DESIGN AND ANALYSIS OF EPU XBPM IN TPS

I. C. Sheng, C. K. Kuan, Y. T. Chung, H. Y. Yang, J. Y. Chueng, C. M. Cheng,
NSRRC, Hsinchu 30076, Taiwan, R.O.C.
Deming Shu, ANL, Argonne, IL 60439, USA

Abstract

Several planer and elliptical polarized undulators (EPU) beam lines have been proposed and are to be built for Taiwan Photon Source (TPS) in National Synchrotron Research Center (NSRRC). Due to its complexity, with changing of vertical as well as horizontal deflection parameters ($K_y = 4,\ \ K_x = 2.64$), one finds that regular diamond bladed photon beam position monitor (XBPM) would not be sufficient to detect the center position of EPU. A new conceptual design of EPU XBPM has been design and analysed.

INTRODUCTION

Taiwan Photon Source (TPS) project is under construction in National Synchrotron Radiation Research Center (NSRRC). This 518m circumference synchrotron accelerator will generate 3GeV, 500mA high energy X-ray. Seven beam lines are proposed in day one after commissioning. Besides linear undulator beam lines, one tandem EPU beam line will be developed for high resolution inelastic soft X-ray scattering experiment.

Due to its two dimensional magnetic array feature, EPU undulator will generate wide range of elliptical-shape power beam profile. Unlike regular planar undulator, vertical power beam height is no longer $\frac{2}{\gamma}$ (where γ is known as the *Lorentz factor*). The maximum and minimum major axis of elliptical beam profile depend on deflection parameters along x and y directions ($K_y = 4,\ \ K_x = 2.64$). Thus the design of X-ray beam position monitor (XBPM) becomes a challenging task since the diamond blades, as a detector, might subject to EPU high heat load when deflection parameters vary. NSRRC is collaborating with Argonne National Laboratory (ANL) to develop the XBPM for EPU to accommodate this situation. The designs, as well as several thermal analyses are presented in this report.

EPU POWER PROFILE

Many combinations of deflection parameters for EPU have been also proposed. Table 1 illustrates some of EPU48 power profiles for TPS; only EPU48 (48 mm insertion device gap) will be discussed in this report since it has more severe power density.

Figure 1 shows two dimensional power density contour of a typical EPU48 when $K_y = 4,\ \ K_x = 2.64$:

Table 1: TPS EPU Parameters

Parameters	EPU48	EPU48	EPU48	EPU46
$\lambda(cm)$	4.8	4.8	4.8	4.6
N	83	75	75	81
K_y	4.0	0.8	3.9	3.6
K_x	2.64	1.6		2.57
Power beam size (x in mrad)	1.36	0.27	1.32	1.23
Power beam size (y in mrad)	0.9	0.55	0.34	0.99
Total power (kW)	13.0	1.6	7.7	11.3
Peak power density ($kW / mrad^2$)	16	6	28	15

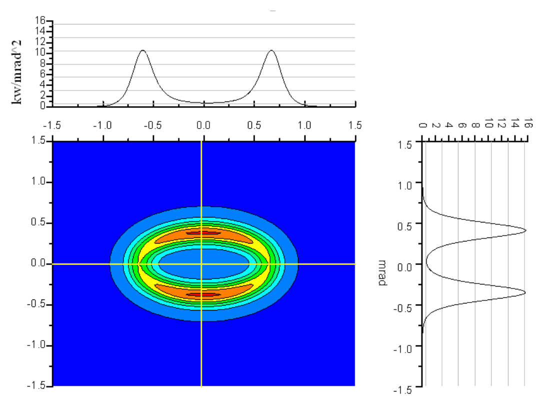

Figure 1: TPS EPU48 synchrotron radiation contour $K_y = 4,\ \ K_x = 2.64$.

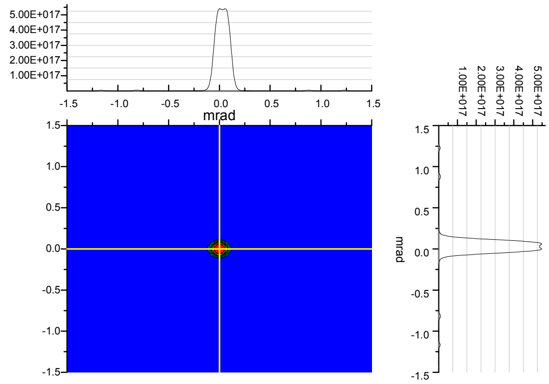

Figure 2: TPS EPU48 first harmonic photon flux contour $K_y = 4,\ \ K_x = 2.64$.

As shown in Fig. 2, since at first harmonic the photon distribution (in unit of ph/s/mr^2/0.1%) is very concentrated at the origin (+/- 0.25mrad), in order for the diamond blades to induce photoelectrical effect efficiently, four blades will have to intrude into the donut shape power density so that they can receive sufficient amount photons. That is, the diamond blades shall subject to high power load.

DESIGN

Four gold plated CVD diamond blades are mounted on a copper block as shown in Fig. 3, the edges of the diamond blades are facing the beam direction of EPU. As EPU passes through, blades will detect number of the photons strikes on the diamond surface, which consequently generate electrons due to photoelectrical effect. Diamond blades are carefully mounted on the copper block by few screws. Four additional diamond blades are also mounted on the corners which are not shown in the current design.

Instead of place diamond blade vertically as was designed for planner undulator [1, 2], as shown in Fig. 3, an inclined diamond blade is implemented, the reason is because both deflection parameters (or magnetic fields) K_x and K_y might vary, therefore the foot print of synchrotron radiation might become, for example, circular undulator (both K_x and K_y are identical) , planar undulator (K_x=0) or even vertical EPU ($K_x > K_y$), To satisfy all of above scenario, inclined diamond blade design is the only solution as far as general beam profile is concern.

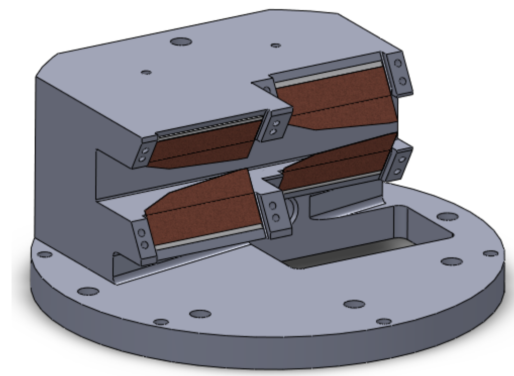

Figure 3: TPS EPU XPM design.

A ceramic plate is mounted between diamond blade and copper cooling body for electrical insulation purpose. Behind the bottom of the copper block, water cooling is applied to dissipate the heat received by synchrotron power.

THERMAL ANALYSIS

The thermal analysis is performed by SOLIDWORKS simulation tool. A simpler and more conservative power implementation has been reported [3] and is applied in the analysis. Three materials are implemented in the model: diamond, ceramic and cooper. To reduce vibration from external sources, water flow rate is limited which result in low film coefficient ($h = 0.5$ w/cm^2 K), the maximum power density is 83 w/mm^2 striking on the edge of the diamond blade (0.13 mm thickness diamond).

Assuming $0\ ^oC$ water temperature, temperature rise contour of EPU XBPM is shown in Fig. 4:

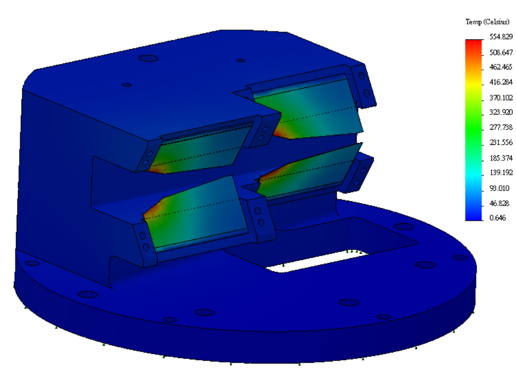

Figure 4: TPS EPU48 XBPM temperature contour when $K_y = 4,\ \ K_x = 2.64$.

Maximum temperature appears on the edge of the blades as EPU power directly strikes on the edge with vertical incident angle 36^o with magnitude of $554\ ^oC$.

ISBN 978-3-95450-115-1

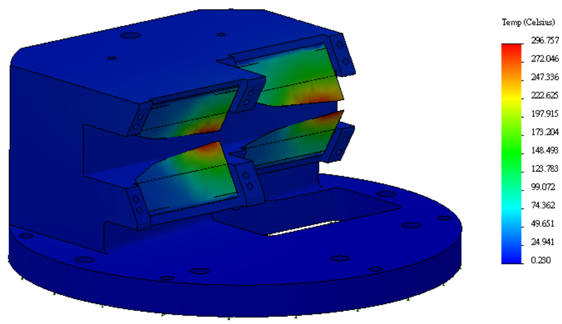

Figure 5: TPS EPU48 XBPM temperature contour when $K_x = 1.6,\ \ K_y = 0.8$.

As to another scenario where deflection parameters become $K_x = 1.6,\ \ K_y = 0.8$, the power beam size is much smaller than that was described before, that is, the edge of the power strikes only on the bottom edge of the diamond blades, and since the power density is also less than previous case, the maximum temperature rise is only less than $300\ ^oC$, as is illustrated in Fig. 5.

Since the blades are mounted on the cooling body with ceramic plate in between and conductivity of ceramic in general has poor conductance than diamond or gold, overall conductance path from diamond blade to cooling surface wouldn't be very efficient. Further improvements would be needed.

DISCUSSION

A preliminary XBPM design particularly for EPU has been designed. Unlike original XBPM for planner undulator, the orientation of diamond blades for EPU XBPM is inclined with respect to x-y plane so that position of EPU can still be detected disregarding the change of K_y and K_x deflection parameters.

Copper block is used as a support to fix diamond blades. In order to minimize vibration source from water flow, only few drops of water is supplied on the bottom of the copper base to enhance the cooling,

Thermal analysis reveals that the maximum temperature appears on the tip of the diamond blades is over $500\ ^oC$ when deflection parameters are $K_y = 4,\ \ K_x = 2.64$ and $300\ ^oC$ for $K_x = 1.6,\ \ K_y = 0.8$, respectively.

Further enhancing cooling design may have to consider reducing the maximum temperature on the diamond blade.

REFERENCES

[1] Deming Shu, et al., "Progress of the APS High Heat Load X-ray Beam Position Monitor Development", AIP Conference Proceedings, Vol. 417, pp. 173-177.

[2] Deming Shu, "Development of Synthetic-Diamond-Based Front End XBPM at the Advanced Photon Source", NSLS-II Mini-Workshop on X-ray Beam Monitors, February 26, 2009.

[3] I. C. Sheng and C. K. Kuan, "Power Density Distribution and Associated Thermal Analysis of an Elliptical Polarizing Undulator", Nucl. Instr. and Meth. A (2011), doi: 10.1016/j.nima.2011.01.048.