretched wire measurement are presented in Figs. 6 and 7, respectively.

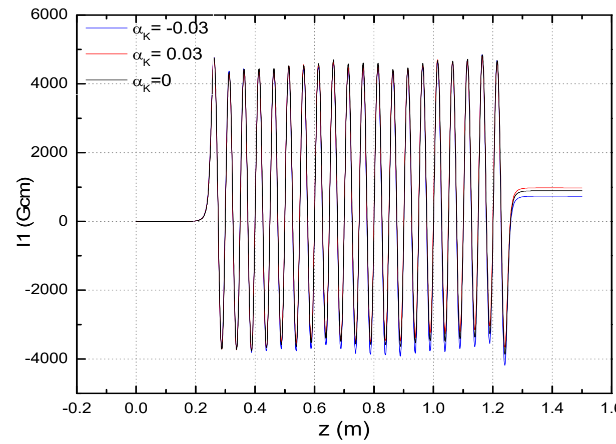

Figure 4: First field integral of undulator.

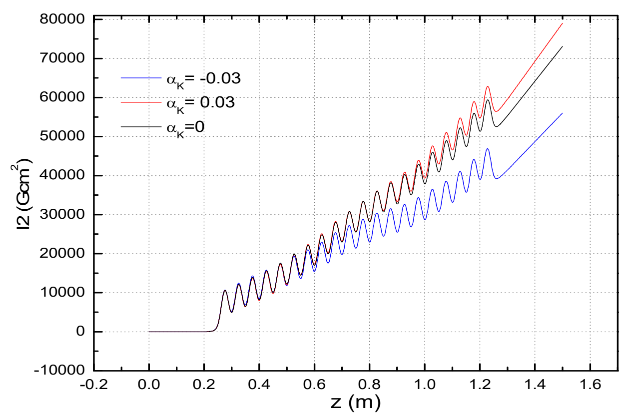

Figure 5: Second field integral of undulator.

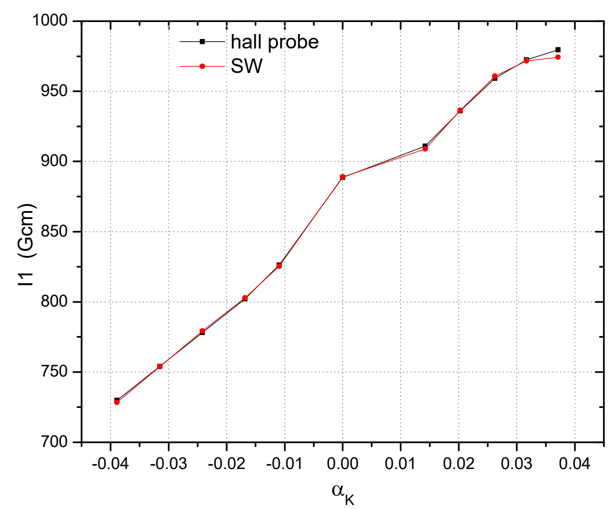

Figure 6: comparison of first field integral.

Figure 8 shows the phase error along the undulator length with different value of taper parameter and rms value of phase error at 18 mm gap untapered undulator is 6.3° which is increased with degree of taper either negative or positive provided to the undulator shown in Fig. 9.

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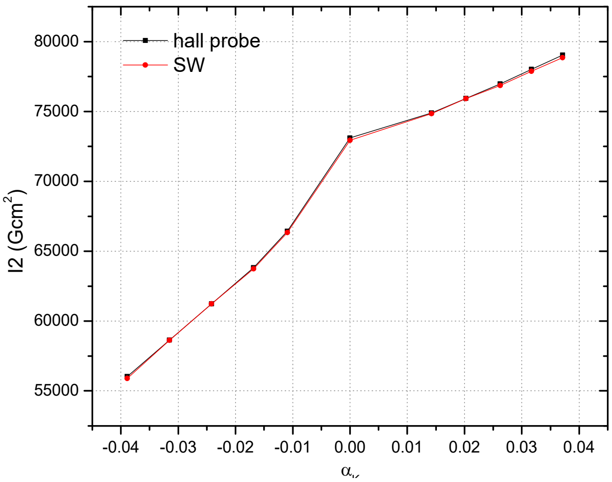

Figure 7: comparison of second field integral.

Figures 10 and 11 illustrate the measurement of magnetic field integrals of the undulator by stretched wire at different undulator gaps. The measurement is performed multiple times while closing and opening the gap of undulator provides no significant magnetic hysteresis in the undulator.

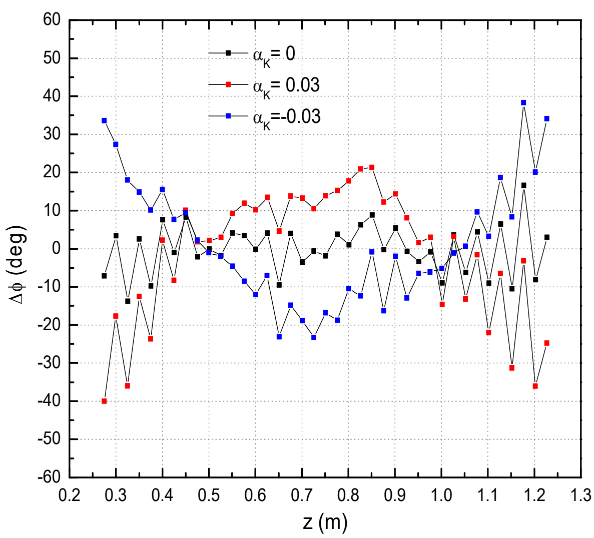

Figure 8: phase error.

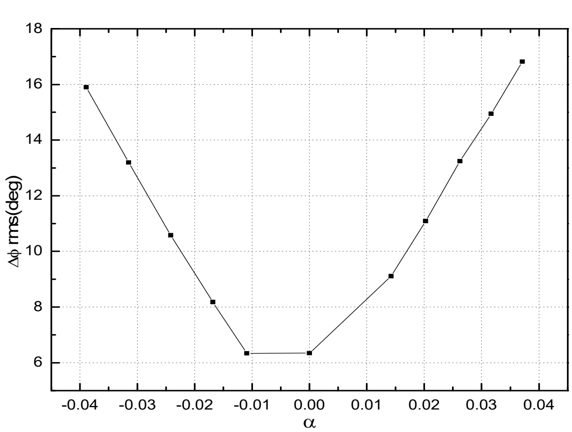

Figure 9: rms phase error.

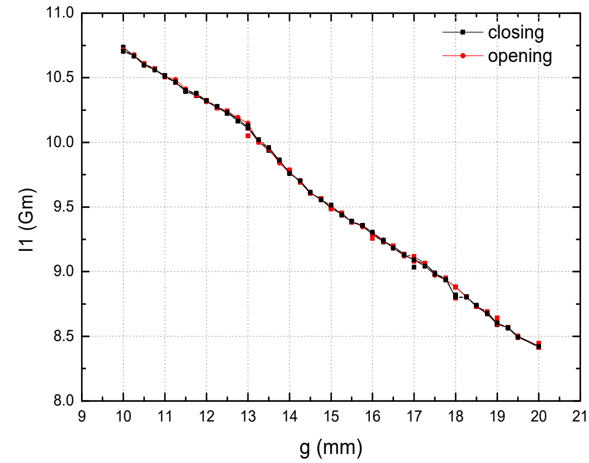

Figure 10: First integral while opening and closing gaps.

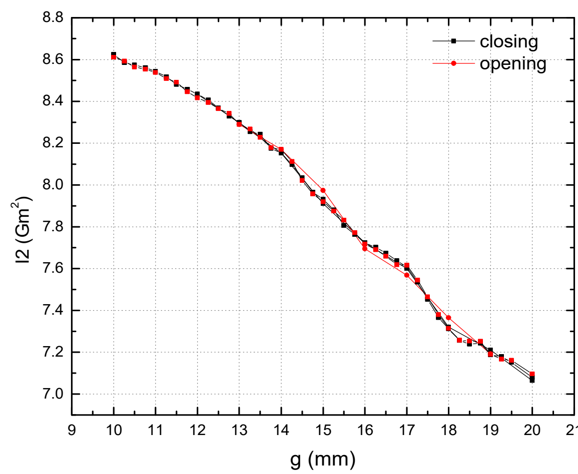

Figure 11: Second integral while opening and closing gaps.

CONCLUSION

The magnetic measurements of the tapered gap undulator are carried out in the Hall probe and stretched wire systems. Both the measurements show extreme agreements.

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