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UNDULATOR DEVELOPMENT ACTIVITIES AT DAVV-INDORE

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Abstract

Insertion Device Design Laboratory, DAVV has development activities on in-house design, fabrication and measurement of prototype undulators for synchrotron radiation and free electron laser application. The first prototype U50 was built with six periods, 50mm each period. It was PPM type. The next prototype U20 hybrid device based on NdFeB-Cobalt steel was built with aim to produce 0.24T to 0.05T in 10-20mm gap. The undulator is a 20mm period and there are 25 periods. The next one is U50-II PPM structure with 20 periods. In this paper we review the designs of all these undulators and briefly outline the user facilities of Hall probe bench, Pulsed wire bench and stretched wire magnetic measurement systems at IDDL.

U 50 UNDULATOR

A planar undulator of Halbach Configuration made from Pure Permanent magnet type of NdFeB magnets named as U50 is design and developed in IDD lab DAVV [1]. One period is of 5 cm and there are six periods in a jaw and the total length of the undulator is 30cm.The undulator is a variable gap type. The minimum gap is 22 mm which can be varied up to 50mm. The magnet size is 12.5 mm × 12.5 mm×50mm.

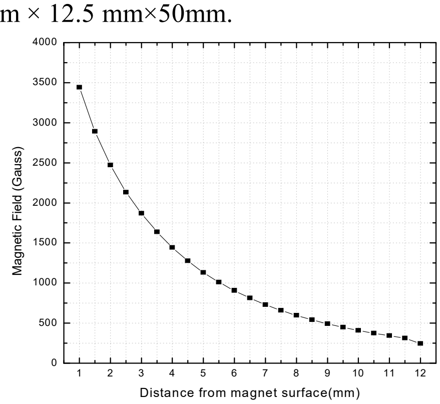

Figure 1: Magnetic field versus undulator gap for U50 undulator.

Figure.1 shows the graph for peak magnetic field with the variation in the distance from the surface of the undulator. At 1mm distance the field is around 3500Gauss.

The planar undulator was modify to a harmonic undulator by placing the shims on the required positions. We used CRGO shims for third harmonic undulator of $1.5\,mm \times 9.0\,mm \times 28\,mm$ in thickness, height and length respectively. The shims fitted in the Perspex sheet will be place on the upper and lower jaw of the undulator. By using the same method we will also modify the wiggler for $5^{th}, 7^{th}, 9^{th}$ harmonic undulator [2].

U 20 UNDULATOR

It has completed the design of a hybrid undulator [3] and installed in the measurement bench for performance studies. U20 is a NdFeB based hybrid undulator with two NdFeB magnets and two poles per period. The undulator has twenty five periods and twenty *mm* each period length. The poles are made from Cobalt steel. The gap is variable from 10mm to 80mm.Fig.2 shows the radia model of U 20 undulator and Fig 3. Shows the schematic of arrangement of undulator in a jaw. The gap is manually driven by Ball screw arrangement. The maximum field is 3000Gauss at 10mm and $\Delta B/B = 0.025$. Figure 4 shows the photograph of the hybrid undulator with its support structure.

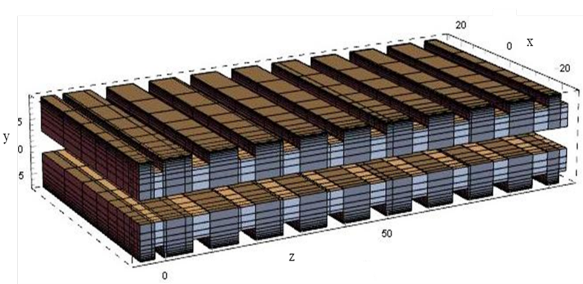

Figure 2: Radia model of U-20 undulator.

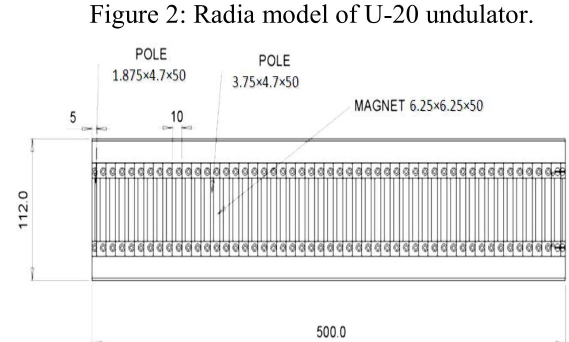

Figure 3: 0.5m Hybrid undulator design.

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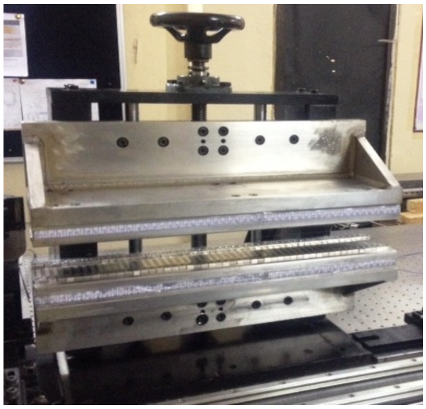

Figure 4: Hybrid Undulator.

Once the undulator is fabricated and installed in the structure, its magnetic filed profile is measured by Hall probe and RMS value for field and undulator peramete is is compared with the Radia result with the variation in the gap which is shown in the Fig.5. Figure 6 shows the inetrgarls with variation in the gap of the undulator.

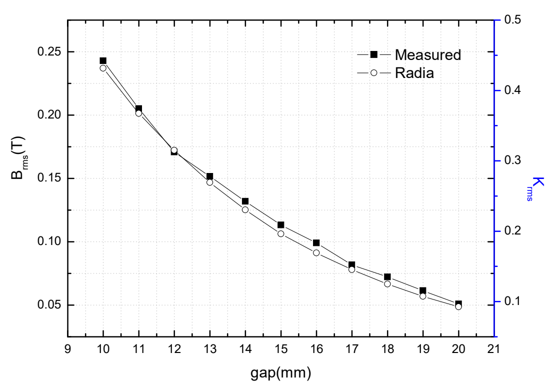

Figure 5: RMS magnetic field and undulator parameter versus undulator gap.

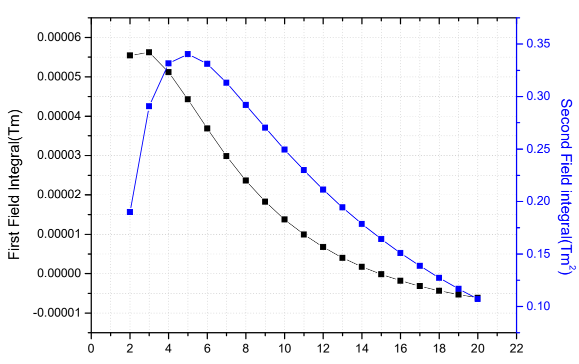

Figure 6: Field integrals for different gap.

The field in-homogeneities along the undulator length is an important design issue of consideration to a low phase error device. In Fig.7, the field in-homogeneities has been analyzed for the operating gap of the device. The maximum deviation in the magnetic flux density is less than 80 Gauss at 10 mm gap.

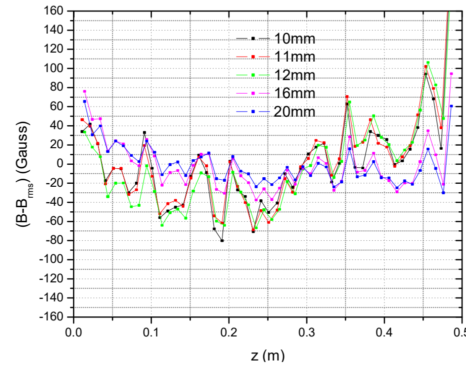

Figure 7: Field non uniformity of U20 along the undulator length.

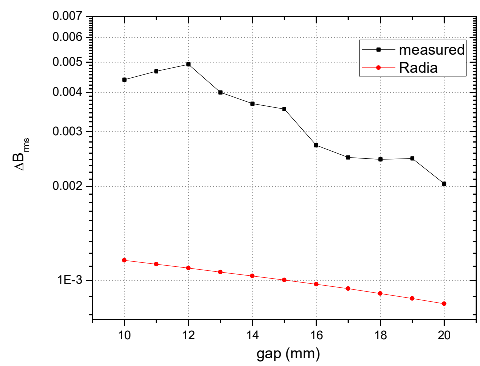

Figure 8: Deviation of magnetic flux density of U20 versus gap.

In Fig.8 , we plot ΔB_{rms} as defined in Eq.(1) with gaps for both Hall Probe and Radia data. The Radia shows the variation in 8 to 11 Gauss where the Hall probe results gives the variation of 20 to 43 Gauss in the operating gaps.

$$\Delta B_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\left|B_i\right| - B_{rms}\right)^2} \qquad (1)$$

A comparison of the phase error plots from Hall probe data and Radia and is given in Fig. 9. At 10 mm gap, the plot reads 4.240, 3.120 .

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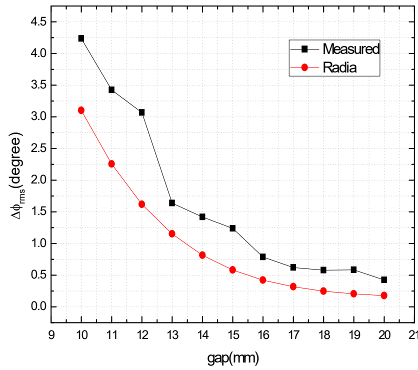

Fig 9. Phase error vesus gap.

U 50-II UNDULATOR

A new pure permanent magnet undulator is under development. It has 20 periods of 50mm period length so that the length of undulator is 1000mm long. The magnets blocks are hold on single SS 316 jaw by T- clamps. Figure 10 Shows the schematic of the undulator design and Fig. 11. Shows the schematic of the side view for the U 50-II undulator.

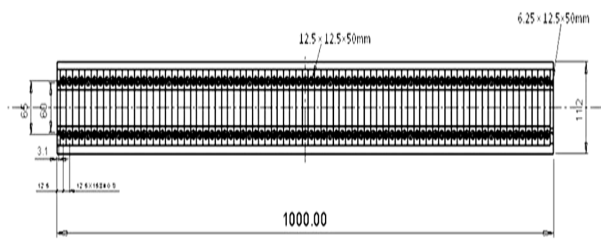

Figure 10: 1m PPM undulator design.

The dimension of the jaw is 1000×112×33mm. The jaws are prepared and are under testing by stretched wire method and the support structure is under development stage.

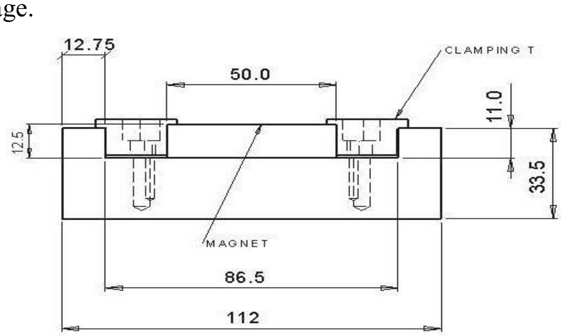

Figure 11: 1m PPM undulator design from side view.

The two jaws are hanged on a support structure providing variable gap from 3 to 30mm. The two jaws are fitted on a array and that array can move independently by four linear slides. The two arrays have vertical movement for varying gap and a rotary movement to upper jaw for maintaining parallelism between the two jaws. The vertical movement is such that we can manually change the either side of the array by four hand wheels so we can adjust the gap from four corners enabling the array to be longitudinal gap tapering for the magnetic field profile. The top array is attached with encoder of resolution 0.01degrees that provides lateral movement to the upper jaw. By this lateral movement we can adjust the alignment of both the jaws. All the readings are display on DRO (digital read out) of resolution 0.001mm. Figure 12 and Fig. 13 shows the front and side view schematic of the support structure. The support structure is heavy and made of Stainless steel for maintain the force of 2000N at 3mm gap between the two magnetic jaws. The total weight of the structure with arrays and undulator jaw is 400Kg.

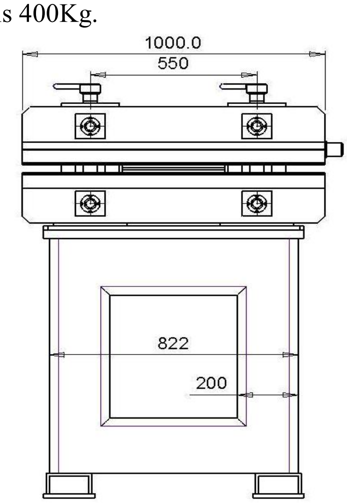

Figure 12: 1m PPM undulator with support structure.

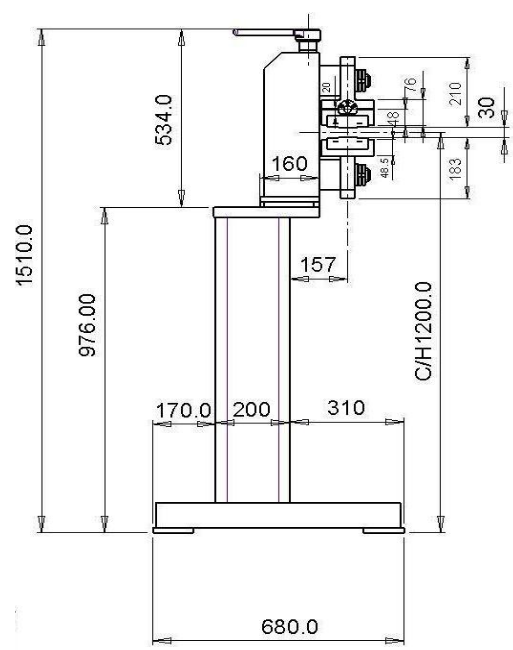

Figure 13: 1m PPM undulator with support structure (side view).

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In Fig. 14 the peak magnetic field is shown from rhe calculations of Radia. Figure 15 is the result of field integrals by Radia. Then the jaws are assembled in the support structure and for the gap of 35mm the magnetic field profile is compared with the radia results which is shown in the Fig. 9.

The Hall probe measurement are under process we will measured the field from 10mm to 35mm in our Hall probe measurement system.

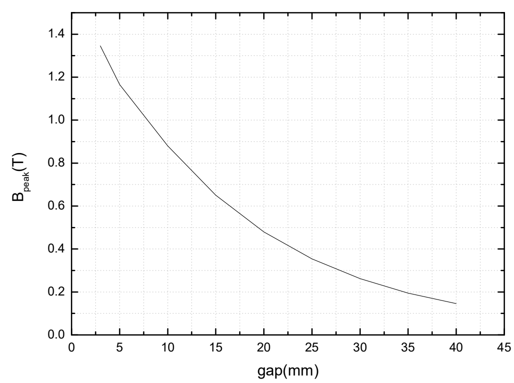

Figure 14: Peak magnetic field at different gaps.

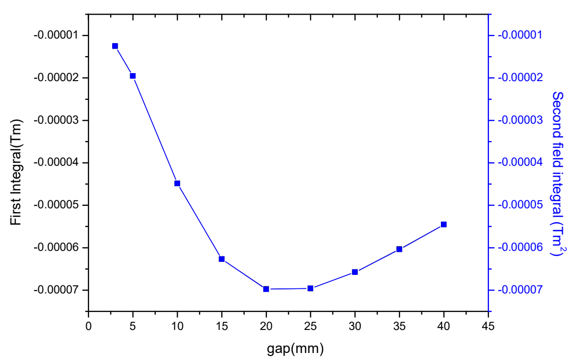

Figure 15: Field integrals for different gap.

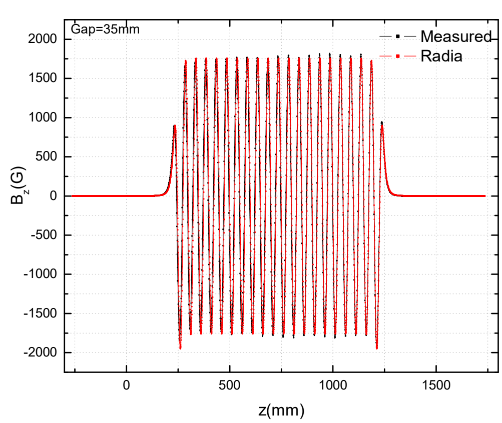

Figure 16: Magnetic field profile for the gap of 35mm.

U-14 UNDULATOR (PROPOSED)

Commercial NbTi wires with a cross section of 1 mm x 0.5 mm including its insulation will be used for fabrication of 14 mm period superconducting undulator [4-5]. The undulators will be composed of racetrack coils connected in series and wound on two ferromagnetic poles made up of carbon steel. The SCU will consist of 26 poles and 25 coils. Figure.17 shows the longitudinal view of the pole-coil of the superconducting undulator. The regular pole is 2 mm in length (beam direction), 40 mm in width (undulating direction) and 8 mm in height (vertical direction). The regular coil length with five turns is 5 mm (5 turns x 1 mm) and the coil height with 16 layers is 8 mm (16 layers x 0.5 mm). The undulator begins with a pole and runs with pole-coil–pole arrangement and ends with a pole in an asymmetric field configuration. The end field configuration in the scheme is 1:3/4:1/4. The total length of the magnetic structure (22 regular poles = 44 mm, 21 coils= 105 mm, end design= 2 x 13.56 mm (2 x (1.6 mm+5 mm+1.96 mm+5mm)) reaches a total length of 176.12 mm.

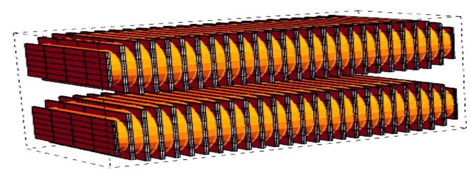

Figure 17: Longitudinal view of the SCU with end termination.

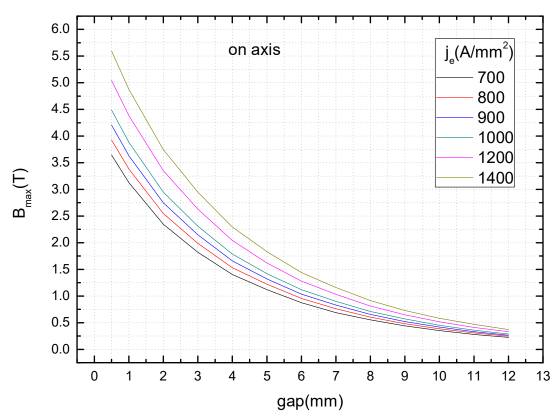

Figure 18: Magnetic flux density versus gap at different current density.

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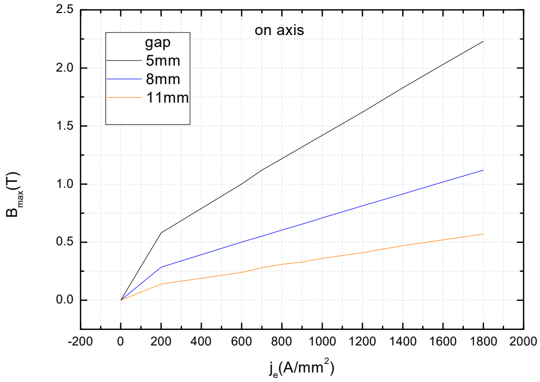

Figure 19: Magnetic flux density versus current density at different gaps.

An empirical fit formula with a, b, c coefficients similar to a hybrid undulator structure. The results fit an analytical formula for on axis field measurement

$$B_{axis}(\mathrm{T}) = a(J_e)\exp[-\mathrm{b}(J_e)\mathrm{g} + c(J_e)\mathrm{g}^2]$$
$$a(J_e) = 2.018 + 0.0031 J_e$$
$$b(J_e) = 0.24731 + 0.10436\exp(-0.0012 J_e)$$
$$c(J_e) = 0.00142 + 0.00682\exp(-0.0012 J_e)$$

In the formula g is in mm and current densities are in A/mm2. The magnetic flux density at the surface of the coil is empirically fit as,

$$B_{coil}(\mathrm{T}) = A_1(J_e) + A_2(J_e)\exp[-B(J_e)\mathrm{g}]$$
$$A_1(J_e) = 1.02017 + 0.00155 J_e$$
$$A_2(J_e) = 0.93484 + 0.00155 J_e$$
$$B(J_e) = 0.4807 + 0.12691\exp(-0.0015 J_e)$$

In Fig. 18. variation of magnetic field with different gap for different current density is shown and Fig. 19 shows the graph for the magnetic field density with the variation in the current density for different gap. In Fig. 20 the field integrals are calculated for different current density for different gap of the undulator.

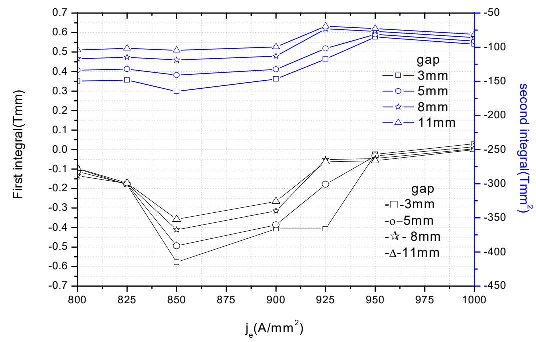

Figure 20: Field integrals versus current density for different gap.

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